Projects
Many of the MIT Media Lab research projects described in the following pages are conducted under the auspices of sponsor-supported, interdisciplinary Media Lab centers, joint research programs, and initiatives. They include:

Center for Civic Media

Communities need information to make decisions and take action: to provide aid to neighbors in need, to purchase an environmentally sustainable product and shun a wasteful one, to choose leaders on local and global scales. Communities are also rich repositories of information and knowledge, and often develop their own innovative tools and practices for information sharing. Existing systems to inform communities are changing rapidly, and new ecosystems are emerging where old distinctions like writer/audience and journalist/amateur have collapsed. The Civic Media group is a partnership between the MIT Media Lab and Comparative Media Studies at MIT. Together, we work to understand these new ecosystems and to build tools and systems that help communities collect and share information and connect that information to action. We work closely with communities to understand their needs and strengths, and to develop useful tools together using collaborative design principles. We particularly focus on tools that can help amplify the voices of communities often excluded from the digital public sphere and connect them with new audiences, as well as on systems that help us understand media ecologies, augment civic participation, and foster digital inclusion.

Center for Extreme Bionics

Half of the world's population currently suffers from some form of physical or neurological disability. At some point in our lives, it is all too likely that a family member or friend will be struck by a limiting or incapacitating condition, from dementia, to the loss of a limb, to a debilitating disease such as Parkinson's. Today we acknowledge—and even "accept"—serious physical and mental impairments as inherent to the human condition. But must these conditions be accepted as "normal"? What if, instead, through the invention and deployment of novel technologies, we could control biological processes within the body in order to repair or even eradicate them? What if there were no such thing as human disability? These questions drive the work of Media Lab faculty members Hugh Herr and Ed Boyden, and MIT Institute Professor Robert Langer, and what has led them and the MIT Media Lab to propose the establishment of a new Center for Extreme Bionics. This dynamic new interdisciplinary organization will draw on the existing strengths of research in synthetic neurobiology, biomechatronics, and biomaterials, combined with enhanced capabilities for design development and prototyping.

Community Biotech Initiative

Humanity's capacity to engineer the living world is a collective concern that requires collective engagement. While synthetic biology has expanded the breadth of technical participation to include a host of engineering disciplines, the next generation of innovators in biotechnology will include diverse communities across cultural, socioeconomic, artistic, and creative domains. The Community Biotech Initiative is developing tools and technologies to enable the broadest possible participation in biotechnology. Our projects include the creation of low-cost enabling hardware, infrastructure for sharing, and new interfaces for artistic expression with biology.

Digital Currency Initiative

The Internet enabled people to easily call each other without a phone company, send a document without a mail carrier, or publish an article without a newspaper. As a result, more than 2.9 billion people depend on a decentralized communications protocol—the Internet—to more efficiently communicate with one another. Similarly, cryptocurrencies like bitcoin enable permission-less innovation for entrepreneurs and technologists to build world-changing applications that answer the demand for global transactions that has been created by global communication. The Digital Currency Initiative strives to be a neutral leader of world-class research to push the boundaries of knowledge around cryptocurrency and its underlying distributed ledger technology. We seek to clarify the real-world impact of these technologies, inspired by their potential for public good and mindful of the risks and ethical questions attached to them. We act in support of the MIT and open-source cryptocurrency communities and yet are open to collaborating with all sectors of society.

ML Learning Initiative

Media Lab founding faculty member Seymour Papert laid the foundation for a new theory of learning through construction. He created tools for children to be designers and creators, rather than just consumers of technology, positing that learning happens best when people are actively constructing knowledge through creative experimentation and the design of sharable objects. Today, the ML Learning Initiative is built on similar principles and aims to bring the collective creativity to bear on the future of learning.
The ML Learning Initiative explores new approaches to learning. We study learning across many dimensions, ranging from neurons to nations, from early childhood to lifelong scholarship, and from human creativity to machine intelligence. The program is built around a cohort of learning innovators from across the diverse Media Lab groups. We are designing tools and technologies that change how, when, where, and what we learn; and developing new solutions to enable and enhance learning everywhere, including at the Media Lab itself. In addition to creating tools and models, the initiative provides non-profit and for-profit mechanisms to help promising innovations to scale.

Open Agriculture (OpenAg) Initiative
The MIT Media Lab Open Agriculture (OpenAg) Initiative is on a mission to create healthier, more engaging, and more inventive future food systems. We believe the precursor to a healthier and more sustainable food system will be the creation of an open-source ecosystem of food technologies that enable and promote transparency, networked experimentation, education, and hyper-local production. The OpenAg Initiative brings together partners from industry, government, and academia to develop an open source “food tech” research collective for the creation of the global agricultural hardware, software, and data commons. Together we will build collaborative tools and open technology platforms for the exploration of future food systems.

Open Ocean Initiative
The ocean is vast. It covers more than 70 percent of the surface of our planet and holds 97 percent of the water on Earth. The ocean is exciting. We swim, surf, dive, and play in it. We romanticize pirates, dream of merfolk, and love to be frightened of sea monsters. The ocean is critical. We rely on the sea for food, energy, and environmental protection. And yet, the ocean remains mysterious. Only 15 percent of the seafloor has been mapped by modern methods, and perhaps 5 percent has ever been seen by human eyes. The Open Ocean Initiative works at the intersection of science, technology, art, and society to design and deploy new ways to understand the ocean and connect people to it in novel ways, empowering a global community of explorers. Together, we will discover the unknown, the extremes, and the wonder of the sea—because the ocean is for everyone.

Space Exploration Initiative
The public grand opening of space draws near. Much as biology has witnessed an explosion of DIY biohacking in recent years, the dropping costs of space launches and cubesats enable a new mode of engagement in low Earth orbit (LEO) and beyond. What was once an exclusive, expensive, and narrowly serious pursuit begins to thaw. With the dawn of “New Space,” a burgeoning group of private, commercial space companies excites a new philosophy of involvement with space technology. Space will be hackable. Space will be playful. Space will be accessible to the space enthusiast—through the reach of their DIY instruments, experiments, sensors and satellites, and eventually through space tourism. This opportunity to design our interplanetary lives beckons to us. Our mission is to design a life worth living up there. We aim to drive innovation at the frontiers of space exploration, from the holy grail of “life in space” to widespread societal involvement in “open space.” Humanity stands on the cusp of interplanetary civilization and space is our next, grand frontier. While many organizations already tackle, quite effectively, the engineering and scientific challenges, the Media Lab is distinct in its freedom to imagine bold visions that venture beyond the rational constraints of most academic grants. We’ll prototype provocative space architectures, new communication networks, and astro-bacteria wearables. We’ll open-source payload designs and repurpose existing satellites—and deploy! Our collective creativity strives to bring science fiction to life. Space may not be our final frontier, but should be our next.

The most current information about our research is available on the MIT Media Lab website, at http://www.media.mit.edu/research.
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Place Recognition and Categorization

Personalized Machine Learning for Autism Therapy

Onsite Stress Measurement

Modulating peripheral and cortical arousal using a musical motor response task

Meet the Ganimals

Mapping the Stress of Medical Visits

Cube Puzzles

Deep Reinforcement Learning for Pain Management

EDA Explorer

Electrocardiogram collection in noisy ambulatory environments with Android smartphone devices

ELSA: Empathy learning, socially-aware agents

EMMA: An emotionally intelligent personal assistant for improving wellbeing

Emotion Navigation

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Emotion/wellbeing x skincare cosmetics

Fathom: Probabilistic graphical models to help mental health counselors

FEEL: A cloud system for frequent event and biophysiological signal labeling

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Mobile health interventions for drug addiction and PTSD

Modulating peripheral and cortical arousal using a musical motor response task

Onsite Stress Measurement

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Personalized Animated Movies

Personalized Machine Learning for Autism Therapy

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Place Recognition and Categorization

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Predicting perceived emotions in animated GIFs with 3D convolutional neural networks

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Real-time assessment of suicidal thoughts and behaviors

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Object-Based Media
Changing storytelling, communication, and everyday life through sensing, understanding, and new interface technologies

1. **8K Time Machine**
   *V. Michael Bove, Hisayuki Ohmata (NHK), Yukiko Oshio (NHK)*
   Archived TV programs evoke earlier times. This application combines a video and music archive with an immersive screen and a simple user interface suitable for everyone, from children to the elderly, to create a "Time Machine" effect. The only key for exploring is the user's age. People can enjoy over 1,300 TV programs from the last seven decades without having to do tedious text searches. This catalogue intuitively guides the user with an image array (64 different videos on one screen at the same time) that simplifies navigation and makes it immediate, rather than referencing it to previous screens.

2. **AirTap**
   *V. Michael Bove, Ali Shtarbanov*
   We demonstrate a method for augmenting existing visual interfaces, including 3D and conventional displays, with haptic feedback capabilities, by utilizing a large number of closely spaced vortex-ring generators mounted along the periphery of the display. We present our first prototype of a multimodal interactive interface platform with 16 independently-controlled air-vortex ring generators with one angular degree of freedom each. Our system has applications as an interactive interface, as a research tool, as an automotive control interface, and as a platform for creative expressions.

3. **ArtBoat**
   *Laura Perovich*
   ArtBoat is a tool for communities to make collaborative light paintings in public spaces and reimagine the future of their cities. Visit our project website at artboatcommunity.com.
   ArtBoat consists of a remote control boat with light strips that change color in response to a custom light design board. During ArtBoat events, community members can drive remote controlled boats, control the color of lights on the boats, or take long exposure photographs to make collaborative light graffiti that explores how art can help communities claim public spaces.
   Our first ArtBoat community event was on July 29, 2018 at Magazine Beach Park in Cambridge, MA. Thanks to our Magazine Beach host Cathie Zusy, our photographers Jorge Valdez (IG: jorgevlma), Ron Hoffmann (IG: archiscapes.us), Neil Gaikwad (IG: Neil Gaikwad Photography), Garance Malivel, and Jimmy Day, our boat facilitators, and our participants. Our second ArtBoat event was on September 22, 2018 at Herter Park Amphitheater in Boston, MA, as part of the 15th anniversary Revels RiverSing!
   If you’d like to join our mailing list to find out about future ArtBoat events, email artboat@lauraperovich.com or fill out this form.
   ArtBoat is a sister project of SeeBoat. It is an open source project licensed under GPLv2 and Creative Commons.

4. **BigBarChart**
   *V. Michael Bove, Laura Perovich*
   BigBarChart is an immersive, 3D bar chart that provides a new physical way for people to interact with data. It takes data beyond visualizations to map out a new area—data experiences—that are multisensory, embodied, and aesthetic interactions. BigBarChart is made up of a number of bars that extend up to 10 feet to create an immersive experience. Bars change height and color in response to interactions that are direct (a person entering the room), tangible (pushing down on a bar to get meta information), or digital (controlling bars and performing statistical analyses through a tablet). BigBarChart helps both scientists and the general public understand information from a new perspective. Early prototypes are available.

5. **Bird: a 3D Cursor for 3D Interaction in Virtual Reality**
   *Aubrey Simonson*
   Bird is a hand-controlled pointing system that translates a user’s finger movements and positions into the motion of a 3D pointer in a virtual space. The name Bird stems from its similarity to a computer mouse, named for an animal occupying the ground, evolved with the addition of a third degree of freedom into an animal occupying the air.
6. **Bubble: Wearable assistive grasping augmentation based on soft inflatables**

   **Ali Shtarbanov**

   Bubble is a pneumatically actuated wearable system that enables people with hand disabilities to use their own hands to grasp objects without fully bending their fingers. Bubble offers a novel approach to grasping, where slim, ultra-lightweight silicone actuators are attached to the fingers. When the user wishes to grasp an object, the silicone units inflate pneumatically to fill the available space around the object. The inflatable units are interchangeable, can be independently inflated, and can be positioned anywhere on the fingers and in any orientation, thereby enabling a wide variety of grasping gestures.

7. **Calliope**

   **V. Michael Bove, Edwina Portocarrero, Ye Wang**

   Calliope was designed by building on the lessons learnt from the NeverEnding Drawing Machine. Rather than a static system that lives indoors, Calliope was inspired by the portability of "en plein air" painting and the pochade box that made it possible. Thinking of "the world as your palette," Calliope is a portable, paper-based platform for interactive, networked story making which allows physical editing of shared digital media at a distance. With Calliope, we shrank the size and cost by using a system of mirrors and the availability of pocket projectors. We were also interested in exploring the difference between a system that allowed "from many to many" collaboration to a more intimate "one to one" design. Like the Never-Ending Drawing Machine, Calliope is composed of networked "creation-stations" that seamlessly blend analog and digital media which uses the page-turning book format to synchronize networked co-creation.

   When using the Never-Ending Drawing Machine, we noticed people had trouble pressing the "big red button" since their hands were mostly busy. Calliope substituted the button for a pedal to be pressed. Unlike the Never-Ending Drawing Machine, Calliope uses human-readable tags, designed as dominoes, which can be drawn directly onto the paper with a marker by the user.

   One of the most valuable outcomes of blending analog and digital media, was the ability to save every version, allowing to then explore the process of creation. The NEDM though did not have a way that the user could access this without having to interface with the computer’s file system. For Calliope, we designed a tag which, upon placing it over the desired page, lets you see all the versions that came before the last one. Furthermore, Calliope now can record audio! When the "rooster" tag is placed, one can record onto that page and play back, extending the palette to the aural realms. The intention remains: to offer opportunities for cross-cultural and cross-generational collaboration among peers with expertise in different media.

8. **Common sense for artificial intelligence**

   **ConceptNet, or Open Mind Common Sense, is a long-standing project designed to help computers understand the meanings of words that people use. Starting in 1999, we were the first crowd-sourced project used to train an Artificial Intelligence and one of the first uses of crowdsourcing.**

   ConceptNet originated from the crowdsourcing project Open Mind Common Sense, which was launched in 1999 at the MIT Media Lab. It has since grown to include knowledge from other crowdsourced resources, expert-created resources, and games with a purpose.

   It is currently an open data project providing freely-available knowledge graphs and NLP models in 73 languages.

   Over the years this project has had many collaborators and have lived in the Society of Mind, Software Agents, and Digital Intuition groups as well.

9. **Consumer Holo-Video**

   **V. Michael Bove, Bianca Datta, Sunny Jolly, Nickolaos Savidis, Daniel Smalley (BYU)**

   The goal of this project, building upon work begun by Stephen Benton and the Spatial Imaging group, is to enable consumer devices such as tablets, phones, or glasses to display holographic video images in real time, suitable for entertainment, engineering, telepresence, or medical imaging. Our research addresses real-time scene capture and transmission, computational strategies, display technologies, interaction models, and applications.

10. **Conversational Characters: AI agents for entertainment**

    **We want to create immersive, personalized, and scalable digital experiences. In order to do that, we need to fundamentally rethink the way intelligent agents are built. Currently, agent technology is designed to quickly get a user with a single problem to their solution; success is how quickly you accomplish this task. We are rethinking agents to be about story quality, experience, and interaction design. We plan on separating the bits of the agent: the dialogue generation, world modeling, conversational planning, and emotion. In order to do that, we must first design NLP that work within the confines of a world that is often very different than our own—with limited data to do it!**
11. **Cosmetic Light**

**Nina Lutz, Vik Parthiban**

From skin to light: an artistic dialog between cosmetics, lasers, and lighting between the human and microscopic scale.

Cosmetics essentially diffract and scatter light in a way that makes the wearer appear different to the naked eye. In this project we propose an illumination grammar between cosmetic projects and coherent light lasers, as a suggestion for alternative interior lighting as well as artistic effect and expression. From skin to light, we explore these artistic archetypes.

12. **Deep Relationship Discovery**

**Pedro Colon-Hernandez**

Relationship discovery between two entities is a problem that has to be addressed when constructing a Knowledge Base (KB). A solution to this problem is important because the KB built from the discovered relations can play a key role in downstream tasks, such as analogical reasoning. An example of this kind of reasoning is whether a dog desires cake: a dog is an animal, cake is food, animals desire food, therefore a dog desires cake. We constructed a system that is trained on a commonsense KB and whose inputs are pairs of concepts and its outputs are the strength of commonsense assertions between the concepts. Our approach is unique because it can handle out of vocabulary entities and can generalize commonsense to out of knowledge concepts. We utilize the system to be able to infer the answer for out of knowledge assertions such as the aforementioned whether a dog desires cake.

13. **design(human)design**

**Philippa Mothersill**

design(human)design is a tool that builds on insights about the design process inspired by research carried out at IDEO Cambridge. The idea is that there are a few design “variables” that designers play with, and that they often like to provoke their creativity with “random but purposeful” inspirations—which present the designer with a random selection of design variables to act as a “structured serendipitous” creative prompt.

design(human)design comprises a deck of cards that act as a creative game to prompt new design ideas. The deck consists of sets of cards containing examples of each of the design variables, e.g. an object, an app, a book, etc., for the artifact design variable. Designers randomly select a card from each of the variable sets and create their design inspired by the MadLibs-style prompt sentence construct. Blank cards for each of the variables are also included so that designers can add their own examples.

To make the complete and selective randomization and personalization of the variables even easier, an interactive design(human)design website was created at designhumandesign.media.mit.edu. The list of design variables are contained in a Google Spreadsheet that again can be added to by designers to customise their prompts.

14. **Dressed in Data**

**V. Michael Bove, Laura Perovich**

This project steps beyond data visualizations to create data experiences. It aims to engage not only the analytic mind, but also the artistic and emotional self. In this project, chemicals found in people’s bodies and homes are turned into a series of fashions. Quantities, properties, and sources of chemicals are represented through various parameters of the fashion, such as fabric color, textures, and sizes. Wearing these outfits allows people to live the data—to experience tangibly the findings from their homes and bodies. This is the first project in a series of works that seek to create aesthetic data experiences that prompt researchers and laypeople to engage with information in new ways.

15. **DUSK**

**V. Michael Bove, Bianca Datta**

DUSK was created as part of the Media Lab’s Advancing Wellbeing initiative (supported by the Robert Wood Johnson Foundation) to create private, restful spaces for people in the workplace. DUSK promotes a vision of a new type of “nap pod,” where workers are encouraged to use the structure on a daily basis for regular breaks and meditation. The user is provided with the much-needed privacy to take a phone call, focus, or rest inside the pod for short periods during the day. The inside can be silent, or filled with binaural beats audio; pitch black, or illuminated by a sunlamp; whatever works for users to get the rest and relaxation needed to continue to be healthy and productive. DUSK is created with a parametric press-fit design, making it scalable and suitable for fabrication customizable on a per-user basis.
The design process is no longer limited to one group of individuals, as number, level, and cost make tools ever more accessible. As we move towards tools that allow us to create our own materials, having a set of rules with which to evaluate, interpret, and design them will become increasingly important. One way of approaching this problem is by unpacking the ways in which materials create meaning. This project explores the more emotive aspects of materials, such as haptic responses to, cognitive evaluation of, and emotive perception of materials to understand how materials communicate meaning. The development of an effective methodology aims to lower the barriers of fabrication of engaging objects. By incorporating qualities that were not previously quantifiable, we aim to encourage a more interactive design process that allows for the production of experiences tailored to individual preference, and a framework for conversations around material issues.

Whether or not we’re experts in the design language of objects, we have an unconscious understanding of the emotional character of their forms. EmotiveModeler integrates knowledge about our emotive perception of shapes into a CAD tool that uses descriptive adjectives as an input to aid both expert and novice designers in creating objects that can communicate emotive character.

Following upon work begun in the Graspables project, we are exploring what happens when a wide range of everyday consumer products can sense, interpret into human terms (using pattern recognition methods), and retain memories, such that users can construct a narrative with the aid of the recollections of the “diaries” of their sporting equipment, luggage, furniture, toys, and other items.
Emily Salvador

Motivation

The need for inexpensive, reliable, 3D, 360-degree display technologies grows as augmented reality applications continue to increase in popularity. There is room for innovation in the field, as many volumetric displays have moving components, are prohibitively expensive, aren’t 360-degree, or some combination of those factors. By creating a 360-degree autostereoscopic display that is cost-effective and reliable, we could expand the audience who would benefit from collaborative, interactive experiences. Additionally, while augmented reality headsets are increasingly popular, a volumetric display readily encourages accessible, collaborative interaction without separating users by wearable technology. This technology could impact a variety of industries and demographics as the connected media landscape continues to expand.

Approach - Hardware

This system is comprised on three main components. First, a 4K monitor displays properly distorted, lenticularized content using a custom shader. That light-field information is then partitioned by a refracting medium, either a radial lenticular array or a holographic optical element. After the rays of light from the pixels bend through the refracting medium, the rays then bounce off the conical mirror, producing the proper image for each viewing angle.

Hardware - Radial Lenticular

The radial lenticular design is dictated by several parameters which all trade-off with one another. For the design of this lenticular, I plan to focus on maximizing the resolution and size of the image rendered in the cone, while also maintaining a reasonable number of viewing angles. Variables that can be changed include the number of cameras (which corresponds to the number of discreet viewing zones), the number of views per lenticular slice, and the number of times a particular sequence of views should repeat. Those variables dictate the minimum viewing radius size, the angular size of each lenticular slice, the angle of influence for each viewing zone, and the size of the image rendered in the cone. It is important to consider what a user can reasonably see reflected in the cone, before the rays no longer bounce back to the user.

Resolution is one over the number of views per each lenticular wedge. As the user moves radially around the display, the rendered views that are opposite the user (i.e., on the other side of the radial mirror) cannot be seen. Because of this assertion that the user doesn’t need to see all of the potential views from a static position, radial lenticulars operate differently than linear lenticulars. With a linear lenticular, every view that will be displayed needs to exist under every lenticular lens for the effect to work. For example, if there are eight potential images lenticularized, there would be a slice of each of those eight views underneath each lenticular lens. However, with this setup, it is not necessary to produce every view under every lenticular lens, because each lenticular lens only needs to display the views that the user could potentially see from that lens. Because of that, there is a rolling priority system for which views to display under each lenticular lens. If the user is standing directly in front of where a viewing zone is located for a particular image, the lenticular lenses closest to the user should have that view centrally located under the lenticular. The lenticulars that are adjacent to that area should still have information that can reach the user; however, the views have to shift to accommodate the off-axis position. In that way, there is a rolling priority system, where the generated view that is closer to the user will appear centrally under the lenticular lens and incrementally move off-center and eventually disappear as the user moves radially around the display.

Hardware - Interactivity

For hardware integration for interactivity, I plan to use Intel Realsense cameras, microphones, and arduino powered LEDs that all communicate with Unity. There is a plugin to use Intel Realsense in the unity environment, along with libraries that allow for more detailed signal processing and pose analysis. I will use serial messaging in unity to send message to the arduino that will control the LEDs that will wrap around the housing of the device. The LEDs will be used to indicate important signals to users. Those signals include that the system can see the user and whether the user appears to be engaging as well as can signal when the program is performing a request that requires time. Additionally, I will use unity to receive and process microphone inputs.

Software - Custom Shader

Unity has built in support for creating complex shaders that can be applied real-time. In Unity, I will write a shader that appropriately partitions the views based on the number of cameras in the scene, the number of views per each lenticular lens, and the number of times each sequence of views should repeat. Before the views can be lenticularized the media from the camera must be rotated around the display to match where it will physically appear on the reflected cone. If you don’t do this step, all of the views will be rendered on top of each other, resulting in an incorrect result. By rotating the views to their appropriate location, the imagery you should see when standing on the left of the display will appear on the left and
same for all other directions. After the views have been rotated to the appropriate location, each of the camera’s views are sliced and reordered within the shader to produce the lenticularized result.

Software - Interactivity

Intel Realsense and similar depth sensing devices like Kinect and Leap Motion provide SDKs that allow developers to readily stream depth and color data into Unity. The Intel Realsense data can be further processed and interpreted using software like Nuitrack to do skeleton tracking which exposes body pose and joint positions. This can be used to allow the system to know when a user is close enough to the display or standing a particular place. This is good for gesture tracking as well. The color data from the Intel Realsense camera can be processed in OpenCV which has a Unity SDK. With OpenCV, the color data can be analyzed for object detection, face detection, and recognition and face pose analysis. This allows the system to recognize objects, people, and face pose (which could be used to interpret affective state). Face and gaze detection could be used in lieu of trigger words like “OK Google” and “Alexa” as presumably the users have intent to interact with the system if they’re looking at the character/sensors.

The sound recordings are used to detect volume, pitch, and speech. The speech is analyzed using a cloud-based service, which then streams the input and a response back to unity to influence how the character animates and responds. The speech analysis could be used to interpret special assigned words to trigger activities, games, or special animations or content in the display. The response generated by the cloud-service can be used to animate the characters mouth if the character audibly responds to users. The coupling of depth/RGB data and audio allow for more nuanced understanding of a user’s intent and affective state. In combination, this could be used to drive sympathetic animations from the character. Because the RGB data allows for face recognition, the character can potentially store information about users to be retrieved whenever that user interacts with the system.

Software - Procedural Character

I chose an animated dog character as the embodied representative for several key affordances. The face and body of this character have already been rigged and those parameters are accessible in Unity. The design of the character is ideal for this system and for expressing emotion because the head size is large relative to the body and the facial features of the character are contrasted which will read better with this device. Additionally, because this character is familiar and has recognizable physical embodiments of emotion, the user will more readily understand key animation poses. For example, if the character is happy, it will wag its tail and stick out its tongue, but if it’s nervous or upset, it will put its head and ears down. Based on the signals received and processed from the Intel Realsense camera and microphone, the dog character will animate. Those inputs will impact the character’s emotional pose, LookAt() behavior, and special animation sequences.

Evaluation

The ultimate goal of this project is to produce a low-cost, reliable, 3D, 360-degree autostereoscopic display. I will visually inspect the hardware/software implementation to determine if the desired 360-degree display is produced and measure the specifications of this display to other closely related devices. I will evaluate our software/hardware implementation by creating test patterns to discretize each individual view zone. Additionally, we will perform user studies to verify that the interaction system is intuitive and engaging.

User Study

The questions I’d like to answer about this project lie at the intersection of the affordances of the display itself and the media users can interact with. Because I’m designing a procedural character for this display, I want to explore believability and engagement through the user study as well as whether placing a character in-situ in a space impacts user experience. The nearest neighbor devices for the study will be an AR headset and a 2D monitor. In this individual-use user study, participants will engage in activities that evaluate the character’s ability to engage. The participants will complete a close ended warm-up task both meant to acclimate and provide a concrete objective. After the warm-up task is completed (e.g., playing catch), the participants will be asked to engage in a more exploratory capacity with the character on each of the displays. The activity will involve engaging the character’s LookAt() behavior, object detection, face-pose detection, speech recognition, and visual accessories (like the LED light-strip). The order in which the participants use each display will be randomized to avoid conflating intuitive use with prior experience with the activity they’re asked to compete.
If this device were to become commercially viable, it would have to be accessible for a wide variety of ages and expertise level. Because of that, I will look for a diverse group of participants with varying degrees of prior experience with technologies like video games, AR/VR, and voice assistants. As I design and implement features for my project, I will carefully prioritize scope that builds towards the user-study experience.

Future Work

If the radial lenticular works optimally, it would be amazing to explore a portable version of this novel volumetric display. Because the optical elements of this device have no moving parts and are lightweight, this display would be a great candidate for portability. It’d be fascinating to expand on the AI character’s capabilities by adding context aware infrastructure that changes how the character responds depending on localized metadata curation.

Ethically, this technology has the potential to make volumetric displays incredibly accessible at scale, because both the mylar cone and radial lenticular would cost less than one dollar to fabricate when productized. This would severely reduce cost on a market where displays typically cost thousands of dollars per unit.

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There's been an abundance of large holographic displays portrayed throughout science fiction literature and films in recent decades. These fantastical depictions often show large consoles surrounded by multiple people working together to manipulate floating images and data. Although the users appear to interact seamlessly with the 3D data, there is a nagging question that goes unanswered: How do multiple people interact with a large 3D scene?

Perhaps the question seems trivial, but consider the following. Most 3D displays currently available are around the size of a microwave. When groups interact with these displays, although they each have their own perspective, they are essentially all seeing the same information. So even if one person zooms in on part of the image, all the users understand what is happening.

ListenTree is an audio-haptic display embedded in the natural environment. Visitors to our installation notice a faint sound emerging from a tree. By resting their heads against the tree, they are able to hear sound through bone conduction. To create this effect, an audio exciter transducer is weatherproofed and attached to the tree's roots, transforming it into a living speaker, channeling audio through its branches, and providing vibrotactile feedback. In one deployment, we used ListenTree to display live sound from an outdoor ecological monitoring sensor network, bringing a faraway wetland into the urban landscape. Our intervention is motivated by a need for forms of display that fade into the background, inviting attention rather than requiring it. We consume most digital information through devices that alienate us from our surroundings; ListenTree points to a future where digital information might become enmeshed in material.

A Live Object is a small device that can stream media content wirelessly to nearby mobile devices without an Internet connection. Live Objects are associated with real objects in the environment, such as an art piece in a museum, a statue in a public space, or a product in a store. Users exploring a space can discover nearby Live Objects and view content associated with them, as well as leave comments for future visitors. The mobile device retains a record of the media viewed (and links to additional content), while the objects can retain a record of who viewed them. Future extensions will look into making the system more social, exploring game applications such as media "scavenger hunts" built on top of the platform, and incorporating other types of media such as live and historical data from sensors associated with the objects.

The control of living systems as part of design interfaces is of interest to both the scientific and design communities due to the ability of living organisms to sense and respond to their environments. They may, for example, detect and break down harmful environmental agents, or create beneficial products when environmental levels dropped below a certain threshold. However, it is also important for these systems to be reversible, so that the biological components are only active when their functionality is necessary, and the system can remain dormant otherwise.

The Living Material Library is an exploration of tunable hybrid systems. Our work in this area demonstrates the means through which intrinsic material properties may be functionally changed through environmental factors and, in turn, serve as dynamic substrates for living systems. Nearly all organisms have highly developed sensing capabilities, and have been shown to behaviorally respond to changes in substrate properties. By creating a tunable and reversible material system, we explore how cell behavior such as adhesion, patterning, and differentiation may be influenced via an active interface.

In this iteration, we propose a reversible material system that allows for control of living interactions (much like a light switch). We are particularly interested in fluid material systems (such as electrorheological fluids) that transition from a liquid-like to a solid-like state when exposed to electric fields and currents.

This endeavor brings to light the complex relationship between dynamic materials and living systems. While other methods of cell intervention often rely on light, chemicals, or temperature, here we explore substrate material properties as inputs for organisms. Our library may allow for more directed inquiry into processes such as collective cell durotaxis, general mechanotaxis, and active sensing. This marks an initial foray into establishing candidate design methods for responsive applications.
27. **ModeSense**

V. Michael Bove, Ali Shtarbanov

ModeSense is a full stack system that enables indoor environments to become aware of what is happening in them, and then enables the environment to locally inform (offline) all nearby phones and other electronic devices about the most appropriate operating mode in the present time and space. We have developed an ultra-low cost, $5 device that can be installed in conference rooms, lecture halls, movie theaters, homes, and cars, which can dynamically determine the contexts in those areas and then locally broadcast the corresponding mode. Any phones in those areas are then aware of the mode in which they ought to be at that time, and can change their behavior accordingly.

28. **Networked Playscapes: Dig Deep**

V. Michael Bove, Edwina Portocarrero

Networked Playscapes re-images outdoor play by merging the flexibility of the digital world with the tangible, sensorial properties of physical play to create hybrid interactions for the urban environment.

Dig Deep takes the classic sandbox found in children's playgrounds and merges it with the common fantasy of "digging your way to the other side of the world" to create a networked interaction in tune with child cosmogony.

29. **Ofrenda Digital**

Catherine Havasi, Nina Lutz, Daniel Novy, Jason Alonso — Software for AI Characters
Sam Seaman — UROP, Fabrication and Design
Jessie Wang — UROP, Electronics and Fabrication
Support
Marianne Olsen — Senior Mechanical Engineering Thesis — Fabrication of Plaster Molded Skulls

¿Cómo puede la tecnología influir en las celebraciones culturales? // How can technology influence cultural celebrations?

Ofrenda Digital is a Digitally Augmented Physical Shrine. It utilizes dynamic projection mapping to bring a layer of dynamic information and animations to a physical ofrenda as seen in Día de Muertos.

This project immerses the user in Día de Muertos and the Spanish language. Users can interact with a variety of data driven narratives from celebrations across Mexico. Utilizing data from media across Mexico we can generate digital faces and designs around this celebration.

Each location brings up new media and context, along with generative faces. These faces are generated using a conditional styleGAN based off the photos in this area and colors generated by an archival color quantization method.

Along with being an exploratory tool, Ofrenda Digital is also an archival tool. It not only archives information from the celebration, but users can utilize it as a more traditional ofrenda. Its digital overlay structure can take in digital and physical media from users in a unique profile.

We seek to improve and apply technologies to preservation of cultural tradition as well as conversations around loss. This project is motivated by the fact that as mass migration and social and climate instability occur, these types of traditions linked to physical shrines and public spaces come under threat.

Furthermore, this project seeks to bring new layers of technology and deepen the conversation around this celebration and Latinidad.

30. **Open Water Data**

Laura Perovich, Sara Wylie (Northeastern University), Roseann Bongiovanni (GreenRoots), and ECO (GreenRoots)

The Open Water Data project explores data physicalization as a path to community engagement and action on important environmental issues. For our 2018 installation Chemicals in the Creek, we released glowing lanterns representing water quality permit violations from local facilities onto the river as part of a performance of local environmental challenges that informed a community conversation on these issues.
PerForm explores the intuitive meanings associated with the shape of objects, and how a deformable tool can allow for interaction based on a language of form. How can we use intuitive associations from senses to create intuitive interfaces where the user communicates concepts through shapes? PerForm addresses that question by allowing users to transform a physical tool to fit their intentions. A user can play different musical instruments or take different actions in games, simply by varying the shape of the tool. Since the meanings associated with the shapes would be dependent on context, we are giving special focus to studying mappings of between timbral components of sound and characteristics of shape.

**SOUND-SHAPE CORRESPONDENCES**

PerForm explores how the associations between visual and auditory perception can be used in interaction design. We developed a physical interface that users can transform by bending to create geometric shapes or symbols. By investigating possible correlations, natural or forged, between perceptual components of shape and its correlates in sound, we enable the tool to become a new instrument, with different sound timbre depending on the geometry of the object.

**A DEFORMABLE GAME CONTROLLER**

One of the applications of this shapeable device would be to enable different modes of interaction through changes in shape. Instead of having to buy multiple controller devices for each genre of gaming or kind of interaction, or simply using a single, fixed-form controller that limits the embodied experience, a device capable of transformation would enable users to have a more imaginative and creative gaming experience, even enabling new kinds of games in which the user can invent tools by varying shapes.

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Pillow-Talk is a set of connected objects intended to assist in the capture and recall digitally stored dreams and memories via natural and tangible interfaces. It consists of two devices, one of which is a pillow embedded with a voice recorder that is activated upon squeezing together several conductive patches at the corner of the pillow. This interaction minimizes the steps necessary to record a fresh memory of a dream immediately upon awakening. After the dream is recorded into the pillow, the audio file is transmitted wirelessly to a jar containing shimmering LEDs to display the “capture” of a new memory, and electronics in the jar can play back the recordings through a small speaker under its lid when it is opened.

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Holographic displays offer many advantages, including comfort and maximum realism. In this project we adapt our guided-wave light-modulator technology to see-through lenses to create a wearable 3D display suitable for augmented or virtual reality applications. As part of this work we also are developing a femtosecond-laser-based process that can fabricate the entire device by “printing.”

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We are creating consumer-grade appliances and authoring methodologies that will allow hallucinatory phenomena to be programmed and utilized for information display and narrative storytelling.

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What if our mobile devices could sense and then adapt to the spatial, temporal, and social context of their local environments? Imagine if your smartphone was smart enough to know that it should not be ringing loudly when you are in an important meeting, or that it should not be in silent mode when you are trying to find where you have misplaced it at home. We have created an inexpensive secure system that delivers this goal by embedding contextual information into the environment rather than the phone. In that way, all mobile devices at a given location can detect the broadcasted contextual information using Wi-Fi and change their behavior accordingly, without requiring any handshake or internet connection. By leveraging the latest and most inexpensive Wi-Fi modules on the market, and by building our own embedded firmware, server-side software, and mobile app, we are able to deploy this system in a secure and massively scalable way.

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We developed a CycleGAN based system to learn retrofitting mappings for word embeddings. The purpose of the system is that it generalizes the retrofitting operation for out of knowledge entities.
V. Michael Bove, Laura Perovich, Don Blair, Sara Wiley (Northeastern University)

Two of the most important traits of environmental hazards today are their invisibility and the fact that they are experienced by communities, not just individuals. Yet we don’t have a good way to make hazards like chemical pollution visible and intuitive. SeeBoat and the thermal fishing bob seek to visceralize rather than simply visualize data by creating a physical data experience that makes water pollution data present in communities.

SeeBoat is a remote control boat with sensors (temperature, turbidity, conductivity, pH) that measure local water quality and LEDs that display the data on site by changing color in real time. Data is also logged to be physically displayed elsewhere and can be further recorded using long-exposure photos. Making environmental data experiential and interactive will help both communities and researchers better understand pollution and its implications.

The Thermal Fishing Bob is an early version of this tool that has a spherical form factor and focuses on measuring water temperature as a marker for combined sewer overflows (CSOs) that may pollute rivers.

This project began in partnership with Sara Wylie (Northeastern University) in Spring 2015. Early work included Thermal Fishing Bob workshops, design iteration, prototyping, system testing with users in the Mystic River and Charles River, long exposure photography events, and further concept development. In Spring of 2017, Perovich and Wylie began a collaboration with Roseann Bongiovanni of GreenRoots, an environmental justice community group in Chelsea, MA, to test and iterate on the devices so they best suit the environmental and social context in the local community. As part of this process, Perovich continued to develop the technical side of the project to create SeeBoat, a remote control boat based system, including sensors for turbidity, conductivity, pH, radio based data communication, and designs for and early implementation of an Android app for collecting and viewing quantitative sensor data. Perovich, Wylie, and Bongiovanni are also pursuing related routes of research and community engagement around open access environmental data, the politics of space, community based data installations, and evaluating individual and group learning through extended participatory action research projects.

A publication describing their first year of collaboration can be found in their paper:

Laura J. Perovich, Sara Wylie, Roseann Bongiovanni (2018) Pokémon Go, pH, and projectors: Applying transformation design and participatory action research to an environmental justice collaboration in Chelsea, MA, Cogent Arts & Humanities, 5:1, 1-22. (Link to PDF.)

In July of 2018, the team began to collaborate with high school students and staff at the Microsoft Garage Makerspace to test the ease of fabrication of SeeBoat in a more general audience and to continue development of the SeeBoat Android app for numeric data display.

Thanks to ECO, David Ortiz, Adela Gonzalez, Leo Martinez, GreenRoots staff, Don Blair, Catherine D'Ignazio, the Boston University Law Clinic, and Dr. Sharon Harlan for their support and input on this project. Thanks to MIT undergraduates Sophia Struckman, Rod Bayliss, Robert Henning, and Claudia Chen who contributed to the technical aspect of these workshops and citizen science tool development, photographers Jorge Valdez and Shirin Adhami, the Wylie Lab at Northeastern University, Dr. V. Michael Bove and members of the Object-Based Media group at the MIT Media Lab, the MIT Arts Scholars, the Public Lab community, Mare Librum, the MIT Sailing Pavilion, and the Council for the Arts at MIT.

V. Michael Bove, Yosuke Bando, Henry Holtzman, Arata Miyamoto

ShAir is a platform for instantly and easily creating local content-shareable spaces without requiring an Internet connection or location information. ShAir-enabled devices can opportunistically communicate with other mobile devices and optional pervasive storage devices such as Wi-Fi SD cards whenever they enter radio range of one another. Digital content can hop through devices in the background without user intervention. Applications that can be built on top of the platform include ad-hoc photo/video/music sharing and distribution, opportunistic social networking and games, digital business card exchange during meetings and conferences, and local news article-sharing on trains and buses.

V. Michael Bove, Carol Rozendo

We are adding an olfactory dimension to storytelling in order to create more immersive and evocative experiences. Smell Narratives allows the authoring of a “smell track,” involving individual or proportionally mixed fragrance components.
V. Michael Bove, Santiago Eloy Alfaro

Adding augmented reality to the living-room TV, we are exploring the technical and creative implications of using a mobile phone or tablet (and possibly also dedicated devices like toys) as a controllable "second screen" for enhancing television viewing. Thus, a viewer could use the phone to look beyond the edges of the television to see the audience for a studio-based program, to pan around a sporting event, to take snapshots for a scavenger hunt, or to simulate binoculars to zoom in on a part of the scene. Recent developments include the creation of a mobile device app for Apple products and user studies involving several genres of broadcast television programming.

Pedro Colon-Hernandez

The 8K Data Manipulator is a Unity game engine application which harnesses the gesture recognition and limb tracking available through Microsoft Kinect and combines it with the multitouch capability of our 8K display. Using either gesture at a distance or close-up touch, a user can rotate, zoom, and slice a very large graphical dataset. The 8K Data Manipulator is currently being used to visualize seismic data; however, it is capable of loading an arbitrary point cloud or volume, supporting medical, terrestrial, biochemical, social network, design, and other applications.

Pedro Colon-Hernandez

An 85-inch television screen combined with 8K resolution provides a tool through which multiple users can perform quick, highly detailed, visual analysis of a dataset to identify anomalies. In order to test this, we developed a fully 3D application similar to the popular picture game Where’s Waldo. In the Where’s Waldo game, users must find a person (Waldo) within a densely-populated picture. In the developed application, users utilize touch and gestures to navigate a large 3D city in which a person of a varying size is placed randomly. The application serves as a proof of concept that multiple users can interact with one large, high resolution dataset to visually find anomalies.
Fadel Adib: Signal Kinetics
Extending human and computer abilities in sensing, communication, and actuation through signals and networks

Fadel Adib, Reza Ghaffarivardavagh, Junsu Jang, Jose Muguira Iturralde, Osvy Rodriguez

We present Piezo-Acoustic Backscatter (PAB), the first technology that enables backscatter networking in underwater environments. PAB relies on the piezoelectric effect to enable underwater communication and sensing at near-zero power. Its architecture is inspired by radio backscatter which works well in air but cannot work well underwater due to the exponential attenuation of radio signals in water.

PAB nodes harvest energy from underwater acoustic signals using piezoelectric interfaces and communicate by modulating the piezoelectric impedance. Our design introduces innovations that enable concurrent multiple access through circuit-based frequency tuning of backscatter modulation and a MAC that exploits the properties of PAB nodes to deliver higher network throughput and decode network collisions.

We built a prototype of our design using custom-designed, mechanically fabricated transducers and an end-to-end battery-free hardware implementation. We tested our nodes in large experimental water tanks at the MIT Sea Grant. Our results demonstrate single-link throughputs up to 3 kbps and power-up ranges up to 10 m. Finally, we show how our design can be used to measure acidity, temperature, and pressure. Looking ahead, the system can be used in ocean exploration, marine life sensing, and underwater climate change monitoring.

This work is funded by the Office of Naval Research.

Fadel Adib

Today’s health sensors (which monitor breathing, heartbeats, steps, etc.) require their users to wear them on their bodies. In contrast, our technologies can monitor human health without requiring the user to wear any device on his/her body. To do so, we capture and analyze wireless signals reflected off the human body; we then use these reflected signals to extract breathing and heartbeats without any physical contact with the human body. We are currently exploring techniques to remotely sense additional health metrics like blood pressure, oxygen saturation, and glucose levels. Monitoring these health metrics can render ICU (intensive care unit) vital sign monitors completely noninvasive and enable continuous monitoring of diabetes patients.

Fadel Adib, Zhihong Luo, Yunfei Ma, Giovanni Traverso (MIT Koch Institute, Harvard Medical School, Brigham & Women’s Hospital) Christoph Steiger (MIT Koch Institute, Harvard Medical School, Brigham & Women’s Hospital)

In-Vivo Networking (IVN) is the new technology that can wirelessly power and communicate with tiny battery-free devices inside the body.

In-Vivo Networking (IVN) is the new technology that can wirelessly power and communicate with tiny devices implanted deep within the human body. Such devices could be used to deliver drugs, monitor conditions inside the body, or treat disease by stimulating the brain with electricity or light.

The implants are powered by radio frequency waves, which are safe for humans. In tests in animals, we showed that the waves can power devices located 10 centimeters deep in tissue, from a distance of one meter.
RF-EATS is a new system that can verify the authenticity of food and liquids in closed containers without opening them or requiring any contact with their contents.

What kinds of food/liquids can RF-EATS be used to verify?

Below are some of the applications for which we have successfully demonstrated RF-EATS's ability to verify and detect:

- **Fake medicine.** Fake medicine is a major challenge in many developing-world countries, leading to dozens of fatalities every year. A recent incident involved fake cough medicine bottles, where 90% of the active ingredient was replaced with diethylene glycol, a compound used in making antifreeze agents.

- **Adulterated baby formula.** In 2008, the Chinese milk scandal broke out after the hospitalization of 50,000 babies due to kidney damage. Manufacturers had watered down baby formulas up to 83% and mixed them with melamine CAS NO. 108-78-1, a compound used in making plastics. The purpose of adding melamine (by manufacturers) was to conceal dilution by artificially increasing protein levels.

- **Tainted alcohol and diluted alcohol.** Tainted alcohol is an ongoing problem in many developing-world countries, including China, Indonesia, Iran, Turkey, India, and Mexico. Alcohol is tainted by mixing it with cheaper methanol, and consuming it leads to hundreds of cases of blindness and death every year.

- **Fake extra-virgin olive oil.** Recent studies have shown that 69% of US-imported extra virgin olive oil has been adulterated by mixing it with cheaper oils (e.g., peanut oil). This can lead to health hazards for consumers with (peanut) allergies. Standard adulteration levels range between 70-80%.

- **Wine fraud.** Wine fraud takes many forms. A common one involves selling consumers wine vintages that are dated to earlier years, artificially inflating their price.

- **Counterfeit perfume.** Counterfeit beauty products abound, leading Estée Lauder to confiscate over 2.6 million counterfeit items in 2016 alone. Many such products are sold online.

How accurate is the system?

Our results demonstrate that RF-EATS can achieve over 90% classification accuracy across a wide variety of applications.

How does RF-EATS work?

RF-EATS is the first RFID-based system that can noninvasively sense food and liquids in closed containers and operate correctly in environments it hasn't seen before. RFIDs are inexpensive, battery-less tags that are placed on billions of products worldwide, including food items. RF-EATS leverages the near-field coupling between a tag’s antenna and a container's contents to sense them noninvasively.

At a high level, the RFID’s signal is impacted by the dielectric of the content inside the container. So, when the content changes, its dielectric change will impact the RFID’s response.

The challenge, however, is that RFID signals are not just impacted by materials inside a container, but also by other objects in the environment around them, including other items, furniture, and even the human body.

Our solution is a new wireless AI model that enables RF-EATS to verify food and liquids despite changes in the surrounding environment. It is based on a novel RF (radio frequency) kernel function, called multipath kernel, that can be used to simulate different wireless environments. By simulating different environments, it can adapt to them.

Our results show that the system's accuracy is indeed dependent on the content of the container, specifically on dielectric differences between authentic and fake content.

To learn more about how the system works, read our paper.

This project is supported by a J-WAFS seed grant.

If you're interested in exploring the potential of using RF-EATS for detecting different kinds of contaminants or material properties, contact us at rfiq@media.mit.edu.

Fadel Adib, Yunfei Ma, Nicholas Selby

Presenting RFind, a new technology that allows us to locate almost any object with extreme accuracy by transforming low-cost, battery-free wireless stickers into powerful radars. At a high level, our technology operates by measuring the time it takes the signal to travel from the wireless sticker to an access point. By taking into account the speed of propagation of light, we can then map the time to an exact location (with sub-centimeter precision) in 3D space.

Fadel Adib, Unsoo Ha, Alaa Khaddaj, Junshan Leng

RF-EATS: Food and liquid sensing in practical environments using RFIDs
48. **RFIQ: Food quality and safety detection using wireless stickers**

Fadel Adib, Unsoo Ha, Junshan Leng, Yunfei Ma

We have developed a wireless system that leverages the inexpensive RFID tags already on hundreds of billions of products to sense potential food contamination. Our system, called RFIQ (Radio Frequency IQ), aims at democratizing food quality and safety, bringing it to the hands of consumers.

49. **RFly: Drones that find missing objects using battery-free RFIDs**

Fadel Adib, Yunfei Ma, Nicholas Selby

Can drones find missing items? Every year, companies lose billions of dollars due to misplaced items and faulty inventory records in their warehouses. Consider that the smallest Walmart warehouse is larger than 17 football fields, making it impossible to keep track of all items in the warehouse.

To overcome this challenge, we introduce RFly, a drone-based wireless system that can scan and locate items in warehouses. The system leverages cheap, battery-free RFID (Radio Frequency Identifier) stickers, which are attached to every item in the warehouse similar to barcodes. These RFIDs power up and respond with a unique identifier when commanded by a wireless device called a reader. To scan a warehouse, a drone operator dispatches a small, inexpensive, and safe drone which flies throughout a warehouse, cataloging and localizing all the RFIDs in a warehouse. The video below shows how the system operates.

50. **saving Face**

Fadel Adib, Kevin Esvelt, Pattie Maes, Joseph A. Paradiso, Guadalupe Babio Fernandez, Eyal Perry, Camilo Rojas, Irmandy Wicaksono, Cedric Honnet (visiting scientist, Responsive Environments); Niels Poulsen (visiting student, Fluid Interfaces); Nicolas Ayoub (visiting student, City Science); Zhi Wei Gan (MIT undergraduate); Korrawat (James) Pruegsanusak (MIT EECS); Franklin Zhang (MIT EECS); Aaron Stinnett (MIT IDM).

51. **Seeing Through Walls**

Fadel Adib

Our group develops technologies that can see through walls and perform motion capture through occlusions. To do so, we rely on wireless signals, like WiFi. These signals traverse walls and reflect off humans behind the wall before returning to a wireless receiver. We design and develop new algorithms and software-hardware systems that can extract these signals and analyze them to capture human motion from behind a wall.

52. **TurboTrack: 3D backscatter localization for fine-grained robotics**

Fadel Adib, Zhihong Luo, Yunfei Ma

TurboTrack is a 3D localization system for fine-grained robotic tasks, with unique capability to localize backscatter nodes with sub-centimeter accuracy without any constraints on their locations or mobility. We showed that TurboTrack can work in multiple collaborative applications with robotic arms and nanodrones including indoor tracking, packaging, assembly, and handover.

This research is partially funded by the National Science Foundation (NSF) and a Google Faculty Research Award.

53. **Wireless communication from underwater to the air**

Fadel Adib, Junsu Jang, Francesco Tonolini

Did you know that submarines today still cannot wirelessly communicate with airplanes? For decades, communicating between underwater and the air has remained an unsolved problem. Underwater, submarines use acoustic signals (or SONAR) to communicate; in the air, airplanes use radio signals like cellular or WiFi. But neither of these signals can work across both water and air.

We present TARF (Translational Acoustic-RF communication), the first technology that enables communication between underwater and the air. A TARF transmitter sends standard sound (or SONAR signals). Sound travels as pressure waves; when these waves hit the surface, they cause it to vibrate. To pick up these vibrations, a TARF receiver in the air uses a very sensitive radar. The radar transmits a signal which reflects off the water surface and comes back. As the water surface vibrates, it causes small changes to the received radar signal, enabling a TARF receiver to sense the tiny vibrations caused by the underwater acoustic transmitter.

The video below explains how TARF works and some of its applications.
Edward Boyden: Synthetic Neurobiology

Revealing insights into the human condition and repairing brain disorders via novel tools for mapping and fixing brain computations

54. 8K Brain Tour

V. Michael Bove, Edward Boyden, Shoh Asano, Yosuke Bando, Takahito Ito, Mika Kanaya
We present an 8K (7680 x 4320 pixels) visualization system for terabyte-scale, three-dimensional microscopy images of a brain slice that can facilitate neuroscience research. High resolution, large format (65” or 188 cm x 106 cm) rendering allows the viewer to dive into the massive dataset of 700 billion voxels capturing thousands of neurons and to investigate nanoscale and macroscale structures of the neurons simultaneously.

55. Cognitive Integration: The Nature of the Mind

Edward Boyden, Kevin Slavin, Joscha Bach, Adam Marblestone
While we have learned much about human behavior and neurobiology, there is arguably no field that studies the mind itself. We want to overcome the fragmentation of the cognitive sciences. We aim to create models and concepts that bridge between methodologies, and can support theory-driven research. Among the most interesting questions: How do our minds construct the dynamic simulation environment that we subjectively inhabit, and how can this be realized in a neural substrate? How can neuronal representations be compositional? What determines the experiential qualities of cognitive processes? What makes us human?

56. Implosion Fabrication

Edward Boyden, Fei Chen, Daniel Oran, Paul Tillberg

Shrinking problems in 3D printing

Although a range of materials can now be fabricated using additive manufacturing techniques, these usually involve assembly of a series of stacked layers, which restricts three-dimensional (3D) geometry. Oran et al. developed a method to print a range of materials, including metals and semiconductors, inside a gel scaffold (see the Perspective by Long and Williams). When the hydrogels were dehydrated, they shrunk 10-fold, which pushed the feature sizes down to the nanoscale.

Lithographic nanofabrication is often limited to successive fabrication of two-dimensional (2D) layers. We present a strategy for the direct assembly of 3D nanomaterials consisting of metals, semiconductors, and biomolecules arranged in virtually any 3D geometry. We used hydrogels as scaffolds for volumetric deposition of materials at defined points in space. We then optically patterned these scaffolds in three dimensions, attached one or more functional materials, and then shrink and dehydrated them in a controlled way to achieve nanoscale feature sizes in a solid substrate. We demonstrate that our process, Implosion Fabrication (ImpFab), can directly write highly conductive, 3D silver nanostructures within an acrylic scaffold via volumetric silver deposition. Using ImpFab, we achieve resolutions in the tens of nanometers and complex, non-self-supporting 3D geometries of interest for optical metamaterials.

57. Optogenetics: Molecules enabling neural control by light

Edward Boyden

We have pioneered the development of fully genetically encoded reagents that, when targeted to specific cells, enable their physiology to be controlled via light. These reagents, known as optogenetic tools, enable temporally precise control of neural electrical activity, cellular signaling, and other high-speed physiological processes using light. Such tools are in widespread use in neuroscience and bioengineering, for the study of how specific neurons contribute to cognition, emotion, and movement, and to brain disorder states, or to the remedy thereof. These tools are also being evaluated as components of prototype optical neural control prosthetics for ultra-precise treatment of intractable brain disorders. Derived from the natural world, these tools highlight the power of ecological diversity, in yielding technologies for analyzing biological complexity and addressing human health. We distribute these tools as freely as possible, and routinely host visitors to learn optogenetics.
Our research presents three classes of textile sensors.

Prototype strategies for treating brain disorders

Edward Boyden

New technologies for recording neural activity, controlling neural activity, or building brain circuits, may be capable someday of serving in therapeutic roles for improving the health of human patients - enabling the restoration of lost senses, the control of aberrant or pathological neural dynamics, and the augmentation of cognition and empathy, through prosthetic means. High throughput molecular and physiological analysis methods may also open up new diagnostic possibilities. We are inventing new noninvasive methods for targetedly controlling brain dynamics in living human subjects, and also exploring novel ways of reading activity from the brain in noninvasive fashion. We are assessing, often in collaborations with other groups, the translational possibilities opened up by our technologies, exploring the safety and efficacy of our technologies in multiple animal models, in order to discover potential applications of our tools to various clinically relevant scenarios. New kinds of "brain co-processor" may be possible which can work efficaciously with the brain to augment its computational abilities, e.g. in the context of cognitive, emotional, sensory, or motor disability.

SensorKnits: Architecting textile sensors with machine knitting

Hiroshi Ishii, Joseph A. Paradiso, Don Derek Haddad, Daniel Oran, Jifei Ou

Digital machine knitting is a highly programmable manufacturing process that has been utilized to produce apparel, accessories, and footwear. Our research presents three classes of textile sensors exploiting the resistive, piezoresistive, and capacitive properties of various textile structures enabled by machine knitting with conductive yarn.

Tools for mapping the molecular architecture and wiring of the brain

Edward Boyden

Complex biological systems such as brain circuits are extended 3-D structures made out of nanoscale building blocks such as proteins, RNAs, and lipids, which are often organized with nanoscale precision. This presents a fundamental tension in biology — to understand a biological system like a brain circuit, you might need to map a large diversity of nanoscale building blocks, across an extended spatial expanse. We are developing a new suite of tools that enable the mapping of the location and identity of the molecular building blocks of complex biological systems such as the brain, aiming to map out the architecture of such systems with enough precision to understand how the structures of biological systems lead to function and dysfunction. One of the technologies we are developing, expansion microscopy (ExM), enables large 3D objects to be imaged with nanoscale precision, by physically expanding preserved biological systems (in contrast to all previous microscopies, that magnify light from the sample via lenses). We are working to improve expansion microscopy further, and are working, often in interdisciplinary collaborations, on a suite of new labeling and analysis techniques that exploit the biochemical freedom enabled by the expanded state. We are also applying expansion microscopy to the scalable mapping of complex biological systems, including brain circuits. Such brain circuit maps may be detailed enough to enable detailed computer simulations of neural circuits. Finally, we are extending and applying such tools to the early detection and understanding of complex diseases such as cancers and autoimmune diseases, and to the analysis of aging.

Tools for recording high-speed brain dynamics

Edward Boyden

The brain is a three-dimensional, densely-wired circuit that computes via large sets of widely distributed neurons interacting at fast timescales. In order to understand the brain, ideally it would be possible to observe the electrical activity, and other intra- and intercellular signaling pathways, of many neurons — and ideally entire brains — with as great a degree of precision as possible, so as to understand the neural codes and dynamics that are produced by the circuits of the brain. Our lab and our collaborators are developing a number of innovations — such as new fluorescent reporters of cellular signals such as voltage, and new robotic and nanotechnological probes — to enable such analyses of neural circuit dynamics. These tools will hopefully enable pictures of how neurons work together to implement brain computations, and how these computations go awry in brain disorder states. Such neural observation strategies may also serve as detailed biomarkers of brain disorders or indicators of potential drug side effects. These technologies may, in conjunction with optogenetics, enable closed-loop neural control technologies, which can introduce information into the brain as a function of brain state (“brain co-processors”), enabling new kinds of circuit characterization tool as well as new kinds of advanced brain-repair prosthetic. To build these tools, we are developing supporting approaches such as robots and molecular strategies for multidimensional directed evolution of protein-based tools in mammalian cells.

Understanding normal and pathological brain computations

Edward Boyden

We are providing our tools to the community, and also using them within our lab, to analyze how specific brain mechanisms (molecular, cellular, circuit-level) give rise to behaviors and pathological states. These studies may yield fundamental insights into how best to go about treating brain disorders.
Cynthia Breazeal: Personal Robots

Building socially engaging robots and interactive technologies to help people live healthier lives, connect with others, and learn better

63. **Affective Robotic Ring**

**M.S. Suryateja Jammalamadaka, Manushaqe Muco, Ravi Tejwani**

An affective robotic ring which allows users to interact with multiple robots using finger gestures.
- Runs on Robotic Operating System (ROS)
- Affective: measures real-time electrodermal activity (EDA) of the user
- Allows the user to select from multiple robots, and guide different actions through finger movements
- Haptic feedback to user as they select various actions for a robot
- Provides a user Interface on android app, to visualize the actions of multiple robots and real-time EDA reading

A final project for the course "Sensor Technologies for Interactive Environments" (MAS.836).

64. **AI + Data Privacy Activities for K-9 Students**

**Cynthia Breazeal, Daniella DiPaola, Stephanie Nguyen**

Policymakers, practitioners, and researchers are grappling with some herculean questions regarding kids’ safety online. Homemade slime with Doctor Squish, 5-minute crafts, and Minecraft videos: What constitutes "kids content" and how do content-creators convey this effectively? How does YouTube limit and minimize data collection in practice? What does a reasonable parent-child consent process look like?

These conversations are often led by legal experts, technocrats, and academic researchers. To better understand children’s perspective and intuition of data privacy and collection, we organized a workshop with the end-user experts themselves: kids.

This project seeks to inform youth about data and privacy topics through a series of hands-on activities. The goal is to encourage students to form their own opinions and think more critically about the platforms they use every day, instead of solely listing the dangers and the “what not to do’s.”

This curriculum was piloted in January 2020 with the Girl Scouts of Eastern Massachusetts and the Edward M. Kennedy Institute.

65. **AI + Ethics Curriculum for Middle School**

**Cynthia Breazeal, Daniella DiPaola, Blakeley H. Payne**

**How do we raise conscientious consumers and designers of AI?**

Children today live in the age of artificial intelligence. On average, US children tend to receive their first smartphone at age 10, and by age 12 over half of all children have their own social media account. Additionally, it’s estimated that by 2022, there will be 58 million new jobs in the area of artificial intelligence. Thus, it’s important that the youth of today are both conscientious consumers and designers of AI.

This project seeks to develop an open source curriculum for middle school students on the topic of artificial intelligence. Through a series of lessons and activities, students learn technical concepts—such as how to train a simple classifier—and the ethical implications those technical concepts entail, such as algorithmic bias.

66. **Assessing Children’s Relationships with Social Robots**

**Cynthia Breazeal, Jacqueline M Kory Westlund, Hae Won Park, Randi Williams**

Social robots are increasingly being developed for long-term interactions with children in domains such as healthcare, education, therapy, and entertainment. In prior research, we have seen that children treat robots as more than mere artifacts, e.g., ascribing them mental states, psychological attributes, and moral standing. Thus, while children’s relationships with robots may not be like the relationships they have with their parents, pets, imaginary friends, or smart devices, they will form relationships of some kind. As such, we need to deeply understand how children’s relationships with robots develop through time, and find ways to characterize and measure these relationships. However, there are few validated assessments for measuring young children’s long-term relationships. Thus, we have adapted or created a variety of assessments for use in this context for children aged 5-6 years.

Four of these assessments are presented in the associated paper.

This paper shows that children can appropriately respond to these assessments with reasonably high internal reliability, and that these assessments are able to capture child-robot relationship adjustments over a long-term interaction.
Cognimates: Collaborative creative learning with embodied intelligent agents

Cynthia Breazeal, Stefania Druga, Sarah T. Vu, Tammy Qiu, Eesh Likith

Cognimates is a platform where parents and children (7-10 years old) participate in creative programming activities in which they learn how to build games, program robots, and train their own AI models. Some of the activities are mediated by embodied intelligent agents which help learners scaffold learning and better collaborate. Learn more about our research, projects, and learning guides.

Conversational agents and connected toys are becoming common in homes. Increasing exposure to “intelligent” technology raises important questions about the ways that children understand it and how they could learn with and from it. Embodied intelligent agents, such as social robots, afford longer-term engagement in the home for children and their families.

Building on the prior experience in the Personal Robots group of designing social robots for nurturing children’s curiosity and learning, we built a platform where children and parents can learn to program with embodied intelligent agents which in turn become learning companions (Cognimates). The goal is to enable learners to interact with a social robot but also program it, train it to remember and learn things over time, and have reflective conversations with their peers prompted by it.

Why, how, and when can embodied intelligent agents support children and parents to learn via reflective teaching? What are the new intergenerational learning pathways that Cognimates could facilitate? How can these future learning companions be integrated into various learning applications and what are the generalizable design considerations? In this research project we are addressing these questions by allowing children and parents to use a visual programming interface to control and customize an embodied intelligent agent.

Demo video

Creative AI: A curriculum around creativity, generative AI, and ethics

Cynthia Breazeal, Safinah Arshad Ali, Daniella DiPaola

As the presence of artificial intelligence expands significantly in children’s lives of learning and play, it is critical that students learn to be conscientious consumers of AI from an early age. Though the need for democratizing AI education is starting to be recognized, there are no current efforts to educate school-age children on the workings and implications of generative adversarial networks (GANs), despite their potential widespread use and misuse.

The goal of this curriculum is to teach middle school children about generative machine learning techniques and how students can partner with machines in creative expression such as art, music, poems and more. We will explore tools and techniques such as neural networks and GANs across various forms of media, such as text, images, music, and videos. We frame this curriculum as an exploration of creativity, such that children’s creative and imaginative capabilities can be enhanced by innovative technologies. Further, we aim to foster discussions throughout the workshop to highlight important ethical issues around generative AI, such as creative IP and generation of hyperrealist fake media. This course is meant to be hands-on and encourages the explorative creation of art with and without AI tools.

Throughout this course, students will have discussions around open-ended questions such as:

What is art? Who is the creator?

What is AI? What is not AI?

Who owns the art co-created with a machine?

How does generative AI work? How can I use generative AI to create media?

These questions will allow them to reflect on how machine art differs from human created art, as well as the role that machines play in technology-guided creation.

The curriculum will be taught with a series of plugged and unplugged activities, through which students will learn about generators and discriminators, examine the impact of algorithmic bias, and explore AI-driven artistic methods such as style transfer. They will also be co-creating with pre-trained GANs, gaining valuable experience in tweaking and evaluating an intelligent system. The workshop culminates in students creating their own GAN to create something personally meaningful for them. Students will organically understand the relevance and importance of this curriculum through applications of GANs that may touch their everyday lives, including interactive collaboration tools or deep fakes. By engaging with AI in different creative contexts and exercising computational action through GAN projects, students will be able to think critically about the media they create in the age of artificial intelligence.
Cynthia Breazeal, Safinah Arshad Ali

Children’s creativity—the ability to come up with novel, surprising, and valuable ideas—has been known to contribute to their learning outcomes and personal growth. Standardized ways to measure creativity and divergent thinking reported that as children enter elementary school, their creativity slumps and thinking becomes more convergent, especially around the 4th grade. One cause for this is school curricula become more structured and lose the aspect of creative play. This is especially concerning for kids growing up in the era of artificial intelligence, where mechanical and repetitive jobs that require structured thinking move to machines. To be successful in this world of intelligent agents, we must empower children not only to understand how these intelligent agents work, but also to be able to think creatively about generating new artifacts in consort with such agents, which requires imaginative, novel thought.

In this work, we explore whether a social robot’s interaction with children can be an effective way to help children think more creatively. We suggest two ways in which robots used as pedagogical tools can help children think more creatively: 1) through artificial creativity demonstration, such as showing the use of novel ideas, and 2) through offering creativity scaffolding, such as asking reflective questions, validating novel ideas, and engaging in creative conflict.

We designed four collaborative game-based activities that involve child-robot interaction and afford different forms of creative expression: 1) Droodle Game, which affords verbal creativity, 2) Magic Draw, which affords figural creativity, 3) WeDo Construction with Jibo, which affords construction creativity, and 4) Escape Adventure, which affords divergent thinking and creative problem solving. We designed the behavior of the robot such that it either scaffolds the child for creative thinking, or the robot gives the appearance of creative thinking by artificially emulating human creativity. We evaluated the role of the social robot in influencing children’s creativity by running comparative studies between children playing these creativity games while interacting with the robot with creativity-inducing behaviors (creative condition), and without creativity-inducing behaviors (non-creative condition). Children who interacted with the creative robot exhibited higher levels of creativity than children who interacted with a non-creative control robot. We conclude that children can model a social robotic peer’s creative expression via social emulation. When scaffolded for creativity, children exhibited higher levels of creativity. This enabled us to develop a robot scaffolding paradigm which fosters creativity in young children.

This project contributes design guidelines for child-robot interactions which promote creative thinking, and provides evidence that these creativity inducing behaviors exhibited by social robots can foster creativity in young children.

Cynthia Breazeal, Pedro Reynolds-Cuellar, Nikhita Singh, Tinsley Galyean, Eric Glickman-Tondreau, Stephanie Gottwald, Robin Morris, Maryanne Wolf

Curious Learning is an open platform that addresses the deployment and learning challenges faced by under-resourced communities, particularly their limited access to literacy instruction.

We are developing a system of early literacy apps, games, toys, and robots that will triage how children are learning, diagnose literacy deficits, and deploy dosages of content to encourage app play using a mentoring algorithm that recommends an appropriate activity given a child’s progress. Currently, over 200 Android-based tablets have been sent to children around the world; these devices are instrumented to provide a very detailed picture of how kids are using these technologies. We are using this big data to discover usage and learning models that will inform future educational development. The open-source software enables any Android device to be transformed into a literacy mentor. This platform is presently deployed in Ethiopia, Uganda, India, South Africa, and rural United States.

The open-source tablet software enables data collection across the deployment sites. By employing a data-driven approach to understanding learning behaviors across cultures and contexts, this project seeks to design and develop a personalized, adaptive learning platform.
Most countries are projected to see the number of people ages 65 and older surpass the population under the age of 15 by 2050. The limitations of current solutions to assisting older adults, the increased social and emotional toll on caregivers, and the inability of institutions to create structural solutions in a timely manner calls for a paradigm shift in the way we approach aging.

As these new meanings of age, aged, and aging are re-negotiated at a personal and collective level, the main goal of this research initiative is to study aging adults’ daily living assistance, social and emotional needs, and intergenerational connection while exploring the optimized modalities for embodied agents to successfully deliver these interactions. We see embodied agents as a method to enable older adults to age-in-place, supporting them in ways such as promoting social connectedness, tracking vitals, coaching in emotional wellness, and assisting with medical adherence.

Our work is rooted in partnering with the community through co-design and participatory design methods to inform robot design by empowering older adults to engage in our research. We prioritize developing robot interactions that can be tested long-term in older adults’ homes to better inform how social robots can shape aging-in-place.

Currently, we are running a long-term codesign study with older adults. Over the course of the year, older adults will engage in interviews, interactive artwork, living with a robot, prototyping on a robot, and design guideline generation.

If you are 70 years of age or older and interested in participating in future study opportunities, please contact Anastasia Ostrowski (akostrow@media.mit.edu).

Doodle Bot is a robot-based creative AI learning platform for high school students. It consists of an introduction to robotics, hardware, software programming, and machine learning. Students build, program, and train a smart drawing robot.

As a part of our broader AI education efforts, we developed the Doodle Bot toolkit that specifically aims to teach high school children about using machine learning for creative applications. We focus on generative networks and recurrent neural networks.

We piloted this kit with over 30 students in Guadalajara, Mexico and Cambridge, USA.
Inspiration

Sleep is a forgotten country of the mind. A vast majority of our technologies are built for our waking state, even though a third of our lives are spent asleep. Current technological interfaces miss an opportunity to access the unique, imaginative, elastic cognition ongoing during dreams and semi-lucid states. In turn, each of us misses an opportunity to use interfaces to influence our own processes of memory consolidation, creative insight generation, gist extraction, and emotion regulation that are so deeply sleep-dependent.

In this project, we explore ways to augment human creativity by extending, influencing, and capturing dreams in Stage 1 sleep. It is currently impossible to force ourselves to be creative because so much creative idea association and creative incubation happens in the absence of executive control and directed attention. Sleep offers an opportunity for prompting creative thought in the absence of directed attention, if only dreams can be controlled.

Scientific Background

During sleep onset, a window of opportunity arises in the form of hypnagogia, a semi-lucid sleep state where we all begin dreaming before we fall fully unconscious. Hypnagogia is characterized by phenomenological unpredictability, distorted perception of space and time, and spontaneous, fluid idea association. Edison, Tesla, Poe, and Dalí each accessed this state by napping with a steel ball in hand to capture creative ideas generated in hypnagogic microdreams when it dropped to the floor below.

Engineering and Experimentation

In this project we modernize this technique, using an interactive social robot accompanied with a custom sleep stage tracking system, and auditory biofeedback. We are able to influence, extract information from, and extend hypnagogic microdreams for the first time: we found that active use of hypnagogia with the system can augment human creativity. This system enables future research into sleep, an underutilized and understudied state of mind vital for memory, learning, and creativity. This system is a tested prototype. Dormio has a published study in alt.CHI (see publications section), a second publication under review, and is being used in four independent labs for ongoing sleep research. We’re actively presenting and testing the work in varied settings, like the McLean Technology in Psychiatry Summit and the International Sleep Replay Workshop, to gain information about sleep interventions in various conditions. We’ve just completed a second study (with 50 participants) on dream incubation and creativity augmentation.

But sleep onset is still poorly understood, and dreams are still really a mystery—we’re learning! Please reach out if anything seems off, or just to chat.

This work has been hugely collaborative. The following people, in alphabetical order by first name, have all made it possible: Abhinandan Jain, Adam Haar Horowitz, Christina Chen, Eyal Perry, Ishaan Grover, Kathleen Esfahany, Matthew Ha, Oscar Rosello, Pattie Maes, Pedro Reynolds-Cuéllar, Robert Stickgold, and Tomás Vega. For an in-depth dive, see the FAQ below and see more on this website.

If you want all the details, please read this thesis and offer any feedback!

Engagement with Voice-User Interface Agents

Cynthia Breazeal, Anastasia Ostrowski, Hae Won Park

Voice-user interfaces (VUIs), such as Amazon Echo and Google Home, are increasingly becoming present in domestic environments. Users attribute agency and personality traits to these AI agents. Due to the social attributes of these technologies, users try to understand the agents’ characteristics based on social norms. These factors affect user experience quality and overall engagement, which, when considering first experiences, can impact continuous usage and engagement with VUI technology.

Our work examines users’ first impressions and interactions with VUI agents, such as Google Home, Amazon Echo, and Jibo, with varying brands and modalities. Using personality and experience questionnaires, we seek to understand how VUI modalities, form, and personality affect engagement with VUIs.

In studies thus far, we have investigated how social embodiment, interpersonal movement, and branding influence users’ perceptions of VUIs.
How to Train Your Robot Companion is a curriculum for students in 5-8th grade to explore artificial intelligence and ethics. In this course, students participate in a range of hot-topic discussions and hands-on, creative activities to learn about how artificial intelligence is impacting society today. Students design robot companions to solve real-world problems and use machine learning to make them intelligent. At the end of the week, there is a showcase where students can share their inventions with their communities and the public.

Collaboration
We are working with i2 Learning to develop this curriculum and deliver it to general education teachers in schools around Massachusetts. i2 Learning is an organization that develops STEM curricula and professional development sessions so that all teachers can feel confident in their ability to bring hands-on STEM lessons to their classrooms. In addition to i2 Camps over the summer, i2 Learning also leads the Massachusetts STEM Week where teachers flip their classrooms upside-down for a week-long dive into STEM.

Teacher Training
With i2, we trained teachers to deliver this week-long course to their students. Our hope is to empower teachers to understand AI well enough to facilitate accurate and meaningful conversations about the impact of technology on society and the role that their students can play in shaping the future. We aim to study how teachers engage with the curriculum and their students so that we can scale learning about AI in a formal education setting.

Huggable: A social robot for pediatric care
The Huggable is a new type of robotic companion for health care, education, and social communication applications. The Huggable is much more than a fun, interactive robotic companion; it functions as an essential team member of a triadic interaction. Therefore, the Huggable is not meant to replace any particular person in a social network, but rather to enhance it.

Children and their parents may undergo challenging experiences when admitted for inpatient care at pediatric hospitals. While most hospitals make efforts to provide socio-emotional support for patients and their families during care, gaps still exist between human resource supply and demand. The Huggable project aims to close this gap by creating a social robot able to mitigate stress, anxiety, and pain in pediatric patients by engaging them in playful interactions. In collaboration with Boston Children's Hospital and Northeastern University, we ran an experimental study to compare the effects of the Huggable robot to a virtual character on a screen and a plush teddy bear. We demonstrated that children are more eager to emotionally connect with and be physically activated by a robot than a virtual character, illustrating the potential of social robots to provide socio-emotional support during inpatient pediatrics care.

Jibo Social Robotic Research Platform
The Jibo Research Platform is an in-the-field deployable Social Robotics experimentation and data collection infrastructure. Built upon the world's first commercial social robot for the home, it extends Jibo's design, hardware, and data security for research purposes.

Machine Behavior
Machines powered by artificial intelligence (AI) increasingly mediate our social, cultural, economic, and political interactions. Understanding the behavior of AI systems is essential to our ability to control their actions, reap their benefits, and minimize their harms. We argue this necessitates a broad scientific research agenda to study machine behavior that incorporates but expands beyond the discipline of computer science and requires insights from across the sciences. Here we first outline a set of questions fundamental to this emerging field. We then explore the technical, legal, and institutional constraints facing the study of machine behavior.
Cynthia Breazeal, Ishaan Grover, Jin Joo Lee, Nikhita Singh

Understanding social-emotional behaviors in storytelling interactions plays a critical role in the development of interactive and educational technologies for children. A challenge when designing for such interactions using technologies like social robots, virtual agents, and tablets is understanding the social-emotional behaviors pertinent to the storytelling context—especially when emulating a natural peer-to-peer relationship between the child and the technology.

We present P2PSTORY, a dataset of young children (5-6 years old) engaging in natural peer-to-peer storytelling interactions with fellow classmates. The dataset contains 58 recorded storytelling sessions along with a diverse set of behavioral annotations as well as developmental and demographic profiles of each child participant.

The CHI 2018 paper presenting this dataset can be found here:

See below for instructions on how to access the dataset.

Cynthia Breazeal, Huili Chen, Hae Won Park, Samuel Spaulding

The process by which children learn native languages is markedly different from the process of learning a second, or non-native, language. Children are typically immersed in their native languages. They receive input from the adults and other children surrounding them, based on immediate need and interaction, during every waking hour.

Second language learners are exposed to input from the new language in very different ways, most commonly in a classroom setting. The second language learner relies heavily on memory skills with sparse interaction, in contrast to the first language learner that can rely on environmental reinforcement and social interaction to learn words.

Social robots have the potential to drastically improve on this paradigm, making the second-language learning experience more like the experience of learning a native language by engaging the child in a rich, interactive exposure to the target language, especially aspects not typically covered by traditional technological solutions, such as prosody, fundamental phonetics, common linguistic structures, etc.

Our project explores how to design child-robot interactions that encourage child-driven language learning, that adapt and personalize each child’s learning experience. We incorporate game design and machine learning into the child-robot interaction design. The child and robot play through a suite of educational games together. Using real-time sensor data and gameplay features, the robot constructs a model of each child’s learning and emotional trajectory, then uses these models to inform its own decision making during the game. Thus, the robot’s behaviors become personalized to individual children based on their learning style, personality and knowledge/emotional states during gameplay.

Cynthia Breazeal, Huili Chen, Jon Ferguson, Jim Gray, Ishaan Grover, Hae Won Park, Pedro Reynolds-Cueilar, Nikhita Singh, Samuel Spaulding, Randi Williams, Xiaoje (Brayden) Zhang, Stephanie Gottwald (Tufts), Goren Gordon (Tel Aviv), Susan Engel (Williams College)

Could a social robot collaboratively exchange stories with children as a peer and help improve their linguistic and storytelling skills? We use machine learning algorithms to develop Companion AI to make robots learn to be helpful to young learners. Our robots learn actions that improve children’s storytelling and keep them engaged. We are also interested in how a social robot can personalize its interaction with each child over multiple encounters, because every child learns and engages differently.

In Fall 2019, we sent 18 Jibo robots to kindergarten classrooms in Atlanta. Most children in these schools come from less privileged neighborhoods, and the main focus is in prepping children with basic literacy skills, so they’re ready to learn when they get to each grade level. This ongoing project will last for the whole school year, during which time our robots will provide one-on-one, personalized story-time interaction for the young readers. Please inspect our website for teachers and parents to find detailed information about the activities.

Cynthia Breazeal, Mirko Gelsomini, Jin Joo Lee, Hae Won Park, Tonghui Zhu

Realtime detection of social cues in children’s voices

In everyday conversation, people use what are known as backchannels to signal to someone that they are still listening, paying attention, and engaged. As listeners, we smile, nod, and say “uh-huh” to convey attentiveness, and we do this naturally with little thought. We give this feedback not randomly but at certain moments in the conversation because speakers give off social cues that signal upcoming backchanneling opportunities.
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<td>83</td>
<td>Robot Mindset and Curiosity</td>
<td>Cynthia Breazeal, Safinah Arshad Ali, Anastasia Ostrowski, Hae Won Park, Goren Gordon (Tel Aviv)</td>
<td>Young Learner’s Companion: Developing robots’ growth mindset and pro-curious behavior and fostering the same in young learners via long-term interaction. A growth mindset and curiosity have significant impact on children’s academic and social achievements. We are developing and evaluating a novel expressive cognitive-affective architecture that synergistically integrates models of curiosity, understanding of mindsets, and expressive social behaviors to advance the state-of-the-art of robot companions. In doing so, we aim to contribute major advancements in the design of AI algorithms for artificial curiosity, artificial mindset, and their verbal and non-verbal expressiveness in a social robot companion for children. In our longitudinal study, we aim to evaluate the robot companion’s ability to sustain engagement and promote children’s curiosity and growth mindset for improved learning outcomes in an educational play context.</td>
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<td>84</td>
<td>Social Robots for Children with Autism</td>
<td>Cynthia Breazeal, Rosalind W. Picard, Safinah Arshad Ali</td>
<td>Families with ASD often struggle with social and emotional communication. This work explores the role of an embodied agent (a social robot) as an Augmentative and Alternative Communication (AAC) tool for families with ASD. We evaluate the usefulness of a social agent in aiding i) emotional recognition, and ii) emotional expression, over using traditional Picture Exchange Communication Systems (PECS), and tablet based AAC tools. In order to evaluate emotion recognition by children, we suggest several self report methods designed for children with ASD, evaluate each of these tools, and suggest best suited measures for self report. We iteratively design a tablet based tool that enables storytelling through a social robot.</td>
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<td>Talking Machines: Democratizing the design of voice-based agents for the home</td>
<td>Cynthia Breazeal, Anastasia Ostrowski, Hae Won Park, Nikhita Singh</td>
<td>Embodied voice-based agents, such as Amazon’s Echo, Google Home, and Jibo, are becoming increasingly present in the home environment. For most, these agents represent their first experience of living with artificial intelligence in such private and personal spaces. However, little is known about people’s desires, preferences, and boundaries for these technologies. This projects seeks to answer questions surrounding this space: How do we live with voice-based agents in the home? How do different generations interact with voice-based agents? How should these technologies be designed to incorporate people’s preferences, desires, and boundaries? What tools can be used to understand this space? This work presents insights from a long-term exploration with over 70 children, adults, and older adults over a one-year period to interact with, discover, experience, reflect upon, and design voice-based agents. In addition, design tools and learnings from the experience have been developed into an open-source design kit to enable designers and researchers to explore these ideas with the broader population. For more information, please contact Nikhita Singh (<a href="mailto:nikhita@media.mit.edu">nikhita@media.mit.edu</a>) and Anastasia Ostrowski (<a href="mailto:akoostrow@media.mit.edu">akoostrow@media.mit.edu</a>).</td>
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<td>Text-to-Motion: Automatic sequencing of animative robot motions</td>
<td>Cynthia Breazeal, Hae Won Park</td>
<td>Text-to-Motion generates a sequence of contingent robot animations to accompany the sentiment analyzed from an input sentence and its spoken audio. We trained a linear classifier to transfer our corpus of animated robot speech from DeepMoji network, a long short-term memory (LSTM) network with an attention model trained on billion tweets.</td>
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<td>88</td>
<td>The role of social robots in fostering human empathy</td>
<td>Cynthia Breazeal, Pedro Reynolds-Cuellar</td>
<td>Empathy is a core human skill. From early stages of our lives, being able to understand and behave with empathy is fundamental to our social experience. Research in the field of social robotics suggests that given a set of behaviors from a social robot, a child can perceive this agent as empathic. In this project, we explore a novel approach to modeling empathy in children using a social robot. Two social robots were programmed to have conversations containing interactions depicting empathic and non-empathic behaviors. Children were provided with opportunities to act on these interactions as well as to comment on the robot’s behavior afterward.</td>
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Tools to investigate societal impacts of robots and AI

Cynthia Breazeal, Anastasia Ostrowski, Hae Won Park

Artificial intelligence (AI) agents in an embodied form, such as Jibo, Amazon Alexa, and Google Home, are increasingly becoming part of our daily lives and our homes. While there have been numerous studies in lab settings documenting short-term individual interactions with intelligent agents, we are at a point where we need to be exploring the larger impact of these technologies in the world, living with real people over longer periods of time.

From a design research perspective, understanding and developing robots and AI that intersect with society is a “wicked problem,” a problem with many components that cannot be solved without interdisciplinary approaches. Design research within interdisciplinary applications has sought to develop approaches, methods, tools, and techniques to investigate the impact of technologies and inform future development. This work focuses on developing tools for exploring robots’ and AI’s impact on daily lives to better inform the development of these technologies by elucidating academia’s and industry’s requirements of tools for this domain.

For more information, please contact Anastasia Ostrowski (akostrow@media.mit.edu).
## Canan Dagdeviren: Conformable Decoders

**Converting the patterns of nature and the human body into beneficial signals and energy**

### A Protocol to Characterize pH Sensing Materials and Systems

**Canan Dagdeviren, Mohamed Tarek**

Although significant progress is being made in identifying pH sensing materials and device configurations, a standard protocol for benchmarking performance of next-generation pH devices is still lacking. In particular, key properties of characterization systems, such as inherent component contributions, time plots for extended-gate field-effect transistor (EGFET) measurements, and the input resistance ($R_{in}$), often go unreported in studies of pH sensing systems. These properties strongly influence the characterization system and can lead to mistaken attribution of properties to the device. In this project, a series of essential characterization tests and parameters are reported to evaluate pH systems, such as the zinc oxide (ZnO) EGFET, in a standardized protocol. This EGFET ZnO sensor has a sensitivity of $-58.1 \text{ mV pH}^{-1}$, drift range from 2.5 to 14.2 $\mu \text{A h}^{-1}$, and response time of 136 s. By using a ZnO sensing electrode, it is demonstrated that (i) intrinsic contributions of reference electrode and commercial transistor (for EGFET) are not negligible; (ii) time plots for EGFET configuration and defining a critical point at the onset of drift are essential for accurate sensitivity, response time, and drift reporting; and (iii) the results of the pH sensing system are strongly dependent on the input resistance of the used characterization instruments.

### A tailored, electronic textile conformable suit for large-scale spatiotemporal physiological sensing in vivo

**Canan Dagdeviren, Irmandy Wicaksono**

The rapid advancement of electronic devices and fabrication technologies has further promoted the field of wearables and smart textiles. However, most of the current efforts in textile electronics focus on a single modality and cover a small area. In this work, we introduce a new platform of modular, conformable (i.e., flexible and stretchable) distributed sensor networks that can be embedded into digitally-knit textiles. This platform can be customized for various forms, sizes and functions using standard, accessible and high-throughput textile manufacturing and garment patterning techniques. Here, we have developed a tailored, electronic textile conformable suit (E-TeCS) to perform large-scale, multi-modal physiological (temperature, heart rate, and respiration) sensing in vivo.

### Conformal Piezoelectric Mechanical Energy Harvesters: Mechanically Invisible Human Dynamos

**Canan Dagdeviren**

Nearly all classes of wearable and implantable biomedical devices depend on battery power for continuous operation. However, the life span of batteries is limited, rarely exceeding a few hours for wearables and a few years for implants. Consequently, battery replacements and, often times, surgical procedures are required to change the depleted batteries of implants, exposing people to high risks of surgical complications and/or high financial costs. This project seeks to develop conformal piezoelectric patches integrated to personal garments to extract energy from body movements such as motion of arms, fingers, and legs. The completion of this project could improve quality life for people and potentially provide environmentally friendly power.

### Flexible piezoelectric devices for gastrointestinal motility sensing

**Canan Dagdeviren, Zijun Wei**

Improvements in ingestible electronics with the capacity to sense physiological and pathophysiological states have transformed the standard of care for patients. Yet, despite advances in device development, significant risks associated with solid, non-flexible gastrointestinal transiting systems remain. Here, we report the design and use of an ingestible, flexible piezoelectric device that senses mechanical deformation within the gastric cavity. We demonstrate the capabilities of the sensor in both in vitro and ex vivo simulated gastric models, quantify its key behaviours in the gastrointestinal tract using computational modelling and validate its functionality in awake and ambulating swine. Our proof-of-concept device may lead to the development of ingestible piezoelectric devices that might safely sense mechanical variations and harvest mechanical energy inside the gastrointestinal tract for the diagnosis and treatment of motility disorders, as well as for monitoring ingestion in bariatric applications.
Recent advances in medications for neurodegenerative disorders are expanding opportunities for improving the debilitating symptoms suffered by patients. Existing pharmacologic treatments, however, often rely on systemic drug administration, which result in broad drug distribution and consequent increased risk for toxicity. Given that many key neural circuitries have sub-cubic millimeter volumes and cell-specific characteristics, small-volume drug administration into affected brain areas with minimal diffusion and leakage is essential. We report the development of an implantable, remotely controllable, miniaturized neural drug delivery system permitting dynamic adjustment of therapy with pinpoint spatial accuracy. We demonstrate that this device can chemically modulate local neuronal activity in small-animal (rodent) and large-animal (nonhuman primate) models, while simultaneously allowing the recording of neural activity to enable feedback control.

Canan Dagdeviren, Farita Tasnim

The past two decades have seen unprecedented progress in the development of novel materials, form factors, and functionalities in neuroimplantable technologies, including electrocorticography (ECoG) systems, multielectrode arrays (MEAs), Stentrode, and deep brain probes. This review highlights the key considerations for the development of such devices intended for acute implantation and chronic use, from the perspective of biocompatible hybrid materials incorporation, conformable device design, implantation procedures, and mechanical and biological risk factors. These topics are connected with the role that the US Food and Drug Administration (FDA) plays in its regulation of neuroimplantable technologies based on the above parameters. Existing neuroimplantable devices and efforts to improve their materials and implantation protocols are first discussed in detail. Then the effects of device implantation with regards to biocompatibility and brain heterogeneity are explored. Topics examined include brain-specific risk factors, such as bacterial infection, tissue scarring, inflammation, and vasculature damage, as well as efforts to manage these dangers through emerging hybrid, bioelectronic device architectures. The current challenges of gaining clinical approval by the FDA—in particular, its relationship to biological, mechanical, and materials risk factors—are summarized. This work concludes by discussing the available regulatory pathways to accelerate next-generation neuroimplantable devices to market.

Canan Dagdeviren, Farita Tasnim
| 96. | Brainstorm: Anima Mundi | Jeantine Lunshof, Eswar Iyer (Wyss Institute, Harvard University), Mark Skylar-Scott (Harvard John A. Paulson School of Engineering and Applied Sciences)  
We’d like to introduce you to a very special neuroscience project that we are currently conducting in the setting of a traditional fine arts museum.  
Join the conversation on the Responsive Science Brainstorm project site.  
Responsive Science uses the PubPub platform, which allows for direct interaction. PubPub was developed at MIT Media Lab. |
| 97. | City as Classroom, City as Laboratory | Devora Najjar, Avery Normandin  
Often, we neglect to see the city as living, complex, and dynamic. However, shrouded by its masses of concrete and steel lie unique ecosystems awaiting exploration and inquiry. Now more than ever, as urban populations boom and city boundaries expand, there exists a pressing need to understand urban ecology, the environmental impact of cities and their development, and the importance of designing in concert with nature, rather than against it. Yet, in spite of this, curricula for youth focused on ecology canonically instruct on topics which apply exclusively to natural, undeveloped systems—even in metropolitan schools where access to “nature” is difficult or a privilege.  
City as Classroom, City as Laboratory began as a series of educational workshops (2018) for youth in the Greater Boston area, ages 8 to 14, to simultaneously address the lack of nature-conscious design education, as well as our failure to leverage cities as invaluable resources for exploratory learning. Throughout the sessions, students explored Boston's “urban wilds” in order to become enveloped in the hybrid ecology of dynamic and ever-growing. The curriculum emphasizes low-cost, hands-on approaches for culturing ecological identity such that students are able to recognize and appreciate the complex ecological processes ongoing in urban contexts, and thus understand cities as novel ecosystems.  
The goal of this educational framework is to inspire urban youth to champion future endeavors related to the environmental and political spheres (in efforts related to conservation, wildlife protection, sustainability, infrastructure development) and to see the city as a forum for intervention.  
To learn more about the pilot curriculum and its deployment, check out this blogpost.  
Urban Ecology in Public Libraries  
Beginning in fall of 2019, the City as Classroom curriculum will be modified for deployment in public libraries as part of Media Lab’s Public Library Innovation Exchange (PLIX) program. We are currently planning a pilot series which will focus on the development of landscape literacy over four sessions.  
For questions, please contact Avery Normandin (ave@media.mit.edu). |
| 98. | Computer-Assisted Transgenesis | Kevin Esvelt, Erika Alden DeBenedictis, Cody Gilleland, Jianghong Min  
This is a new platform to automate experiments in genetic engineering and bring large-scale moonshot projects within reach. Too often, lab experiments are limited in scale by human fatigue and costs associated with manual labor. In particular, the process of delivering genetic materials via manual microinjection remains a long-standing bottleneck. We are developing a computer-assisted microinjection platform to streamline the production of transgenic organisms. Briefly, organisms are immobilized in a gel and microinjections are performed using precision robotics using computer vision algorithms. This platform demonstrated high-throughput gene editing in an animal model (C. elegans) for the first time. We will use this technology to refine and create safeguards for our gene drive technology. |
Kevin Esvelt, Joanna Buchthal, Charleston Noble, John Min, Jason Olejarz, Alejandro Chavez, Andrea L. Smidler, Erika A. DeBenedictis, George M. Church, and Martin A. Nowak.

Who should decide whether, when, and how to alter the environment? These are hard questions, especially when the decisions will impact people in many different communities or nations. Daisy drive systems may help by empowering local communities to make decisions concerning their local environments without imposing them on anyone else.

The problem with current CRISPR-based gene drive systems is that they can spread indefinitely—potentially affecting every population of the target species throughout the world. It's unclear how such "global" drives can be safely tested, much less whether nations will ever agree to use them. To return power to the hands of local communities, we devised a new form of drive system called a "daisy drive" that can only affect local environments. The trick was to teach DNA to count and limit gene drive spreading to a pre-programmed number of generations. We hope that daisy drives will simplify decision-making and promote responsible use by allowing local communities to decide how to solve their own ecological problems.

Devora Najjar, Avery Normandin, Pedro Reynolds-Cuellar, Joshua Van Zak
EEEeb Spring 2019: Urban Oceans
March 24, April 7 and 21, May 19, June 2
To register, please visit this link.

Sponsored and run by members of the MIT Media Lab and the Empowered Brain Institute, Ecology, Evolution, and Engineering for Empowered Brains is an eight-week, sensory-friendly series of related educational workshops for neurodiverse individuals (ages 8 - 14) which aims to hone skills in understanding, interpreting, and protecting the natural environment. Through creative, hands-on teaching exercises and field visits, participants become comfortable with basic ecological principles, as well as emerging technologies used to sculpt ecological and evolutionary processes. We discuss contemporary issues related to conservation and highlight engineering strategies with which to address these obstacles. Through project-based learning, students will have the opportunity to develop understanding by experimentation—or play—and workshops will emphasize immersion, rather than memorization. Wholly, we seek to foster a safe and creative learning space in which students are able to develop the necessary technical literacy to become future leaders in the myriad realms of environmental science.

For questions, please contact Avery Normandin (ave@media.mit.edu).

Kevin Esvelt

Lyme disease is the most common vector-borne infection in North America. People are infected when bitten by ticks; ticks are typically infected when they bite white-footed mice, the primary "reservoir" of the disease. We are exploring the possibility of permanently immunizing mouse populations to block transmission by making and releasing mice that produce protective mouse antibodies from birth and pass immunity on to their pups. The project has been guided by representatives in offshore island communities from inception. Communities will choose which type of antibodies, pick uninhabited islands to serve as field trial sites, select independent monitors, and ultimately decide whether to volunteer their own islands for the next stage. If successful, prevention could be expanded to the mainland using local or global gene drive systems. Whether or not communities decide to proceed, we hope the process will become a model for responsive science worldwide.

Kevin Esvelt

The world uses an estimated 100 million mice in laboratory research experiments each year. These experiments are monitored and regulated to protect animal welfare whenever possible. However, analgesics cannot completely eliminate suffering, and many studies cannot use opiates or anti-inflammatory drugs because they would interfere with the biological process being studied. The benefits of animal research may outweigh the cost in animal suffering, but it would be better to perform these experiments without animal suffering.

This project seeks to develop strains of mice that experience far less pain and suffering than current animals, but that are equally suited to laboratory and medical research. Specifically, it will be possible for researchers to perfectly prevent these mice from experiencing either acute or chronic (neuropathic) pain as needed. If successful, widespread adoption of these mice could drastically reduce animal suffering in laboratories worldwide.
Responsive Science is a way of conducting research that invites openness and community involvement from the earliest stages of each project. Real-time interaction between scientists, citizens, and broader communities allows questions and concerns to be identified before experiments are performed, fosters open discussion, and encourages research studies and new technologies to be redesigned in response to societal feedback.
Kevin Esvelt, Alex 'Sandy' Pentland, Ramesh Raskar, Input from experts from Harvard University, Stanford University, and SUNY Buffalo; clinical input from Mayo Clinic and Massachusetts General Hospital; and mentors from the World Health Organization, the US Department of Health and Human Services, and the Graduate Institute of International and Development Studies. A number of leaders and personnel from the global company EY are volunteering their time across many disciplines, including strategy and inclusion on the core initiative leadership team. Numerous additional companies are also participating in this way, including TripleBlind, Public Consulting Group, and Earned Media Consultants Experts from government agencies and academic institutes in Canada, Germany, India, Italy, the United Kingdom, and Vietnam are also helping to guide the platform's development.

Safe Paths is an MIT-led, free, open source technology that enables jurisdictions and individuals to maximize privacy, while also maximizing the effectiveness of contact tracing in the case of a positive diagnosis. The Safe Paths platform, currently in beta, comprises both a smartphone application, PrivateKit, and a web application, Safe Places. The PrivateKit app will enable users to match the personal diary of location data on their smartphones with anonymized, redacted, and blurred location history of infected patients. The digital contact tracing uses overlapped GPS and Bluetooth trails that allow an individual to check if they have crossed paths with someone who was later diagnosed positive for the virus. Through Safe Places, public health officials are equipped to redact location trails of diagnosed carriers and thus broadcast location information with privacy protection for both diagnosed patients and for local businesses.

Context

Fast containment is key to halting an epidemic outbreak. But with the long incubation period of a virus like COVID-19, it is extremely difficult to identify individuals who may have been in contact with carriers of the virus and are thus at risk of contagion. Across the globe, the use of smartphones has been tested to track location and solve this problem, raising concerns about mass surveillance. However, with our privacy-first method, the user remains in control of their data — providing a fundamentally different approach to app-based epidemic analytics.

Resilience requires citizens and organizations to self-organize so that they can predict and respond to challenges (e.g., climate change) and disruptions (e.g., COVID-19). Such orchestration would be easy if everyone involved shared data about their past activities and future intentions openly, and responded to scientific evidence in ways that supported long term resilience, fairness, inclusiveness and accountability. This is, however, is challenging due to the need to maintain privacy, consent, trade secrets and compatible incentives.

The current epidemic highlights this challenge. A “big brother” system in some countries has made a big difference in public health intervention via contact tracing, quarantine adherence verification, health verification, as well as tools for health officials such as spread analysis, resource allocation and incentive methods.

Unfortunately, network analysis of social activities leads to a surveillance state. Thus, there are several big challenges to capture, analyze and act in a closed loop: (i) population scale understanding of a fast or slow moving threat without coercing an individual to reveal anything identifiable about themselves, (ii) analyze and providing precise guidance to an individual without the orchestration system knowing to who and what message is delivered and (iii) incentivize and verify the action while maintaining a sense of agency and privacy for the individual.

These seemingly impossible problems can now be addressed thanks to: (i) deep penetration of smartphones and IoT which can act to capture, compute, disseminate and act on information, (ii) the data sources associated with these devices (iii) practical and scalable privacy preserving algorithms and (iv) incentive mechanisms for networks of people and agents which act to guide individuals to support not only themselves but the society as a whole.

Transparent, accountable, and inclusive ecosystems that can simultaneously address the privacy and utility of data in building resilient societal systems are key to humanity’s future. In the short run, digital tracing and infection spread analysis, monitoring of logistics and service chains, and simulation to help policy makers will help the current public health challenges. In the medium term, such systems will be critical in restarting socio-economic activities and get the society on track to more perm

For upcoming version releases, Private Kit: Safe Paths will deploy the following capabilities:

V1 - Log location history

V2 - Match personal location history with infected patient anonymous redacted trace files provided by public health officials

V3 - Match personal location history with encrypted anonymous redacted infected patient trace files provided by city officials
As noted, Private Kit: Safe Paths works in conjunction with the MIT-developed GIS web app, Safe Places.

Safe Places will be used by public health officials to:

Collect time-stamped location data from one of the three sources, Private Kit: Safe Paths, Google location history, and patient interviews

Produce partially obscured trace files that meet jurisdiction legal requirements for anonymity that can be posted openly on the web and utilized for contact tracing in Private Kit: Safe Paths

By enabling contact tracing, Private Kit: Safe Paths will help to reduce panic and "flatten the curve" of Coronavirus spread by enabling those who have been exposed and are showing symptoms to make more informed decisions on when to seek testing and self-quarantine—without losing individual privacy and while reducing the fear unknown exposure.

Fadel Adib, Kevin Esvelt, Pattie Maes, Joseph A. Paradiso, Guadalupe Babio Fernandez, Eyal Perry, Camilo Rojas, Irmandy Wicaksono, Cedric Honnet (visiting scientist, Responsive Environments); Niels Poulsen (visiting student, Fluid Interfaces); Nicolas Ayoub (visiting student, City Science); Zhi Wei Gan (MIT undergraduate); Korrawat (James) Pruegsanusak (MIT EECS); Franklin Zhang (MIT EECS); Aaron Stinnett (MIT IDM).

Kevin Esvelt, Cody Gilleland, Jianghong Min

How will gene drive systems evolve once released into the wild? Can they be reliably overwritten and blocked by immunizing reversal drives? Might they spread into related species? These are difficult questions because wild populations are so much larger than laboratory colonies, meaning critical evolutionary events would never be observed in the lab. We seek to develop nematode worms as a model system to help answer these questions. Nematodes are genetically tractable, reproduce twice each week, and are readily grown in populations numbering in the billions. This allows us to study drive systems intended for other organisms in nematodes. Synthetic site targeting, split drives, and ecological confinement will prevent spread into wild nematodes. Because nematodes are easy to culture and count using Foldscope microscopes, we intend to work with educators to enable students, museum-goers, and citizen scientists to participate in gene drive research.

Kevin Esvelt, Erika Alden DeBenedictis

Humanity has harnessed evolution to sculpt domesticated animals, crops, and molecules, but the process remains a black box. Which combinations of evolutionary parameters will enable us to discover the best solutions? We plan to answer this question by performing massively parallel directed evolution experiments. Our system will use phage-assisted continuous evolution (PACE), a method of building synthetic ecosystems in which billions of fast-replicating viruses compete to optimize a molecular function of our choice. We are developing methods of running many experiments in parallel, each with real-time fitness monitoring and customized evolutionary conditions such as mutation rate, selection stringency, and evolutionary goal-switching. We will use these methods to systematically characterize the relationship between evolutionary parameters and outcomes.
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<td>108.</td>
<td>Hugh Herr, David Hill</td>
<td>During the gait cycle, the human ankle complex serves as a primary power generator while simultaneously stabilizing the entire limb. These actions are controlled by an intricate interplay of several lower leg muscles that cannot be fully uncovered using experimental methods alone. A combination of experiments and mathematical modeling may be used to estimate aspects of neuromusculoskeletal functions that control human gait. In this research, a three-dimensional neuromuscular model of the human ankle-foot complex based on biplanar fluoroscopy gait analysis is presented. Driven by kinematics, kinetics, and electromyography (EMG), the model seeks to solve the redundancy problem, individual muscle-tendon contributions to net joint torque, in ankle and subtalar joint actuation during overground gait. An optimization approach was employed to calculate sets of morphological parameters that simultaneously maximize the neuromuscular model’s metabolic efficiency and fit to experimental joint torques. Optimal morphological parameter sets produce estimates of force contributions and states for individual muscles.</td>
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<td>109.</td>
<td>Hugh Herr, Matthew Carty, Tyler Clites, Lisa Freed, Shriya Srinivasan</td>
<td>Humans can accurately sense the position, speed, and torque of their limbs, even with their eyes shut. This sense, known as proprioception, allows humans to precisely control their body movements. Today’s conventional prosthetic limbs do not provide feedback to the nervous system. Because of this, people with amputated limbs cannot feel the position, speed, and torque of their prosthetic joints without looking at them, making it difficult to control their movement. In order to create a more complete prosthetic control experience, researchers at the Center for Extreme Bionics at the MIT Media Lab invented the agonist-antagonist myoneural interface (AMI). The AMI is a method to restore proprioception to persons with amputation.</td>
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<td>110.</td>
<td>Hugh Herr, Kevin Mattheus Moerman, Dana Solav</td>
<td>Local changes in the volume, shape, and mechanical properties of the residual limb can be caused by adjacent joint motion, muscle activation, hydration, atrophy, and more. These changes affect socket fit quality and might cause inefficient load distribution, discomfort, and dermatological problems. Analyzing these effects is an important step in considering their influence on socket fit, and in accounting for their contribution within the socket design process. In this study, a 360° 3D digital image correlation (3D-DIC) system was developed for the full-field deformation measurements of the residuum. A multi-camera rig was designed for capturing synchronized image sets as well as force measurements from a hand-held indenter. Custom camera calibration and data-processing procedures were specifically designed to transform image data into 3D point clouds, and automatically merge data obtained from multiple views into continuous surfaces. Moreover, a specially developed data-analysis procedure was applied for correlating pairs of largely deformed images of speckled surfaces, from which displacements, deformation gradients, and strains were calculated. Characterization of the full-field deformations using 3D-DIC provides insight into the patterns and sources of the phenomena. In addition, local and subject-specific soft tissue mechanical properties were obtained by analyzing surface deformation and force measurement during indentation using inverse FE analysis. These data can be used to accurately describe the residuum’s biomechanical behavior. Consequently, prosthetic socket designs that take into account these effects can be considered.</td>
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<td>111.</td>
<td>Hugh Herr, Matthew Carney, Tyler Clites, Lisa Freed, Tsung-Han Hsieh, Tony Shu, Seong Ho Yeon, Matthew J Carty, MD (BWH), Rickard Branemark, MD, PhD, MS (UCSF)</td>
<td>Recent advancements in orthopedic implants have made way for a new generation of bionic limbs that attach directly to the skeleton. Leveraging these “osseointegrated” implants to pass wires out of the body enables robust, long-term communication with residual muscles and the nervous system. We are exploring the ways in which the improved neural communication afforded by osseointegration can impact the experience of controlling a limb prosthesis.</td>
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112. **Artificial Gastrocnemius**

Hugh Herr

Human walking neuromechanical models show how each muscle works during normal, level-ground walking. They are mainly modeled with clutches and linear springs, and are able to capture dominant normal walking behavior. This suggests to us to use a series-elastic clutch at the knee joint for below-knee amputees. We have developed the powered ankle prosthesis, which generates enough force to enable a user to walk “normally.” However, amputees still have problems at the knee joint due to the lack of gastrocnemius, which works as an ankle-knee flexor and a plantar flexor. We hypothesize that metabolic cost and EMG patterns of an amputee with our powered ankle and virtual gastrocnemius will dramatically improve.

113. **Automated and data-driven computational design of subject-specific prosthetic sockets**

Hugh Herr, Lisa Freed, Kevin Mattheus Moerman, Bryan Ranger, Dana Solav

Complications of prosthetic leg use in persons with lower extremity amputation often occur at the prosthetic socket, and includes delayed wound healing, recurrent skin ulcerations, and pressure damage to soft tissues. Such complications can result in limited mobility, which further contributes to conditions such as obesity, musculoskeletal pathologies, and cardiovascular disease. Conventional prosthetic socket fabrication is an artisanal process requiring substantial human hours, financial cost and patient involvement for evaluation. Computer aided design (CAD) and computer aided manufacturing (CAM) methods have been explored as an alternative. However, these tools have not reached full clinical efficacy and do not inform the design in a data-driven sense since the actual design process remains a manual and experience-based procedure. The long-term goal of our research is to develop a fully-quantitative process for prosthetic socket design and production that requires minimal patient involvement and can be delivered at affordable price points.

A pre-print for our novel patient-specific and data-driven computational framework for the automated design of biomechanical interfaces is presented here. Optimization of the design of biomechanical interfaces is complex since it is affected by the interplay of the geometry and mechanical properties of both the tissue and the interface. The proposed framework is presented for the application of transtibial amputee prostheses where the interface is formed by a prosthetic liner and socket. Conventional socket design and manufacturing is largely artisan, non-standard, and insufficiently data-driven, leading to discrepancies between the quality of sockets produced by different prosthetists. Furthermore, current prosthetic liners are often not patient-specific. The proposed framework involves: A) non-invasive imaging to record patient geometry, B) indentation to assess tissue mechanical properties, C) data-driven and automated creation of patient-specific designs, D) patient-specific finite element analysis (FEA) and design evaluation, and finally E) computer aided manufacturing. Uniquely, the FEA procedure controls both the design and mechanical properties of the devices, and simulates, not only the loading during use, but also the pre-load induced by the donning of both the liner and the socket independently. Through FEA evaluation, detailed information on internal and external tissue loading, which are directly responsible for discomfort and injury, are available. Further, these provide quantitative evidence on the implications of design choices, e.g.: 1) alterations in the design can be used to locally enhance or reduce tissue loading, 2) compliant features can aid in relieving local surface pressure. The proposed methods form a patient-specific, data-driven and repeatable design framework for biomechanical interfaces, and by enabling FEA-based optimization reduces the requirement for repeated patient involvement in the currently manual and iterative design process.

114. **Biomimetic active prosthesis for above-knee amputees**

Hugh Herr, Matthew Carney, Luke Mooney

Using biologically inspired design principles, a biomimetic robotic knee prosthesis is proposed that uses a clutchable series-elastic actuator. In this design, a clutch is placed in parallel to a combined motor and spring. This architecture permits the mechanism to provide biomimetic walking dynamics while requiring minimal electromechanical energy from the prosthesis. The overarching goal for this project is to design a new generation of robotic knee prostheses capable of generating significant energy during level-ground walking, that can be stored in a battery and used to power a robotic ankle prosthesis and other net-positive locomotion modes (e.g., stair ascent).

115. **Biplanar Fluoroscopy Gait Analysis**

Hugh Herr, David Hill, Kevin Mattheus Moerman, Dana Solav, Susan E. D’Andrea

Biplanar fluoroscopy (BiFlo) enables three-dimensional bone kinematics analysis using x-ray videos and bone geometry from segmented CT. Hindered by a small capture volume relative to traditional optical motion capture (MOCAP), BiFlo applications to human movement are generally limited to single-joint motions with constrained range. Here, a hybrid procedure is developed for multi-joint gait analysis using BiFlo and MOCAP in tandem. Kinematic analysis of bones surrounding the knee, ankle, and foot was performed. Results show that this hybrid protocol effectively measures knee and ankle kinematics in all three body planes. Additionally, sagittal plane kinematics for select foot bone segments (proximal phalanges, metatarsals, and midfoot) was realized. The proposed procedure offers a novel approach to human gait analysis that eliminates errors originated by soft tissue artifacts, and is especially useful for ankle joint analysis, whose complexities are often simplified in MOCAP studies.
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<td>116</td>
<td>Computational Biomechanics</td>
<td>Hugh Herr, Kevin Mattheus Moerman, Bryan Ranger, Virginia Silva Araujo Monteiro, Dana Solav, Xingbang Yang</td>
<td>This research track focuses on the use of computational (and experimental) techniques to understand the biomechanical behavior of human tissue as well as the musculoskeletal system. This knowledge feeds into novel methods for computational modeling based design of biomechatronic devices which in turn aim to restore or improve the human body. These devices include prosthetic and orthotic devices, and exoskeletons.</td>
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<td>117</td>
<td>Control of muscle-actuated systems via electrical stimulation</td>
<td>Hugh Herr</td>
<td>Motivated by applications in rehabilitation and robotics, we are developing methodologies to control muscle-actuated systems via electrical stimulation. As a demonstration of such potential, we are developing centimeter-scale robotic systems that utilize muscle for actuation and glucose as a primary source of fuel. This is an interesting control problem because muscles: a) are mechanical state-dependent actuators; b) exhibit strong nonlinearities; and c) have slow time-varying properties due to fatigue-re recuperation, growth-atrophy, and damage-healing cycles. We are investigating a variety of adaptive and robust control techniques to enable us to achieve trajectory tracking, as well as mechanical power-output control under sustained oscillatory conditions. To implement and test our algorithms, we developed an experimental capability that allows us to characterize and control muscle in real time, while imposing a wide variety of dynamical boundary conditions.</td>
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<td>118</td>
<td>Effect of a powered ankle on shock absorption and interfacial pressure</td>
<td>Hugh Herr, David Hill</td>
<td>Lower-extremity amputees face a series of potentially serious post-operative complications. Among these are increased risk of further amputations, excessive stress on the unaffected and residual limbs, and discomfort at the human-prosthesis interface. Currently, conventional, passive prostheses have made strides towards alleviating the risk of experiencing complications, but we believe that the limit of “dumb” elastic prostheses has been reached; in order to make further strides we must integrate “smart” technology in the form of sensors and actuators into lower-limb prostheses. This project compares the elements of shock absorption and socket pressure between passive and active ankle-foot prostheses. It is an attempt to quantitatively evaluate the patient’s comfort.</td>
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<td>119</td>
<td>FitSocket: Measurement for attaching objects to people</td>
<td>Hugh Herr, Neri Oxman, Jean-Francois Duval, Arthur J Petron</td>
<td>A better understanding of the biomechanics of human tissue allows for better attachment of load-bearing objects to people. Think of shoes, ski boots, car seats, orthotics, and more. We are focusing on prosthetic sockets, the cup-shaped devices that attach an amputated limb to a lower-limb prosthesis, which currently are made through unscientific, artisanal methods that do not have repeatable quality and comfort from one individual to the next. The FitSocket project aims to identify the correlation between leg tissue properties and the design of a comfortable socket. The FitSocket is a robotic socket measurement device that directly measures tissue properties. With these data, we can rapid-prototype test sockets and socket molds in order to make rigid, spatially variable stiffness, and spatially/temporally variable stiffness sockets.</td>
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<td>120</td>
<td>FlexSEA: Flexible, scalable electronics architecture for wearable robotics applications</td>
<td>Hugh Herr, Jean-Francois Duval</td>
<td>This project aims to enable fast prototyping of a multi-axis and multi-joint active prosthesis by developing a new modular electronics system. This system provides the required hardware and software to do precise motion control, data acquisition, and networking. Scalability is achieved through the use of a fast industrial communication protocol between the modules, and by a standardization of the peripherals’ interfaces: it is possible to add functionalities to the system simply by plugging in additional cards. Hardware and software encapsulation are used to provide high-performance, real-time control of the actuators, while keeping the high-level algorithmic development and prototyping simple, fast, and easy.</td>
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<td>121</td>
<td>Human walking model predicts joint mechanics, electromyography, and mechanical economy</td>
<td>Hugh Herr, Matt Furtney, Stanford Research Institute</td>
<td>We are studying the mechanical behavior of leg muscles and tendons during human walking in order to motivate the design of power-efficient robotic legs. The Endo-Herr walking model uses only three actuators (leg muscles) to power locomotion. It uses springs and clutches in place of other essential tendons and muscles to store energy and transfer energy from one joint to another during walking. Since mechanical clutches require much less energy than electric motors, this model can be used to design highly efficient robotic legs and exoskeletons. Current work includes analysis of the model at variable walking speeds and informing design specifications for a collaborative “SuperFlex” exosuit project.</td>
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Augmentation of human locomotion has proved an elusive goal. Natural human walking is extremely efficient, and the complex articulation of the human leg poses significant engineering difficulties. We present a wearable exoskeleton designed to reduce the metabolic cost of jogging. The exoskeleton places a stiff fiberglass spring in parallel with the complete leg during stance phase, then removes it so that the knee may bend during leg swing. The result is a bouncing gait with reduced reliance on the musculature of the knee and ankle.

Matthew Carney, Che-Wei Wang, Aaron Cantrell, Philip Brown, Nick Moser, Jesse Jarrell, Dave Carlberg, Patrick Kennedy, Jake Horsey, Mike Stone, Steph Whalen, Nelson Madaleno, Ruben Rosa, Paul Voss

Designed for mass manufacture and rapid deployment, we are building an open hardware, reusable, sterilizable, modular, and filter-media agnostic face mask that aims to hit the N95 efficacy criteria.

Matthew Carney, Lucy Du, Matthew Handford, Jiu-Yih Kuan, Ken A. Pasch, Emily Rogers, Tony Shu, Roman Stolyarov, Matt Weber, Seong Ho Yeon

Mechanical, electrical, and dynamic control systems recreate biological behavior with synthetic hardware.

Hugh Herr, Kevin Mattheus Moerman, Dana Solav

Three-dimensional Digital Image Correlation (3D-DIC) is a non-contact optical-numerical technique for evaluating the dynamic mechanical behavior at the surface of structures and materials, including biological tissues. 3D-DIC can be used to extract shape and full-field displacements and strains with high resolution, at various length scales. While various commercial and academic 3D-DIC software exist, the field lacks 3D-DIC packages which offer straightforward calibration and data-merging solutions for multi-view analysis, which is particularly desirable in biomedical applications. To address these limitations, we present MultiDIC, an open-source MATLAB toolbox, featuring the first 3D-DIC software specifically dedicated to multi-view setups. MultiDIC integrates robust two-dimensional subset-based DIC software with specially tailored calibration procedures, to reconstruct the dynamic behavior of surfaces from multiple stereo-pairs. MultiDIC contains novel algorithms to automatically merge meshes from multiple stereo-pairs, and to compute and visualize 3D shape and full-field motion, deformation, and strain. User interfaces provide capabilities to perform 3D-DIC analyses without interacting with MATLAB syntax, while standalone functions also allow proficient MATLAB users to write custom scripts for specific experimental requirements. This paper discusses the challenges underlying multi-view 3D-DIC, details the proposed solutions, and describes the algorithms implemented in MultiDIC. The performance of MultiDIC is tested using a low-cost experimental system featuring a 360-deg 12-camera setup. The software and system are evaluated using measurement of a cylindrical object with known geometry subjected to rigid body motion and measurement of the lower limb of a human subject. The findings confirm that shape, motion, and full-field deformations and strains can be accurately measured, and demonstrate the feasibility of MultiDIC in multi-view in-vivo biomedical applications.
Hugh Herr, Tyler Clites, Lisa Freed, Benjamin Maimon, Ron Riso, Shriya Srinivasan, Cameron Taylor, Seong Ho Yeon, Matthew J. Carty, MD (BWH), Rickard Branemark, MD, PhD (UCSF)

Nerve-Muscle Graft Chamber and micro-channel arrays for interface to peripheral nerves for prosthesis control.

This research effort consists of two sub-projects with the goal to develop a small implantable device for achieving bi-directional communication with the amputated nerves in a prosthesis user's residuum. The nerve-muscle graft chamber (NMGC) is a small implanted device which contains one or more electrically isolated chambers (ca. 20mm l x 4mm h x 4mm w) that can be filled with muscle or cutaneous tissue. The electrical activities of the components of a compound peripheral nerve that in the intact limb sub-served different motor functions can be separated by mechanically dividing the nerve and placing each isolated nerve segment into apposition with a small piece of muscle tissue in each of the separate chambers of the NMGC. For example, the muscle filled chambers can be ganged together in a modular design so that a single implanted device containing three chambers would interface to motor nerve fascicles that provide prosthesis command signals for three different motor functions. For a mixed peripheral nerve that is known to contain cutaneous fascicles as well as motor fascicles, an additional compartment could be added that contains cutaneous tissue. This would be done to provide an appropriate target for regenerating cutaneous nerve fibers to prevent the cutaneous axons from competing with regenerating motor nerve fibers and errantly taking up residence in the muscle tissues. Also, by provide cutaneous target tissue, regenerating sensory afferent nerve fiber are less likely to result in the formation of potentially painful neuromas.

The second sub-project aims to develop a micro-channel array into which peripheral nerve fibers will grow into. Because the micro-channels are on the order of 100 to 200 um I.D., only a small number of nerve fibers will be present in an individual micro-channel. This can potentially provide greater separation of axons by their functionality. Such separation by function is important when seeking to provide cutaneous and proprioceptive feedback by means of direct electrical activation of the sensory components of the interfaced peripheral nerves.

Edward Boyden, Hugh Herr, Tyler Clites, Lisa Freed, Benjamin Maimon, Ron Riso, Shriya Srinivasan, Cameron Taylor, Seong Ho Yeon, Matthew J. Carty, MD (BWH), Rickard Branemark, MD, PhD (UCSF)

Recent advances in artificial limbs have resulted in the provision of powered ankle and knee function for lower extremity amputees and powered elbow, wrist, and finger joints for upper extremity prostheses. Researchers still struggle, however, with how to provide prosthesis users with full volitional and simultaneous control of the powered joints. This project seeks to develop means to allow amputees to control their powered prostheses by activating the peripheral nerves present in their residual limb. Such neural control can be more natural than currently used myoelectric control, since the same functions previously served by particular motor fascicles can be directed to the corresponding prosthesis actuators for simultaneous joint control, as in normal limbs. Future plans include the capability to electrically activate the sensory components of residual limb nerves to provide amputees with tactile feedback and an awareness of joint position from their prostheses.

Hugh Herr, Samantha Gutierrez-Arango, Shriya Srinivasan

This study investigates the effect of preserving proprioceptive peripheral neuromuscular constructs (through AMI amputation) on central sensorimotor cortical reorganization. Through task-based functional MRI, heightened functional connectivity, preservation of sensorimotor function, and enhanced sensory capacities for improved neuroprosthetic controllability are observed in patients with AMI amputation as compared with their matched standard amputation controls.

This project is in collaboration with the Martinos Center for Biomedical Imaging.

Matthew Carney, Jean-Francois Duval, Matthew Handford, Tsung-Han Hsieh, Tony Shu, Seong Ho Yeon

The design of next-generation bionic ankles and knees aims to improve bionic actuators on all metrics: range of motion, power density, bandwidth, and mass, while adopting a futuristic aesthetic. We are pushing the limits of materials and magnets, combined with new control topologies to enforce a new paradigm in both autonomous and volitional controlled powered prostheses.

Open access enginXiv pre-prints are available:

Energetic Consequences of Series and Parallel Springs in Lower-Extremity Powered Prostheses

Design and Preliminary Results of a Reaction Force Series Elastic Actuator for Bionic Ankle Prostheses
The human ankle provides a significant amount of net positive work during the stance period of walking, especially at moderate to fast walking speeds. Conversely, conventional ankle-foot prostheses are completely passive during stance, and consequently, cannot provide net positive work. Clinical studies indicate that transtibial amputees using conventional prostheses experience many problems during locomotion, including a high gait metabolism, a low gait speed, and gait asymmetry. Researchers believe the main cause for the observed locomotion is due to the inability of conventional prostheses to provide net positive work during stance. The objective of this project is to develop a powered ankle-foot prosthesis that is capable of providing net positive work during the stance period of walking. To this end, we are investigating the mechanical design and control system architectures for the prosthesis. We are also conducting a clinical evaluation of the proposed prosthesis on different amputee participants.

Lower-extremity amputation surgery has not seen significant change since the Civil War. This research is focused on the development of novel amputation paradigms that leverage native biological end organs to interpret efferent motor commands and to provide meaningful neural feedback from an artificial limb. Surgical replication of natural agonist-antagonist muscle pairings within the residuum allow us to use biomimetic constructs to communicate joint state and torque from the prosthesis directly to the peripheral nervous system. We hypothesize that these architectures will facilitate control of advanced prosthetic systems to improve gait and reduce metabolic cost of transport.

Current unmotorized prostheses do not provide adequate energy return during late stance to improve level-ground locomotion. Robotic prostheses can provide power during late-stance to improve metabolic economy in an amputee during level-ground walking. This project seeks to improve the types of terrain a robotic ankle can successfully navigate by using command signals taken from the intact and residual limbs of an amputee. By combining these command signals with sensors attached to the robotic ankle, it might be possible to further understand the role of physiological signals in the terrain adaptation of robotic ankles.

Although there have been great advances in the control of lower extremity prostheses, transitioning between terrains such as ramps or stairs remains a major challenge for the field. The mobility of leg amputees is thus limited, impacting their quality of life and independence. This project aims to solve this problem by designing, implementing, and integrating a combined terrain-adaptive and volitional controller for powered lower limb prostheses. The controller will be able to predict terrain changes using data from both intrinsic sensors and electromyography (EMG) signals from the user; adapt the ankle position before footfall in a biologically accurate manner; and provide a torque profile consistent with biological ankle kinetics during stance. The result will allow amputees to traverse and transition among flat ground, stairs, and slopes of varying grade with lower energy and pain, greater balance, and without manually changing the walking mode of their prosthesis.

This project explores the effects of hardware intervention on human gait. Our current system works in parallel with a subject’s biological legs to provide an unprecedented level of gait enhancement, without causing discomfort or inhibiting natural motion. Multiple controller designs are being developed to explore the effects of intervention on the metabolic cost of transport, as well as gait pathologies and adaptation. This system provides a powerful tool in the analysis of human locomotion that will lead to potential innovations in mobility, rehabilitation, and athletics.

This project aims to build a powerful system as a scientific tool for bridging the gap in the literature by determining the dynamic biomechanics of the lower-limb joints and metabolic effects of physical interventions during natural locomotion. This system is meant for use in applying forces to the human body and measuring force, displacement, and other physiological properties simultaneously, helping investigate controllability and efficacy of mechanical devices physically interacting with a human subject.
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<th><strong>Transdermal Optogenetic Peripheral Nerve Stimulation</strong></th>
<th>Edward Boyden, Hugh Herr, Lisa Freed, Benjamin Maimon, Shriya Srinivasan</th>
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<td>Optogenetic techniques have recently been applied to peripheral nerves as a scientific tool with the translatable goal of alleviating a variety of disorders, including chronic pain, muscle fatigue, glucose-related pathologies, and others. When compared to the electrical stimulation of peripheral nerves, there are numerous advantages: the ability to target molecularly defined subtypes, access to opsins engendering neural inhibition, and optical recruitment of motor axons in a fashion that mimics natural recruitment, which eliminates the fatigue roadblock inherent to functional electrical stimulation. The ability to control peripheral nerves situated under deep tissue structures with transdermal, optical signals would be of enormous benefit, integrating all of the advantages conferred by optogenetics while averting the drawbacks associated with implantable devices, such as mechanical failure, device tissue heating, and a chronic foreign body response.</td>
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<td>We work to develop novel molecular and optical methods in an effort to enable this transdermal optogenetic peripheral nerve control. A further example of a potential clinical application involves optogenetically targeting the vagus nerve, a peripheral cranial nerve implicated in numerous ailments, including epilepsy, migraines, obesity, hypertension, fibromyalgia, Crohn’s disease, asthma, depression, and obsessive-compulsive disorder. An efficient method of stimulating the vagus nerve with minimal side-effects and high target specificity, such as described here, may have profound implications to the study of various illnesses and disabilities.</td>
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<th>137.</th>
<th><strong>Ultrasound imaging for transtibial prosthetic interface design</strong></th>
<th>Hugh Herr, Kevin Mattheus Moerman, Bryan Ranger, Brian W. Anthony</th>
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<td>In the United States, there are an estimated 1.7 million people living with amputation, with that number expected to double by 2050. Complications of prosthetic leg use in persons with lower extremity amputation (LEA) include delayed wound healing, recurrent skin ulcerations, and pressure damage to soft tissues. This can result in limited mobility, which further contributes to conditions such as obesity, musculoskeletal pathologies (e.g., osteoarthritis, osteopenia, and osteoporosis), as well as cardiovascular disease. Traditionally, fabrication of prosthetic sockets remains a fundamentally artisanal process with limited input of quantitative data. Even with advances in computer-aided design and manufacturing (CAD/CAM), prosthetists often modify sockets using non-quantitative craft processes requiring substantial human hours and financial cost. The goal of this research is to develop and validate musculoskeletal ultrasound imaging techniques for creating predictive biomechanical models of residual limbs that will reduce the barrier for and cost of computer aided design (CAD)-driven prosthetic socket design in the US and in low-and middle-income countries.</td>
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<tr>
<th>138.</th>
<th><strong>Volitional control of a powered ankle-foot prosthesis</strong></th>
<th>Hugh Herr, Oliver A Kannape</th>
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<td>This project focuses on giving transtibial amputees volitional control over their prostheses by combining electromyographic (EMG) activity from the amputees’ residual limb muscles with intrinsic controllers on the prosthesis. The aim is to generalize biomimetic behavior of the prosthesis, making it independent of walking terrains and transitions.</td>
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Hiroshi Ishii: Tangible Media

Seamlessly coupling the worlds of bits and atoms by giving dynamic physical form to digital information and computation

The project investigates how to make origami structure with inflatables with various materials. We introduce a universal bending mechanism that creates programmable shape-changing behaviors with paper, plastics, and fabrics. We developed a software tool that generates this bending mechanism for a given geometry, simulates its transformation, and exports the compound geometry as digital fabrication files. A custom heat-sealing head that can be mounted on usual three-axis CNC machines to precisely fabricate the designed transforming material is presented. We envision this technology could be used for designing interactive wearables and toys, and for the packaging industry.

Visit http://tangible.media.mit.edu/project/aeromorph/.

Honorable Mention Paper Award, UIST 2016

AnimaStage

We present AnimaStage: a hands-on animated craft platform based on an actuated stage. Utilizing a pin-based shape display, users can animate their crafts made from various materials. Through this system, we intend to lower the barrier for artists and designers to create actuated objects and to contribute to interaction design using shape-changing interfaces for inter-material interactions.

We introduce a three-phase design process for AnimaStage with examples of animated crafts. We implemented the system with several control modalities that allow users to manipulate the motion of the crafts so that they could easily explore their desired motion through an iterative process. Dynamic landscapes can also be rendered to complement the animated crafts. We conducted a user study to observe the subject and process by which people make crafts using AnimaStage. We invited participants with different backgrounds to design and create crafts using multiple materials and craft techniques. A variety of outcomes and application spaces were found in this study.

Project Page

Daniel Visan Levine

How can people learn advanced motor skills such as front flips and tennis swings without starting from a young age? The answer, following the work of Masters et. al., we believe, is implicitly. Implicit learning is associated with higher retention and knowledge transfer, but that is unable to be explicitly articulated as a set of rules. To achieve implicit learning is difficult, but may be taught using obscured feedback — that is, feedback that does not directly describe the result of an action.

With AUFLIP, we sought to provide auditory feedback to help newcomers learn front flips. We created a wearable system with a simplified model of a front flip that compares a user’s time to peak rotation against their ideal time. As the user approaches their ideal performance, the system begins playing a chord, only completing the chord if the user manages to rotate at their ideal peak time. We tested this system by integrating it into an environment where professional coaches teach novices how to perform front flips; we found preliminary results suggesting that users wearing the device exhibited implicit learning.

Amos Golan, Ken Nakagaki, Jifei Ou, Penelope Eugenia Webb
Cells’ biomechanical responses to external stimuli have been intensively studied but rarely implemented into devices that interact with the human body. We demonstrate that the hygroscopic and biofluorescent behaviors of living cells can be engineered to design biohybrid wearables, which give multifunctional responsiveness to human sweat. By depositing genetically tractable microbes on a humidity-inert material to form a heterogeneous multilayered structure, we obtained biohybrid films that can reversibly change shape and biofluorescence intensity within a few seconds in response to environmental humidity gradients. Experimental characterization and mechanical modeling of the film were performed to guide the design of a wearable running suit and a fluorescent shoe prototype with bio-flaps that dynamically modulates ventilation in synergy with the body’s need for cooling.

**ChainFORM**

ChainFORM is a modular hardware system for designing linear shape-changing interfaces. Each module is developed based on a servo motor with added flexible circuit board, and is capable of touch detection, visual output, angular sensing, and motor actuation. Moreover, because each module can communicate with other modules linearly, it allows users and designers to adjust and customize the length of the interface. Using the functionality of the hardware system, we propose a wide range of applications, including line-based shape changing display, reconfigurable stylus, rapid prototyping tool for actuated crafts, and customizable haptic glove. We conducted a technical evaluation and a user study to explore capabilities and potential requirements for future improvement.

**Cillia: 3D-printed micro pillar structures for surface texture, actuation, and sensing**

In nature, hair has numerous functions such as providing warmth, adhesion, locomotion, sensing, and a sense of touch, as well as its well-known aesthetic qualities. This work presents a computational method of 3D printing hair structures. It allows us to design and generate hair geometry at 50 micrometer resolution and assign various functionalities to the hair. The ability to fabricate customized hair structures enables us to create superfine surface texture, mechanical adhesion properties, new passive actuators, and touch sensors on a 3D-printed artifact. We also present several applications to show how the 3D-printed hair can be used for designing everyday interactive objects.

**Circuit Robots: Mass manufacturing of self-actuating robots**

Currently, the manufacturing of self-actuating and self-sensing robots requires non-standard manufacturing techniques and assembly steps to integrate electrical and mechanical systems. In this work, we developed a novel manufacturing technique, where such robots can be produced at a flexible electronics factory. We developed the technique using standard industrial machines, processes, and materials. Using a lamination process, we were able to integrate air pouches or shape memory alloy (SMA) inside a polyamide-based flexible circuit to produce bending actuators. The bend angle of the actuators is sensed with a chain of inertial measurement units integrated on the actuator. Air-pouch actuators can produce a force of 2.24 N, and a maximum bend angle of 74 degrees. To demonstrate, we manufactured a five-legged robot with the developed actuators and bend sensors, with all the supporting electronics (e.g., microcontrollers, radio) directly integrated into the flexible printed circuit. Such robots are flat and lightweight (15 grams) and thus conveniently compact for transportation and storage. We believe that our technique can allow inexpensive and fast prototyping and deployment of self-actuating and self-sensing robots.

**CONJURE**

A recent focus of our lab has been making use of Tangible Displays and Body Object Space to develop new assistive technologies. As a test case, we prototyped the Mario side-scrolling game for visually impaired users, using body movement analogies to control Mario in the game. Mario and 2D side scrollers present a particularly interesting case, as they keep the main character location in the center of the display and move the world around the character. The shape display itself provides spatial audio of enemy positions. We make use of the AUFLIP sensor platform to pick up body movements—walking and jumping, causing Mario to do the same in-game. This enables users to keep their hands engaged to understand the game landscape, while using their body to control Mario at the same time.
HydroMorph is an interactive display based on shapes formed by a stream of water. Inspired by the membrane formed when a water stream hits a smooth surface (e.g., a spoon), we developed a system that dynamically controls the shape of a water membrane. This project explores a design space of interactions around water shapes, and proposes a set of user scenarios in applications across scales, from the faucet to the fountain. Through this work, we look to enrich our interaction with water, an everyday material, with the added dimension of transformation.

As part of human evolution and revolution, food is among the earliest forms of human interaction, but it has remained essentially unchanged from ancient to modern times. What if we introduced engineered and programmable food materials? With that change, food can change its role from passive to active. Food can “communicate” using its inherent behaviors combined with engineering accuracy. Food becomes media and interface. During an MIT winter course we initiated and taught, we encouraged students to design pneumatic food. Students successfully implemented inflatable sugar and cheese products. To inflate food, we use both an engineering approach and a biological approach; to solidify the inflated food, we introduce both heat via the oven, and coldness with liquid nitrogen.

Shape displays can be used to render both 3D physical content and user interface elements. We propose to use shape displays in three different ways to mediate interaction: facilitate, providing dynamic physical affordances through shape change; restrict, guiding users through dynamic physical constraints; and manipulate, actuating passive physical objects on the interface surface. We demonstrate this on a new, high-resolution shape display.

This project introduces layer jamming as an enabling technology for designing deformable, stiffness-tunable, thin sheet interfaces. Interfaces that exhibit tunable stiffness properties can yield dynamic haptic feedback and shape deformation capabilities. In contrast to particle jamming, layer jamming allows for constructing thin and lightweight form factors of an interface. We propose five-layer structure designs and an approach that composites multiple materials to control the deformability of the interfaces. We also present methods to embed different types of sensing and pneumatic actuation layers on the layer-jamming unit. Through three application prototypes we demonstrate the benefits of using layer jamming in interface design. Finally, we provide a survey of materials that have proven successful for layer jamming.

kinetiX is a transformable material featuring a design that resembles a cellular structure. It consists of rigid plates or rods and elastic hinges. These modular elements can be combined in a wide variety of ways and assembled into multifarious forms.

This project describes a group of auxetic-inspired material structures that can transform into various shapes upon compression. While the majority of the studies of auxetic materials focus on their mechanical properties and topological variations, our work proposes a parametric design approach that gives auxetic structures the ability to deform beyond shrinking or expanding. To do so, we see the auxetic structure as a parametric four-bar linkage. We developed four cellular-based material structure units composed of rigid plates and elastic/rotary hinges. Different compositions of these units lead to a variety of tunable shape-changing possibilities, such as uniform scaling, shearing, bending and rotating. By tessellating those transformations together, we can create various higher level transformations for design. The simulation is validated by the 3D printed structures.

We hope this work will inspire research in metamaterials design, shape-changing materials, and transformable architecture.

LeakyPhones is a public/private headset that was designed to encourage face-to-face interactions, curiosity, and healthier social skills by letting users “peek” into each other’s music just by looking at one another.

Gaze is an important social signal in human interaction. Though its interpretation may vary across cultures, it is generally agreed that eye contact indicates interest and the point of attention in a conversation. Despite this, many common personal computing technologies, such as our smartphones and headphones, require significant visual and auditory attention thereby inhibiting our ability to interact with others. LeakyPhones offers a new approach for addressing this challenge.
Hiroshi Ishii, Ken Nakagaki

We propose a novel shape-changing interface that consists of a single line. Lines have several interesting characteristics from the perspective of interaction design: abstractness of data representation; a variety of inherent interactions/affordances; and constraints such as boundaries or borderlines. By using such aspects of lines together with added transformation capability, we present various applications in different scenarios: shape-changing cords, mobiles, body constraints, and data manipulation to investigate the design space of line-based shape-changing interfaces.

Amos Golan

The future of human life outside of Earth will heavily depend on the ability to fabricate and manufacture things. Yet fabrication in space poses numerous difficulties. Some of these challenges include storage space in vehicles, availability of raw materials, lack of machines, and shortage of manpower.

Other challenges in fabricating objects in space are simply a result of the different physical environment; the lack of gravity introduces unexpected material behaviour, as other forces aside from gravity become dominant. Surface tension, for example, becomes very dominant in determining the shape of liquid materials and adhesion between liquids and other materials also plays a more dominant role.

Because of the reasons stated above, 3D printing in space was conceptually limited to fused deposition modeling (FDM) technologies, which are less susceptible to problems resulting from the harsh conditions. Liquid- or powder-based printing technologies are assumed to be very problematic for space fabrication because of liquid behavior in microgravity conditions. On the other hand, FDM technologies have a lot of limitations such as the inability to create transparent structures or layerless shapes with defined smooth curvatures.

In this experiment, we would like to harness surface tension’s dominance in liquid behavior under zero gravity conditions to create various controllable and accurate, layerless and transparent geometries using UV-curable resin. The resin will be hardened using a high-power UV light source.

We will focus on rapid fabrication (in under 17 seconds) of the following shapes:

Shapes that are hard to make on Earth without special machinery, e.g., perfect lenses.

Shapes and materials that could be necessary in the space environment and are hard to make with existing methods available in space, such as ball bearings.

Hiroshi Ishii, Daniel Leithinger, Ken Nakagaki, Luke Vink, Daniel Windham, Jared Counts, Daniel Leithinger, Sean Follmer

Shape-changing interfaces give physical shape to digital data so that users can feel and manipulate data with their hands and body. Combining techniques from haptics with the field of shape-changing interfaces, we propose a technique to build a perceptive model of material properties by taking advantage of the shape display’s ability to dynamically render flexibility, elasticity, and viscosity in response to the direct manipulation of any computationally rendered physical shape. Using a computer-generated relationship between the manipulated pins and nearby pins in the shape display, we can create human proprioception of various material properties. Our results show that users can identify varying material properties in our simulations through direct manipulation, and that this perception is gathered mainly from their physical relationship (touch) with the shape display and its dynamic movements.

Hiroshi Ishii, Xiao Xiao

MirrorFugue is an installation for a player piano that evokes the impression that the “reflection” of a disembodied pianist is playing the physically moving keys. Live music emanates from a grand piano, whose keys move under the supple touch of a pianist’s hands reflected on the lacquered surface of the instrument. The pianist’s face is displayed on the music stand, with subtle expressions projecting the emotions of the music. MirrorFugue recreates the feeling of a live performance, but no one is actually there. The pianist is an illusion of light and mirrors, a ghost both present and absent. Viewing MirrorFugue evokes the sense of walking into a memory, where the pianist plays without awareness of the viewer’s presence; or, it is as if viewers were ghosts in another’s dream, able to sit down in place of the performing pianist and play along.
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<td>158</td>
<td>Pneuduino</td>
<td>Hiroshi Ishii, Felix Heibeck, Jifei Ou, Lining Yao</td>
<td>Pneuduino is a hardware platform for kids, students, artists, designers, and researchers who are interested in controlling air flow and pressure for their projects. The Pneuduino toolkit is currently used in workshops with high school or college students. While each workshop has a different focus, they all introduce concepts of air as actuator and sensor as well as different fabrication methods to create transforming artifacts. Air is one the most abundant resources on earth. By adding computation ability to air, we can create new types of materials that enable us to design robots that are soft, furniture that is adaptive, clothing that is intelligent, and art pieces that are breathing.</td>
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<td>159</td>
<td>Pneumatic Shape-Changing Interfaces</td>
<td>Hiroshi Ishii, Jifei Ou, Lining Yao</td>
<td>An enabling technology to build shape-changing interfaces through pneumatically driven, soft-composite materials. The composite materials integrate the capabilities of both input sensing and active shape output. We explore four applications: a multi-shape mobile device, table-top shape-changing tangibles, dynamically programmable texture for gaming, and a shape-shifting lighting apparatus.</td>
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<td>160</td>
<td>Printflatables: Printing human-scale, functional, and dynamic inflatable objects</td>
<td>Hiroshi Ishii, Pattie Maes, Yasuaki Kakehi, Jifei Ou, Harpreet Sareen, Udayan Umapathi, Patrick Shin, MIT Mechanical Engineering</td>
<td>Printflatables is a design and fabrication system for human-scale, functional and dynamic inflatable objects. The user begins with specifying an intended 3D model which is decomposed to two dimensional fabrication geometry. This forms the input for a numerically controlled contact iron that seals layers of thermoplastic fabric. In this project, we showcase the system design in detail, the pneumatic primitives that this technique enables and merits of being able to make large, functional and dynamic pneumatic artifacts. We demonstrate the design output through multiple objects which could motivate fabrication of inflatable media and pressure-based interfaces.</td>
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<td>161</td>
<td>Programmable Droplets</td>
<td>Hiroshi Ishii, Udayan Umapathi, Patrick Shin (undergraduate researcher), Sam Gen Chin (undergraduate researcher), Dimitris Koutentakis (undergraduate researcher), Carolyn E. Will (undergraduate researcher), Rui Qing (Center for Bits and Atoms)</td>
<td>State-of-the-art liquid handling systems are generally pump-driven systems connected with valves and tubes. These systems are manually assembled, expensive, and unreliable. With the growth of the genomic and drug industries, we are moving toward increasingly complex biological processes requiring very small volume liquid manipulation capability. Manually assembled mechanical systems do not scale to parallel manipulation of large amounts of small volume liquids. However, the electronics industry has demonstrated how to build robust integrated systems for information manipulation. With this as our motivation, we look toward electronics and integrated circuits to bring miniaturization, complexity, and integration to enable the next generation of biology.</td>
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<td>162</td>
<td>Radical Atoms</td>
<td>Hiroshi Ishii, Leonardo A. Bonanni, Jean-Baptiste Labrune, Daniel Leithinger, Xiao Xiao</td>
<td>Radical Atoms is our vision of interactions with future materials. Radical Atoms goes beyond Tangible Bits by assuming a hypothetical generation of materials that can change form and appearance dynamically, becoming as reconfigurable as pixels on a screen. Radical Atoms is a computationally transformable and reconfigurable material that is bidirectionally coupled with an underlying digital model (bits) so that dynamic changes of physical form can be reflected in digital states in real time, and vice versa.</td>
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<td>SensorKnits: Architecting textile sensors with machine knitting</td>
<td>Hiroshi Ishii, Joseph A. Paradiso, Don Derek Haddad, Daniel Oran, Jifei Ou</td>
<td>Digital machine knitting is a highly programmable manufacturing process that has been utilized to produce apparel, accessories, and footwear. Our research presents three classes of textile sensors exploiting the resistive, piezoresistive, and capacitive properties of various textile structures enabled by machine knitting with conductive yarn.</td>
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TRANSFORM fuses technology and design to celebrate its transformation from still furniture to a dynamic machine driven by a stream of data and energy. TRANSFORM aims to inspire viewers with unexpected transformations and the aesthetics of the complex machine in motion. First exhibited at LEXUS DESIGN AMAZING MILAN (April 2014), the work comprises three dynamic shape displays that move over one thousand pins up and down in real time to transform the tabletop into a dynamic tangible display. The kinetic energy of the viewers, captured by a sensor, drives the wave motion represented by the dynamic pins. The motion design is inspired by dynamic interactions among wind, water, and sand in nature, Escher’s representations of perpetual motion, and the attributes of sand castles built at the seashore. TRANSFORM tells of the conflict between nature and machine, and its reconciliation, through the ever-changing tabletop landscape.

Introducing TRANSFORM, a shape-changing desk. TRANSFORM is an exploration of how shape display technology can be integrated into our everyday lives as interactive, transforming furniture. These interfaces not only serve as traditional computing devices, but also support a variety of physical activities. By creating shapes on demand or by moving objects around, TRANSFORM changes the ergonomics and aesthetic dimensions of furniture, supporting a variety of use cases at home and work: it holds and moves objects like fruit, game tokens, office supplies, and tablets, creates dividers on demand, and generates interactive sculptures to convey messages and audio.

In this work, we propose a novel fabrication method for 3D objects based on the principle of spooling. By wrapping off-the-shelf materials such as thread, ribbon, tape or wire onto a core structure, new objects can be created and existing objects can be augmented with desired aesthetic and functional qualities. Our system, WraPr, enables gesture-based modelling and controlled thread deposition. We outline and explore the design space for this approach. Various examples are fabricated to demonstrate the possibility to attain a range of physical and functional properties. The simplicity of the proposed method opens the grounds for a light-weight fabrication approach for the generation of new structures and the customization of existing objects using soft materials.
Joseph M. Jacobson: Molecular Machines

Engineering at the limits of complexity with molecular-scale parts

Affinity: Deep Learning API for Molecular Geometry

Joseph M. Jacobson, Maksym Korablyov, Kfir Schreiber, Andrew Gritsevskiy, Isaac Wolverton, Aditi Harini, Manvitha Ponapatti

Affinity is a high-level machine learning API (Application Programming Interface) dedicated exclusively to molecular geometry. Affinity is written in TensorFlow; a small proportion of high-performance code is in low-level C++. Depending on the application it can be configured as multi-CPU, multi-CPU single GPU, or multi-GPU system. Affinity has its own web page at affinity.mit.edu

DeepPPI

Kfir Schreiber

Protein-protein interactions (PPIs) are an essential part of many biological pathways in living organisms. With use cases such as regulation of gene expression, enzymatic catalyzation, and muscle contraction, understanding PPIs is a critical step toward a better understanding of life itself. Moreover, aberrant human PPIs may lead to multiple diseases, such as Alzheimer’s, Creutzfeldt–Jakob, and cancer. Despite the undisputed importance of PPIs, only a small portion of the human interactome is known.

The PPI mapping problem is composed of two subproblems: the Interaction Problem—identifying the two or more proteins involved in a particular interaction; and the Position Problem—recognizing the residues within the interacting proteins that are crucial for the interaction (also known as hot spots or interacting residues). Current experimental techniques for PPI mapping, like Yeast 2 Hybrid or Alanine scans, are limited in scale, tedious, and expensive, therefore establishing the need for a fast, efficient, and accurate computational system.

DeepPPI is a Deep Learning algorithm that uses known PPIs to identify recurring patterns in the human interactome. These underlying patterns can be used, in turn, to predict both the existence of a new interaction and the interacting residues within the relevant proteins. Through this project, we hope to answer a fundamental biological question: How does nature, via evolution, create new protein-protein interactions? Additionally, we believe that DeepPPI will serve as a large-scale computational alternative to Alannine Scans and other experimental methods, contributing to the study of diseases and development of new therapeutics.

Designer molecular mops:

Shilei Hao, Rui Qing, Shuguang Zhang

In April 2019, Shuguang Zhang’s lab started to use the QTY code to design a class of water-soluble cytokine receptors, including interferon receptors and interleukin receptors, to overcome a major medical problem called a cytokine storm. A cytokine storm is a potentially life-threatening side effect seen in CAR-T (chimaera antigen receptor T-cells) treatment of leukemia, lymphoma and perhaps other cancers. Symptoms include fever, fatigue, loss of appetite, muscle and joint pain, nausea, vomiting, diarrhea, rashes, fast breathing, rapid heartbeat, low blood pressure, seizures, headache, confusion, delirium, hallucinations, tremor, and loss of coordination. A cytokine storm is the overreaction of patients’ own immune systems that can result in multi-organ failure. COVID-19 is known to cause severe and often fatal cytokine storm in patients with acute infection.

One year ago, Zhang’s lab set out to design a chimera of the water-soluble QTY-variant of cytokine receptors fused with the Fc domain of Immunoglobulin G (IgG). The resulting chimeric cytokine receptors can function as “molecular mops” as they bind with excessive cytokines released in the cytokine storm, thus protecting the patient from multi-organ failure. The development of a broad spectrum of hydrophilic, functional cytokine receptor-IgG compounds may provide significant therapeutic benefits.

Shuguang Zhang has always emphasized asking good questions and pursuing curiosity-driven research. He often quotes Francis Crick: “If you ask big questions, you get big answers.” Such curiosity-driven research again demonstrates that it is very important to ask a big question in order to overcome a major medical problem in clinics, rather than pursuing crisis-driven, reactive research. The research initiated in April 2019 is directly relevant to the treatment of the most severely infected COVID-19 patients. Curiosity-driven, or even proactive research often leads to preparedness which is key to preventing future disasters.
Technological advances in the past decade have allowed us to take a close look at the proteomes of living organisms. As a result, more than 120,000 solved protein structures are readily available, and we are still on an exponential growth curve. By looking at the proteomes of current living organisms, we are essentially taking snapshots of the successful results in this evolutionary process of continuous adaptation to the environment. Could we process the information available to us from nature to design new proteins, without the need for millions of years of Darwinian evolution?

To answer this question, we are developing an integrated Deep Learning framework for the evolutionary analysis, search, and design of proteins, which we call Evolutron. Evolutron is based on a hierarchical decomposition of proteins into a set of functional motif embeddings. Two of our strongest motivations for this work are gene therapy and drug discovery. In both cases, protein analysis and design play a fundamental role in the implementation of safe and effective therapeutics.

Bioelectronics is an emerging interdisciplinary field which utilizes biomolecules in electronics, mimics biological architectures, or builds electronic-living organism interfaces. One important aspect of the field is to fabricate sensors for label-free biomolecules detection. Researchers previously designed sensors based on i) metal-oxide-semiconductor (MOSFET), ii) polymers, and iii) inorganic crystalline materials which produce good sensitivity, but lack selectivity. Recent efforts are devoted to directly connecting biological receptors with electronic systems. G protein-coupled receptors (GPCRs) serve as suitable candidates as they are the largest family of membrane receptors that detect information (molecules and lights) and transduce to cell internal signals to regulate body functions.

There are ~1,000 GPCR proteins in human cells, each one highly specific to a particular signal. QTY-designed, detergent-free GPCR receptors can be modified and attached to recombinant-SbpA proteins, which are capable of reproducing two-dimensional crystalline monolayers on various electronic surfaces, as demonstrated by Prof. Uwe Sleytr in Vienna, Austria. SbpA 2D crystalline guides the orientation of the attached GPCRQTY receptors and exposes their active binding sites. The self-assembly yields functional molecules with high density \( >10^{12} \) molecule/cm\(^2\). The bioelectronics platform yields detectable electrical, electrochemical, or optical signals in response to the biological stimuli from the receptor layer. When coupled with different types of receptors, this approach may be a platform for bioelectronics and ultrasensitive-sensing systems.

The CRISPR-Cas9 system has proven to be a versatile tool for genome editing, with numerous implications in medicine, agriculture, bioenergy, food security, and beyond. The range of targetable DNA sequences is limited, however, by the need for a short sequence of DNA beside the target site, called the PAM. In total, there are only a handful of CRISPR enzymes with a short enough PAM sequence to be able to target a large portion of the total DNA in a genome. In this study, we identify a natural Cas9 enzyme from the bacterial genome of Streptococcus canis that has a PAM sequence with only a single G as its PAM sequence (5'-NNG-3'), allowing flexible targeting of up to 50% of all DNA sequences in living organisms. This new molecular tool potentially grants unprecedented access to correct disease-related mutations, enhance agricultural methods, and expand research efforts.

In addition to a large number of membrane proteins that comprise most alpha-helix transmembrane segments, there are also many transmembrane proteins with mostly beta-sheets, called beta-barrel membrane proteins. These beta-barrel proteins are often involved in molecular transports. Some are enzymes that are involved in lipid metabolism. We now use the QTY code to design water-soluble beta-barrel transmembrane proteins. Such water-soluble, beta-barrel proteins will facilitate studies of the molecular mechanisms of high selectivity of molecular transport and how these beta-barrel membrane proteins carry out lipid catalysis and metabolism. New insight gained from these studies may be useful for further designs of new molecular devices.
G protein-coupled receptors (GPCRs) are vital for diverse biological functions, including vision, smell, and aging. They are also involved in a wide range of diseases, and are among the most important targets of medicinal drugs. Tools that facilitate GPCR studies or GPCR-based technologies or therapies are thus critical to develop. We used QTY code (glutamine, threonine, tyrosine) to systematically replace 29 membrane-facing leucine (L), isoleucine (I), valine (V), and phenylalanine (F) residues in the transmembrane alpha-helices of the GPCR CXCR4. This variant, CXCR4QTY29, became more water-soluble, while retaining the ability to bind its natural ligand CXCL12. When transfected CXCR4QTY29 gene into HEK293 cells, the translated CXCR4QTY29 receptor inserted into the cell membrane and retained its cellular signaling activity. This QTY code can significantly improve GPCR and membrane protein studies by making it possible to design functional hydrophilic receptors. The QTY code can be applied to diverse α-helical transmembrane proteins, and may aid in the development of other applications, including clinical therapies.

Joseph M. Jacobson, Pranam Chatterjee, Noah Jakimo

We are currently developing novel DNA editing technologies to broaden the scope of genome engineering. Our strategy is based on identifying and engineering endonucleases from diverse living systems, along with targeting with synthetic molecules. Together these components confer greater stability, minimize off-target DNA cleavage, and eliminate sequence restrictions for precision genetic manipulations within cells.

Rui Qing, Shuguang Zhang

There are 20 chemokine receptors that bind their respective chemokines. It is not currently understood how these structurally similar receptors distinguish their ligands; namely, how EC loops and transmembrane domains of these receptors are involved in ligand-binding activities. With the detergent-free GPCRs, we show that it is now possible to design and produce chimeric receptor proteins to study ligand-binding mechanisms. We exchanged the N terminus and 3 EC loops of natural chemokine receptor CXCR4 to append them onto the 7TM α-helices of detergent-free variant CCR5QTY, and systematically studied which ligands it binds. These designer chimeric receptors provide insight into how natural receptors bind their respective ligands. These chimeric receptors with tunable functionality may have applications for bioelectronics sensing devices.

QTY-designed, detergent-free chemokine receptors have been expressed in SF9 insect cells, as well as produced using a low cost and simple E.coli system with much higher throughput. These QTY-designed receptor variants exhibit remarkable heat stability in the presence of arginine additive, retaining ligand binding activity after 100°C treatment. New protein variants can also be designed using the same alpha-helical segments but switching the extracellular (EC) loop, e.g., using variant B’s EC loop to directly attach to variant A’s alpha-helical segments. This approach helps our understanding of the binding mechanism of QTY variants and natural membrane receptors, as well as enables a novel pathway for the design and production of multi-functional, water-soluble membrane receptors, with tunable properties for in vitro and in vivo applications.
Kent Larson: City Science
Looking beyond smart cities

177. 3D Mobility
 Kent Larson, Guadalupe Babio Fernandez, Arnaud Grignard
Unfolding the way we move.

Mobility has shaped the built environment since humans started settling together. From industrial towns to post-industrial innovation and service hubs, the mobility mode of the era was key in shaping not only the physical attributes of cities, but also the efficacy. In order to allocate the massive migration from rural areas, cities are growing and becoming more dense. Although high density can minimize transportation cost and energy, several problems start to appear if they are not planned carefully. Urban ventilation potential is reduced and open seen spaces are limited, compromising our experience and life quality. Residential, office, and retail get closer but remain arranged in conventional ways. A two-dimensional street that organizes the way we live and keeps transportation methods are in permanent conflict. Too fast for those who live in it, and too slow and congested for those that go by.

Urban mobility is becoming more electric, more autonomous, more shared, and more connected, indicators that call for a mobility revolution, and designers have the chance to reinvent the way city is experienced.

Today, more than ever, the scale and rate of urban expansion is making mobility solutions a key concern, which will impact large segments of the global population since it is estimated that by 2050, more than two thirds of the global population will be living in cities. We propose a new experience and mobility around cities, unfolding the city networks and using its third dimensions, different mobility, speed modes (static, mass transportation, internal transportation), public areas appearing in rooftops, and mix-use spaces in interstitial parts of buildings. Through simulation as a tool, we can understand the impact of this new disrupting mobility system, avoiding to repeat mistakes like those made in the past.

Kent Larson, Luis Alberto Alonso Pastor, Ronan Doorley, Arnaud Grignard, Ariel Noyman

How can we get more value from the same buildings?

Cities contain many different resources and spaces and typically, these resources operate as products with a single function and a single owner and/or renter. However, the owner’s demand for space often varies daily or seasonally, meaning that many buildings tend to be underutilized and are often vacant or partially vacant for large portions of each day.

Meanwhile, the “sharing economy” has been one of the most significant economic shifts in the last 10 years, with companies like Uber and Airbnb experiencing explosive growth. Along these lines, Aalto University—a member of the MIT Media Lab City Science network—has developed the concept of City-as-a-Service, where building space and other resources are shared among institutions, businesses, and citizens in a community. Aalto has already begun experimenting with School-as-a-Service, as a prototype of City-as-a-Service on their campus in Espoo.

Kent Larson, Luis Alberto Alonso Pastor, Juanita Devis, Ronan Doorley, Arnaud Grignard, Yan Leng, Ariel Noyman, Carsten Smuts, J. Ira Winder, Yan Zhang, Dalma Foldesi, Jung In Seo, Ariel Noyman, Yasushi Sakai, Mikita Samsonau, Poseidon Ho, Carson Smuts

View the main City Science Andorra project profile.

Research in dynamic tools, mix users (citizens, workers) amenities, services, and land use, with the goal of promoting sustainable development.

Kent Larson, Luis Alberto Alonso Pastor, Juanita Devis, Arnaud Grignard, Carsten Smuts, Núria Macià (Fundació ActuaTech), Juanita Devis, Marcel Corominas (Andorrarodrones), Guillem Santacreu (Government of Andorra), Esteve Bardoset (Government of Andorra), Alexi Dorca (University of Andorra), Marc Unzueta (University of Barcelona), Marc Pons (OBSA), Marc Vilella (OBSA), Oriol Traveset (OBSA), Jordi Martin (University of Girona), Xavier Forne (FEDA), Josep Ribes (ActuaTech), Oriol Lordan (University of Barcelona), Cristina Yañez (UdA), Francesco Pilla, Anna Penzo, Tossaporn Saengja, Ronald Dooley, Yan Leng, Anna Sinelnikova, Brian Wheatman, Alejandro Noriega

View the main City Science Andorra project profile.
The MIT Media Lab’s City Science research group, the University of Andorra, and national and international companies are collaborating in order to bring an innovative ecosystem into the capital of Andorra. This innovation district aims to engage local citizens, researchers, and R&D from the companies in order to build together an Andorran living lab, an “innovation district” where national and international companies can test and deploy their products and ideas and cultivate human capital.

**Current Projects**
- Andorra Innovation Space
- Andorra Cultural Heritage
- Drones patterns and flows, collaboration living lab
- Young Future

**Andorra | Innovation**

The MIT Media Lab’s City Science research group, the University of Andorra, and national and international companies are collaborating in order to bring an innovative ecosystem into the capital of Andorra. This innovation district aims to engage local citizens, researchers, and R&D from the companies in order to build together an Andorran living lab, an “innovation district” where national and international companies can test and deploy their products and ideas and cultivate human capital.

**Current Projects**
- Andorra Innovation Space
- Andorra Cultural Heritage
- Drones patterns and flows, collaboration living lab
- Young Future

**Andorra | Tourism**

With more than eight million visitors a year, tourism represents almost 30% of the economy of Andorra. By gathering and analyzing data from social media, call detail records, and wifi, we can understand the country’s dynamics of tourism and commerce as well as design interventions that can improve the experience for tourists, encouraging them to visit Andorra more frequently, stay longer, and increase spending.

**Current Projects**
- Event Analysis
- Social Network
- Location Recommendation system

**Event Analysis**

Based on the analysis of call detail records and social media, the goal of this project is to understand the tourist behaviors in Andorra. After mining those anonymized data, we have been able to learn different patterns and behaviors of the tourism in Andorra thanks to an agent-based model developed in order to represent the flow of people. This simulation is also coupled with an interactive table called CityMatrix.

**Assessing Disease Exposure Risk With Location Histories And Protecting Privacy**

Governments and researchers around the world are implementing digital contact tracing solutions to stem the spread of infectious disease, namely COVID-19. Many of these solutions threaten individual rights and privacy. Our goal is to break past the false dichotomy of effective versus privacy-preserving contact tracing. We offer an alternative approach to assess and communicate users’ risk of exposure to an infectious disease while preserving individual privacy.

**AR Enhanced Wall Plants: Escape Pod**

An environment of plants and mirrors that extends beyond the terrarium walls.

**Kent Larson, Luis Alberto Alonso Pastor, Juanita Devis, Ronan Doorley, Arnaud Grignard, Ariel Noyman, Carson Smuts, Marcel Corominas (Andorradrones), Guillem Santacreu (Govern d’Andorra), Esteve Barolet (Govern d’Andorra), Aleix Dorca (Universitat d’Andorra), Marc Unzueta (Universitat Politècnica de Catalunya), Jordi Guerrero (Parc Científic i Tecnològic de la Universitat de Girona), Oriol Lordan (Universitat Politècnica de Catalunya), Cristina Yáñez (Universitat d’Andorra), Xavier Forné (FEDA), Núria Macià (Fundació ActuaTECH), Cristina Yáñez (Universitat d’Andorra), Lara Martínez (Universitat d’Andorra), David Mas (Departament de Patrimoni Cultural d’Andorra), Abel Fortó García (Departament de Patrimoni Cultural d’Andorra), Sara Ubach Balagüé (Departament de Patrimoni Cultural d’Andorra), Dalma Földesi, Núria Macià, Guillem Francisco Giné, Marc Vilella

View the main City Science Andorra project profile.

**Andorra | Innovation**

Kent Larson, Luis Alberto Alonso Pastor, Juanita Devis, Ronan Doorley, Arnaud Grignard, Ariel Noyman, Carson Smuts, Marcel Corominas (Andorradrones), Guillem Santacreu (Govern d’Andorra), Esteve Barolet (Govern d’Andorra), Aleix Dorca (Universitat d’Andorra), Marc Unzueta (Universitat Politècnica de Catalunya), Jordi Guerrero (Parc Científic i Tecnològic de la Universitat de Girona), Oriol Lordan (Universitat Politècnica de Catalunya), Cristina Yáñez (Universitat d’Andorra), Xavier Forné (FEDA), Núria Macià (Fundació ActuaTECH), Cristina Yáñez (Universitat d’Andorra), Lara Martínez (Universitat d’Andorra), David Mas (Departament de Patrimoni Cultural d’Andorra), Abel Fortó García (Departament de Patrimoni Cultural d’Andorra), Sara Ubach Balagüé (Departament de Patrimoni Cultural d’Andorra), Dalma Földesi, Núria Macià, Guillem Francisco Giné, Marc Vilella

View the main City Science Andorra project profile.

**Andorra | Tourism**

Kent Larson, Luis Alberto Alonso Pastor, Juanita Devis, Ronan Doorley, Arnaud Grignard, Nina Lutz, Ariel Noyman, J. Ira Winder, Naichun Chen, Yan Leng, Alejandro Noriega, Joseph Cunningham, Rejul Sachdev, Claire Tsao, David Sukhin, Tanya Ivonchyk, Wei Hou Wu, Ryan Zang, Núria Macià (Fundació ActuaTech), Marc Vilella (OBSA), Nina Lutz

View the main City Science Andorra project profile.

**AR Enhanced Wall Plants: Escape Pod**

Alex Berke

An environment of plants and mirrors that extends beyond the terrarium walls.

**Assessing Disease Exposure Risk With Location Histories And Protecting Privacy**

Kent Larson, Alex ’Sandy’ Pentland, Ramesh Raskar, Michiel Bakker, Alex Berke, Dan Calacci, Praneeth Vepakomma

Governments and researchers around the world are implementing digital contact tracing solutions to stem the spread of infectious disease, namely COVID-19. Many of these solutions threaten individual rights and privacy. Our goal is to break past the false dichotomy of effective versus privacy-preserving contact tracing. We offer an alternative approach to assess and communicate users’ risk of exposure to an infectious disease while preserving individual privacy.
Autonomous vehicles (AVs), drones, and other types of robots will revolutionize our way of traveling and understanding urban space. In order to operate, all of these devices are expected to collect, analyze, and share sensitive data about our daily activities. However, current approaches of handling these datasets rely on centralized models (e.g., corporate databases, cloud-based services, etc.). Recently, it has been shown that the security and privacy-preserving capabilities of these centralized models present significant challenges for future deployments. For this reason, this project proposes BASIC, the Blockchained Agent-based Simulator for Cities. This tool aims to verify the feasibility of using blockchain as a communication layer between agents (e.g., citizens, robots, etc.) in simulated urban scenarios. In order to test the proposed tool, we propose a car-sharing scenario populated with AVs within the city of Cambridge (Massachusetts, USA).

As bikes navigate city streets after dark, they are often equipped with lights. The lights make the bikes visible to cars or other bikers, and the hazards of traffic less dangerous.

Imagine that as solitary bikes come together, their lights begin to pulsate at the same cadence. The bikers may not know each other, or may only be passing each other briefly, but for the moments they are together, their lights synchronize. The effect is a visually united presence, as groups of bikes illuminate themselves with a gently pulsing, collective light source.

The development of transportation improvements in any city poses a range of challenges, including meaningfully involving relevant stakeholders. With many members of the public generally skeptical of government’s ability to generate solutions that will work for them, transport agencies and community organizations are looking for better ways to engage each other and the general public in developing project ideas. One problem is that existing representational tools are not well suited for allowing diverse stakeholders to understand, evaluate, and provide feedback on the geographically distributed benefits and tradeoffs of potential transport decisions. These decisions range widely, from local pedestrian flows around public transport stations, to parking provision on streets, to corridor alignment and priority schemes that can affect regional connectivity.

In recent years, however, new cooperative planning tools have emerged, made possible by the rapidly growing availability of open-source data platforms and interactive computing technology. These technologies promise to facilitate the inclusion of local knowledge in a way that could transform public participation.

Starting from the premise that meaningful public engagement is fundamental to doing transit right, together with the Mobility Futures Collaborative at MIT Department of Urban Studies and Planning (DUSP), we developed several interactive planning tools to see if they can enable inclusive and authentic dialogue. Open dialogue is a cornerstone of meaningful engagement and learning in collaborative planning settings. We designed the interactive tools to allow individuals to explore impacts and alternatives at the regional, neighborhood, and street scales. With support from the Barr Foundation, and in partnership with Nuestra Comunidad, a local community development organization, the tools were deployed in a series of public workshops held in October 2015 in Boston’s Roxbury neighborhood. These pilot workshops focused on the potential for implementing Bus Rapid Transit (BRT). While the tools were tested using the case of BRT corridors in the Boston area, we believe they have applicability to planning for a broader range of transportation alternatives in a variety of settings.

These tools include the CityScope—an interactive platform that utilizes physical models (built from LEGO bricks) and 3-D projection—to enable community members to engage in neighborhood and street-level decisions including alternative bus corridor designs and station-level variations (such as pre-pay boarding). The second tool, CoAXs, is a new interactive platform for collaborative transit planning that builds on open-source urban analytics tools such as Conveyal Transport Analyst.
Ariel Noyman
Cloud-Based Urban Data Platform

cityIO (input/output) is a cloud- and database-driven platform which allows remote participation, database augmentation, and high-end complex visualization. CityIO operates anywhere, on multiple platforms and devices, using client-side apps or web-based interfaces. The CityIO platform is built for scale and to serve large volumes of end-users in real time, in order to augment multi-participant discussions and decision-making processes. Utilizing the mass adaptation of mobile and hand-held devices, CityIO promotes an equal and decentralized discussion for multiparty stakeholders. CityIO offers a suite of augmented reality data-visualization tools that utilize server-side data and analysis. CityIO allows client-side interactions in multiple forms:

AUGMENTED REALITY URBAN SIMULATION

CityIO is intended to reduce complexity in design and planning tools and to support data-driven environments for planners, designers, and decision makers. CityIO uses modern simulation tools and employs cutting-edge AR applications in order to offer an immersive user experience for both planning professionals and the general public. These simulations can augment indoor and outdoor environments, physical models, and technical drawings.

REMOTE AND DECENTRALIZED PUBLIC PARTICIPATION

Using self-explanatory web and mobile apps with high-end visualization and user interfaces, CityIO offers cities, municipalities, and planning authorities the ability to better communicate complex planning processes and to aggregate the public’s opinion in real time. CityIO’s scalable server side allows multiple users to collaborate, participate, and voice their opinions on design and planning initiatives.

CITYIO HAMBURG

CityIO Hamburg augments CityMatrix table. This deployment allows design in the urban context of the Rothenburgsort neighborhood.

Kent Larson, Luis Alberto Alonso Pastor, Arnaud Grignard, Yan Zhang, Alex Aubuchon, Kevin A Lyons

An Urban Decision-Support System Augmented by Artificial Intelligence

The decision-making process in urban design and urban planning is outdated. Currently, urban decision-making is mostly a top-down process, with community participation only in its late stages. Furthermore, many design decisions are subjective, rather than based on quantifiable performance and data. Current tools for urban planning do not allow both expert and non-expert stakeholders to explore a range of complex scenarios rapidly with real-time feedback.

CityMatrix was an effort towards evidence-based, democratic decision-making. Its contributions lie in the application of Machine Learning as a versatile, quick, accurate, and low-cost approach to enable real-time feedback of complex urban simulations and the implementation of the optimization searching algorithms to provide open-ended decision-making suggestions. The goals of CityMatrix were:

Designing an intuitive Tangible User Interface (TUI) to improve the accessibility of the decision-making process for non-experts.

Creating real-time feedback on multi-objective urban performances to help users evaluate their decisions, thus to enable rapid, collaborative decision-making.

Constructing a suggestion-making system that frees stakeholders from excessive, quantitative considerations and allows them to focus on the qualitative aspects of the city, thus helping them define and achieve their goals more efficiently.

CityMatrix was augmented by Artificial Intelligence (AI) techniques including Machine Learning simulation predictions and optimization search algorithms. The hypothesis explored in this work was that the decision quality could be improved by the organic combination of both strengths of human intelligence and machine intelligence.

The system was pilot-tested and evaluated by comparing the problem-solving results of volunteers, with or without AI suggestions. Both quantitative and qualitative analytic results showed that CityMatrix is a promising tool that helps both professional and non-professional users understand the city better to make more collaborative and better-informed decisions.
Kent Larson, Luis Alberto Alonso Pastor, Arnaud Grignard, Ariel Noyman

Aalto University, Finland, and the MIT Media Lab’s City Science group are co-developing a version of the MIT CityScope platform for urban analysis, efficient resource utilization, and spatial programming for campus development, using Otaniemi as a testbed. Aalto joins a network of City Science collaborators which includes Tongji University (Shanghai), Taipei Tech (Taiwan), HafenCity University (Hamburg), and ActuaTech (Andorra).

Kent Larson, Luis Alberto Alonso Pastor, Juanita Devis, Ronan Doorley, Arnaud Grignard, Maitane Iruretagoyena, Michael Lin, Ariel Noyman, Carson Smuts, Phil Tinn, Yan Zhang, Núria Macià (Fundació ActuaTech), Marc Vilella (OBSA), Marc Pons (OBSA), Guillem Francisco Giné (OBSA), Cristina Yañez (UdA)

Andorra and the City Science research group at the MIT Media Lab are taking on the challenge of turning Andorra into an "Internationally Recognized Intelligent Country." The Andorra Living Lab project combines different research topics (tourism, innovation, energy and environment, mobility, dynamic urban planning) for the future urban challenges of the country. We are collaborating on a unique initiative providing Andorrans with the research, knowledge, methods, and tools to carry out such transformation.

Learn more below about City Science Andorra research below.

Kent Larson, Luis Alberto Alonso Pastor, Margaret Church, Arnaud Grignard, Maitane Iruretagoyena

The City Science Lab@Guadalajara is a collaboration with the University of Guadalajara (UdeG), a network composed of 15 campuses within the state of Jalisco, Mexico. The University offers undergraduate and graduate studies to around 130,000 students. With this collaboration, UdeG and MIT aim to understand urban performance metrics using evidence-based decision making tools at the community scale. The teams hope to enable more equitable, secure, and resilient communities using the components of the City Science process.

Learn more below about City Science Guadalajara projects below:

Kent Larson, Luis Alberto Alonso Pastor, Margaret Church, Arnaud Grignard, Ariel Noyman

MIT City Science is working with HafenCity University to develop CityScope for the neighborhood of Rothenburgsort in Hamburg, Germany. The goal is to create an interactive stakeholder engagement tool that also serves as the platform for joint research of modules for city simulation. Researchers are developing modules for walkability, neighborhood connectivity, energy efficiency, and economic activity, among others.

Read more about this project here.

Kent Larson, Luis Alberto Alonso Pastor, Margaret Church, Ronan Doorley, Arnaud Grignard, Michael Lin, Ariel Noyman, Yasushi Sakai, Phil Tinn, Yan Zhang

Tongji University, Shanghai, and the MIT Media Lab’s City Science group are co-developing a version of the MIT CityScope platform for urban analysis, efficient resource utilization, and spatial programming. The MIT CityScope is a tangible, augmented reality platform used to visualize complex urban relationships, simulate the impact of multiple urban interventions, and support decision-making in a dynamic, iterative, evidence-based process.

Hossein Rahnama

City Science Lab Toronto was established in cooperation with Ryerson University in Toronto, Canada. It started in 2018 and is the newest city in the City Science Network. The lab will be embedded in the Faculty of Communications and Design and will be part of the University’s Paradox Initiative. The two groups plan to build and work on the development and simulation of urban interventions, such as micro-units for young people, shared work and collaboration spaces, educational facilities, financial services innovations, and new mobility and parking systems. This information will be analyzed and visualized using different platforms including the CityScope. The two groups plan to define new parameters which may include financial modeling, design of innovation flow, public health, new mobility systems, and/or energy networks. A number of large financial institutions, telecommunications companies, and hospitality groups are the founding corporate supporters of the initiative. The lab’s director is Professor Hossein Rahnama, who is also a visiting faculty member at the MIT Media Lab.
MIT City Science has developed an international network of cooperative City Science Labs. We are developing concepts and key technology that can be extended, deployed, and evaluated by our collaborators in unique contexts around the globe. Over the next few years, we plan to develop new and exciting projects in less affluent, rapidly growing cities in Latin America, Africa, and India where the impact of a new process to address the challenges of urbanization may be the greatest.

Kent Larson, Luis Alberto Alonso Pastor, Nicolas Ayoub, Arnaud Grignard, Ariel Noyman, Yasushi Sakai, Carson Smuts, Yan Zhang

We are at the dawn of a mobility revolution, where autonomous vehicles will replace cars controlled by humans. We can imagine this developing along two possible divergent paths with very different implications for cities. Will we create an ownership society with private, driverless cars? Or a world of lightweight, shared social mobility robots available to all? In this CityScope project, extreme versions of these two futures are presented. In one, streets are dominated by machines and density leads to congestion and anxiety. The other is a more vibrant city where humans recapture streets and density increases equity and creative interactions. We propose that new mobility systems must be explored to meet the profound challenges of the future and to enable dynamic and evolving places that respond to the complexities of life.

Kent Larson, Chenhan Jiang, Yang Liu, Thomas Sanchez Lengeling, Yan Zhang, Weiting Xiong - former visiting student at MIT City Science and a PhD candidate from the School of Architecture, Southeast University, China
Tianyi Fan - former student worker at MIT City Science and recent graduate of Master of Science in Real Estate Development at MIT
Tianyu Su - former student worker at MIT City Science and a Master’s student in the MIT Urban Mobility Lab
Will Shun Du - professional Unity 3D developer

College of Design and Innovation of Tongji University, Shanghai, and the MIT Media Lab’s City Science group are co-developing a version of the MIT CityScope platform to support the urban decision making that promotes urban vibrancy and innovation potential.

The “NICE2035 LivingLine” project in Shanghai, China, is a design-driven, community-based urban innovation initiated by Professor Yongqi Lou, Dean of College of Design of Innovation. LivingLine is a crowdsourcing and co-creation project aiming at building an ecosystem of innovation and entrepreneurship on the internal street of a typical gated residential neighborhood. By introducing radical programs such as living labs, co-working space, and startup-incubators into underutilized storefront space, LivingLine’s goal is to revitalize the urban space and to prototype diverse future lifestyles.

Kent Larson, Ariel Noyman, J. Ira Winder

This project depicts the design, deployment and operation of a Tangible Regulation Platform, a physical-technological apparatus made for the distillation of regulations. The platform is set to exemplify the effects of regulations on a designated territory, allowing planners, designers, stakeholders and community members a common ground for discussion and decision making. An accessible and self-explanatory tool, this platform illustrates the relationship between urban form and regulations, offering a seamless and transparent process of regulation-based urban design. Lastly, projecting on the foreseen future of law and urbanism, this project proposes an alternative data and performance-based approach for the making of new regulations. Beyond excelling the processes of design under regulations, this platform and other new tools are offered to help facilitate a discussion on the way future regulations will be devised, improving both the design processes and their final outcome.
CityScope Volpe

Luis Alberto Alonso Pastor, Markus Elkatsha, Arnaud Grignard, Ariel Noyman, Yan Zhang, Markus F. Elkatsha, Dalma Foldesi, Jung In Seo

CityScope Volpe is demonstrating most of the urban planning, analysis, and prediction features developed for the CityScope project. The site, a 14-acre parcel on the northern part of MIT/Kendall Square area of Cambridge, has been acquired and is being developed by MIT. City Science researchers designed and built a CityScope urban performance tool that is aiming to predict the outcomes of multiple planning and development scenarios.

Crypto Voting + US Elections: Reality and Science Fiction

Kent Larson, Alex Berke

This is a two-part project. One part is about reality. The other part is science fiction. Both are about mobile, blockchain, and cryptographically secure voting systems in the context of US elections.

Securing elections and increasing access to voting are critical for our democracy to function properly. There has been recent focus on using mobile apps and blockchain-based systems to address these needs, but some of these systems can cause more harm than good. The Reality piece is about the innovations that can make secure and transparent elections possible, and where internet-voting, mobile apps, and blockchains fit in.

The Science Fiction piece uses storytelling to explore how our voting systems can and should work. It looks ahead at two potential futures for US democracy that branch from our present. One story is a dystopia where technology is misused, resulting in a disengaged and disenfranchised public, where wealth determines voting power. The other story is a utopia where elections are celebrated holidays, where technology makes voting more secure, and social changes make voting more accessible.

This work came out of the MIT Digital Currency Initiative’s Blockchain Ethics course.

Deep Urban Interaction

Yan Zhang

Analyze and visualize urban interaction with computer vision and deep neural net.

Dynamic Traffic Prediction in Andorra: a Bayesian network approach

Kent Larson, Luis Alberto Alonso Pastor, Ronan Doorley, Arnaud Grignard

Data Fusion for Dynamic Traffic Prediction

Traffic congestion has huge negative impacts on the productivity, health and personal lives of city dwellers. To manage this problem effectively, transportation engineers need to predict traffic congestion throughout the road network at all hours of the day. Prediction of traffic typically involves travel surveys that are expensive, time consuming and do not capture temporal variation in travel demand. However, anonymised location data from mobile phones present an alternative source of data which is passively collected, widely available and naturally captures temporal trends. On the other hand, these data contain other biases and so if we use these data for transportation models, we must take care to correct for these biases using more reliable data. As part of the City Science collaboration with Andorra, we used a Bayesian network to build a calibrated transportation model for the country based on geolocated telecoms data and validated using a small sample of traffic counts.

Escape Pod

Kent Larson, Chrissoula Kapelonis, Nina Lutz, Lucas Cassiano Pereira Silva, Carson Smuts

The esc-Pod (or Escape Pod) is an exploratory platform for researchers investigating moments of refuge within our bustling work lives. The core of the esc-Pod consists of actuated work and rest surfaces. This allows for moments of productivity and relaxation to occur within a single space. The outer skin provides variable transparency, enabling a spectrum of visibility settings according to privacy requirements. The inner skin provides an infrastructure for the modulation of spatial experiences. Each panel is a pixel, connecting itself to the skin network, and can embody an array of senses.

FindingPlaces

Kent Larson, Ariel Noyman

What is FindingPlaces?

In reaction to the sudden arrival of tens of thousands of refugees in the city of Hamburg (DE) in 2015, the Lord Mayor requested the CityScienceLab (CSL) at HafenCity University to facilitate a public discussion and decision-making process on locations for refugee accommodation in Hamburg neighborhoods. With highly sensitive socio-political implications, this project demanded a well-designed technological and procedural approach. CSL employed an innovative Human-Computer Interaction tool, CityScope, to facilitate public participation and urban decision-making. A workshop process was also designed to help multiple participants and stakeholders interact effectively. Running from May to July 2016, the FindingPlaces (FP) project enabled about 400 participants to identify 160 locations accepted by Hamburg’s citizens, out of which 44 passed legal confirmation by the authorities. Overall, on a qualitative level, the project facilitated surprisingly constructive and collaborative interaction, raising awareness and a sense of ownership among participants.
207. **Grain Prism**

*Gabriela Bila Advincula, Don Derek Haddad*

The Grain Prism is a hybrid musical instrument that combines granular synthesis and live audio recordings. Presented in a capacitive touch interface, users are invited to create experimental sound textures with their own recordings. The interface’s touch plates are introduced within a series of obscure glyphs, instigating the player to decipher the hidden sonic messages. This way, the mysterious interface opens space to aleatoricism in the act of conjuring sound, and therefore the discovery of “happy accidents” in making electronic music.

Project presented at NIME 2019 (New Interfaces for Music Expression).

208. **Hackable Bike**

*Yasushi Sakai*

To explore future mobility modes, the City Science group is working with Media Lab member company Panasonic to explore the use and potential adaptations of the popular MamaChari bikes. Like other mobility modes, the MamaChari bikes have developed and adapted over the past decades. Bikes for women first became popular during Japan’s economic boom in the 1980s when many households benefited from one income, and women were encouraged to stay home and take care of their children. Women used bikes to quickly navigate their cities and make frequent trips to shops and schools, kids in tow. Even as women gradually entered the workforce in the 1990s and 2000s, the stereotype of the Japanese biking woman remained. By 2008, electric assist bikes were introduced to the market, and again they targeted women with children as the primary users. Today MamaChari bikes are stable, secure and ubiquitous in Japan, yet they have yet to enter other global markets.

The City Science group strives to understand current uses of the MamaChari and adapt the bike for new and future uses globally. Ideation workshops were completed in February and May 2018.

Learn more about the first workshop here: [https://www.media.mit.edu/posts/mamachari/](https://www.media.mit.edu/posts/mamachari/)

209. **Human-Machine Interaction (HMI) in Social & Public Environments**

*Yi-Cheng Jiang, Michael Lin, Yago Lizaribar Carrillo, Lucas Cassiano Pereira Silva, Phil Tinn, Jerry Wei Hua Yao, Chang-Qi Zhang, Narindra Peaks, Nick Meyer*

Facilitating coexistence, trust-building, and collaboration among people and machines.

New modes of 21st century urban transportation are becoming more lightweight, electrified, connected, shared, and autonomous. Cohabitation of humans and machines is an increasingly important question, and one which requires careful attention and design. We strive to enable new forms of human-machine co-existence, trust, and collaboration.

**This work focuses on enabling:**

Intuitive and effective two-way communication between vehicles and pedestrians;

Street safety and traffic-yielding mechanisms; and

Behavior change related to the adoption of active mobility mode, or electric assist.

210. **Income, Race, Bikes**

*Kent Larson, Alex Berke, Steve Gattuso*

Is the placement of bike-share docks equitable?

This interactive map explores the question visually.

The map shows the addition of bike-share docks, as well as the changes in income and race throughout the years the bike-share program has been in service. You can toggle the display to see only income, or race, or bikes data, or any of their combinations.

[https://aberke.github.io/income-race-bikes](https://aberke.github.io/income-race-bikes)

The project currently includes the New York and Boston areas, with more cities coming soon.

211. **KinderCity**

*Laya Anasu*

KinderCity is a pilot project that attempts to understand the intangibles of city perception. It attempts to understand how people, across ages, children and adults, perceive places and spaces that are playful, creative and inspiring.
| Section 12. | Last Mile Logistics | Kent Larson, J. Ira Winder  
Developed by Ira Winder with the MIT Centre for Transportation and Logistics, the model seeks to use real population data and create a simulation to optimize delivery cost and coverage. This could be modified and applied to many disciplines, industries, and population types. The platform has the user place stores on a Tactile Matrix, a type of tangible interface, and displays the output of their potential delivery coverage and cost. This optimization game of sorts is a whole new approach to maximizing delivery potential. The interactive interface and layers of finely granulated and detailed data allow the user to make meaningful interventions and see the intertwining of many rich data sets.  
Photos by James Li. Video by Nina Lutz. |
|-------------------------------------------------|-------------------------------------------------|
| Section 13. | MoCho: Mobility choices and societal impacts | Ronan Doorley, Ariel Noyman, Yasushi Sakai  
MoCho (short for “Mobility Choices”) is a CityScope module focused on mobility choices and societal impacts. This tool helps predict the choices of mobility modes made at the individual level throughout the entire Boston Metro area.  
Check out a live demo of MoCho predictions here. |
**An Alternative Autonomous Revolution**  
System design for emerging urban contexts and societal aspirations  
The Persuasive Electric Vehicle (PEV) aims to solve urban mobility challenges with a healthy, convenient, sustainable alternative to cars. The PEV is a low-cost, agile, shared-use autonomous bike that can be either an electrically assisted tricycle for passenger commuting or an autonomous carrier for package delivery.  
The PEV uses standard bicycle components and is lightweight (<50kg) yet robust. Its sensors are easy to reconfigure and it has a 250W mid-drive electric motor and 10Ah battery pack that provides 25 miles of travel per charge and a top speed of 20 miles per hour.  
Our vision for the PEV: a rider summons the PEV through a phone app, and the nearest available PEV arrives autonomously to meet the rider. Upon completing the trip, the PEV simply moves on to its next passenger or package pickup. The PEV can be autonomous, operated by the rider, or provide the rider with an electric assist. PEV’s operate in bike lanes, avoiding the congestion and adding incentives to make more bikeable cities. |
| Section 15. | Piccolo Kitchen | Kent Larson, Suleiman Alhadidi, Borja Apaolaza Emparanza, Alejandro Garcia, Maitane Iruretagoyena, Sotirios Kotsopoulos, Aditya Mehrotra  
This project aims to create a modular platform for exploring micro-kitchens that are culture specific. Cooking is a personal experience that has cultural attributes. This project explores new modes of cooking using robotically enabled cabinets and appliances to minimize the footprint of the kitchen, while maximizing the ability for users to cook large meals, socialize, and utilize the same space during non-meal times for work. Piccolo kitchen is one of the components of the micro-units that are currently under development as part of the CityHome 02 projects. |
| Section 16. | Private Location Data for the Public Good and Urban Understanding | Kent Larson, Alex Berke, Ronan Doorley, Esteban Moro Egido  
There is a continuous and ubiquitous collection of precise, timestamped, geolocation data from apps and devices, being amassed by private firms. This data collection can be considered an ongoing “population survey” and can serve many of the same uses as traditional government travel surveys. Instead, these “location based services” (LBS) datasets are used for advertisement targeting, company analytics, and other means for private profit. This work is about leveraging LBS data to benefit the public from whom it is sourced.  
However, the utility of these datasets must be balanced with the privacy of individuals within them.  
**Privacy**  
This work focuses on protecting the privacy of individuals within location datasets. To do so we develop a novel approach with machine learning deep neural networks to produce synthetic data that has the same attributes as the original data in aggregate, but sufficiently varies at the individual level in order to protect user privacy. |
Proxymix is a visualization tool to understand the influence of spatial configuration on human collaboration. This agent-based model at the architectural scale enables more optimal uses of space by incorporating a human behavioral component in the design process. This project is open source and open to external contributors on this GitHub repository: https://github.com/CityScope/CS_Proxymix

In architecture, the building skin is the primary interface for mediating the environment of the external with the internal. But today, this mediation is mechanical, deterministic, and static—often seeing the human as a generalizable and problematic input. With advances in material science however, there is great potential to disrupt these traditional manufactured environments of architecture and turn them into responsive mediated environments. What this thesis aims to explore is this idea of the receptive skin—a sensate and dynamic multi-material interface for environmental mediation. This suggests that by departing from the view that buildings are static artifacts, we may instead begin to see buildings as organic, living entities.

Through the development of a working prototype, this project explores how such an interface may manifest itself, through dynamic material composites, instead of mechanical and electronic means. The final prototype is a “proof of concept,” a built example of this novel design methodology, which unites material performance with sensate technologies, as a way to enable new interactions between building and environment.

This study explores a novel method to analyze diverse behavioral patterns in large urban populations and to associate them with discrete urban features. This work utilizes machine learning and anonymized telecom data to understand which fragments of the city has greater potential to attract dense and diverse populations over longer periods of time. Finally, this work suggests a road map for building spatial prediction tools in an effort to improve city-design and planning processes.

The RGBox is an experimental game to teach fundamentals of additive color mixing theory. As opposed to the behavior of pigments that get darker once mixed together (subtractive mixing), light colors get brighter once you increase the amounts of red, green, and blue in the mix. The RGBox is intended to give users intuition with this concept via a tangible experience. The interface is composed by an LED strip and potentiometers. Within a given time, the user has to match an initial randomized color by adding or subtracting color amounts from a black pixel.

Developed at MIT Media Lab and International Design Centre.
A number of leaders and personnel from the global company EY are volunteering their time across many disciplines, including strategy and inclusion on the core initiative leadership team. Numerous additional companies are also participating in this way, including TripleBlind, Public Consulting Group, and Earned Media Consultants. Experts from government agencies and academic institutes in Canada, Germany, India, Italy, the United Kingdom, and Vietnam are also helping to guide the platform’s development.

Safe Paths is an MIT-led, free, open-source technology that enables jurisdictions and individuals to maximize privacy, while also maximizing the effectiveness of contact tracing in the case of a positive diagnosis. The Safe Paths platform, currently in beta, comprises both a smartphone application, PrivateKit, and a web application, Safe Places. The PrivateKit app will enable users to match the personal diary of location data on their smartphones with anonymized, redacted, and blurred location history of infected patients. The digital contact tracing uses overlapped GPS and Bluetooth trails that allow an individual to check if they have crossed paths with someone who was later diagnosed positive for the virus. Through Safe Places, public health officials are equipped to redact location trails of diagnosed carriers and thus broadcast location information with privacy protection for both diagnosed patients and for local businesses.

Context
Fast containment is key to halting an epidemic outbreak. But with the long incubation period of a virus like COVID-19, it is extremely difficult to identify individuals who may have been in contact with carriers of the virus and are thus at risk of contagion. Across the globe, the use of smartphones has been tested to track location and solve this problem, raising concerns about mass surveillance. However, with our privacy-first method, the user remains in control of their data—providing a fundamentally different approach to app-based epidemic analytics.

Resilience requires citizens and organizations to self-organize so that they can predict and respond to challenges (e.g., climate change) and disruptions (e.g., COVID-19). Such orchestration would be easy if everyone involved shared data about their past activities and future intentions openly, and responded to scientific evidence in ways that supported long term resilience, fairness, inclusiveness and accountability. This is, however, is challenging due to the need to maintain privacy, consent, trade secrets and compatible incentives.

The current epidemic highlights this challenge. A “big brother” system in some countries has made a big difference in public health intervention via contact tracing, quarantine adherence verification, health verification, as well as tools for health officials such as spread analysis, resource allocation and incentive methods.

Unfortunately, network analysis of social activities leads to a surveillance state. Thus, there are several big challenges to capture, analyze and act in a closed loop: (i) population scale understanding of a fast or slow moving threat without coercing an individual to reveal anything identifiable about themselves, (ii) analyze and providing precise guidance to an individual without the orchestration system knowing to who and what message is delivered and (iii) incentivize and verify the action while maintaining a sense of agency and privacy for the individual.

These seemingly impossible problems can now be addressed thanks to (i) deep penetration of smartphones and IoT which can act to capture, compute, disseminate and act on information, (ii) the data sources associated with these devices (iii) practical and scalable privacy preserving algorithms and (iv) incentive mechanisms for networks of people and agents which act to guide individuals to support not only themselves but the society as a whole.

Transparent, accountable, and inclusive ecosystems that can simultaneously address the privacy and utility of data in building resilient societal systems are key to humanity’s future.

In the short run, digital tracing and infection spread analysis, monitoring of logistics and service chains, and simulation to help policy makers will help the current public health challenges. In the medium term, such systems will be critical in restarting socio-economic activities and get the society on track to more permit

For upcoming version releases, Private Kit: Safe Paths will deploy the following capabilities:

V1 - Log location history
V2 - Match personal location history with infected patient anonymous redacted trace files provided by public health officials
V3 - Match personal location history with encrypted anonymous redacted infected patient trace files provided by city officials
As noted, Private Kit: Safe Paths works in conjunction with the MIT-developed GIS web app, Safe Places.

Safe Places will be used by public health officials to:

- Collect time-stamped location data from one of the three sources, Private Kit: Safe Paths, Google location history, and patient interviews
- Produce partially obscured trace files that meet jurisdiction legal requirements for anonymity that can be posted openly on the web and utilized for contact tracing in Private Kit: Safe Paths
- By enabling contact tracing, Private Kit: Safe Paths will help to reduce panic and "flatten the curve" of Coronavirus spread by enabling those who have been exposed and are showing symptoms to make more informed decisions on when to seek testing and self-quarantine—without losing individual privacy and while reducing the fear unknown exposure.

Michael Lin, Phil Tinn, Fernando Sanchez, Richard Chew, Philip Lee
Forecasting the supply of fleets to meet emerging travel demands and service needs in cities

The availability of vehicles is a critical factor behind successful shared-use mobility services. Proper management of supply-demand dynamics is paramount for achieving viability in a new mobility service, as achieving scale often requires a large capital investment. Under-supplying the fleet would result in low service availability and user dissatisfaction; over-supplying results in inefficient use of resources. In addition, as a new shared mobility platform diversifies its service across both passenger and freight delivery, its required scale of operation and investment becomes more difficult to estimate.

In this service deployment simulation research, the City Science group aims to create an accessible simulation tool to enable cities to forecast the size of deployment of new shared mobility services using the Persuasive Electric Vehicle (PEV) delivering passengers and packages as an initial test case. The simulation tool also allows for testing various system design features, such as strategies for rebalancing fleets and for distributing charging stations.

Web Demo

Chrisoula Kapelonis, Carson Smuts
Spatial Flux: Body and architecture in space

Structurally, zero gravity means that we do not have to contend with architecture’s greatest arch-nemesis, gravity. This opens up a new world of possibilities where we can deploy structures that no longer have to counteract/resist gravitational force. We would like to explore new forms of rapid inflatable prototyping. Most importantly, this prototype explores surfaces utilizing materials that would normally fail on Earth, yet flourish in zero gravity.

This year the MIT Media Lab’s City Science group had an opportunity to think of architecture at the scale of the body that was literally out of this world. These are the results.

Lucas Cassiano Pereira Silva, Carson Smuts
TerMITes

TerMITes are wireless environmental sensors that capture data to help us better understand our environments and human behavior. The sensor data is time-stamped and place-tagged, but otherwise hardware agnostic. TerMITes support multi-modal sensor attachments using common protocols and can be attached to objects in the home such as doors, windows, drawers, cabinets, tables, and chairs to register object usage. TerMITes directly log on to the Internet via low-power Wi-Fi for ease of connection and automatically upload to a centralized database. TerMITes bridge existing methods for qualitative inquiry about our experiences in various planes to quantitative recording based on sensor input. TerMITes are currently used to gather data on humidity, presence detection, ambient light, motion, carbon dioxide, and temperature.

Kent Larson, Ariel Noymann, R Danhavai, C Mueller, Narroa Coretti, Markus Elkatcha
The Deep Image of the City

How do you image a city that doesn’t exist?

DeepScope is a novel platform for interactive, real-time, and setup-less urban design visualization. It attempts to substitute common practices of urban design with a machine-learnt, generative visualization approach. By implementing a deep convolutional generative adversarial network (DCGAN) and CityScope, a tangible user interface, this project allows for real-time prototyping and visualizations of urban design processes.

Kent Larson, Carlos Aizpuruza Azconobieta, Luis Alberto Alonso Pastor, Oier Arino Zaldua, Mohammad Hadhrawi, Maitane Iruretagoyena, Hasier Larrea
Theme | Changing Places

Changing Places researchers are developing scalable strategies for creating hyper-efficient, technology-enabled spaces that can help make living more affordable, productive, enjoyable, and creative for urban dwellers.
City Science researchers are developing a slew of tangible and digital platforms dedicated to solving spatial design and urban planning challenges. The tools range from simulations that quantify the impact of disruptive interventions in cities to communicable collaboration applications. We develop and deploy these tools around the world and maintain open source repositories for the majority of deployments. “CityScope” is a concept for shared, interactive computation for urban planning.

All current CityScope development, tools, and software are open source here.

Urban populations around the world are rapidly growing. To improve livability, urban residents must reduce dependency on fossil fuels and private cars, while needing efficient equitable access to inexpensive and reliable transportation.

Urbanization has outpaced transportation innovation as we know it, and urban transportation issues are far more complex and diverse than they appear when viewed from a car seat. Going beyond the robotization and electrification of cars, we conceptualize, prototype and pilot mobility interventions through the following five research activities:

This initiative is for identifying cost-efficient and lightweight infrastructure systems for deployment in rapidly urbanizing areas.

How can new technologies respond to society’s diverse industrial, socio-economic, and educational needs?

Despite AI and robotics being widely trumpeted as keys to the new Industrial Revolution, access to their development remains largely restricted to companies and institutions that are rich in capital and/or data, potentially further deepening the socio-economic disparity observed across continents. As a likely result, these new technologies generate limited positive externalities. For instance, are automobiles really the most critical area in need of self-driving technology? Where else might AI and robotics be applied to lead to increased urban livability, socioeconomic equity, and the vibrancy of local businesses?

Building upon the architecture of MIT’s open-source race car platform, the City Science group introduces a new open-ended and heavy-duty self-driving platform. Torque is intended to be used by educators and makers and is ideal for hackathons and classroom instruction. Torque will soon allow rapid prototyping of usage scenarios and services for various contexts and needs.

With the support of a new genre of smart urban infrastructure, we believe this “autonomy-lite” approach will soon allow lightweight autonomous vehicles to be widely deployed and navigate smoothly in most urban environments.

Theme | CityScope
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Theme | Mobility On-Demand
---
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Theme | The Power of Without
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This initiative is for identifying cost-efficient and lightweight infrastructure systems for deployment in rapidly urbanizing areas.

Theme | Torque
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Open-Source Autonomous Platform for Educational and Service Design Applications

How can new technologies respond to society’s diverse industrial, socio-economic, and educational needs?

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Theme | Urban Tattoo
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Scalable Urban Infrastructure for Human-Machine Cohabitation

New infrastructure to help sustain public-sector participation and operation, and maximize public interest and safety.

Advancements in autonomous technology have led automobile makers and tech companies to focus on reinventing the automobile—increasing computational capability and enhancing sensor systems. But due to strict road-safety regulations, this vehicle-centric, inside-out approach may take years to materialize, and when it does, restricting “autonomy” to selected vehicles will limit autonomy’s impact on street safety and accessibility.

To address current issues, The City Science group focuses on ways to offload often-heavy computational requirements from the vehicle through affordable interventions to street infrastructure by creating human-machine readable traffic signs and urban markers.

With the support of a new genre of smart urban infrastructure, we believe this “autonomy-lite” approach will soon allow lightweight autonomous vehicles to be widely deployed and navigate smoothly in most urban environments.
Gabriela Bila Advincula, Ariel Noyman
Graphics on incompleteness

The City Science Summit 2019, CITIES WITHOUT, explored a future without top-down and obsolete systems. During the two-day event, talks and workshops discussed new ways to address issues in rapidly urbanizing cities.

But withoutness goes further. It is the permanent state of incompleteness and therefore constant change of everything. Deriving from this idea, a series of three short movies (each one introducing the main themes of the science talks) and the summit’s visual identity was created.
Zach Lieberman: Future Sketches
Exploring the essence of code as a creative medium

233. **Colorchives**

Zach Lieberman, Nina Lutz, Omoruyi Atekha (UROP—help with prototyping color space conversion)
Color quantization is a long studied issue in computer graphics. The idea of color quantization is utilizing decompression to represent an image in less pixels than its original format. Color quantization is also utilized to generate color palettes from images.

The goal of Colorchives is to develop a prototyping tool for designers to generate color palettes, specifically towards event based photos for archival purposes. The tool will allow users to upload images and generate a variety of palettes given different parameters and color spaces. This makes for a more intuitive artistic representation of various images that current color quantization algorithms are not optimized for.

This is in progress work, please contact Nina Lutz for inquiries.

234. **Gender Affirming Makeup**

Catherine Havasi, Nina Lutz, Daniel Novy
What if we could leverage technology and modern cosmetics for good? To empower people to explore identities? To give anyone, regardless of skill level, the tools to bend, express, and explore various gender identities and traits?

The goal of this project is to use mathematics and computation to create a tool that will allow a user to add more feminine, masculine, or androgynous traits to themselves with cosmetics. After interacting with renders and the tool’s preferences, the user will receive a list of cosmetics and then follow along with the tool in real time while they apply their makeup.

This tool is meant to be accessible, to be free and open source technology, and made for users of all skin tones, shapes, and preferences. To allow anyone to express their identities.

This work is ongoing and will have regular updates, beta releases, and user surveys coming soon.

235. **Ofrenda Digital**

Catherine Havasi, Nina Lutz, Daniel Novy, Jason Alonso — Software for AI Characters
Sam Seaman — UROP, Fabrication and Design
Jessie Wang — UROP, Electronics and Fabrication
Support
Marianne Olsen — Senior Mechanical Engineering Thesis — Fabrication of Plaster Molded Skulls
¿Cómo puede la tecnología influir en las celebraciones culturales? // How can technology influence cultural celebrations?

Ofrenda Digital is a Digitally Augmented Physical Shrine. It utilizes dynamic projection mapping to bring a layer of dynamic information and animations to a physical ofrenda as seen in Día de Muertos.

This project immerses the user in Día de Muertos and the Spanish language. Users can interactive with a variety of data driven narratives from celebrations across Mexico. Utilizing data from media across Mexico we can generate digital faces and designs around this celebration.

Each location brings up new media and context, along with generative faces. These faces are generated using a conditional styleGAN based off the photos in this area and colors generated by an archival color quantization method.

Along with being an exploratory tool, Ofrenda Digital is also an archival tool. It not only archives information from the celebration, but users can utilize it as a more traditional ofrenda. Its digital overlay structure can take in digital and physical media from users in a unique profile.

We seek to improve and apply technologies to preservation of cultural tradition as well as conversations around loss. This project is motivated by the fact that as mass migration and social and climate instability occur, these types of traditions linked to physical shrines and public spaces come under threat.

Furthermore, this project seeks to bring new layers of technology and deepen the conversation around this celebration and Latinidad.
This pedagogy of experiments seeks to accurately model and manufacture a new form of lighting fixtures and framework around architectural lighting. This is an ongoing project, so please be expecting more updates and materials.

These new fixtures are made of polyester resin and a particle distribution called a colloid. Unlike traditional light bulb models, rather than having illumination come from individual lighting fixtures that are wired to a common electric source, we are using one lighting source in the form of a laser to illuminate each fixture.

By using controlled resin casting alongside numerical simulation of structured colloids, we can program and evaluate different substances held in distribution with a 9 dimensionality lighting model. This allows us to understand the type of lighting output that can be achieved with various materials and shapes, as well as predict the aesthetic properties that these lighting sources may allow us. From various colors to different glittery reflects, this framework allows both technical and artistic framework.
Andrew Lippman: Viral Communications
Creating scalable technologies that evolve with user inventiveness

237. **As You Need It**
Andrew Lippman, Yasmine (Jasmin) Rubinovitz
Video or broadcast news is viewed in a far wider set of circumstances than it ever has been before. It is composed with the assumption of a complete, situated viewing, but in fact it is often grabbed on-the-fly as a momentary experience. As You Need It is a semantic summarizer that deconstructs a multi-part segment for presentation as “chunks of importance.” We are learning if a story can be cut down to a useful update that takes less time than a traffic light, or as much time as a given user has. This project uses and contributes to another group project, SuperGlue.

238. **Broadercasting**
Andrew Lippman, Hisham Bedri, Mike Hao Jiang
Ditch the truck. Live, collaborative broadcasting through mixed reality.

239. **Captions++**
Andrew Lippman, Tomer Weller
Modern web presentations such as Youtube feature videos with commentary appended at the bottom. In our new imagining of Videotext, we put the two together: comments appear as active bubbles along the playback time line. We thereby associate the commentary with the place in the video to which it refers. It gains context. This project is in the early test stage and is presented for discussion and further development in summer 2016.

240. **CivicLink**
Andrew Lippman, Oceane Boulais, Britney Johnson, Daniel Marquez, Sam Posner,
Major political campaigns and nonprofit organizations use bespoke systems to organize, inform, and solicit members. These top-down systems often require professional IT support and are proprietary, expensive, and inaccessible to smaller organizations. CivicLink is a bottom-up system designed to work at any scale, with a particular focus on the needs of small, grassroots campaigns and community groups. It is a plug-and-play organizing system in a box: a self-hosted, free, and open source platform for groups to facilitate discussions and coordinate events, and an infrastructure for building distributed networks that connect individuals and organizations around common issues.

241. **DbDb**
Andrew Lippman, Travis Rich
DbDb (pronounced DubDub) is a collaborative, visually based analysis and simulation platform. We promote open distribution of experimental data by allowing researchers to present a graphical representation of their data and processing techniques that collaborators can build on and augment. This helps test the reproducibility of results and allows others to learn and apply their own techniques. Our intention is for the research community as a whole to benefit from a growing body of open, analytical techniques. DbDb provides an interface for archiving data, executing code, and visualizing a tree of forked analyses. It is part of the Viral initiative on open, author-driven publishing, collaboration, and analysis. It is intended to be linked to PubPub, the main project.

242. **Defacto: Decentralized crowdsourced news verification system**
Andrew Lippman, Mike Hao Jiang, UROPs Spring 2019: Nicholas Guo (backend), Hiya Vazirani (design), Sophia Rim (design), Bryan Chen (fullstack), Gohar Khan (frontend), Demar Edwards (frontend)
Despite recent efforts, current fact-checking organizations cannot keep up with the amount of information that is produced and spread throughout the internet [1]. One of the biggest challenges is to minimize the time it takes to verify the claims of a story. We are building a decentralized, crowd-sourced news verification system that aims to leverage the “wisdom of crowds” to generate timely labels that can be used to put a badge on news articles. The labels are stored on IPFS using The Underlay—a protocol developed by the Knowledge Futures Group at MIT. Governance mechanisms and incentive structures are implemented to hold all parties accountable and to prevent unbalanced concentration of power.

Follow this link for more information.

**Oceane Boulais**

New work: Fisheries in the Pacific Islands operate in an opaque market where an auditing tool built on a distributed ledger would be beneficial to the local economy by providing an immutable "stamp" that could leverage semi-trusted, third party auditors and vet fisheries for:

- labor conditions on-board
- types of fish caught (Skipjack, Yellowfin, Bigeye)
- sustainability of fishing method (fish aggregating device (FAD), seine net fishing, longline)

**Andrew Lippman, Mike Hao Jiang**

Media filter bubbles sacrifice shared reality amongst US citizens. We aim to burst these echo chambers by presenting short, automatically summarized news clips to users through a mobile app. The user watches these short clips in sequence and has the option to press a lightbulb that signifies whether the news segment have been enlightening. These clips are generated from SuperGlue metadata and is based on News*2. It uses an “Anti-recommender system” that actively expands the user’s horizon—contrary to traditional recommender systems that aim to thicken the walls of echo chambers.

Follow this link for more information.

**Andrew Lippman, Britney Johnson, Leopold Mebazaa, Travis Rich, Yasmine (Jasmin) Rubinovitz, Penelope Eugenia Webb**

This is a grassroots challenge to get friends to participate in democracy by making calls to congresspeople in all 50 states. Live phone calls are the best way to directly express your opinion on an issue to your elected officials. Your mission is to pass message this along to friends who will make calls and also pass the message/link along to others who will do the same. It’s a social chain letter and a call to action for a better participatory democracy. We help you make your call and you pass on an invitation for your friends to do the same. Your invite can stress your opinion on a given issue.

The winners are the first ten chains to reach 50 states and accumulate the most challenge points. You get 250 points for making a call, 125 points for a call that your friend makes, 65 points for the call their friend makes, on and on. Everyone on the chain earns points. Points count for your first call to each of your two senators and your representative. You get a bonus for a "grand slam"—a network that reaches all 435 representatives and 100 senators.

There is a leaderboard and a network view so you can track how you are doing. You can also see how much of the country your chain is covering.

**Cesar A. Hidalgo, Andrew Lippman, Kevin Zeng Hu, Travis Rich**

An animated GIF is a magical thing. It has the power to compactly convey emotion, empathy, and context in a subtle way that text or emoticons often miss. GIFGIF is a project to combine that magic with quantitative methods. Our goal is to create a tool that lets people explore the world of GIFs by the emotions they evoke, rather than by manually entered tags. A web site with 200,000 users maps the GIFs to an emotion space and lets you peruse them interactively.

**Andrew Lippman, Hisham Bedri, Michael Draskovitch**

News reporting today suffers from sensationalism. News agencies are constantly fighting for attention and clicks, leading to headlines and photos that exaggerate a single perspective.

What if you could get a full perspective on certain news topics by exploring the news in AR? The spatial nature of AR allows a user to gain a more complete perspective on a story. Having a constant holographic widget on your desk also allows you to follow developing stories, such as a foreign conflict. In addition, the interactive nature of AR means that users can explore the news in a delightful way.
This project delivers a series of Github-signal based metrics that would be useful to both the layman and investor, helping look beyond the rocky trends of the cryptocurrency market to the actual viability of the token as a utility or security from the perspective of developer dynamic. By doing a quantitative analysis of source code and developer activity within a community, we can provide a rich set of insights into the health of a token's foundation.

**Assessment Methodology**

Building upon previous research, we gathered a ranked list of 13,695 repositories that correlate with 1,011 tokens—where we assess a token (i.e., Bitcoin) which has multiple repositories (i.e., bips, bitcoin, libbase58). The repository metadata information includes url data, forks_count, subscribers_count, network_count, open_issues_count, watchers_count, stargazers_count, size, created_at, updated_at, pushed_at, has_wiki, has_downloads, has_issues, is_fork. We have built a classifier that accepts this metadata as input features and returns a label to help us assess ranking qualities of the specified token.

Co-authored with Yashashree Kokje

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**Humanized Cryptoassets**

**Oceane Boulais**

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Co-authored with Yashashree Kokje

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**IoT Recorder**

**Andrew Lippman, Thariq Shihipar**

The physical world is increasingly coming online. We have things that measure, sense, and broadcast to the rest of the world. We call this the Internet of Things (IoT). But our cameras are blind to this new layer of metadata on reality. The IoT recorder is a camera that understands what IoT devices it sees and what data they are streaming, thus creating a rich information "caption-track" for the videos it records. Using this meta-data, we intend to explore how this enables new video applications, starting with cooking.

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**Kicks x Cliques**

**Britney Johnson, Aaron Stinnett, MIT idm**

Leveraging sneaker culture to influence civic engagement.

Marginalized groups have influence on digital platforms but are often unheard in other forums. We show how culturally resonant physical artifacts extend community reach and impact. We leverage the sneaker, a growing political symbol and cultural influence, to impact community participation.

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**layer**

**Andrew Lippman, David Anderton-Yang, Diego Escobedo, Emily Hu, Nikhil Reddy, Sameena Shaffeeullah.**

Layer decentralizes recommendation systems and intersects third-party recommendations with your locally stored, personal information to result in privacy-respecting, relevant recommendations.

We envision growing the repertoire of personal information beyond purchase choices.

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**Let's see a game!**

**Andrew Lippman, Hisham Bedri, Mike Hao Jiang**

In "Let's see a game!" we expose the different perspectives in TV sports and news in order to build broadcasting systems that unify rather than divide. We use the galvanizing impact of sports and live events as a forum, and then we add production and viewing opportunities to distinguish fact from opinion and to challenge the basis of those opinions.

In 1951, when the Dartmouth football team played against Princeton, there was deep disagreement between the two schools as to what had happened during the game. In "They Saw a Game: A Case Study," the psychologists Albert Hastorf and Hadley Cantril found that when the same motion picture of the game was shown to a sample of undergraduates at each school, each individual perceived a different game, and their versions of the game was just as "real" as other versions were to other people.

However, little is known about whether and how broadcasting media are adding fuel to the fire. In order to study the relationship between storytelling/perspectives and opinion formation, we built the following two applications: "Let's see a game!" and "Let's watch news!"

In the first step, we built an interactive application that exposes different perspectives in sports broadcasting. The application plays two broadcasts of the same game, created for each team's home audience. The user can tune into an audio channel by moving the slider. Additional buttons allow the user to take other actions.
Increasingly in the US, people have to take responsibility for their health information. Simultaneously, medical providers must make patient data available. MedRec fully decentralizes access rights via an Ethereum blockchain, thereby giving patients control over record distribution. Our model is the World Wide Web: MedRec is a network. Patients and providers operate nodes that authorize others to retrieve data. It is a basis for a generally useful permissioning system.

There is no website or central repository of permissions. Instead, patients and medical records originators establish a relationship and based on that, the patient creates smart contracts that other members of the network can use to authorize access to a record database. The parameters of contracts are kept in a blockchain that is maintained by all member providers/originators who at the same time use those contracts to provide access to their database. The patient/user contracts themselves are held by the patients in a wallet that resides on their device[s] as an app. This app is secure and recoverable in case the physical device is lost or damaged.

For a full overview, technical documentation, and updates, visit the project’s website.

NewsMaker decouples news snippets from multiple news sources, and challenges you to re-create an objective news article using them. Once you create the article, the various news sources of your snippet melange are revealed to you, making you rethink your association/disassociation with your chosen news sources.

+nudge helps people to become their imagined future self one nudge at a time.

Distracted by all of the demands on our time from urgent notifications, reminders, and advertising on our phones and laptops, it is increasingly challenging to align our day to day actions with what we believe matters most inside. +nudge creates specifically tuned, subtle reminders throughout your day to reflect and be mindful of the things in life that really matter to you, and as a consequence assist you in making better, more holistic decisions.

PubPub reinvents publication to align with the way the web was designed: collaborative, evolving, and open. PubPub uses a graphical format that is deliberately simple and allows illustrations and text that are programs as well as static PDFs. The intention is to create an author-driven, distributed alternative to academic journals that is tuned to the dynamic nature of many of our modern experiments and discoveries. It is optimized for public discussion and academic journals, and is being used for both. It is equally useful for a newsroom to develop a story that is intended for both print and online distribution.

Many people think their vote doesn’t count—that a single vote would not change an election’s outcome—and they stay home on Election Day. However, your vote is a public statement of beliefs, amplified because many people in your voting district may agree with you, but do not (and in many cases cannot) vote. Your vote gives a voice to those many others.

For example, congressional elections affect everyone in the district, regardless of whether they are eligible to vote. The same senators represent everyone in your state. The same ballot questions affect everyone in your community.

Using data we’ve gathered from the United States Census Bureau, we have calculated just how many people you’re representing with your vote. We directly compare the number of votes in recent congressional elections (by district) to the total population of the district.

When you vote, you’re not only voting for your own best interest, but you’re also voting for the best interest of those around you.

Visit https://www.relativotey.org and recognize your relative voting power!

Search Intent Optimization unwinds SEO by externalizing intent. Users select their intent during a search’s initiation. We offer a set of example controls to distinguish between shopping and information access. Adding your intent suppresses irrelevant noise results—no more “I’m feeling lucky.”
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<tr>
<td><strong>Self-Advertising</strong></td>
<td>Andrew Lippman, David Anderton-Yang</td>
<td>Self-Advertising reclaims and repurposes attention from advertising media online. We use the Internet, we often feel advertising following us around, distracting our focus, and leading us down misaligned paths, or we block it out entirely. Here we explore repurposing the advertising space online to be aligned with our goals and desires.</td>
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<td><strong>SuperGlue</strong></td>
<td>Andrew Lippman, David Anderton-Yang, Mike Hao Jiang, Tejal Wakchoure, Tomer Weller</td>
<td>SuperGlue is a core news research initiative that is a “digestion system” and metadata generator for mass media. An evolving set of analysis modules annotate 14 DirecTV live news broadcast channels as well as web pages and tweets. The video is archived and synchronized with the analysis. Currently, the system provides named-entity extraction, audio expression markers, face detectors, scene/edit point locators, excitement trackers, and thumbnail summarization. We use this to organize material for presentation, analysis, and summarization. SuperGlue supports other news-related experiments. SuperGlue is a framework for media digestion and metadata generation. The digestion work flow also has applications for media more broadly including conversational ecommerce.</td>
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<td><strong>SuperGlue Kinesics</strong></td>
<td>Andrew Lippman, Mike Hao Jiang, Tejal Wakchoure</td>
<td>The relationship between news content and its presentation has been a long-studied problem in the communications domain. Often, channels with a relatively smaller audience create a more powerful impact by amplifying the intensity of their content through a marked (usually biased) manner of presentation. SuperGlue Kinesics is a step in the direction of the investigation of this relationship and its influence on the public at large. SuperGlue Kinesics is a media analyzer that fuses multiple modalities to create a comprehensive model for the cross-analysis of facial expressions, body gestures, posture, scene context, and other nonverbal cues in broadcast news. We explore the nature of news portrayal on different media outlets to understand how they affect their audiences and contribute to the formation of potentially dangerous &quot;echo chambers.&quot;</td>
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<td>**Theme</td>
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This Is How is a platform for connecting makers with small businesses through stories. Small businesses share their stories in the form of video bytes in which they explain what they do and why, what their requirements and constraints are, and what kinds of issues they have. Makers can then annotate the video, ask further questions, and propose solutions for issues. The video is passed through SuperGlue for annotation and to categorize and find commonalities among requests.

How something is presented can be as important as the message itself. In the age of political polarization and election meddling, it is of vital importance to understand which factors contribute to the formation of public opinions. Television is one of the main sources of information for a large portion of the general population.

In order to understand discrepancies in news perception, what they are caused by and which implications they might have on shaping public political debate, we first need to understand how television news are constructed and define presentational aspects of the news. Given that, we can build tools that analyze news consumption by the public.

We aim to use various artificial intelligence techniques to model the "subcarriers of information" present in a TV newscast, to automatically detect and understand visual and auditory cues beyond the spoken word including the layout of the set, the affect of the participants, the nature of the motion, and other cues. Our goal is to develop an algorithmic understanding of journalistic choices in the way news content is presented. We also attempt develop an understanding of higher-level characteristics of television news such as television set atmosphere or political bias. This altogether would enable a broad-range, comprehensive algorithmic analysis of how news presentation is trying to shape the public political debate.

VR Codes are dynamic data invisibly hidden in television and graphic displays. They allow the display to present simultaneously visual information in an unimpeded way, and real-time data to a camera. Our intention is to make social displays that many can use at once; using VR codes, users can draw data from a display and control its use on a mobile device. We think of VR Codes as analogous to QR codes for video, and envision a future where every display in the environment contains latent information embedded in VR codes.

Wall of Now is a multi-dimensional media browser of recent news items. It attempts to address our need to know everything by presenting a deliberately overwhelming amount of media, while simplifying the categorization of the content into single entities. Every column in the wall represents a different type of entity: people, countries, states, companies, and organizations. Each column contains the top-trending stories of that type in the last 24 hours. Pressing on an entity will reveal a stream of video that relates to that specific entity. The Wall of Now is a single-view experience that challenges previous perceptions of screen space utilization towards a future of extremely large, high-resolution displays.
Seemingly an old TV box which turns out to offer an abundance of control over content selection: each aspect of news can be selected for using old-style controls. The main goal is to make people aware of their choices and biases and to make them curious to tune the controls and to watch something different. Hitting the TV resets the controls to random values and lets user discover completely new unexpected content.

The main underlying assumption behind the idea of YouTune is that while it is very difficult to influence people’s opinions and change their beliefs explicitly without a willingness on their part to change these beliefs, we could attempt to influence people implicitly by providing a tool that, first, would make users aware of the choices they take: to watch what they want or are used to, the user has to explicitly set controls. Unlike traditional broadcast and online media platforms, YouTune does not allow users to select content based on channel or program, so in order to find content that the person is usually interested in, with YouTune they would need to manually select characteristics of the content they want to watch. And second, we believe that YouTune will make people curious to change the control values they are used to and therefore to discover unexpected content that could potentially influence their opinions in an implicit way.

With YouTune the user can choose between different characteristics and tune into some value of the chosen characteristic to see short news stories. The idea is to make statistics experienceable without showing graphs: a person using YouTune would subconsciously aggregate statistical patterns and understand which tricks and stylistic tools channels tend to use to cover certain topics.

Project updates via PubPub
Tod Machover: Opera of the Future
Extending expression, learning, and health through innovations in musical composition, performance, and participation

271. Adaptive Music for Affect Improvement
Rosalind W. Picard, David Su, Yan Liu (Harvard GSD)
Adaptive Music for Affect Improvement (AMAI) is a music generation and playback system with the goal of steering the listener toward a state of more positive affect. AMAI utilizes techniques from game music in order to adjust elements of the music being heard; such adjustments are made adaptively in response to the valence levels of the listener as measured via facial expression and emotion detection.

272. Aether Muse
Charles Holbrow
Aether Muse proposes an extension for live internet streams of musical audio/video performance. We explore how a two-way data connection between distributed audience listening can enhance the connection between a musician and their audience. By generating synchronized visualization for client watching the performance in the browser, musicians gain a new means to communicate with their fans and grow their audiences.

This project also showcases “tcchh,” a custom digital audio effect for warping and stretching a live audio signal.

273. Ambisonic surround-sound audio compression
Tod Machover, Charles Holbrow
Traditional music production and studio engineering depends on dynamic range compression audio signal processors that precisely and dynamically control the gain of an audio signal in the time domain. This project expands on the traditional dynamic range compression model by adding a spatial dimension. Ambisonic Compression allows audio engineers to dynamically control the spatial properties of a three-dimensional sound field, opening new possibilities for surround-sound design and spatial music performance.

274. Breathing Window
Tod Machover, Rebecca Kleinberger
Breathing Window is a tool for non-verbal dialogue that reflects on your own breathing while also offering a window on another person’s respiration. This prototype is an example of shared human experiences (SHEs) crafted to improve the quality of human understanding and interactions. Our work on SHEs focuses on first encounters with strangers. We meet strangers every day, and without prior background knowledge of the individual we often form opinions based on prejudices and differences. In this work, we bring respiration to the foreground as one common experience of all living creatures.

275. ...but not simpler...
Tod Machover
This collection of Tod Machover’s music focuses on chamber and orchestral music composed during the last decade, both with and without electronic enhancement. Machover’s music is a fascinating blend of expressive and lyrical melody combined with a sophisticated ear for textural complexity. The resulting music is always a treat for the ears—colorful, vibrant, and rhythmically propulsive. The largest composition on this disc is the piano concerto Jeux Deux, scored for large orchestra (the work was commissioned and first performed by the Boston Symphony Orchestra), with the soloist performing on a “hyperpiano”—a concert grand piano which interacts with sensors and computer programs in order to expand its technical possibilities. Machover produces cutting-edge music with a heart!

276. CEE: Color Expanse Examination
Alexandra Rieger
The CEE (Color Expanse Examination) system is an explorative approach to evaluating human color acuity. Color perception is shaped and altered by cultural development, ocular conditions, as well as neurological health. Human ability to differentiate and identify color can also be an indicator of wellbeing ranging from emotional status to Alzheimer’s Disease progression. In Alzheimer’s, some of the most significant early changes occur in color vision. In spite of this, color testing is rarely included in cognitive baseline examinations.
Alexandra Rieger

Chronosonogy: Sonic sensory time shifting

Alexandra Rieger

Chronosonogy was born through extending the neuroscience research of Teki Et Al, which reveals "Distinct Neural Substrates of Duration-Based and Beat-Based Auditory Timing" and Fassnidge Et Al's work examining "Visual Interference of Auditory Signal Detection."

Our perception of time is impacted by combining factors of visual-auditory override and imaginary notes sensations. Chronosonogy is both an experience and a newly discovered time-shifting phenomenon that activates a neurological quirk situated in fronto-temporal-parietal regions of our brains.

Tod Machover, Benjamin Bloomberg, Charles Holbrow, Rebecca Kleinberger, David Nunez, Simone Ovsey, Sarah Platte, Peter A. Torpey, Akito Oshiro van Troyer, Garrett Parrish

City Symphonies: Massive musical collaboration

Tod Machover, Benjamin Bloomberg, Charles Holbrow, Rebecca Kleinberger, David Nunez, Simone Ovsey, Sarah Platte, Peter A. Torpey, Akito Oshiro van Troyer, Garrett Parrish

The City Symphony project by the Opera of the Future group brings creative musical participation to everyone while encouraging collaboration between artists and amateurs, with symphony orchestras (and many other organizations) as the principal galvanizers. City Symphonies invite the citizens of a particular place to listen to the world around them, to discover the "music" in that place, and to work together to create a sonic portrait of that city that reveals its essential qualities and most important issues and questions to audiences locally and around the world. Going beyond crowd-sourcing, City Symphonies propose a new model of collaboration, where people of all ages and backgrounds work together to make beautiful, meaningful music that none of them—including the highest-level professionals—could have made alone.

Tod Machover and Opera of the Future launched the City Symphony project in 2012, and since then have created collaborative symphonies with the cities of Toronto (Toronto Symphony Orchestra, 2013), Edinburgh (Edinburgh International Festival, Royal Scottish National Orchestra, 2013), Perth (Perth International Festival, West Australian Symphony Orchestra, 2014), Lucerne (Lucerne Festival, Lucerne Festival Academy Orchestra, 2015), and Detroit (Detroit Symphony Orchestra with Knight Foundation, 2015). Machover and his research group collaborated with these cities to explore new relationships between author/audience, composition/improvisation, music/noise, and online/offline while emphasizing the potential of each locale to inspire its citizens to engage with their community through music in a profound way. One of the most rewarding aspects of the City Symphonies project is that the processes employed to achieve the final work are designed to grow naturally out of each particular city and context. For this reason, the five City Symphonies realized to date by Tod Machover and the MIT Media Lab have differed widely in terms of use of imagery/video, interactive performance elements, incorporation of local musicians, and the balance of acoustic/electronic sounds.

Alexandra Rieger

Cognitarium 2.0

Alexandra Rieger

Cognitarium 2.0 is a planetarium for the mind. Enter a world of 40 Hz sounds, multicolored lights and mind-entraining frequencies. Cognitarium 2.0 combines early groundbreaking research in gamma frequencies, multi sensory music and cognition research, to leap into the future of cognitive health and cross-modal experiences. This edition of the Cognitarium is a collaboration combining creative cognition research by Alexandra Rieger, lighting physics and control from Ben Bloomberg, the gamma drones of David Su, and 40 Hz sculpted sound as defined by Tod Machover.

Tod Machover, Benjamin Bloomberg, Elena Jessop, Simone Ovsey, Peter A. Torpey, Akito Oshiro van Troyer

Death and the Powers: Redefining Opera

Tod Machover, Benjamin Bloomberg, Elena Jessop, Simone Ovsey, Peter A. Torpey, Akito Oshiro van Troyer

Death and the Powers is a groundbreaking opera that brings a variety of technological, conceptual, and aesthetic innovations to the theatrical world. It is a one-act, full-evening work that tells the story of Simon Powers, a successful and powerful businessman and inventor, reaching the end of his life and facing the question of his legacy. He is now conducting his final experiment, passing from one form of existence to another in an effort to project himself into the future. Simon Powers is himself now a System. His family, friends, and associates must decide what this means, whether or not he is actually alive, how it affects them, and whether to follow.

Death and the Powers was composed by Tod Machover and developed at the MIT Media Lab along with Diane Paulus (director) and Alex McDowell (production designer). The opera uses the techniques of tomorrow to address age-old human concerns of life and legacy. The unique performance environment, including autonomous robots, expressive scenery, new Hyperinstruments, and human actors, blurs the line between animate and inanimate. The opera premiered in Monte Carlo in Fall 2010, with additional performances in Boston and Chicago in 2011 and a new production with a global, interactive simulcast in Dallas in February 2014. The DVD of the Dallas performance of Powers was released in April 2015.
281. **Diastrophisms**

   Nicole L’Huillier, Yasushi Sakai, Thomas Sanchez Lengeling

   Diastrophisms is a sound installation with a modular system that sends images through rhythmic patterns. It is built on a set of debris from the Alto Río building that was destroyed by the 27F earthquake in 2010 in Chile. With Diastrophisms we were looking for a poetical, critical and political crossing between technology and matter, in order to raise questions about the relationship between human beings and nature, and to consider the construction of memory in a community by questioning the notion of monument, as well as to imagine new forms of communication in times of crisis.

   Work by: Nicole L’Huillier, Thomas Sanchez Lengeling, and Yasushi Sakai

   Exhibited at Siggraph Art Gallery 2018, curated by Andres Burbano. A paper about this work was published in Leonardo Journal for the special edition of Siggraph 2018 Art Papers and Art Gallery Exhibition. The paper was written by Nicole L’Huillier and Valentina Montero.

   Diastrophisms was also exhibited as “Diastrofismos” at the Media Arts Bienal, Santiago de Chile, 2017, curated by Valentina Montero.

282. **Disembodied Performance**

   Tod Machover, Elena Jessop, Peter A. Torpey

   Early in the opera “Death and the Powers,” the main character, Simon Powers, is subsumed into a technological environment of his own creation. The set comes alive through robotic, visual, and sonic elements that allow the actor to extend his range and influence across the stage in unique and dynamic ways. This environment assumes the behavior and expression of the absent Simon; to distill the essence of this character, we recover performance parameters in real time from physiological sensors, voice, and vision systems. Gesture and performance parameters are then mapped to a visual language that allows the off-stage actor to express emotion and interact with others on stage. To accomplish this, we developed a suite of innovative analysis, mapping, and rendering software systems.

283. **El Poema de la Fabrica Cósmica**

   Nicole L’Huillier

   This sonic rite consists of a listening session of the performance of the place, guided by the Para-Cantora, a sonic device that acts as a medium between worlds. It becomes a parasite of the place and through environmental sensing, real-time mapping, and six speakers, it diffuses the chant of the apparently silent agents around us. It is a transductive device that contains different environmental sensors that are mapped in real time into different sounds (synthesizers, samples, textures, words, and other voices) that create a musical performance of the place, unveiling the performativity of non-human agents on the environment and their expressive capacities. In places where the natural and technological collide there are particular disturbances that are transduced by this parasitic medium to create a sonic poem that is imprinted in our collective material memory and sensitizes us through the aural. Become a membrane and resonate like a drum. Connect with your quark-gluon-plasma origins.

   Shake your material existence, and let this parasitic medium guide you through a concert of a specific moment in space and time. This is an exercise of listening to emerge together, stimulate perception, confuse reality, and resonate with the sense that we are as much part of nature as we are part of culture.

   This experimental performance took place in different parts of the world where the natural and technological collide, as part of the Simetría Residency (CERN, ALMA and ESO). Recordings and listening sessions were hosted at CERN in the LHC ALICE Detector in Switzerland, the ALMA Observatory OSF, in the Atacama Desert in Chile, and Paranal Observatory, ESO, in the Atacama Desert in Chile.

   Sensors in the sculpture: Barometric pressure, altitude, temperature, accelerometer, electromagnetic fields, anemometer, wind turbine, light, proximity, and vibrations.

   It has six independent channels and it works with battery, so it is absolutely self contained.

284. **Emotionally Intelligent Playback**

   Hane Lee, David Su

   Emotionally Intelligent Music Playback opens possibilities to various emotional trajectories through a piece of music. The listener can navigate through emotional territories via a touchscreen interface. The system transitions seamlessly to corresponding emotional interpretations extracted from various existing renditions of the same composition.
Nothing is more important in today's troubled world than the process of eliminating prejudice and misunderstanding, and replacing them with communication and empathy. We explore the possibility of creating public experiences to dramatically increase individual and community awareness of the power of empathy on an unprecedented scale. We draw on numerous precedents from the Opera of the Future group that have proposed concepts and technologies to inspire and intensify human connectedness (such as Sleep No More, Death and the Powers, Vocal Vibrations, City Symphonies, and Hyperinstruments) and from worldwide instances of transformative shared human experience (such as the Overview Effect, Human Libraries, Immersive Theatre, and non-sectarian spiritual traditions). The objective is to create a model of a multisensory, participatory, spatially radical installation that will break down barriers between people of immensely different backgrounds, providing instantaneous understanding of—as well as long-term commitment to—empathic communication.

Charles Holbrow

The web enables massive realtime communication and collaboration, but most media on the web does not take advantage of these features. Media on the internet typically uses the web only as a distribution medium.

If we are going to make next-generation internet media, we need to think about how to integrate the unique properties of the web into the media itself. This involves rethinking the role and design of web servers so they facilitate realtime interaction instead of serving requests.

Models for internet-enabled interaction and collaboration like forums, chatroom, live documents, metrics and A/B testing, are not designed with interactive media in mind.

This project is our very first exploration using custom web server technology and a new interaction model to facilitate online collaboration.

David Su

Evergreen Blues is a suite of interactive songs that together provide a collaborative musical narrative experience in the form of a multiplayer operatic game.

Two players simultaneously control the construction and direction of a piece of music through the use of a real-time lyrical conversation system, allowing for granular control of musical expression. Choices made in one song influence the outcomes of the next, paving the way for multi-scene interactive experiences grounded in narrative principles of persistence and emotional consequence.

This work seeks to provide a novel means of creating and understanding multi-user, interactive music systems in which users participate in active and collaborative music-making in conjunction with narrative engagement. It is the goal that this work will open up new possibilities for experiencing music, narrative, and social interaction.

Charles Holbrow

Songs released on music streaming services are static, never changing after their initial release. Evolving Media proposes a content production and publishing pipeline, enabling artists and content creators to release media that evolves and matures as it is consumed. To take advantage of this capability, we are re-thinking the tools and processes used to create and update media content.

The current implementation integrates our custom augmented reality stack to rapidly iterate and publish synchronized audio/video content to the web.

Tod Machover, Rebecca Kleinberger, Alisha Panjwani

Fablur explores the limit of the self in its relationship to others through the medium of clothing. The augmented gown uses a rear dome projection system on the surface of the fabric. The system comprises laser projectors and mirror structures talking wirelessly with a computer, within which is contained both content and warp projection mapping software. This novel technological interface presents both a performative element and a seamless integration in a woman’s life experience. This wearable project questions the boundary between the self and others, the boundary between the individual and society, and the boundary between the body and nature.
Fensadense is a new work for 10-piece ensemble composed by Tod Machover, commissioned for the Lucerne Festival in summer 2015. The project represents the next generation of hyperinstruments, involving the measurement of relative qualities of many performers where previous systems only looked at a single performer. Off-the-shelf components were used to collect data about movement and muscle tension of each musician. The data was analyzed using the Hyperproduction platform to create meaningful production control for lighting and sound systems based on the connection of the performers, with a focus on qualities such as momentum, connection, and tension of the ensemble as a whole. The project premiered at the Lucerne Festival, and a spring European tour just concluded this May 2016.

Fensadense site created by our former UROPer, Garrett Parrish.

Listen to a complete recording of the Lucerne performance here.

Hane Lee

“The sense of freedom...entails not simply the absence of frustration but the absence of obstacles to possible choices and activities—absence of obstructions on roads along which a man can decide to walk.” —Isaiah Berlin

Can we understand freedom as a subjective sensation?

The Freedom Simulator is a set of three experiences that aim to induce a feeling of freedom. These experiences question the manifestation and significance of freedom in our everyday lives.

Each experience is based on a modern political philosophy perspective on freedom: positive freedom, negative freedom, and freedom in light of ethical individualism. Various techniques such as spatial audio, motion tracking, and real-time video projection are utilized.

Alexandra Rieger

The Gamma Instrument is a small-format interactive device hovering between the realms of musical instrument and medical instrument. A capacitive hand-following interface allows one to create abstract gamma sounds while surrounded by an orbit of gamma-frequency lights. Creating musical tones on the device could heighten gamma entrainment as it mimics higher-level cognition and gamma-band processing noted in musicians. This device is part of a larger exploration of 40 Hz frequencies and Alzheimer’s prevention/reduction within the context of the Aging Brain Initiative at MIT. The tabletop multi-sensory experience brings aspects of the Cognitarium to an interactive and portable platform.

David Su

Gammalan is an interactive musical experience that uses music information retrieval techniques in conjunction with game design principles to engage audiences in creative behavior that combines the power of familiar songs with neural entrainment on multiple temporal scales.

A preliminary system analyzes and processes existing recordings, manipulating properties such as rhythm and harmony, while introducing synthesized frequencies in a musically informed manner. The recordings are then presented in an exploratory 3D game-like environment that encourages active and playful engagement with the recorded music.

Alexandra Rieger

Introducing the newest edition of the gamma musical/medical instruments - the Gamma MOON (Musical Omnисensory Orbital Neuroinstrument). This instrument features a capacitive interface which delivers multisensory gamma stimulation through audio, visual, haptic and tactile feedback. In collaboration with the Aging Brain Alzheimer’s Initiative at MIT, the Gamma MOON pilots a novel treatment form-factor with the goal of device deployment in large-scale clinical trials. Research reveals that gamma instrument interaction can strengthen cognitive function and sensory perception while increasing focus even in neurocognitively healthy individuals. Contact arrangement allows both patients and performers to create high-level musical abstractions as well as follow traditional notational melodies. Gamma MOON’s heightened sensorial engagement recruits increased cognitive entrainment, multimodal expression and creative freedom.
Alexandra Rieger

The Gamma SENSE (Sensory Engaging Nebulised Scent Experience) is a pioneering instrumental addition to the gamma instrument series. The device delivers multisensory gamma stimulation through auditory, visual, and olfactory channels.

"This medical/musical instrument is based upon our groundbreaking pilot studies revealing (even non-synesthetic) humans link scent to sonic pitches. Due to the steep fall-off rate once gamma stimulation concludes, this olfactory mechanism probes the possibility of slowing 40 Hz frequency attenuation in patients."

As research continues, the Gamma SENSE device was developed to aid in the testing and identification of the olfactory perceptive triggers which recruit and sustain identified cognitive frequencies. In collaboration with the Aging Brain Alzheimer’s Initiative at MIT, the Gamma SENSE pilots a novel, testing form-factor with the goal of deployment in large-scale clinical trials. The Gamma SENSE instrument also features one of the first touchpad arrangements designed to support EEG testing via the low-motion/high output format. As motion creates unwanted noise artifacts during electroencephalograms, this instrument requires the subtlest of finger-motions to trigger dynamic musical expression. The Gamma SENSE propels myriad frontiers through expression, function, and design.

Tod Machover, Tristan Jehan, Rebecca Kleinberger

The Hyperinstruments project creates expanded musical instruments and uses technology to give extra power and finesse to virtuosic performers. They were designed to augment a wide range of traditional musical instruments and have been used by some of the world’s foremost performers (Yo-Yo Ma, the Los Angeles Philharmonic, Peter Gabriel, and Penn & Teller). Research focuses on designing computer systems that measure and interpret human expression and feeling, exploring appropriate modalities and content of interactive art and entertainment environments, and building sophisticated interactive musical instruments for non-professional musicians, students, music lovers, and the general public. Recent projects involve the production a new version of the “classic” Hyperstring Trilogy for the Lucerne Festival, and the design of a new generation of Hyperinstruments, for Fensadense and other projects, that emphasizes measurement and interpretation of inter-player expression and communication, rather than simply the enhancement of solo performance.

Tod Machover, Benjamin Bloomberg

Hyperproduction is a conceptual framework and a software toolkit that allows producers to specify a descriptive computational model and consequently an abstract state for a live experience through traditional operating paradigms, such as mixing audio or operation of lighting, sound, and video systems. The hyperproduction system is able to interpret this universal state and automatically utilize additional production systems, allowing for a small number of producers to cohesively guide the attention and perspective of an audience using many or very complex production systems simultaneously. The toolkit is under active development and has been used for new pieces such as Fensadense, and to recreate older systems such as those for the original Hyperstring Trilogy as part of the Lucerne Festival in 2015. Work continues to enable new structures and abstraction within the framework.

Tod Machover, Tristan Jehan

Music software that lets anyone compose music. The first music software program designed to teach students and adults how to compose music simply by drawing lines on the screen.
300. **ImmerSound VR**

Rebecca Kleinberger

ImmerSound is a virtual reality experience wherein one can compose music by drawing in 3D. The resulting composition is a sculpted soundscape to be experienced both visually and in 3D audio.

The user starts by choosing an instrument in the system and testing the sound that this instrument would produce at different locations. Then the user can "paint" a melody in space, where the elevation of the "sound brush" defines the pitch of the instrument, and the speed of the hand corresponds to the tempo of the melody created. A wide range of instruments enables the creation of rich compositions with percussion, bass, classical instruments, and ambient sounds.

This project associates sounds and space in a new way by offering an intuitive and natural way to interact with music. One can also imagine the same type of visual compositional space used as a neutral zone for collaboration between two or more people in different geographical locations and from different cultural backgrounds, using the universal language of music to connect in less-biased ways. This system is a first example of the potential of virtual reality for music and experiences of connection.

301. **Internernity**

Charles Holbrow

Internernity is a dynamic musical composition built into the World Wide Web. The Internet changed the way that we listen to music, but music itself remains essentially unchanged. Can we create music that uses the Internet for more than a distribution medium? Can we make music that could not exist without the Internet?

Internernity is an experimental integration of music composition and the World Wide Web. Instead of releasing this music as a static file, it was released in the form of a website. When the site launched, users could play the composition continuously from beginning to end. But each new connection to the web server changes the musical structure in some small way...and eventually the original composition is unrecognizable.

Certain interactions with the site may extend its lifetime, while certain interactions nudge the music towards inevitable disintegration. Will you get to hear the piece before it is broken forever?

302. **JoyBranch**

Rebecca Kleinberger, Gabriel Miller, David Su, Davie Su, Gabriel Miller, Sampson, and the San Diego Zoo

The Joy Branch project explores different user interfaces to allow parrots to shape their sonic environment. Animal agency—control of the environment—is an important and underutilized element of captive care. Parrot species are vocal learners, and as such are highly attuned to their sonic environment. Much of their brains are involved in the production and analysis of sound, and yet their sonic environment in managed care does not provide a rich experience. In this project, we assess the efficacy of new enrichment techniques that have the potential to improve the lives of these birds through music. The project involves the placement of sonic enrichment elements into the birds' enclosures under controlled and supervised conditions.

The "joystick branch" element exposes only a standard wooden perch to the birds. The aim is to create naturalistic interactive methods for birds to generate sounds, and to assess their optional engagement with these new modes of control.

303. **Looking Through the Piano**

Hannah Lienhard, Manaswi Mishra, Karsten Schuhl

Looking Through the Piano is a project created to visualize all of the past projects from the Opera of the Future group. The piano acts as an interface and a timeline, allowing the user to hold down one or more keys to see and hear information about different projects throughout the group’s history.

304. **Man of My Words**

Hane Lee

Man of My Words is a wearable self-feedback voice changer for women to challenge internalized sexism. The experience is designed in two parts:

Auditory The electronic part of the device consists of a Bluetooth microphone and earbuds. When the female user speaks into the microphone, her voice is altered into a male voice and returned through the earbuds. By giving the perception of speaking in a male voice, this device is intended to break the association that the users have between themselves, their female, "weak" voice, and lack of authority.

Visual The top hat and a fake mustache, apart from their functional purpose of holding the microphone, were designed to create a more immersive, satirical experience. This device aims to more easily approach a serious social issue through comfortable humor.
Media Scores
Tod Machover, Peter A. Torpey
Media scores provide a means to orchestrate multiple modalities in the creation of expressive works of art and performance. New technologies afford numerous opportunities to tell stories and create expressive artworks through a variety of media. Media scores extend the concept of a musical score to other modalities in order to facilitate the process of authoring and performing multimedia compositions, providing a medium through which to realize a modern-day Gesamtkunstwerk. Through research into the representation and the encoding of expressive intent, systems for composing with media scores are being developed. Using such a tool, the composer will be able to shape an artistic work that may be performed through human and technological means in a variety of media and utilizing various modalities of expression. Media scores offer the potential for authoring content considering live performance data and the potential for audience participation and interaction. This paradigm bridges the extremes of the continuum from composition to performance, allowing for improvisatory compositional acts at performance-time. The media score also provides a common point of reference in collaborative productions as well as the infrastructure for the real-time control of any technologies used during a live performance.

Media Timelines: Understanding the future by studying the past
Charles Holbrow
The world wide web was conceived 30 years ago. What will internet media look like after another 30 years? Should we expect it to be mostly the same? Or will it evolve rapidly in the coming years?
To gain insight into these questions, I have been studying the evolution of other media technologies, and identifying ways that they are both similar and different from the internet.
Media Timelines packages parts of this research in an interactive application that makes it easy to observe and compare the evolution of sound recording, film, and internet media technologies.

Memory Music Box
Rebecca Kleinberger
We are transforming a classic music jewelry box into a digital memory box and Skype portal that enable those not familiar with technology to stay in touch with their family and friends. The box has three different modes. To switch mode the user only has to turn the small crank in the back, like they would do with a regular music box. The crank is linked to a rotary encoder. The back of the box is covered with a two-way mirror covering a small LCD screen; when the screen is turned off, it looks like a regular mirror but when the screen is on, it looks like a display. In the first mode, the box plays the favorite music of the user with the screen off. In the second mode, the display shows photographs of family and friends. By turning the crank or by clicking on the characters in the photographs, the box goes into mode 3, which is a Skype portal enabling the user to instantly call a family member face-to-face. This device is mainly imagined for elderly parents with dementia or memory loss.

MM-RT
Akito Oshiro van Troyer
MM-RT is a tabletop tangible musical interface that employs electromagnetic actuators and small permanent magnets to physically induce sounds on objects. When, for example, a box with permanent magnets inside is placed on top of a pad, an electromagnet installed below the pad actuates the permanent magnets, causing them to bounce and hit the walls of a box. Timbre generation on each box is physically and digitally constrained: Each object comprises different materials and size, and a granular synthesis technique (a digital form of time domain additive synthesis) is used to create the sound producing mechanism.

Music Visualization via Musical Information Retrieval
Tod Machover, Thomas Sanchez Lengeling
In a study of human perception of music in relation to different representations of video graphics, this project explores the automatic synchronization in real time between audio and image. This aims to make the relationship seem smaller and more consistent. The connection is made using techniques that rely on audio signal processing to automatically extract data from the music, which subsequently are mapped to the visual objects. The visual elements are influenced by data obtained from various Musical Information Retrieval (MIR) techniques. By visualizing music, one can stimulate the nervous system to recognize different musical patterns and extract new features.

Myths of the Cosmos
Ariel Ekblaw, Nicole L’Huillier, Prathima Muniyappa
Exploring the Atacama Desert and its intrinsic relationship to the Cosmos
311. **Nebula**

**Rebecca Kleinberger**

Nebula is a voice-controlled interactive software app that allows users to conduct a choir of diverse vocal sounds by using only their voice as input. The system is based on the Constellation project by Akito van Troyer that takes sonic material and organizes it visually to let anyone compose creative soundscapes. Nebula uses hundreds of vocal samples that are represented as individual stars and organized by perceptual and spectral audio features. The samples get triggered and activated when the user sings or produces any sound with the voice. The voice is analyzed in real time, and this analysis is then used to trigger and mix a cascade of sounds with similar features. The voice becomes a kind of conductor’s baton that creates a dialogue without words between the individual and the community. And once a participant uses Nebula, their own voice, first used as a controller, is then transformed into a new sample adding an additional star to the experience for all subsequent participants. The result - a final cosmos of voices—provides material that might be used by composer Tod Machover for the final Philadelphia Voices City Symphony.

312. **Oniorb**

**Hannah Lienhard**

Oniorb is an explorable musical object that was created with the idea of stress relief in mind. It is meant to act as a stress ball that also gives auditory feedback as you squeeze it. The orb is embedded with several different kinds of sensors that collect data from user interactions, which is then mapped to sound frequencies to create a musical output. Oniorb combines aspects of both active and receptive music therapy to create a calming experience for the user, meaning that it allows people to not only experience soothing music, but also gives them a role in creating and shaping the music they are hearing.

313. **ORBIT (Olfactory Response Baseline Identification Test)**

**Alexandra Rieger**

We are currently developing a new approach in conducting sensory examinations via the Olfactory Response Baseline Identification Test (O.R.B.I.T). Based upon prior research (1), findings reveal olfactory testing to be an early detector of Alzheimer’s and Dementia (2), even aiding in differentiating the conditions based on identification distance per nostril. This sensory test device automates a crucial portion of the MCPT (Multisensory Cognition Proficiency Test). The O.R.B.I.T. will be the first of many mechanical designs supporting research in detecting and tracking sensory indicators of neurological performance and health throughout GAMMA treatment.

314. **Panoptic Journey**

**Thomas Sanchez Lengeling**

Imagine if you want to travel to a destination and once you are there hear only car horns, or see only blue, or feel a single spectral color of the city. The project is about experiencing a city in a different way and to discovery distinct paths to travel. This is by including artificial soundscapes and visuals from other contexts. Part of this is knowing what sounds are around us and what are we looking at when we are walking in the city. The new experiences is an extra layer of sensory stimuli in the city. The study includes experiencing a city with colors and sounds from another location that we haven’t been to. This “transfer” process transfers colors and sounds to another location—while still being in the same city. One potentially could transfer emotional content from one city to another one. Overall, the immersive and multi-sensory representation of a map is crucial for allowing participants to fully feel that place. In addition, the goal is to offer a helpful, immersive, subjective - rather than a detached, observational experience.
Philadelphia Voices is the latest in the series of City Symphonies projects that Tod Machover and the Opera of the Future group have created since 2012. Previous City Symphonies have centered on Toronto, Edinburgh, Perth, Lucerne, and Detroit.

Each project paints a musical portrait of a city—using “traditional” musical elements as well as real sounds recorded by residents—to portray the essence of their city’s history and future. Everyone living in that city is invited to collaborate to create the symphony, resulting in an unprecedented creative collaboration around music, sound, and storytelling.

Philadelphia Voices has been in progress since spring 2017 and will culminate in performances in Philadelphia (Kimmel Center) and New York (Carnegie Hall) in April 2018. A special mobile app has been developed to allow anyone with a smartphone to collect sounds and video and to upload those files to a communal database for listening and morphing.

Opera of the Future researchers have created new software that enables anyone to contribute their voice to a specially-designed sonic landscape from Philadelphia. Workshops and special activities have been organized with local singers from every age and background, and Tod Machover has chosen several hundred of them to sing in the final performances with The Philadelphia Orchestra under the baton of its music director, Yannick Nézet-Séguin.

Since Philadelphia is considered the birthplace of American democracy, Philadelphia Voices will investigate the current state of democracy from a Philly perspective. The project will also consider the society in which we want to live, and what we are willing to do to achieve that ideal.

Tod Machover, Benjamin Bloomberg, Charles Holbrow, Elena Jessop, Simone Ovsey, Peter A. Torpey, Garrett Parrish, Justin Martinez, Kevin Nattinger

Death and the Powers: Global Interactive Simulcast

Nicole L’Huillier

Ritual I: The Thing Itself consists of a choreographed robotic body that is in constant flux. It performs a dance of repetitive patterns that become a trance ritual of vibrations and movement. The thing or dancing body stands on a metal sheet that vibrates with every move it makes; this way the body affects its territory with every movement. In return, the vibrations of the metal add to the vibration of the thing itself while it moves, and in this way the body is affected by its territory.

This is a feedback system, a cyclic loop, a transduction network, a ritual dance between a body and its territory. This ritual explores how agency becomes increasingly distributed among bodies and territories, which opens interactions of hybrid selves, blurring the limits of bodies and its environment, understanding them all as an assemblage of vibrant matter. The architecture comprises complex assemblages—nothing is something by itself, but things are themselves by being in a relationship with others. This is an entangled architecture of bodies. This is a way to explore and diversify the imaginative projections and potentials of a kinetic non-human body and how sound and vibration are key to trigger agency and vibrant presence.

It is the thing itself that has been allowed to be deployed as multiple, and thus allowed to be grasped through different viewpoints, before being possibly unified in some later stage depending on the abilities of the collective to unify them.

“Can a man know the truth and tell it to the greatest number and still be misunderstood? Can one man be of the many and still be known?”

Schoenberg in Hollywood is the most recent opera by composer-inventor-professor Tod Machover that explores the complex relationship between uncompromising art and mass appeal, and of whether — and how — art can change the world. Arnold Schoenberg was a man of extraordinary contradictions: now considered one of the twentieth century’s greatest composers, during much of his lifetime Schoenberg was known for — and excelled at — composing music hated by the public and critics; a man whose only compass was his pursuit of pure ideas, Schoenberg also yearned for popularity; Schoenberg’s music absorbs tradition, but it is not hampered by it and always points forward. What happened — and might have happened — when such an uncompromising spirit settled in Hollywood, the epicenter of American popular culture, after he fled Hitler’s Europe in 1935?

Schoenberg in Hollywood begins with a meeting (one that did occur in history) between the legendary producer Irving G. Thalberg of Metro Goldwyn Mayer and Arnold Schoenberg. Thalberg asks Schoenberg to compose music for a film based on Pearl S. Buck’s The Good Earth, a best-seller about the life of peasants in a Chinese village. Although Schoenberg disdained the idea of composing music to please the public, the prospect of writing a Hollywood film score that would reach millions appealed to him greatly. In reality, Schoenberg was not offered the job when he demanded a $50,000 fee—an astronomical sum at the time—from Thalberg. However, Schoenberg in Hollywood exploits — and explores — the hypothetical scenario of what would have happened if Schoenberg had indeed composed for Hollywood. In the opera, Schoenberg imagines the events of his life through the lens of different film genres: silents, noir mysteries, Disney cartoons, musicals, and Westerns, making the movie — and projecting his vision well into the future — that Hollywood never allowed him to do.

Commissioned and presented by Boston Lyric Opera, with much visionary technology for sound, image, and staging created at the MIT Media Lab, Schoenberg in Hollywood is based on a scenario by the late Braham Murray, with a libretto by Simon Robson and directed by Karole Armitage. Schoenberg in Hollywood premiered at the Boston Lyric Opera in November 2018 and travels to the Vienna Volksoper in the 2019/2020 season.

For more, see schoenberg.media.mit.edu.

Seasons Change Together is a collaborative song construction experience for multiple simultaneous participants. It represents a first step towards the creation of a framework, designed for interactive multiplayer musical experiences, that explores the potential for technology-enabled systems to facilitate collaborative creativity through expression, the emotional affordances of musical storytelling, and the spatiotemporal boundaries of co-presence.

Participants are presented with multiple interfaces that determine the musical texture, rhythmic patterns, and lyrical content of an interactive song. Individual participants can freely move between and share interfaces as they wish, allowing the experience to accommodate play sessions with variable user counts as well as encouraging participants to actively engage with all aspects of the song’s construction through collaborative composition.

Drawing inspiration from improvisational practice in addition to game design and interactive storytelling, Seasons Change Together strives to open up new possibilities for experiencing music, narrative, and creativity in a social environment.

SIDR: Deep Learning-Based Real-Time Speaker Identification

Consider each of our individual voices as a flashlight to illuminate how we project ourselves in society and how much sonic space we give ourselves or others. Thus, turn-taking computation through speaker recognition systems has been used as a tool to understand social situations or work meetings. We present SIDR, a deep learning-based, real-time speaker recognition system designed to be used in real-world settings. The system is resilient to noise, and adapts to room acoustics, different languages, and overlapping dialogues. While existing systems require the use of several microphones for each speaker or the need to couple video and sound recordings for accurate recognition of a speaker, SIDR only requires a medium-quality microphone or computer-embedded microphone.
Sonic enrichment at the zoo

Janet Baker, Rebecca Kleinberger, Gabriel Miller, Janelle Sands

This project is a collaboration between the MIT Media Lab and the San Diego Zoo to design and build interactive sonic enrichment systems for animals in managed care. Our approach is based on the potential of animal-animal and human-animal relationship as an environmental enrichment for the welfare of zoo-housed animals specifically in terms of animal vocal communication. Enrichment is a way for caregivers to provide animals with the opportunity to express natural behaviors and reduce stereotypic behaviors.

Sonic Murals

Alexandra Rieger

Giving voice and information to objects and spaces around us.

Objects in our lives are usually either digital or not; mostly a wall is just a wall. The Sonic Murals project explores what happens when we blur those lines. Implementing touch capacitance and conductive pigments in an innovative way, any surface can become a sensor, a tool for data collection, or a musical instrument, as exhibited in this project. When interacting with touch or proximity sensors on a sonic mural, one can experience spacial exploration and sound creation on a more omnisensory level.

Sound Cycles

Tod Machover, Charles Holbrow, Rebecca Kleinberger

Sound Cycles is a new interface for exploring, re-mixing, and composing with large volumes of audio content. The project presents a simple and intuitive interface for scanning through long audio files or pre-recorded music. Sound Cycles integrates with the existing Digital Audio Workstation for on-the-fly editing, audio analysis, and feature extraction.

Spaces that Perform Themselves

Nicole L’Huillier

As we generally experience on earth, there is no space without sound and there is no sound without space. Building on the understanding of music and architecture as creators of spatial experience, this project presents a novel way of unfolding music's spatial qualities in the physical world. Spaces that Perform Themselves exposes an innovative response to the current relationship between sound and space: where we build static spaces to contain dynamic sounds. What if we change the static parameter of the spaces and start building dynamic spaces to contain dynamic sounds?

A multi-sensory kinetic architectural system is built in order to augment our sonic perception through a cross-modal spatial choreography that combines sound, movement, light, color, and vibration. By breaking down boundaries between music and architecture, possibilities of a new typology that morphs responsively with a musical piece can be explored. As a result, spatial and musical composition can exist as one synchronous entity. These spatial choreographies build up the scenario to study the possible relationships between a human body and a robotic architectural body, throughout a dance of perception and matter.

This project seeks to contribute a novel perspective on leveraging technology, art, science, and design to provide a setting to enrich and augment the way we relate to the built environment. The objective is to enhance our perception and challenge models of thinking by presenting a post-humanistic phenomenological encounter of the world.

Speech Companion

Rebecca Kleinberger, Sebastian Franjou

Speech Companion is an exploration in the domain of real-time extraction of musicality from speech. Speech is one of the richest and most ubiquitous modalities of communication used by human beings. Its richness lies in the combination of linguistic and nonlinguistic information. Musicality is one of the most crucial nonlinguistic components of speech and covers tempo and rhythms of the speaker as well as the pitch variation and unique texture of the vocal sounds. Abstracting musicality from a speech in real time presents several challenges from latency to subjective pitch identification or recognizing voiced/unvoiced sounds. In this paper, we describe a new system for real-time extraction of the musical present in everyday speech based on time and pitch quantization. Our system offers several modes from a simple synchronized melody line to a more complex accompaniment much like a singer accompanying herself at the guitar.

With such a system, we offer a proof of concept and a working prototype to explore the real-life situations where the music of speech impacts speakers or listeners such as in the contexts of infant-directed speech, language acquisition, human-animal communication, speech pathology, aphasia reeducation, or even music learning and musical composition.
**326. Symphony for the Koreas**

**Tod Machover**

Symphony for the Koreas will be the latest installment of the celebrated City Symphony series. Over the next few years, Tod Machover and his team will collaborate with citizens from both South and North Korea to create a symphony that reflects what both sides have in common, where conflicts remain, and what might be effective, realistic, and peaceful ways to resolve conflicts through music. Through collaboration with the Lindenbaum orchestra and festival, a South Korean organization dedicated to bringing peace to the Korean Peninsula through music, Machover and his team plan to invite musicians from both Koreas to participate in ongoing creative activities—as well as to live performances—of Symphony for the Koreas. The Lindenbaum organization has been granted unprecedented permission by the South Korean government to communicate and collaborate with the North Korean Government. It has also secured an MOU with the North Korean Ministry of Culture to hold a joint concert between the two Koreas. The final performance is expected to take place at or near the Korean Demilitarized Zone, and will then be toured worldwide.

Since 2012, Tod Machover and his Opera of the Future Group have created City Symphonies for Philadelphia, Detroit, Lucerne, Perth, Edinburgh, Miami and Toronto. In addition to Symphony for the Koreas, Machover is currently working on new City Symphonies for Chennai (India) and for Boston (in collaboration with HUBweek).

**327. Taking a line on a walk**

**Charles Holbrow**

Bauhaus artist Paul Klee considered a line to be one of the atomic elements of art and architecture. He famously described a line drawing as "a dot that went for a walk." What would a dot on a walk look like in three dimensions?

This project uses our custom high-resolution AR rig to find out. See the very first test footage:

**328. Talking Drums**

**Nicole L’Huillier, Yasushi Sakai, Thomas Sanchez Lengeling**

"The Talking Drums" is a sound installation where we created a modular system for sending images through rhythmic patterns. It is an encrypted language to empower a musical community by sending secret messages, avoiding surveillance and listening to each other. It’s inspired by the communication method and instrument used by African communities to send messages across the continent. They did this by drumming, and by a rhythmic language that only could be understood by the community.

For the installation we collected different objects from MIT’s dump, especially obsolete technologies, such as hard drives and old screens.

**329. The SciFi Audio Workstation**

**Charles Holbrow**

The internet changed how we create, distribute, and consume music and media. Modern digital tools for creating music and media provide "cloud enabled" features like automatic backups, an asset marketplace, and real-time collaboration. Despite these features, current tools for creating music are still based on the personal computing paradigms of the 20th century. How will media production change in the 21st century?

Internet engineering introduced the concept of cloud-native applications. What would it mean for end-user experience to be truly cloud-native? This project shows a very early prototype that illustrates some of the possibilities. In this approach, the assets that make up a music project are securely exposed to the Internet, where they can be accessed and manipulated by digital services and and human collaborators.

The long-term goal is to give individual content creators control of their data, and a share of the benefits provided by machine learning analytics. A longer description and technical blueprint can be found in Turning the Digital Audio Workstation Inside Out.
Today, the environments that humans occupy in space are designed for survival. Humans are carefully shuttled to and from space, and during their relatively short stays, they are provided with minimum supplies to remain alive and able to perform experiments. As we begin to plan less for short visits and more for life in space (such as a six to eight month trip to Mars and beyond) the question becomes: What does human culture look like in space?

Nicole L’Huillier and Sands Fish decided to explore how design and creativity might evolve as we begin to do more than merely survive in space.

The Telemetron is a unique mode of musical performance that takes advantage of the poetics of zero gravity, and opens a new field of musical creativity. The project attempts to expand expression beyond the limits of earth-based instruments and performers. Leveraging sensors, data transmission and capture (for performance after flight), as well as their experience as composers and performers, Sands and Nicole explore a new body language for music.

The Telemetron was played for the first time during the inaugural Media Lab Space Exploration Initiative’s Zero G flight. This instrument is a clear dodecahedron chamber that contains customized “chimes” containing gyroscopes. The chimes emit their telemetry as they spin and collide. Sensors record the position, direction, and spin of each chime. These elements create the composition. The performers play the instrument by moving it in space, shaking it, colliding it. The performance can be recorded to be experienced on earth or used as a live instrument during future space flights. The instrument can be played inside space craft or in the vacuum of space without the benefit of sound waves.

Recorded as a beautiful audio-visual experience, this experiment opens the doors for new forms of creative expression, and brings the magic of space to musicians. We hope to reach beyond the utilitarian, and toward the inspiring.

The Telemetron is a musical instrument specially designed to be performed in microgravity environments. It is created to explore the poetics of movement in outer space and the relational aspects of an antigravitational performance between human and non-human bodies. Through this line of work, we explore how the creation of culture might evolve as we leave Earth. The Telemetron project proposes a space in space for everybody - a space to share, to create, to listen.

During the summer of 2018, the Telemetron was presented on different occasions:

The Telemetron was exhibited at Ars Electronica as part of the exhibition "A Glitch in the Stars” curated by the MIT Media Lab Space Exploration Initiative. Nicole L’Huillier designed the exhibition along with Sands Fish and Xin Liu.

The Telemetron was featured at Sónar+D, a festival that explores how creativity is changing our present and imagining new futures. Nicole was invited to speak in the “Making Music in Space” panel. She also gave a workshop called “Antigravitational Luthiers”. Also, the Telemetron was part of The Zero Gravity Band Exhibition.

We published the paper “Telemetron: a musical instrument for performance in zero gravity” at NIME, and Sands Fish presented it at the international conference on New Interfaces for Musical Expression, describing the technical design of our first Telemetron.

Nicole also gave a talk about the Telemetron at the En Orbita Festival in NYC.

The Telemetron was created by Nicole L’Huillier and Sands Fish. With the assistance of Thomas Sanchez Lengeling, Sarah Hua, and Matt Carney. It was created on the context of the Space Exploration Initiative first zero gravity research flight. We are currently working on more space instruments, stay tuned.
The Vocal Vibrations music is now available for exclusive download from Bowers & Wilkins. Vocal Vibrations was exhibited at Le Laboratoire Cambridge in March 2015. The original installation at Le Laboratoire Paris ran from March to September 2014.
Pattie Maes: Fluid Interfaces
Designing systems for cognitive enhancement

Pattie Maes, Harshit Agrawal, Sang-won Leigh
We explore an art form where machines take on an essential role in the aesthetics and processes of the creation. Our main theme can be summarized as "body, hybrid, and evolve," as we study an artistic medium that incorporates mechanical machines that institutes a hybrid creation process as well as an expressive capacity beyond body limits.

Flying Pantograph transposes human-scale drawing acts to a physically remote output canvas in different scales and aesthetics. A drone becomes an "expression agent," modified to carry a pen and be controlled by human motions, then carries out the actual process of drawing on a vertical wall. Not only mechanically extending a human artist, the drone plays a crucial part of the expression as its own motion dynamics and software intelligence add new visual language to the art. This agency forms a strong link between a human artist and the canvas; however, at the same time, it is a deliberate programmatic disconnect that offers space for exploiting machine aesthetics as a core expression medium.

This seemingly straightforward technical realization is in fact a combination of non-trivial mechanical and algorithmic solutions. The drone, a floating machine, is relying on a slim chance of stabilization acquired by battling the vortex of air, the pressure and friction on the canvas surface, and the capricious mind of the human artist. This suspense, the vulnerability to instability, and the aftermath of crashing, poses a contrast with the optimistic idea of technologically evolved capability of a human artist.

At this critical point of balance, we embody an instance of evolution in form of an artistic medium. The interaction between people and our installation itself is one message, where the outcome drawing of the interaction offers another. This pushes forth the idea of collective and technological evolution across scale.

Pattie Maes, Arnav Kapur, Utkarsh Sarawgi, Eric Wadkins, Nora Hollenstein (Visiting PhD candidate from ETH Zurich)
AlterEgo is a non-invasive, wearable, peripheral neural interface that allows humans to converse in natural language with machines, artificial intelligence assistants, services, and other people without any voice—without opening their mouth, and without externally observable movements—simply by articulating words internally. The feedback to the user is given through audio, via bone conduction, without disrupting the user’s usual auditory perception, and making the interface closed-loop. This enables a human-computer interaction that is subjectively experienced as completely internal to the human user—like speaking to one’s self.

A primary focus of this project is to help support communication for people with speech disorders in conditions like ALS (amyotrophic lateral sclerosis) and MS (multiple sclerosis), among others. Beyond that, the system has the potential to seamlessly integrate humans and computers—such that computing, the Internet, and AI would weave into our daily life as a "second self" and augment our cognition and abilities.

The wearable system captures peripheral neural signals when internal speech articulators are volitionally and neurologically activated, during a user’s internal articulation of words. This enables a user to transmit and receive streams of information to and from a computing device or any other person without any observable action, in discretion, without unplugging the user from her environment, without invading the user’s privacy.

Harpreet Sareen,
Our traditional manufacturing, fabrication, and electronics have been centered around synthetic and completely artificial techniques. Coming from an industrial revolution, this is not surprising. However, in recent years, the progress in material science has enabled us to work at a deeper substrate level, much beyond the chip-layer. This has helped us rethink form/structure, sources of power and "hosts" of future electronics.

A Flying Pantograph

AlterEgo

Argus: Water monitoring through nanosensors inside living plants
Pattie Maes, Nataliya Kos'myna, Order is alphabetical. Please check the webpage of the project to find out more about the team who made the project possible! Katie Bacher, Jin Dou, Alexa Gross, Thanh Nguyen - current collaborators (as of October 2019); Caitlin Morris, Utkarsh Sarawgi - past collaborators. [Update 02/04/2020: This project has open positions for UROPs/visiting students or interns. One position focuses around electrical engineering, another one on app development and design and the third one is around ML/AV/Signal Processing. We are particularly interested in finding UROPs for spring/summer period! Please contact nkosmyna@media.mit.edu for more information.]

AttentivU is a device, in the form factor of a pair of glasses, which senses brain activity (electroencephalography - EEG) as well as eye movements (electrooculography - EOG) to measure different cognitive processes in real time, including cognitive load, fatigue, engagement, and focus (please check our FAQ on this page for the definitions). The device can be used for passive or active interventions, for example to monitor the state of the user, providing gentle audio or haptic feedback when the user is less attentive (driving scenario) or adapting the environment when cognitive overload is detected (blocking the notifications). The system can operate in a standalone, non-networked fashion to ensure privacy of the collected data. The use of the AttentivU glasses can be limited to just those moments when the user decides they want to learn to sustain their attention.

We have tested the first generation prototype of the device in workplace (check the paper here) and learning settings (check the paper here and here) with over 100 subjects. We performed experiments with people studying or working by themselves, viewing online lectures as well as listening to a professor at the university. We have now completed the first test of the glasses prototype (check the paper here) with more than 30 subjects who were performing a driving task in a simulator overnight when their attention waned, and the system reminded them with a sound or with a vibration to pay attention to the road. This research paper was rewarded with the honorable mention award at the 2019 AutoUI conference (paper will appear in the end of September 2019). Please check the dedicated page about the car use case scenarios here.

Please check the FAQ (bottom of this page) if you have more questions about the project and/or want to collaborate with us!

Project Lead: Nataliya Kosmyna, Ph.D

Project Team and Contributors (in alphabetical order):

Katie Bacher, Jin Dou, Alexa Gross, Thanh Nguyen - current collaborators (as of October 2019);

Caitlin Morris, Utkarsh Sarawgi - past collaborators.

Several research projects have recently explored the use of physiological sensors such as electroencephalography (EEG - brain activity) or electrooculography (EOG - eye movements) to measure the engagement and vigilance of a driver. However, these systems still suffer from limitations such as an absence of a socially acceptable form-factor and use of impractical, gel-based electrodes. We have developed AttentivU, a device, in the form factor of a pair of glasses, which senses brain activity EEG as well as EOG to measure different cognitive processes in real time, including cognitive load, fatigue, engagement, and focus. The device can be used for passive or active interventions, for example to monitor the state of the user, providing gentle audio or haptic feedback when the user is less attentive or adapting the environment when cognitive overload is detected. The system operates in a standalone, non-networked fashion to ensure privacy of the collected data.

We have now completed the first test of the glasses prototype with more than 30 subjects who were performing a driving task in a simulator overnight when they were tired and drowsy, and the system reminded them with a sound or with a vibration to pay attention to the road.

Pattie Maes, Javier Hernandez, Nataliya Kos'myna, Caitlin Morris, Sebastian Zepf, Please check the webpage of the project to find out more about the team who made the project possible! Thanh Nguyen - current collaborator (as of October 2019); Caitlin Morris - past collaborator.

We present an augmented handheld airbrush that allows unskilled painters to experience the art of spray painting. Inspired by similar smart tools for fabrication, our handheld device uses 6DOF tracking, mechanical augmentation of the airbrush trigger, and a specialized algorithm to let the painter apply color only where indicated by a reference image. It acts both as a physical spraying device and as an intelligent digital guiding tool that provides manual and computerized control. Using an inverse rendering approach allows for a new augmented painting experience with unique results. We present our novel hardware design, control software, and a discussion of the implications of human-computer collaborative painting.

Pattie Maes, Joseph A. Paradiso

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BioEssence is a wearable olfactory display that provides just-in-time release of scents based on the physiological state of the wearer. The device can release up to three scents and passively captures subtle chest vibrations associated with the beating of the heart and respiration through clothes.

Byte.it is a miniaturized, discreet interface that uses teeth gestures for hands-free input for wearable computing.

As humans, we are constantly seeking to communicate and consume information, and mobile devices give us access to the world wide web, our digital selves, and all our digital assets with the touch of our fingers. Context can temporarily reduce our abilities to perform certain activities, preventing us from having a fluid interaction with mobile computing. Hands are not always available, and sustained visual attention is often required for successful task performance and social norms. Current screen-based interfaces are not designed to be used by a person engaged in another attention-demanding activity such as walking, talking, or driving, leading to ineffective interactions and even dangerous situations.

Audio interfaces are a potential solution as they can provide a high-bandwidth communication channel without requiring visual attention. Speech has been the predominant interaction modality for audio interfaces, but it can be ineffective in situations with loud environmental noise, or inappropriate in social or dynamic on-the-go contexts. Recent work has explored teeth gestures as a solution for interaction in these contexts, but these attempts are limited by the number of gestural primitives recognized (bandwidth) and the discreteness of the interfaces used to detect these gestures.

Byte.it expands on this work by exploring the use of a smaller and more unobtrusively positioned sensor (accelerometer and gyroscope) for detecting tooth clicks of different groups of teeth and bite slides for everyday human-computer interaction. Initial results show that an unobtrusive position on the lower mastoid close to the mandibular condyle can be used to classify teeth tapping of four different teeth groups (front, back, left, and right teeth click) with an accuracy of 88 percent, or an accuracy of 84 percent for seven different teeth clicking and bite sliding gestures (front, left, and right click, and front, back, left, and right slide).

The applications currently being explored are centered around dynamic, on-the-go, hands-and-eyes-free contexts. For example, (1) controlling the different commands of a media player, such as play/pause, volume, and current time of a song, podcast, or audiobook. Productivity-wise, being able to subtly (2) start and stop audio recordings of conversations or meetings, and tag relevant events that might be worth reviewing later. Teeth gestures could also allow for a discrete and rapid way to (3) accept or reject incoming alerts, notifications, and reminders, while minimizing task-switch time. A minimal set of teeth gestures could also enable the seamless (4) access of information streams such as messages, emails, news, or relevant notes about the person, place, and/or time of interest that could enhance the current interaction.

This research aims to investigate the following:
1) Understand how people could use teeth gestures to perform specific interaction commands in order to establish a standardized teeth gesture language.
2) Identify the optimal position of the sensor to achieve the highest gesture classification accuracy possible while ensuring a discreet form factor.
3) Measure the performance of our classification algorithm in the wild, while sitting, standing, walking, running, and cycling.
4) Assess the usability of the interface + applications in the wild.

Publication:
Byte.it: Discreet Teeth Gestures for Mobile Device Interaction
Temperature influences our perception and cognition both consciously and subconsciously. These effects are rooted in our bodily experiences and interactions with the environment, and are even embedded as metaphors in our language. By learning how temperature affects us in different contexts, we can make use of that knowledge to create interventions that help us with personal growth.

This project seeks to apply thermal interfaces to assist with emotion and attention regulation. Stress and attention levels can be inferred using implicit user inputs such as electrodermal activity, heart rate variability, and relative facial temperature. This information can then be used to determine appropriate thermal feedback to implicitly modify the user's perception and aid with emotional and attention regulation in a minimally disruptive fashion.

Judith Amores Fernandez, Adam Haar Horowitz, Oscar Rosello

Cocoon is our vision of a programmable dream machine from the future. This device would be enabled by the synthesis of many devices under development at MIT Media Lab's Fluid Interfaces Group. As a dreamer descends into sleep, Cocoon tracks three sleep-stages using brain activity, muscle tension, heart rate, and movement data that are revealed through its dome. External stimuli in the form of scent, audio, and muscle stimulation direct the content of the dreams. Crossing boundaries both disciplinary and experiential, Cocoon offers an embodied investigation of one's own consciousness, a philosophy in the flesh; with it users can observe and engage the torsion of their senses, see and shape dreams which are otherwise entirely uncontrollable, unlirked, and unseen. We hope this speculative vision, and the conversations it inspires, help us reflect on how we develop our existing dream engineering technologies going forward, and how we combine them.

Cocoon has been shown at Ars Electronica 2018, the Beijing Media Arts Biennale 2018, and the Han Shan Art Museum.

Pattie Maes, Hisham Bedri, Wiley Corning, Scott W. Greenwald, Erin Hong

Real-time collaborative self-expression in virtual reality

Misha Sra

This work explores the design of techniques based on the cognitive illusion of “inattentional blindness” which is a failure to notice something happening in front of you when you are focused on something else. The aim is to direct a user’s attention and manage their perception to create VR experiences with high levels of presence. The techniques were tested through a VR implementation of a disruption-free natural walking experience. Video and paper available here: http://web.media.mit.edu/~sra/vmotion.html

Craig Ferguson, Kristy Johnson, Jaya Narain

(Note: this project was previously referred to as ECHOS)

Approximately 3.5 million people in the US have Autism Spectrum Disorder (ASD), of which about 30% are nonverbal or minimally verbal (mv). Individuals with mv-ASD often communicate emotions and desires through vocalizations that do not have typical verbal content, as well as through gestures, e.g., pulling a caregiver to a desired toy. Some vocalizations have self-consistent phonetic content (e.g., “ba” to mean “bathroom”) and others vary in tone, pitch, and duration depending on the individual’s emotional or physical state or intended communication.

We present, to our knowledge, the first project studying communicative intent and affect in naturalistic vocalizations that do not have typical verbal content for people with mv-ASD. Interviewed parents of children with mv-ASD cited miscommunication with people who do not know their child well as a major source of stress. Our long-term vision is to design a device that can help others better understand and communicate with individuals with ASD by training machine learning models using primary caregivers’ unique knowledge of the meaning of an individual’s nonverbal communication. Our focus is currently on developing personalized models to classify vocalizations using in the moment live labels from caregivers via the Commalla labeling app. As part of this work, we are developing scalable methods for collecting and live labeling naturalistic data, and processing methods for using the data in machine learning algorithms. We are currently piloting and refining our data collection, machine learning models, and vision with a small number of families through a highly participatory design process.
Pattie Maes, Vik Parthiban, David Su, Tomas Vega Galvez
Exploring contextual multimodal cues as memory aids

Objective
We are exploring the potential of proximity-triggered contextual audio and visual cues to help early-stage Alzheimer’s patients recall familiar people and places. In particular, we are using proximity beacons to determine when the user is physically close to another person, such as a loved one. The beacons will then trigger cues in the form of:

- audio conveying contextual information such as name, relationship, time/place/details of last interaction;
- images and video (using AR) showing previous interactions along with text displaying contextual information; and
- music in the form of specific songs associated with specific individuals.

Research Questions
We’re interested in tackling the following questions:

Which cue modalities are the most effective in improving recognition in early-stage Alzheimer’s patients?

What advantages and challenges are afforded by each of the different modalities?

Pattie Maes, Harpreet Sareen

Plants can sense the environment, other living entities and regenerate, actuate or grow in response. Our interaction and communication channels with plant organisms in nature are subtle - whether it be looking at their color, orientation, moisture, position of flowers, leaves and such. This subtlety stands in contrast to our interactions with artificial electronic devices that are centered in and around the screens, requiring full attention and induce cognitive load. We envision bringing such interaction out from the screens back into natural world around us.

Beyond external indicators, plants also have electrochemical signals and response mechanisms inside them that make them very similar to our electronic devices. To tap into such capacities already built in nature, we propose a new convergent view of interaction design. Our goal is to merge and power our electronic functionalities with existing biological functions of living plants. Through Cyborg Botany, we re-appropriate some of these natural capabilities of plants for our interactive functions.
Ishaan Grover, Adam Haar Horowitz, Abhinandan Jain, Pedro Reynolds-Cuellar, Oscar Rosello, Tomas Vega Galvez, Eyal Perry, Matthew Ha

Inspiration

Sleep is a forgotten country of the mind. A vast majority of our technologies are built for our waking state, even though a third of our lives are spent asleep. Current technological interfaces miss an opportunity to access the unique, imaginative, elastic cognition ongoing during dreams and semi-lucid states. In turn, each of us misses an opportunity to use interfaces to influence our own processes of memory consolidation, creative insight generation, gist extraction, and emotion regulation that are so deeply sleep-dependent. In this project, we explore ways to augment human creativity by extending, influencing, and capturing dreams in Stage 1 sleep. It is currently impossible to force ourselves to be creative because so much creative idea association and creative incubation happens in the absence of executive control and directed attention. Sleep offers an opportunity for prompting creative thought in the absence of directed attention, if only dreams can be controlled.

Scientific Background

During sleep onset, a window of opportunity arises in the form of hypnagogia, a semi-lucid sleep state where we all begin dreaming before we fall fully unconscious. Hypnagogia is characterized by phenomenological unpredictability, distorted perception of space and time, and spontaneous, fluid idea association. Edison, Tesla, Poe, and Dalí each accessed this state by napping with a steel ball in hand to capture creative ideas generated in hypnagogic microdreams when it dropped to the floor below.

Engineering and Experimentation

In this project we modernize this technique, using an interactive social robot accompanied with a custom sleep stage tracking system, and auditory biofeedback. We are able to influence, extract information from, and extend hypnagogic microdreams for the first time: we found that active use of hypnagogia with the system can augment human creativity. This system enables future research into sleep, an underutilized and understudied state of mind vital for memory, learning, and creativity. This system is a tested prototype. Dormio has a published study in alt.CHI (see publications section), a second publication under review, and is being used in four independent labs for ongoing sleep research. We’re actively presenting and testing the work in varied settings, like the McLean Technology in Psychiatry Summit and the International Sleep Replay Workshop, to gain information about sleep interventions in various conditions. We’ve just completed a second study (with 50 participants) on dream incubation and creativity augmentation. But sleep onset is still poorly understood, and dreams are still really a mystery—we’re learning! Please reach out if anything seems off, or just to chat.

This work has been hugely collaborative. The following people, in alphabetical order by first name, have all made it possible: Abhinandan Jain, Adam Haar Horowitz, Christina Chen, Eyal Perry, Ishaan Grover, Kathleen Esfahany, Matthew Ha, Oscar Rosello, Pattie Maes, Pedro Reynolds-Cuéllar, Robert Stickgold, and Tomás Vega. For an in-depth dive, see the FAQ below and see more on this website.

If you want all the details, please read this thesis and offer any feedback!

Room-scale virtual reality opens up exciting new possibilities for exploratory learning. Phenomena that otherwise cannot be experienced directly (e.g. subjects that are microscopic, remote, or dangerous) can be transformed into environments that are immersive, interactive and social. Electrostatic Playground is a VR physics lab where multiple users can explore and discover principles of electrostatics through experimentation. It also concretizes abstract notions of electrostatics in the form of tangible, interactive objects. Users can learn by directly manipulating physics objects while receiving real-time feedback from the environment. We’ve incorporated the ability to record these interactions in order to provide a means of authoring content, reviewing one’s notes, and teaching others. Electrostatic Playground is a multi-user lab where users can explore and discover principles in electrostatics.

Elowan is a cybernetic lifeform, a plant in direct dialogue with a machine. Using its own internal electrical signals, the plant is interfaced with a robotic extension that drives it toward light.
With advances in virtual reality (VR) and physiological sensing technology, even more immersive computer-mediated communication through life-like characteristics is possible. As a solution for the current lack of culture, expression, and emotions in VR avatars, we propose a two-fold solution. First, integrate bio-signal sensors into the head-mounted display (HMD) and implement techniques to detect aspects of the emotional state of the user. Second, connect the data collected to an expressive avatar: Emotional Beasts. The creation of Emotional Beasts allowed us to experiment with the manipulation of a user’s self-expression in VR space and as well as the perception of others in it, with the goal of pulling the avatar design away from the uncanny valley and making it more expressive, more relatable to our own mannerisms. Based on this we have implemented a prototype system in which VR, human motion, and physiological signals are integrated to allow avatars to become more expressive in virtual environments in real time.

NeuroKnit is the interplay between the physical and virtual that is explored in response to the current lack of culture, expression, and emotions in VR experiences; we propose a two-fold solution. First, the integration of bio-signal sensors into the HMD and techniques to detect aspects of the emotional state of the user. Second, the use of this data to generate expressive avatars.

In physics education, virtual simulations have given us the ability to show and explain phenomena that are otherwise invisible to the naked eye. However, experiments with analog devices still play an important role. They allow us to verify theories and discover ideas through experiments that are not constrained by software. What if we could combine the best of both worlds? We achieve that by building our applications on a projected augmented reality system. By projecting onto physical objects, we can paint the phenomena that are invisible. With our system, we have built “physical playgrounds”: simulations that are projected onto the physical world and that respond to detected objects in the space. Thus, we can draw virtual field lines on real magnets, track and provide history on the location of a pendulum, or even build circuits with both physical and virtual components.

We are developing a new and exciting tool for expression in paint, combining technology and art to bring together the physical and the virtual through the use of robotics, artificial intelligence, signal processing, and wearable technology. Our technology promotes expression in paint not only by making it a lot more accessible, but also by making it flexible, adaptive, and fun, for everyone across the entire spectrum of abilities. With the development of the technology, new forms of art also emerge, such as hyper, hybrid, and collaborative painting. All of these can be extended to remote operation (or co-operation) thanks to the modular system design. For example, a parent and a child can be painting together even when far apart; a disabled person can experience an embodied painting experience; and medical professionals can reach larger populations with physical therapy, occupational therapy, and art therapy, including motor/neuromuscular impaired persons.

Fascia is a smart sleep mask aimed at facilitating sleep studies in natural settings. The mask records physiological signals including EEG, EOG, EMG, heart rate, head movement, and skin temperature. The fabric-based mask includes a flexible circuit positioned on the face that gathers all the relevant PSG data without disturbing sleep quality. The device integrates the sensors close to the skin, while two printed circuit boards house the components for signal processing and storage farther away from the skin. The prototype is designed to maximize the quantity and quality of sensor signals, as well as ensuring user comfort, so as to produce accurate data and reduce the first night effect typical of clinical sleep studies (Agnew Jr et al., 1966). The prototype can also detect emotional expression via facial EMG, which we previously demonstrated in a related device for collecting physiological data with a VR headset (PhysioHMD). This presents a possibility for recording emotional expressions to a dream avatar, as prior research has demonstrated that frowning and smiling muscle tension during sleep corresponds with dreamed emotional content (Rivera-García et al., 2019).
**Flower: EEG visualization with the aid of machine learning**

Neo (Mostafa) Mohsenvand

Flower is a new visualization tool for in-depth study of multi-sensor recordings in the time domain. It has been released for public download as a fully functioning tool available for experimental, research, and creative use. Flower uses unsupervised machine learning to extract latent representations for time-series data (EEG in particular) and show them through different visualization settings. In particular, it adds color and thickness to time-series plots, making them easier to understand and compare. Flower aims to enable more natural intuition around data results, using machine intelligence to translate time-series data for improved understanding by the human eye.

**Food Attack**

Pattie Maes, Niaja Farve

The rise in wearable devices and the desire to quantify various aspects of everyday activities has provided the opportunity to offer just-in-time triggers to aid in achieving pre-determined goals. While a lot is known about the effectiveness of messaging in marketing efforts, less is known about the effectiveness of these marketing techniques on in-the-moment decision-making. We designed an experiment to determine if a simple solution of using just-in-time persuasive messaging could influence participants' eating habits and what types of messaging could be most effective in this effort. Our solution utilizes a head-mounted display to present health-based messages to users as they make real-time snack choices. We are able show that this method is effective and more feasible than current efforts to influence eating habits.

**Frisson**

Adam Haar Horowitz, Abhinandan Jain, Tomas Vega Galvez

**Inspiration**

There's a feeling that comes tingling down the spine in certain moments: when a favorite moment of a favorite song comes on, or when a turn of phrase in a powerful speech really resonates. That feeling of shivers down your spine and tingling on your arms is called aesthetic chills, or frisson.

**Scientific Background**

This wave of chills brought by an experience of frisson is experimentally tied to peak emotional experiences and meaning-making moments during exposure to different stimuli, such as songs or speeches or art pieces. Conveniently, aesthetic chills seem to be an almost universal marker of peak emotional experiences across a wide range of cultures and continents. This universality is really rare—usually, expressions of emotion are quite different across cultural contexts—and this means that we can potentially use chills as a way to study emotion in the body in diverse peoples and places.

The field of embodied cognition, in addition to finding body-based correlates of emotional experience, has also illuminated many links between our physical and psychological experiences. Studies on misattribution of arousal show us we can drive cognition by driving physical sensation, for instance increasing people's heart rate to increase their likelihood of romantic attraction (people feel a fast heart rate and think they must be attracted to someone, reasoning from the body upwards). This points to opportunities, because if we can drive frisson perhaps we can also drive the downstream cognitive effects of frisson: these include pleasure, inspiration, openness to experience, relief in stress, increase in empathy, and experience of meaning.

**Engineering and Experimentation**

This project unites embodied cognition and on-body device design to ask questions about the origin of emotions and the potential to hack our brains and behavior by hacking the body. At once transcendent and physiological, the subtle signals of beauty and semantics meet mechanism as the sublime literally cascades across skin. So we built a device meant to trigger frisson. Alongside Félix Schoeller, a scientist who specializes in researching chills at the Paris CRI, we’re testing whether our device can 1) reliably induce chills in participants and 2) can recreate the downstream cognitive effects of chills, including pleasure and empathy. This device is a working prototype, and we’re in the process of publishing results from our first experiment on stimulating chills and empathy. Our vision is psychophysiology driving thought from the spine upwards!

**Guitar Machine**

Sang-won Leigh

Symbiotic guitar playing between human and machine fingers. The system can be used as a learning tool or a real-time augmentation to the human guitar player, offering previously impossible combinations of notes.

**Guitar Machine II**

Sang-won Leigh, Aby Jain (Electronic design)

Exploring robotic sound generation mixed with human movements on the guitar. Guitar Machine II is a robotic guitar that responds to human gestures, as well as other input means such as midi controllers or algorithmic composition.
Pattie Maes, Kevin Wong

2D screens, even stereoscopic ones, limit our ability to interact with and collaborate on 3D data. We believe that an augmented reality solution, where 3D data is seamlessly integrated in the real world, is promising. We are exploring a collaborative augmented reality system for visualizing and manipulating 3D data using a head-mounted, see-through display, that allows for communication and data manipulation using simple hand gestures.

Oscar Rosello

HeartBit is an interface designed for haptic heart rate biofeedback. A handheld heart beats alongside your own, mirroring the size, weight, and movement of a hidden internal organ, now external and tangible in real-time. HeartBit offers a medium for users to self-regulate in moments of stress, anxiety or exertion: Control your heart to control your breath and body—for relaxation, performance enhancement, or augmented self-awareness.

Neo (Mostafa) Mohsenvand

inSight is a brain decoding system. It uses generative models (BigGAN and MusicVAE) to stimulate the brain with synthetic, but natural-looking videos and melodies. The brain activity of the user is then recorded using an EEG headset. The recorded data is then processed to train an encoder to interpret the brain activity in terms of the latent space of the generative model, effectively allowing the system to generate video and music from the user’s brain activity. inSight can be used for applications such as neurofeedback therapies, creativity, human-human communication and search.

Hiroshi Ishii, Tal Achituv, Amos Golan

LeakyPhones is a public/private headset that was designed to encourage face-to-face interactions, curiosity, and healthier social skills by letting users “peek” into each other’s music just by looking at one another.

Gaze is an important social signal in human interaction. Though its interpretation may vary across cultures, it is generally agreed that eye contact indicates interest and the point of attention in a conversation. Despite this, many common personal computing technologies, such as our smartphones and headphones, require significant visual and auditory attention thereby inhibiting our ability to interact with others. LeakyPhones offers a new approach for addressing this challenge.

Misha Sra, Aske Mottelson

Virtual reality can help realize mediated social experiences where we interact as richly with those around the world as we do with those in the same room. The design of social virtual experiences presents a challenge for remotely located users with differently sized, room-scale setups like those afforded by recent commodity virtual reality devices like the HTC Vive. This work explores how we can allow remote users to learn to dance together in VR by mapping their individual physical spaces to a shared virtual space. Video and paper available here: http://web.media.mit.edu/~sra/dancing.html

Pattie Maes, David S. Kong, Pat Pataranutaporn, Angela Vujic

Living Bits: Opportunities and Challenges for Integrating Living Microorganisms in Human-Computer Interaction

There are trillions of living biological “computers” on, inside, and around the human body: microbes. Microbes have the potential to enhance human-computer interaction (HCI) in entirely new ways. Advances in open-source biotechnology have already enabled designers, artists, and engineers to use microbes in redefining wearables, games, musical instruments, robots, and more. “Living Bits,” inspired by Tangible Bits, is an attempt to think beyond the traditional boundaries that exist between biological cells and computers for integrating microorganism in HCI. In this work we: 1) outline and inspire the possibility for integrating organic and regenerative living systems in HCI, 2) explore and characterize human-microbe interactions across contexts and scales, and 3) provide principles for stimulating discussions, presentations, and brainstorming for microbial interfaces. We aim to make Living Bits accessible to researchers across HCI, synthetic biology, biotechnology, and interaction design to explore the next generation of biological HCI.

The paper won the best paper award from ACM Augmented Humans and will appear on ACM Digital Library.
Inspiration

Dreams are fascinating personally, therapeutically, and scientifically. Who hasn’t woken up in the morning and wondered how they came up with that wild story, and what it could reveal? But studying dreams is limited by the expensive technology used to track the sleep stages in which they occur. Masca is a flexible mask designed for easier, cheaper sleep stage detection. Our device is designed for eyelid motion detection, and adapts to the human body using conformable piezoresistive fabric and silicone to see the various physiological changes occurring as sleep states change without the need for wired amplifiers or sticky electrodes. Our vision is a democratized dream science, wherein people can try out all the laboratory protocols for lucid or therapeutic dreams in the comfort of their own home.

Scientific Background

Eyes and eyelids change movement frequency predictably as sleep stage transitions occur—you can even try this at home, watching a friend or partner sleep, and you’ll see an increase in their eye movement frequency when they hit the REM sleep stage. Trackers which are built for the eyes allow for a simpler, more portable system than the typical high-density EEG required for sleep tracking. This device is modeled after Prof. Robert Stickgold’s Nightcap, who demonstrated you can track sleep stages with simple eye-worn sensors, and we are super grateful for his ongoing assistance with this project.

Engineering and Experimentation

Tracking and influencing of sleep cognition opens up doors to a future in which the consolidation of emotion, memory, and learning which happens in sleep is rendered controllable by wearable electronics. But first we have to know if Masca reliably tracks sleep stages! This device is a working prototype: We’ve only tested this device on a few people so far, and though results look promising, we’ll wait to put those out publicly until we can publish in a peer-reviewed journal. For now, feel free to reach out to us with ideas, new strategies for sleep tracking, or if you want to run your own study using Masca and need a prototype.

Mathematical experiences are intrinsic to our everyday lives, yet mathematics education is mostly confined to textbooks. Seymour Papert used the term “Mathland” to propose a world where one would learn mathematics as naturally as one learns French while growing up in France. We built a mixed reality application that augments the physical world with interactive mathematical concepts and annotations to create a real-life Mathland. Using Mathland, people can collaboratively explore, experience, and experiment with mathematical phenomena in their real, physical environments using tangible objects. Mathland opens up new opportunities for mathematical learning using Papert’s constructionist principles in an immersive environment that affords situated learning, embodied interaction and playful constructionism.

Neo (Mostafa) Mohsenvand

Mnemo is an integrated system to support human biographical memory. Mnemo is directed to serve people with impaired memory (e.g. Alzheimer’s patients) by providing intuitive ways to benefit from large amounts of personal data.

Pattie Maes, Abhinandan Jain, Misha Sra

MoveU is a wearable vestibular stimulation device for providing proprioceptive haptic feedback in virtual reality (VR). The device induces sensations of motion corresponding to virtual motion, thereby increasing immersion in VR and reducing cybersickness.

MoveU non-invasively stimulates the vestibular system using a technique called galvanic vestibular stimulation (GVS). GVS is a specific way to elicit vestibular reflexes using electrical current. This technique has been used for over a century to study the function of the vestibular system. In addition to GVS, the device supports physiological sensing by connecting heart rate, electrodermal activity, and other sensors using a plug-and-play mechanism offering flexibility for further development. MoveU supports multiple categories of virtual reality applications with different types of virtual motions such as driving, navigating by flying, teleporting, or riding.

The device is a working prototype and we evaluated the effects of synchronous vestibular stimulation on mitigating cybersickness and increasing the sense of immersion in a VR environment (see publications for more info).
373. **Move Your Glass**  
Pattie Maes, Niaja Farve  
Move Your Glass is an app built using the JavaScript-based Wearscript library to communicate with the native sensors and camera on the device. The app is an activity and behavior tracker that also tries to increase wellness by nudging the wearer to engage in positive behaviors. In particular, data from the tri-axial accelerometer and camera are collected and analyzed offline using a designated server. These results are then fed into a k-nearest neighbors machine learning routine and compared to training data to provide continuous differentiation between sitting/standing, walking, and running while the user is on the go. The ultimate goal is to log this information (and additional activity parameters) and convey activity summaries and, if necessary, prompts for increasing activity, back to users.

374. **NeverMind: Using AR for memorization**  
Pattie Maes, Marc Exposito Gomez, Oscar Rosello  
NeverMind is an interface and application designed to support human memory. We combine the memory palace memorization method with augmented reality technology to create a tool to help anyone memorize more effectively. Early experiments conducted with a prototype of NeverMind suggest that the long-term memory recall accuracy of sequences of items is nearly tripled compared to paper-based memorization tasks. With this project, we hope to make the memory palace method accessible to novices and demonstrate one way augmented reality can support learning.

375. **On-Face Olfactory Interfaces**  
Pattie Maes, Judith Amores Fernandez, Yanan Wang  
On-face wearables are currently limited to piercings, tattoos, or interactive makeup that aesthetically enhances the user, and have been minimally used for scent-delivery methods. However, on-face scent interfaces could provide an advantage for personal scent delivery in comparison with other modalities or body locations since they are closer to the nose. We present the mechanical and industrial design details of a series of form factors for on-face olfactory wearables that are lightweight and can be adhered to the skin or attached to glasses or piercings. The user can activate the scent release via a custom-made smartphone app that connects to the prototype.

376. **PAL: a wearable on-device deep learning platform for personalized, context-aware, and closed-loop real-time support**  
Glenn Fernandes, Mina Khan, Mayank Manuja, Utkarsh Sarawgi, Akash Vaish  
Overview  
PAL is a wearable platform for personalized, context-aware, and always-present user change. PAL has multimodal sensors (camera, location, movement, heart rate, and on-device deep learning) to recognize user context context-aware, e.g., people, indoor locations, objects, etc. On-device deep learning minimizes computation time to provide real-time and offline context-aware support, and user data is also more private as raw data is not sent to the cloud. PAL offers personalized support for each user and users can train custom trainable low-shot models for personalized context detection and support. We are currently exploring PAL for real-world-loop behavior change support using reinforcement learning for closed-loop behavior change interventions. PAL can also be used for real-time cognitive support (e.g., memory augmentation) and visual assistance (e.g., for visually impaired).
Guillermo Bernal, Haripriya Mehta, Lily Zhou

Paper Dreams explores how human creativity can be supported by artificial intelligence. Prior research on AI and creativity has primarily focused on using machine intelligence to learn “creativity” from humans, from transfer learning of artistic styles to generation of original paintings, poems, and music by the machine. However, the application of current machine learning algorithms to the augmentation of human creativity is a relatively unexplored area. By creating a dynamic human-machine back-and-forth and working with representations inside machine learning models, we can offer people new “smart” tools for brainstorming and creative expression.

Our system in its current form provides users with a canvas where they draw parts of a sketch that the machine tries to recognize and offers to complete. We do this by building a neural network which takes a small number of input variables, called latent variables, and produces the entire sketch as output. In addition, the system also helps users move forward with their creation. To date, Paper Dreams augments the drawing experience in three different ways: by adding textures/colors, suggesting other elements/drawings for the scene, and introducing serendipity. To adjust the level of serendipity, the user has control of a dial that determines how “predictable” vs “unpredictable/out there” they want these machine additions to be.

While the current version of Paper Dreams works with 2D sketches, the same human machine collaborative creativity approach could be applied to other domains such as 3D models and more.

Some of the driving questions for this project are:

To what extent are these new tools enabling creativity?

Can they be used to generate ideas which are truly surprising and new, or are the ideas clichés, based on trivial recombinations of existing ideas?

Can such systems be used to develop fundamental new interface primitives?

How will those new primitives change and expand the way humans think?

Pattie Maes, Guillermo Bernal, Tao Yang

Virtual and augmented reality headsets are unique as they have access to our facial area, an area that presents an excellent opportunity for always-available input and insight into the user’s state. Their position on the face makes it possible to capture bio-signals as well as facial expressions. The PhysioHMD platform introduces a software and hardware modular interface built for collecting affect and physiological data from users wearing a head-mounted display. The platform enables researchers and developers to aggregate and interpret signals in real-time and use them to develop novel, personalized interactions, as well as evaluate virtual experiences. Our design offers seamless integration with standard HMDs, requiring minimal setup effort for developers and those with less experience using game engines. The PhysioHMD platform is a flexible architecture that offers an interface that is not only easy to extend but also complemented by a suite of tools for testing and analysis. We hope that PhysioHMD can become a universal, publicly available testbed for VR and AR researchers.

To create a seamless experience, we have integrated several bio-signal sensors into the faceplate of an HTC VIVE VR headset and utilized the Shimmer3 sensor for emotion-sensing. For the collection of Galvanic Skin Response, dry electrodes were positioned on the forehead area due to the fact that it is one of the areas most dense with sweat glands. GSR data reflects emotional arousal, but in order to identify how arousal, valence, motivation, and cognition interact in response to physical or psychological stimuli, it becomes necessary to complement GSR with other biosensors. For the heart rate, a PPG (photoplethysmogram) sensor, which senses the rate of blood flow by utilizing light to monitor the heart’s pumping action, was placed in the temple region of the user. This is done to get insights into the respondent’s physical state, anxiety and stress levels (arousal), and to determine how changes in their physiological state relate to their actions and decisions.
Neo (Mostafa) Mohsenvand
With the exponential increase of personal data in the forms of images, videos, emails, and social media posts, the time is ripe for building personal AIs that utilize these data to enhance the productivity and creativity of the users. Training AI algorithms require labeled and processed data. However, annotating data is time-consuming and often regarded as the bottleneck of supervised learning. Most tools used for data labeling are tailored for the needs of data-scientists and researchers and are far from being useful for general users. The users of these systems need to know the ontology of possible labels beforehand and use complex interfaces and workflows to maintain the consistency and quality of the resulting dataset. “Q” aims to reformulate data annotation as an engaging conversation by asking appropriate questions and automatically highlighting possible regions of interest. To come up with relevant questions, Q learns from the Wikidata public knowledge graph by computing the probable properties and relationships of entities. It also utilizes the previously annotated pieces of data to speed up the process.

Judith Amores Fernandez
Automatic and real-time sleep scoring is necessary to develop user interfaces that trigger stimuli in specific sleep stages. However, most automatic sleep scoring systems have been focused on offline data analysis. We present the first, real-time sleep staging system that uses deep learning without the need for servers in a smartphone application for a wearable EEG. We employ real-time adaptation of a single channel Electroencephalography (EEG) to infer from a Time-Distributed Convolutional Neural Network (CNN). Polysomnography (PSG)—the gold standard for sleep staging—requires a human scorer and is both complex and resource-intensive. Our work demonstrates an end-to-end, smartphone-based pipeline that can infer sleep stages in just single 30-second epochs, with an overall accuracy of 83.5% on 20-fold cross validation for 5-stage classification of sleep stages using the open Sleep-EDF dataset.

Fadel Adib, Kevin Esvelt, Pattie Maes, Joseph A. Paradiso, Guadalupe Babio Fernandez, Eyal Perry, Camilo Rojas, Irmandy Wicaksono, Cedric Honnet (visiting scientist, Responsive Environments); Niels Poulsen (visiting student, Fluid Interfaces); Nicolas Ayoub (visiting student, City Science); Zhi Wei Gan (MIT undergraduate); Korrawat (James) Pruegsanusak (MIT EECS); Franklin Zhang (MIT EECS); Aaron Stinnett (MIT IDM).

Pattie Maes, Ethan Zuckerman, Tal Achiutv, Luke Berndt (OpenMhz)
Scanner Grabber is a digital police scanner that enables reporters to record, playback, and export audio, as well as archive public safety radio (scanner) conversations. Like a TiVo for scanners, it’s an update on technology that has been stuck in the last century. It’s a great tool for newsrooms. For instance, a problem for reporters is missing the beginning of an important police incident because they have stepped away from their desk at the wrong time. Scanner Grabber solves this because conversations can be played back. Also, snippets of exciting audio, for instance a police chase, can be exported and embedded online. Reporters can listen to files while writing stories, or listen to older conversations to get a more nuanced grasp of police practices or long-term trouble spots. Editors and reporters can use the tool for collaborating, or crowdsourcing/public collaboration.

Pattie Maes, Angela Vujic, Christopher Krause, Georgette Tso, Jiaqi Lin, Bicheng Han
Serosa II is a hydrogel electrode waistband to measure gastrointestinal signals. We sought to create an interface can be worn for long periods of time underneath clothing, and could be accurately placed without the help of a technician or researcher.

With this version, we performed a pilot test to evaluate the signal quality of the hydrogel electrodes. We found that hydrogel electrodes record signal with less power and greater motion artifacts; however, they offer an advantage of more stable impedance over time (see Publications).

We also completed a user evaluation of wearability and types of feedback (visual, auditory, or haptic). Users most understood and enjoyed receiving haptic feedback (vibrations on the wrist). In the study, we asked participants to wear Serosa while completing the Iowa Gambling Card Task. During the task, participants received audio, haptic (vibrations), or visual feedback on “gut” signal, and we compared participant preferences for feedback modality for real-time tasks. (See Master’s Thesis*).

In the future, we see Serosa II being useful to test gut-brain computer interfaces (GBCIs) in real-world environments where the preparation and placement of electrodes by a technician is not available.
Pattie Maes, Rosalind W. Picard, Angela Vujic, Todd P. Coleman, Professor, Department of Bioengineering, USCD
Christopher Krause, UROP (undergraduate research assistant), MIT
Georgette Tso, UROP (undergraduate research assistant), MIT
Jiaqi Lin, Koch Institute, MIT
Bicheng Han, Zhang Lab, Harvard University

Serosa records gastrointestinal (stomach and intestinal) signals. Serosa aims for cognitive enhancement via the mind-gut connection by aiding an individual to modulate gut signal. The gut has been shown to have a connection to emotion, memory, decision-making, and more. The recent boom in microbiome research has begun to describe this interaction on the microbial level. We are inspired by this to begin recording neuronal information from the “gut-brain”—hundreds of millions of neurons that line the gastrointestinal tract—to study their relationship to cognitive phenomena as well.

In our research, have also recorded and analyzed gut signals while participants view emotional films, play the Iowa Gambling Card Task, and from real-world pilot studies. We have iterated and tested multiple electrode types and electrode montages to contribute information to form factor and signal quality. We have seen in our studies a relationship between reported emotions and gut signals, and interoceptive abilities and gut signals, and the trade-offs between varying form factors and electrode types.

We seek to show from our data and contributions how gastrointestinal signals may be used for emotion regulation and other applications for GBCIs. We aim to apply principles of non-invasive brain-computer interfacing (BCI) by using electrodes to record large-scale gut neuron activity and return feedback to the user.

Pattie Maes, Niaja Farve

Our hectic and increasingly digital lives can have a negative effect on our health and wellbeing. Some authors have argued that we socialize less frequently with other people in person and that people feel increasingly lonely. Loneliness has been shown to significantly affect health and wellbeing in a negative way. To combat this, we designed a game, SmileCatcher, which encourages players to engage in in-person, social interactions and get others to smile. Participants wear a device that takes regular pictures of what is in front of them and the system analyzes the pictures captured to detect the number of smiles.

Pattie Maes, Rahul Kumar Namdev

We are developing a very intuitive and interactive platform to make complex information—especially science, technology, engineering, and mathematics (STEM) material—truly accessible to blind and visually impaired students by using a tactile device with no loss of information compared with printed materials. A key goal of this project is to develop tactile information-mapping protocols through which the tactile interface can best convey educational and other graphical materials.

Adam Haar Horowitz, Boo Aguilar, Fernando Magalhaes, João Rosa, Matheus de Paula

The Blank Canvas directs immersion inwards using virtual reality, augmenting awareness of the microscopic worlds inside each of us and the science that is changing them today. It has been shown at Cannes Film Festival, Vision Summit, VR Sci Fest, and the World Economic Forum. This is the first episode of The Blank Canvas, a VR platform that showcases the future of science and scientific communication. So many of the brilliant contemporary innovations in science are lost to the general public because they happen at scales so small we can barely comprehend them. The Blank Canvas leverages the power of immersive technologies to make these ideas come to life in macro planetary scale, explaining themes like DNA editing, hacked viruses, and CRISPR. We build collaborations between scientists and engineers for accurate, inspirational science storytelling that turns textbooks into experience.

Pattie Maes, Rosalind W. Picard, Niaja Farve, Natasha Jaques

Mental wellbeing is intimately tied to both social support and physical activity. The Challenge is a tool aimed at promoting social connections and decreasing sedentary activity in a workplace environment. Our system asks participants to sign up for short physical challenges and pairs them with a partner to perform the activity. Social obligation and social consensus are leveraged to promote participation. Two experiments were conducted in which participants’ overall activity levels were monitored with a fitness tracker. In the first study, we show that the system can improve users’ physical activity, decrease sedentary time, and promote social connection. As part of the second study, we provide a detailed social network analysis of the participants, demonstrating that users’ physical activity and participation depends strongly on their social community.
Pattie Maes, Kristy Johnson, Arnav Kapur, Jaya Narain, Utkarsh Sarawgi

Today’s assistive communication devices are far from perfect. Using state of the art small, wearable sensors and powerful machine learning technologies we have an opportunity to design radically different, highly personalized solutions for assistive communication. We are exploring this approach using an iterative, participatory design and experimentation process involving target users and their families.

We have two projects underway: AlterEgo and ECHOS. While these both use the same general approach of on-body sensors and personalized machine learning to create communication solutions, they are intended for use by two very different target user groups, namely people who have lost the ability to speak due to conditions such as ALS or MS, in the case of AlterEgo, and people with autism who are non-verbal or minimally verbal in the case of ECHOS.

We deeply value feedback from people who are interested in using assistive communication devices. If you are interested in helping us with our research or staying informed, you can do so by filling out this form: Link here. If you provide your contact information here, we will reach out to you if we are recruiting for a study that might be of interest to you.

We are currently conducting a user needs survey on assistive and augmentative communication. The survey takes ~30 minutes to complete. If you or a loved one use or would consider using an assistive technology device, we would deeply appreciate your input here: Link here.

Pattie Maes, Judith Amores Fernandez, Guillermo Bernal, Adam Haar Horowitz, Abhinandan Jain, Oscar Rosello, Tomas Vega Galvez

We are working to build technology that interfaces with the sleeping mind. As the dreamer descends into sleep, we track different sleep-stages using brain activity, muscle tension, heart rate, and movement data. External stimuli in the form of scent, audio, and muscle stimulation affect the content of the dreams.

We are working on integrating multiple projects developed at the Fluid Interfaces group towards a vision where sleep is controllable.

Pattie Maes, Judith Amores Fernandez, Abhinandan Jain, David S. Kong, Pat Pataranutaporn, Oscar Rosello, Angela Vujic

Lab on Body, Synthetic Biology, and Bio-Digital Systems for Health and Human Enhancement

Nataliya Kos’myna

In this work we suggest to harness the power of knowledge-seeking positive experiences, engagement, and curiosity that objects perceived as magical carry in themselves by combining them with pop-cultural references and neuroscience in order to derive a novel intervention to foster a growth mindset in children of 8-12 years old. We created “The Thinking Cap 2.0,” a wearable system in the form-factor of masks, tiaras, or helmets from different sci-fi universes like Star Wars or Avengers, fitted with a commercially available electroencephalography (EEG) headset or headband and a Bluetooth speaker. We adopt the form-factor towards the preferences of the child, which universe or hero is being their favorite one.

We designed and conducted a first study with 50 children to investigate the effect of using “The Thinking Cap” to foster children’s mindset. In the case of our study we assessed the mindset and self-esteem of the children of 8-12 years old before and after the “intervention” using the “Cap” in order to see if any changes in the self-perception of the children could be observed and if the “Cap” helps children gain more self-confidence in their capabilities to solve math problems. The “Cap” uses Brain-Computer Interface (BCI) algorithms to recognize mental imagery of the child pre-trained for a 2-class choice problem. In an initial phase, the “Cap” is used to recognize and report on the brain patterns of the user. We believe that demonstrating such basic recognition of brain signals will lead the child to develop trust in the hat’s ability to “know them.” Thus, when the “Cap” in a later phase praises the child who wears it for their ability and/or effort on a task, the child is likely to listen to it and be affected by its suggestions in their subsequent performance. We hypothesized that using the “Cap” can thus lead to fostering growth mindset.

Our results suggest that interacting with a “Cap” (limited by classification accuracy and recording factors) has a positive impact on children’s mindset as expressed through their communicated beliefs and task-based behaviors. Though our study should be considered and treated as a preliminary proof-of-concept, the results suggest a possibly provocative new kind of relationship and interaction paradigm between children and a wearable EEG system, enhanced by perceived magic and cultural references.

Find out more about the first version of the system, “The Thinking Cap” here.
Peoples’ mindsets, meaning their beliefs about their own intellectual abilities, affect their effort and thereby their performance on tasks. The goal of this project is to investigate if we can change peoples’ mindsets using a technological intervention.

The Thinking Cap is a wearable system that communicates praise for effort and ability in order to improve the resilience and self-esteem of the student wearing it and thus positively influence their motivation and academic achievements (momentary learning).

The Thinking Cap is built into a “Sorting Hat” from the Harry Potter franchise, which we equipped with an embedded electroencephalography (EEG) headset and a Bluetooth speaker. We chose this “magical” object from the well-known film/book franchise because popular press articles have suggested that people are likely to believe they possess the traits the Sorting Hat tells them they have, and consequently behave in related ways. One goal of this study is to investigate these findings in more depth. In our study we measure the self-esteem of children before and after the “intervention of the hat” to determine whether we observe any changes in their self-perception. The Sorting Hat could be replaced by any other object that a child may believe has “magical” powers. The hat uses established state-of-the-art Brain-Computer Interface (BCI) algorithms to recognize several mental processes like motor, auditory, or visual imagery as well as cognitive load and engagement level of the child (see also a related project from our group called AttentivU). In an initial phase, the hat is used to recognize and report on the brain patterns of the child. We use supervised and unsupervised ML algorithms to train the system by asking the user explicitly to imagine/visualize either a simple movement or an object in their head (binary classification in most of the cases). The hat “tells” the child, via the Bluetooth speaker embedded in the hat, which of the two things he/she is thinking about. We hypothesize that, by demonstrating this basic capability of the hat to recognize their brain activity, the child will develop trust in the hat’s abilities to know him or her. Thus, when the hat in a later phase praises the child for their ability or effort on a task (e.g., a math test), the child is likely to be affected by its suggestions in their future performance (“You are doing well on this test now, let’s do one more!”). We hypothesize that using the hat can thus lead to improved academic performance (momentary learning).

If you are interested in participating in this study (your kid should be at least eight years old), please contact us at nkosmyna@media.mit.edu.

Jaya Narain
We are working on communication interfaces for people with speech and language disorders, incorporating technologies like physiological sensing and personalized machine learning. As part of our research, would like to better understand how existing devices are used, and what architectures and features might be useful in new devices.

Do you have a speech or language impairment, or have a close friend or family member who does? We would really appreciate your feedback on our AAC device survey.

Click this link to access the survey.

Sources for logo: Spell deaf talk speech, Information Computer Technology Digital Binary, Alternative Handicapped Accessible sign

Neo (Mostafa) Mohsenvand
The brain uses space to index, organize, and retrieve memories. However, our sense of space depends on our perception of gravity. We plan to test and understand the effect of altering gravity on human memory. Our experiment consists of a virtual reality experience that exposes the user to a sequence of small random mazes. We will compare the results of the experiment under different gravitational conditions.

Pattie Maes, Niaja Farve
WATCH is a system that attempts to measure the possible influence that a new time-management interface will have on improving the habits of a user. Users set goals for each of the activities detected by the app. Detected activities include physical activity and time spent in pre-defined locations. An Android app (WATCH) on their personal phones is able to track their activities (running, walking, and sitting) as well as their GPS location. Their progress in comparison to their goals is displayed on their home screens as a pie chart.
Judith Amores Fernandez

Human-computer interaction (HCI) has traditionally focused on designing and investigating interfaces that provide explicit visual, auditory, or haptic feedback. We propose a new type of user interface that uses smell as an implicit, less conscious output that still influences the person’s cognition. We pair that with implicit, physiological information as the input to the system.

Unlike other modalities, certain types of olfactory stimuli can be presented during sleep, without awakening the subject, as well as during wake time in a very subtle manner without distracting the subject from their primary activity. This offers novel opportunities for interfaces and applications that extend from wake to sleep time. Research has shown that olfactory stimuli during sleep can significantly increase deep sleep and sleep quality as well as improving self-reported mood and positive content of dreams. Moreover, when a scent is paired with a learned material during the day and reactivated at night (Targeted Memory Reactivation) it has been shown to improve memory consolidation. We have also shown that by pairing scent with a VR experience, we can significantly increase subjective relaxation rates and relaxation scores associated with alpha and theta brain frequencies.

We developed novel wearables, concepts, software, and designs that improve considerably on state of the art olfactometers. In comparison with previous scent delivery systems used for sleep studies, our prototype is more than 40 times lighter and 700 times smaller. Current scent technologies used in sleep laboratories are not portable and require the use of nasal masks, large olfactometers, and a minimum of 22 wire attachments to track physiological information. As a result, current technologies are not suitable for mobile, day-time applications or home usage by non-technical users. We designed, built and successfully deployed scent technologies that can release scent based on physiological or context-based information and can be worn during the day and re-activated at night. We have also used these devices to perform the first home-based scientific experiments of scent-delivery for Targeted Memory Reactivation and improvement of sleep quality, and have opened up the opportunity for sleep scientists to do in the wild studies.

Pattie Maes, Abhinandan Jain, Pat Pataranutaporn, Pratik Shah, Casey M. Johnson, MIT
In collaboration with Professor Pedro Lopes, U of Chicago - Jas Brooks, U of Chicago

Wearables are being widely researched for monitoring individuals' health and wellbeing. Current generation wearable devices sense an individual's physiological data such as heart rate, respiration, electrodermal activity, and EEG, but lack in sensing their biological counterparts, which drive the majority of an individual's physiological signals. On the other hand, biosensors for detecting biochemical markers are currently limited to one-time use, are non-continuous, and don't provide flexibility in choosing which biomarker they sense. We present “wearable lab on body,” a platform for active continuous monitoring of human biomarkers from the biological fluid.

Via IEEE Engineering for Biology and Medicine Society (EMBC) - Pataranutaporn et. al., 2019
The project is supported by NASA through Translational Research Institute for Space Health (TRISH) and MIT Media Lab Space Exploration Initiative

Pattie Maes, Valdemar Danry, Pat Pataranutaporn, Yaoli Mao, Columbia University

Wearable Reasoner: Towards Enhanced Human Rationality Through A Wearable Device With An Explainable AI Assistant

Human judgments and decisions are prone to errors in reasoning caused by factors such as personal biases and external misinformation. We explore the possibility of enhanced reasoning by implementing a wearable AI system as a human symbiotic counterpart. We present “Wearable Reasoner,” a proof-of-concept wearable system capable of analyzing if an argument is stated with supporting evidence or not. We explore the impact of argumentation mining and explainability of the AI feedback on the user through an experimental study of verbal statement evaluation tasks. The results demonstrate that the device with explainable feedback is effective in enhancing rationality by helping users differentiate between statements supported by evidence and without. When assisted by an AI system with explainable feedback, users significantly consider claims supported by evidence more reasonable and agree more with them compared to those without. Qualitative interviews demonstrate users’ internal processes of reflection and integration of the new information in their judgment and decision making, emphasizing improved evaluation of presented arguments.

To appear in ACM Augmented Humans '20
Pattie Maes, Joseph A. Paradiso, Glenn Fernandes, Pat Pataranutaporn, Ali Shtarbanov, Parinya Punpongsanon, MIT CSAIL & Osaka University

We present a work-in-progress wearable hand sanitizer that automatically dispenses and sprays alcohol to the wearer's hand and objects that the user is about to touch. Instead of using a pocket sanitizer, which the person needs to remember to make use of after touching objects and surfaces, we want the device to seamlessly integrate with the user's body and behavior to minimally disrupt their daily life. Our goal is to quickly prototype the wearable hand sanitizer with off-the-shelf materials and tools, so that people interested in replicating or improving it can easily do.

Pattie Maes, Pat Pataranutaporn, Tomas Vega Galvez, Lisa Yoo, MIT Abishkar Chhetri, MIT

Wearable Wisdom: An Intelligent Audio-Based System for Mediating Wisdom and Advice

Having good mentors and role models is important for personal growth. However, they are not always available at the time of need. Some of our personal heroes have passed away leaving only their wisdom through writings and other artifacts. We present Wearable Wisdom, an intelligent, audio-based system for mediating wisdom and advice from mentors and personal heroes to a user. It does so by performing automated semantic analysis on the collected wisdom database and generating a simulated voice of a mentor sharing relevant wisdom and advice with the user. The results show that our platform is statistically superior in delivering relevant, yet abstract wisdom as well as providing more inspiration compared to control. We describe the implementation of the Wearable Wisdom system, report on a user study, and discuss potential applications of wisdom computation for supporting personal growth and motivation.
Neri Oxman: Mediated Matter
Designing for, with, and by nature

3D printing of functionally graded materials

**Neri Oxman, Steven Keating**
Functionally graded materials—materials with spatially varying composition or microstructure—are omnipresent in nature. From palm trees with radial density gradients, to the spongy trabeculae structure of bone, to the hardness gradient found in many types of beaks, graded materials offer material and structural efficiency. But in man-made structures such as concrete pillars, materials are typically volumetrically homogenous. While using homogenous materials allows for ease of production, improvements in strength, weight, and material usage can be obtained by designing with functionally graded materials. To achieve graded material objects, we are working to construct a 3D printer capable of dynamic mixing of composition material. Starting with concrete and UV-curable polymers, we aim to create structures, such as a bone-inspired beam, which have functionally graded materials. This research was sponsored by the NSF EAGER award: Bio-Beams: FGM Digital Design & Fabrication.

Additive Manufacturing in Glass: Electrosintering and spark gap glass

**Steven Keating, John Klein**
Our initial experiments in spark electrosintering fabrication have demonstrated a capacity to solidify granular materials (35-88 micron soda ash glass powder) rapidly using high voltages and power in excess of 1kW. The testbed high-voltage setup comprises a 220V 60A variable autotransformer and a 14,400V line transformer. There are two methods to form members using electrosintering: the one-electrode drag (1ED) and two-electrode drag (2ED) techniques. The 1ED leaves the first electrode static while dragging the second through the granular mixture. This maintains a live current through the drag path and increases the thickness of the member due to the dissipation of heat. Large member elements have been produced with a tube diameter of around 0.75”. The 2ED method pulls both electrodes through the granular mixture together, sintering the material between the electrodes in a more controlled manner.

Aguahoja

**Neri Oxman, Christoph Bader, Barrak Darweesh, Jorge Duro-Royo, Joao Pedro Goncalves Marins Costa, Nicolas Hogan, Andrea Ling, Daniel Lizardo, Laia Mogas-Soldevila, Sunanda Sharma, Yen-Ju (Tim) Tai, Joshua Van Zak, James Weaver, Joseph Faraguna, Matthew Bradford, Loewen Cavill, Emily Ryeom, Aury Hay, Yi Gong, Brian Huang, Tzu-Chieh Tang, Shymus Hudson, Prof. Pam Silver, Prof. Tim Lu**
Programmable Water-Based Biocomposites for Digital Design and Fabrication across Scales

Aguahoja is an exploration of nature’s design space. A collection of natural artifacts were digitally designed and robotically fabricated from the molecular components found in tree branches, insect exoskeletons, and our own bones. Here, we propose a novel water-based design approach and fabrication platform that enable tight integration between material synthesis, digital fabrication, and physical behavior, at scales that approach—and often match—those of natural ecologies.

Anthozoa

**Neri Oxman, Steven Keating, Prof. W. Craig Carter, Iris Van Herpen, Stratasys, Keren Oxman**
A 3D-printed dress was debuted during Paris Fashion Week Spring 2013 as part of collaboration with fashion designer Iris Van Herpen for her show “Voltage.” The 3D-printed skirt and cape were produced using Stratasys’s unique Objet Connex multi-material 3D printing technology, which allows a variety of material properties to be printed in a single build. This allowed both hard and soft materials to be incorporated within the design, crucial to the movement and texture of the piece. Core contributors include: Iris Van Herpen, fashion designer (Amsterdam); Keren Oxman, artist and designer (NY); and W. Craig Carter (Department of Materials Science and Engineering, MIT). Fabricated by Stratasys.

Beast

**Neri Oxman**
Beast is an organic-like entity created synthetically by the incorporation of physical parameters into digital form-generation protocols. A single continuous surface, acting both as structure and as skin, is locally modulated for both structural support and corporeal aid. Beast combines structural, environmental, and corporeal performance by adapting its thickness, pattern density, stiffness, flexibility, and translucency to load, curvature, and skin-pressured areas respectively.
Bots of Babel

Neri Oxman, Jorge Duro-Royo, Markus Kayser, Jared Laucks, Laia Mogas-Soldevila

The Biblical story of the Tower of Babel involved a deliberate plan hatched by mankind to construct a platform from which man could fight God. The tower represented the first documented attempt at constructing a vertical city. The divine response to the master plan was to sever communication by instilling a different language in each builder. Tragically, the building’s ultimate destruction came about through the breakdown of communications between its fabricators. In this installation we redeem the Tower of Babel by creating its antithesis. We will construct a virtuous, decentralized, yet highly communicative building environment of cable-suspended fabrication bots that together build structures bigger than themselves. We explore themes of asynchronous motion, multi-nodal fabrication, lightweight additive manufacturing, and the emergence of form through fabrication. (With contributions from Carlos Gonzalez Uribe and Dr. James Weaver (WYSS Institute and Harvard University))

Building-Scale 3D Printing

Neri Oxman, Steven Keating, John Klein

How can additive fabrication technologies be scaled to building-sized construction? We introduce a novel method of mobile swarm printing that allows small robotic agents to construct large structures. The robotic agents extrude a fast-curing material which doubles as both a concrete mold for structural walls and as a thermal insulation layer. This technique offers many benefits over traditional construction methods, such as speed, custom geometry, and cost. As well, direct integration of building utilities such as wiring and plumbing can be incorporated into the printing process. This research was sponsored by the NSF EAGER award: Bio-Beams: FGM Digital Design & Fabrication.

Carpal Skin

Neri Oxman

Carpal Skin is a prototype for a protective glove to protect against Carpal Tunnel Syndrome, a medical condition in which the median nerve is compressed at the wrist, leading to numbness, muscle atrophy, and weakness in the hand. Night-time wrist splinting is the recommended treatment for most patients before going into carpal tunnel release surgery. Carpal Skin is a process by which to map the pain-profile of a particular patient – its intensity and duration – and to distribute hard and soft materials to fit the patient’s anatomical and physiological requirements, limiting movement in a customized fashion. The form-generation process is inspired by animal coating patterns in the control of stiffness variation.

CNSILK: Computer Numerically Controlled Silk Cocoon Construction

Neri Oxman

CNSILK explores the design and fabrication potential of silk fibers–inspired by silkworm cocoons–for the construction of woven habitats. It explores a novel approach to the design and fabrication of silk-based building skins by controlling the mechanical and physical properties of spatial structures inherent in their microstructures using multi-axis fabrication. The method offers construction without assembly, such that material properties vary locally to accommodate for structural and environmental requirements. This approach stands in contrast to functional assemblies and kinetically actuated facades which require a great deal of energy to operate, and are typically maintained by global control. Such material architectures could simultaneously bear structural load, change their transparency so as to control light levels within a spatial compartment (building or vehicle), and open and close embedded pores so as to ventilate a space.

DCP: Digital Construction Environment

Neri Oxman, Levi Cai, Barrak Darweesh, Steven Keating, Julian Leland

The Digital Construction Environment is the first architectural-scale structure fabricated with the Digital Construction Platform (DCP). Using the Mediated Matter group’s Print-In-Place construction technique, an open-domed structure with a diameter of 14.6 m and a height of 3.7 m was manufactured over a print time of 13.5 hours.

Digital Construction Platform

Neri Oxman, Levi Cai, Steven Keating, Julian Leland

The Digital Construction Platform (DCP) is an experimental enabling technology for large-scale digital manufacturing. In contrast to the typical gantry-based approach to digital construction, robotic arm systems offer the promise of greater task flexibility, dynamically expandable workspaces, rapid setup times, and easier implementation with existing construction techniques. Potential applications for this system include fabrication of non-standard architectural forms; incorporation of data gathered on-site in real time into fabrication processes; improvements in construction efficiency, quality, and safety; and exploration of autonomous construction systems for use in disaster relief, hazardous environments, and extraterrestrial exploration.
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<td>Digital Construction Platform v.1</td>
<td>Neri Oxman, Levi Cai, Steven Keating, John Klein, Julian Leland, Dow Chemical, Altec</td>
<td>The Digital Construction Platform (DCP) is an in-progress research project consisting of a compound robotic arm system. The system comprises a 6-axis KUKA robotic arm attached to the endpoint of a 3-axis Altec hydraulic boom arm, which is mounted on a mobile platform. Akin to the biological model of the human shoulder and hand, this compound system utilizes the large boom arm for gross positioning and the small robotic arm for fine positioning and oscillation correction, respectively. Potential applications include fabrication of non-standard architectural forms, integration of real-time on-site sensing data, improvements in construction efficiency, enhanced resolution, lower error rates, and increased safety.</td>
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<tr>
<td>414.</td>
<td>Digitally Reconfigurable Surface</td>
<td>Neri Oxman</td>
<td>The digitally reconfigurable surface is a pin matrix apparatus for directly creating rigid 3D surfaces from a computer-aided design (CAD) input. A digital design is uploaded into the device, and a grid of thousands of tiny pins, much like the popular pin-art toy, are actuated to form the desired surface. A rubber sheet is held by vacuum pressure onto the tops of the pins to smooth out the surface they form; this strong surface can then be used for industrial forming operations, simple resin casting, and many other applications. The novel phase-changing electronic clutch array allows the device to have independent position control over thousands of discrete pins with only a single motorized “push plate,” lowering the complexity and manufacturing cost of this type of device. Research is ongoing into new actuation techniques to further lower the cost and increase the surface resolution of this technology.</td>
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<td>415.</td>
<td>FABRICOLOGY: Variable-property 3D printing as a case for sustainable fabrication</td>
<td>Neri Oxman</td>
<td>Rapid prototyping technologies speed product design by facilitating visualization and testing of prototypes. However, such machines are limited to using one material at a time; even high-end 3D printers, which accommodate the deposition of multiple materials, must do so discretely and not in mixtures. This project aims to build a proof-of-concept of a 3D printer able to dynamically mix and vary the ratios of different materials in order to produce a continuous gradient of material properties with real-time correspondence to structural and environmental constraints.</td>
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<td>416.</td>
<td>FIBERBOTS: Design of a multi-agent, fiber composite digital fabrication system</td>
<td>Christoph Bader, Levi Cai, Barrak Darweesh, Sara Falcone, Joao Pedro Goncalves Marins Costa, Nassia Inglessis, Markus Kayser</td>
<td>FIBERBOTS is a digital fabrication platform fusing cooperative robotic manufacturing with abilities to generate highly sophisticated material architectures. The platform can enable design and digital fabrication of large-scale structures with high spatial resolution leveraging mobile fabrication nodes, or robotic “agents” designed to tune the material make-up of the structure being constructed on the fly as informed by their environment. Some of nature’s most successful organisms collaborate in a swarm fashion. Nature’s builders leverage hierarchical structures in order to control and optimize multiple material properties. Spiders, for instance, spin protein fibers to weave silk webs with tunable local and global material properties, adjusting their material composition and fiber placement to create strong yet flexible structures optimized to capture prey. Other organisms, such as bees, ants and termites cooperate to rapidly build structures much larger than themselves.</td>
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<td>417.</td>
<td>FitSocket: Measurement for attaching objects to people</td>
<td>Hugh Herr, Neri Oxman, Jean-Francois Duval, Arthur J Petron</td>
<td>A better understanding of the biomechanics of human tissue allows for better attachment of load-bearing objects to people. Think of shoes, ski boots, car seats, orthotics, and more. We are focusing on prosthetic sockets, the cup-shaped devices that attach an amputated limb to a lower-limb prosthesis, which currently are made through unscientific, artisanal methods that do not have repeatable quality and comfort from one individual to the next. The FitSocket project aims to identify the correlation between leg tissue properties and the design of a comfortable socket. The FitSocket is a robotic socket measurement device that directly measures tissue properties. With these data, we can rapid-prototype test sockets and socket molds in order to make rigid, spatially variable stiffness, and spatially/temporally variable stiffness sockets.</td>
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<tr>
<td>418.</td>
<td>Functionally graded filament-wound carbon-fiber prosthetic sockets</td>
<td>Neri Oxman, Carlos Gonzalez Uribe, Hugh Herr and the Biomechatronics group</td>
<td>Prosthetic sockets belong to a family of orthotic devices designed for amputee rehabilitation and performance augmentation. Although such products are fabricated out of lightweight composite materials and designed for optimal shape and size, they are limited in their capacity to offer local control of material properties for optimizing load distribution and ergonomic fit over surface and volume areas. Our research offers a novel workflow to enable the digital design and fabrication of customized prosthetic sockets with variable impedance informed by MRI data. We implement parametric environments to enable the controlled distribution of functional gradients of a filament-wound carbon fiber socket.</td>
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Gemini—an acoustical “twin chaise”—spans multiple scales of the human existence extending from the warmth of the womb to the stretches of the Gemini zodiac in deep space. It recapitulates a human cosmos: our body—like the Gemini constellation—drifting in space.

Ancient yet modern, enclosing yet invisible, glass was first created in Mesopotamia and Ancient Egypt 4,500 years ago. Precise recipes for its production—the chemistry and techniques—often remain closely guarded secrets. Glass can be molded, formed, blown, plated or sintered; its formal qualities are closely tied to techniques used for its formation. From the discovery of core-forming process for bead-making in ancient Egypt, through the invention of the metal blow pipe during Roman times, to the modern industrial Pilkington process for making large-scale flat glass; each new breakthrough in glass technology occurred as a result of prolonged experimentation and ingenuity, and has given rise to a new universe of possibilities for uses of the material.

Optically transparent and structurally sound, glass has played a significant role in the evolution of product and architectural design across scales and disciplines, and throughout the ages. Glass processing methods—such as blowing, pressing, and forming—have aimed at achieving increased glass performance and functionality. Nonetheless, techniques and technologies enabling controlled tunability of its optical and mechanical properties at high spatial manufacturing resolution have remained an end without a means.

Hybrid Living Materials (HLMs) are formed by combining living and non-living materials such that the resulting composites take on the functional properties of both.

In the 2019 paper published to Advanced Functional Materials, we detailed the HLM Platform: a method of interfacing a 3D digital design and printing platform with engineered bacteria, in such a way that we achieve programmable, replicable control of gene expression across the surface of 3D printed objects.

Generating 3D Lichtenberg structures in sintered media (i.e. glass) using electricity offers a new approach to digital fabrication. By robotically controlling the electrodes, a digital form can be rapidly fabricated with the benefits of a fine fractal structure. There are numerous applications, ranging from chemical catalysts, to fractal antennas, to product design.
The control of living systems as part of design interfaces is of interest to both the scientific and design communities due to the ability of living organisms to sense and respond to their environments. They may, for example, detect and break down harmful environmental agents, or create beneficial products when environmental levels dropped below a certain threshold. However, it is also important for these systems to be reversible, so that the biological components are only active when their functionality is necessary, and the system can remain dormant otherwise.

The Living Material Library is an exploration of tunable hybrid systems. Our work in this area demonstrates the means through which intrinsic material properties may be functionally changed through environmental factors and, in turn, serve as dynamic substrates for living systems. Nearly all organisms have highly developed sensing capabilities, and have been shown to behaviorally respond to changes in substrate properties. By creating a tunable and reversible material system, we explore how cell behavior such as adhesion, patterning, and differentiation may be influenced via an active interface.

In this iteration, we propose a reversible material system that allows for control of living interactions (much like a light switch). We are particularly interested in fluid material systems (such as electrorheological fluids) that transition from a liquid-like to a solid-like state when exposed to electric fields and currents.

This endeavor brings to light the complex relationship between dynamic materials and living systems. While other methods of cell intervention often rely on light, chemicals, or temperature, here we explore substrate material properties as inputs for organisms. Our library may allow for more directed inquiry into processes such as collective cell durotaxis, general mechanotaxis, and active sensing. This marks an initial foray into establishing candidate design methods for responsive applications.

How can we design relationships between the most primitive and the most sophisticated life forms? Can we design wearables embedded with synthetic microorganisms that can enhance and augment biological functionality? Can we design wearables that generate consumable energy when exposed to the sun?

Maiden Flight is an autonomous biological laboratory environment designed for studying the impact of space flight on the sole reproductive node of a bee colony: the queen bee and her retinue. It represents the first space module of its kind built specifically to cater to queen bees. The hybrid-ecology of the capsule was created to take into account the distributed and uniquely non-human nature of bee biology, in order to consider how to extend the bee reproductive system for environmental extremes. This aim is reflected in the structure of the capsule interior, which was assembled by humans and augmented by the bees’ natural fabrication.

In May 2019, the Mediated Matter group traveled to Texas to launch two laboratory capsules on Blue Origin’s sub-orbital rocket system, New Shepard. Each custom-designed metabolic support capsule comprised an experimental environment for one queen bee and an attending retinue of 10-20 nurse bees for a parabolic flight to a 100-kilometer micro-gravitational space apogee, and back.

We present a multimaterial voxel-printing method enabling the physical visualization of data sets commonly associated with scientific imaging. Leveraging voxel-based control of multimaterial 3D printing, our method enables additive manufacturing of discontinuous data types such as point cloud data, curve and graph data, image-based data, and volumetric data. By converting data sets into dithered material deposition descriptions, through modifications to rasterization processes, we demonstrate that data sets frequently visualized on screen can be converted into physical, materially heterogeneous objects.

Our approach alleviates the need to post-process data sets to boundary representations, preventing alteration of data and loss of information in the produced physicalizations. Therefore, it bridges the gap between digital information representation and physical material composition. We evaluate the visual characteristics and features of our method, assess its relevance and applicability in the production of physical visualizations, and detail the conversion of data sets for multimaterial 3D printing. We conclude with exemplary 3D printed datasets produced by our method pointing towards potential applications across scales, disciplines, and problem domains.
Microfluidics

Printing Multi-Material 3D Microfluidics

Neri Oxman, Steven Keating, Will Patrick, David Sun Kong (MIT Lincoln Laboratory)

Computation and fabrication in biology occur in aqueous environments. Through on-chip mixing, analysis, and fabrication, microfluidic chips have introduced new possibilities in biology for over two decades. Existing construction processes for microfluidics use complex, cumbersome, and expensive lithography methods that produce single-material, multi-layered 2D chips. Multi-material 3D printing presents a promising alternative to existing methods that would allow microfluidics to be fabricated in a single step with functionally graded material properties. We aim to create multi-material microfluidic devices using additive manufacturing to replicate current devices, such as valves and ring mixers, and to explore new possibilities enabled by 3D geometries and functionally graded materials. Applications range from medicine to genetic engineering to product design.

Organic Primitives

Neri Oxman, Steven Keating, Will Patrick, Sunanda Sharma, Eleonore Tham, Steph Hays, Professor Tim Lu, Professor Pam Silver

As humans, we understand information mediated by our senses—through textures, symbols, odors, and tastes. In order to design for a wider array of sensory modalities in representing fluid-based information and enable user interaction with these systems, we have developed Organic Primitives. It is a new medium for transforming objects into information displays. Chemical input is converted into human senses through a set of color-, odor-, and form-changing materials.

PCB Origami

Neri Oxman

The PCB Origami project is an innovative concept for printing digital materials and creating 3D objects with Rigid-flex PCBs and pick-and-place machines. These machines allow printing of digital electronic materials, while controlling the location and property of each of the components printed. By combining this technology with Rigid-flex PCB and computational origami, it is possible to create from a single sheet of PCB almost any 3D shape that is already embedded with electronics, to produce a finished product with that will be both structural and functional.

Meta-Mesh: Computational model for design and fabrication of biomimetic scaled body armors

Neri Oxman, Jorge Duro-Royo, Laia Mogas-Soldevila

A collaboration between Professor Christine Ortiz (project lead), Professor Mary C. Boyce, Katia Zolotovsky, and Swati Varshney (MIT). Operating at the intersection of biomimetic design and additive manufacturing, this research proposes a computational approach for designing multifunctional scaled-armors that offer structural protection and flexibility in movement. Inspired by the segmented exoskeleton of Polypterus senegalus, an ancient fish, we have developed a hierarchical computational model that emulates structure-function relationships found in the biological exoskeleton. Our research provides a methodology for the generation of biomimetic protective surfaces using segmented, articulated components that maintain user mobility alongside full-body coverage of doubly curved surfaces typical of the human body. The research is supported by the MIT Institute for Soldier Nanotechnologies, the Institute for Collaborative Biotechnologies, and the National Security Science and Engineering Faculty Fellowship Program.

Monoque

Neri Oxman

French for “single shell,” Monoque stands for a construction technique that supports structural load using an object’s external skin. Contrary to the traditional design of building skins that distinguish between internal structural frameworks and non-bearing skin elements, this approach promotes heterogeneity and differentiation of material properties. The project demonstrates the notion of a structural skin using a Voronoi pattern, the density of which corresponds to multi-scalar loading conditions. The distribution of shear-stress lines and surface pressure is embodied in the allocation and relative thickness of the vein-like elements built into the skin. Its innovative 3D printing technology provides for the ability to print parts and assemblies made of multiple materials within a single build, as well as to create composite materials that present preset combinations of mechanical properties.

Organic Primitives

Yasuaki Kakehi, Virij Kan, Emma Vargo, Noa Machover, Serena Pan

A large portion of the chemical and biological processes underlying our everyday experience remains imperceptible to us. Be it the contents of rain, the ocean, or human tears, chemical codes mediate interactions between organic systems from the environment to our bodies and food.

As humans, we understand information mediated by our senses—through textures, symbols, odors, and tastes. In order to design for a wider array of sensory modalities in representing fluid-based information and enable user interaction with these systems, we have developed Organic Primitives. It is a new medium for transforming objects into information displays. Chemical input is converted into human senses through a set of color-, odor-, and form-changing materials.

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Printing Living Materials

Neri Oxman, Steven Keating, Will Patrick, Sunanda Sharma, Eleonore Tham, Steph Hays, Professor Tim Lu, Professor Pam Silver

How can biological organisms be incorporated into product, fashion, and architectural design to enable the generation of multi-functional, responsive, and highly adaptable objects? This research pursues the intersection of synthetic biology, digital fabrication, and design. Our goal is to incorporate engineered biological organisms into inorganic and organic materials to vary material properties in space and time. We aim to use synthetic biology to engineer organisms with varied output functionalities and digital fabrication tools to pattern these organisms and induce their specific capabilities with spatiotemporal precision.

Printing Multi-Material 3D Microfluidics

Neri Oxman, Steven Keating, Will Patrick, David Sun Kong (MIT Lincoln Laboratory)

Computation and fabrication in biology occur in aqueous environments. Through on-chip mixing, analysis, and fabrication, microfluidic chips have introduced new possibilities in biology for over two decades. Existing construction processes for microfluidics use complex, cumbersome, and expensive lithography methods that produce single-material, multi-layered 2D chips. Multi-material 3D printing presents a promising alternative to existing methods that would allow microfluidics to be fabricated in a single step with functionally graded material properties. We aim to create multi-material microfluidic devices using additive manufacturing to replicate current devices, such as valves and ring mixers, and to explore new possibilities enabled by 3D geometries and functionally graded materials. Applications range from medicine to genetic engineering to product design.
A major concern for manned missions is space radiation. Ionizing radiation is known to pose both acute and chronic risks to many organisms, including humans. At this time, it is important to expand strategies for radiation protection, including utilizing new materials and fabrication methods that can withstand different forms of radiation. The Mediated Matter group is researching the synthesis of biological pigments, including melamins and carotenoids, for biocompatible radioprotection. Such pigments can be fabricated for a variety of applications, creating a new class of materials and coatings that can protect life on Earth, in deep space, and beyond. Here, we examine the growth and behavior of five pigment-producing microorganisms after their placement in the interior of the International Space Station for one month as part of the RIDES payload. This experiment payload will launch on the SpaceX CRS-20 on March 6, 2020.

The values endorsed by vernacular architecture have traditionally promoted designs constructed and informed by and for the environment, while using local knowledge and indigenous materials. Under the imperatives and growing recognition of sustainable design, Rapid Craft seeks integration between local construction techniques and globally available digital design technologies to preserve, revive, and reshape these cultural traditions.

Raycounting is a method for generating customized light-shading constructions by registering the intensity and orientation of light rays within a given environment. 3D surfaces of double curvature are the result of assigning light parameters to flat planes. The algorithm calculates the intensity, position, and direction of one or multiple light sources placed in a given environment, and assigns local curvature values to each point in space corresponding to the reference plane and the light dimension. Light performance analysis tools are reconstructed programmatically to allow for morphological synthesis based on intensity, frequency, and polarization of light parameters as defined by the user.

Rottlace is a family of masks designed for Icelandic singer-songwriter Björk. Inspired by Björk’s most recent album—Vulnicura— the Mediated Matter Group explored themes associated with self-healing and expressing “the face without a skin.” The series originates with a mask that emulates Björk’s facial structure and concludes with a mask that reveals a new identity, independent of its origin. What originates as a form of portraiture culminates in reincarnation.

The Silk Pavilion explores the relationship between digital and biological fabrication on product and architectural scales. The primary structure was created of 26 polygonal panels made of silk threads laid down by a CNC (Computer-Numerically Controlled) machine.

What are radically sustainable methods for knitting, making and building in the age of the Anthropocene? How can humankind and members of other species such as silkworms collaborate in the construction of objects, products, and buildings? Can we extract silk without boiling cocoons? Standing six meters tall and five meters wide, Silk Pavilion II offers insights into these questions by combining kinetic manufacturing with biological construction, uniting the built and the grown, fusing technology and biology.

The SpiderBot is a suspended robotic gantry system that provides an easily deployable platform from which to print large structures. The body is composed of a deposition nozzle, a reservoir of material, and parallel linear actuators. The robot is connected to stable points high in the environment, such as large trees or buildings. This arrangement is capable of moving large distances without the need for more conventional linear guides, much like a spider does. The system is easy to set up for mobile projects, and will afford sufficient printing resolution and build volume. Expanding foam can be deposited to create a building-scale printed object rapidly. Another material type of interest is the extrusion or spinning of tension elements, like rope or cable. With tension elements, unique structures such as bridges or webs can be wrapped, woven, or strung around environmental features or previously printed materials.
Neri Oxman, Jorge Duro-Royo, Markus Kayser, Sunanda Sharma,

The Synthetic Apiary proposes a new kind of environment, bridging urban and organismic scales by exploring one of the most important organisms for both the human species and our planet: bees. We explore the cohabitation of humans and other species through the creation of a controlled atmosphere and associated behavioral paradigms. The project facilitates Mediated Matter’s ongoing research into biologically augmented digital fabrication with eusocial insect communities in architectural, and possibly urban, scales. Many animal communities in nature present collective behaviors known as “swarming,” prioritizing group survival over individuals, and constantly working to achieve a common goal. Often, swarms of organisms are skilled builders; for example, ants can create extremely complex networks by tunneling, and wasps can generate intricate paper nests with materials sourced from local areas.

Neri Oxman, Christoph Bader, Joao Pedro Goncalves Marins Costa, Joseph Kennedy, Felix Kraemer, Sunanda Sharma, Rachel Smith

Biodiversity on planet Earth is under momentous threat, with extinction rates estimated between 100 and 1,000 times their pre-human level. The Mediated Matter group has been in search of materials and chemical substances that can sustain and enhance biodiversity across living systems, and that have so far endured the perils of climate change. Melanin is one such substance illustrating biodiversity at the genetic, species, and ecosystem levels.

Neri Oxman, Christoph Bader, Dominik Kolb, Sunanda Sharma, Rachel Smith, James Weaver

Novel technologies for additive manufacturing are enabling design and production at nature’s scale. We can seamlessly vary the physical properties of materials at the resolution of a sperm cell, a muscle cell, or a nerve cell. Stiffness, color, hygroscopy, transparency, conductivity, even scent, can be individually tuned for each three-dimensional pixel within a physical object. The generation of products is therefore no longer limited to assemblages of discrete parts with homogeneous properties. Rather like organs, objects can be computationally “grown” and 3D printed to form materially heterogeneous and multi-functional products.

Neri Oxman, Christoph Bader, Joao Pedro Goncalves Marins Costa, Sunanda Sharma, Rachel Smith, James Weaver

Vespers is a collection of masks exploring what it means to design (with) life. From the relic of the death mask to a contemporary living device, the collection embarks on a journey that begins with an ancient typology and culminates with a novel technology for the design and digital fabrication of adaptive and responsive interfaces. We begin with a conceptual piece and end with a tangible set of tools, techniques and technologies combining programmable matter and programmable life.

The project points towards an imminent future where wearable interfaces and building skins are customized not only to fit a particular shape, but also a specific material, chemical and even genetic make-up, tailoring the wearable to both the body and the environment which it inhabits.

Imagine, for example, a wearable interface designed to guide ad-hoc antibiotic formation customized to fit the genetic makeup of its user; or, consider smart packaging or surface coatings devices that can detect contamination; finally, consider environmentally responsive architectural skins that can respond to, and adapt—in real time—to environmental cues. Research at the core of this project offers a new design space for biological augmentation across a wide breadth of application domains, leveraging resolution and scale.

The collection includes three series. The first series features the death mask as a cultural artifact. The final series features a living mask as an enabling technology. The second series mediates between the two, marking the process of “metamorphosis” between the ancient relic and its contemporaneous interpretation. The living masks in the final series embody habitats that guide, inform and “template” gene expression of living microorganisms. Such microorganisms have been synthetically engineered to produce pigments and/or otherwise useful chemical substances for human augmentation such as vitamins, antibodies or antimicrobial drugs. Combined, the three series of the Vespers collection represent the transition from death to life, or from life to death, depending on one’s reading of the collection.

Neri Oxman, Christoph Bader, Dominik Kolb

The Wanderers were unveiled as part of the exhibition: ‘The Sixth Element: Exploring the Natural Beauty of 3D Printing’ on display at EuroMold, 25-28 November, Frankfurt, Germany. This work was done in collaboration with Christoph Bader and Dominik Kolb. The wearables were 3D-printed with Stratasys multi-material 3D printing technology. Members of the Mediated Matter group led by Will Patrick and Sunanda Sharma are currently working on embedding living matter in the form of engineered bacteria within the 3D structures in order to augment the environment.
This research presents water-based robotic fabrication as a design approach and enabling technology for additive manufacturing (AM) of biodegradable hydrogel composites. We focus on expanding the dimensions of the fabrication envelope, developing structural materials for additive deposition, incorporating material-property gradients, and manufacturing architectural-scale biodegradable systems. The technology includes a robotically controlled AM system to produce biodegradable composite objects, combining natural hydrogels with other organic aggregates. It demonstrates the approach by designing, building, and evaluating the mechanics and controls of a multi-chamber extrusion system. Finally, it provides evidence of large-scale composite objects fabricated by our technology that display graded properties and feature sizes ranging from micro- to macro-scale. Fabricated objects may be chemically stabilized or dissolved in water and recycled within minutes. Applications include the fabrication of fully recyclable products or temporary architectural components, such as tent structures with graded mechanical and optical properties.

How might zero gravity space affect silk spinning, and what benefits might such material properties provide for digital fabrication and additive manufacturing once back on Earth? Project ZG Stardust explores the broader theme of material formulation and fabrication in microgravity, particularly the spinning of silk by silkworms. We study how microgravity may impact the worms across all stages of life—egg, larva, cocoon, and adult moth—through changes in their spinning patterns pre- and post-flight. The goal is to implement insights and results in the design of fiber-based goods otherwise not producible on Earth while enabling natural metamorphosis.
### Joseph A. Paradiso: Responsive Environments

**Augmenting and mediating human experience, interaction, and perception with sensor networks**

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<tr>
<th>448. BaguMarsh</th>
<th>Joseph A. Paradiso, Don Derek Haddad, Fei Jiang</th>
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<td>This project takes the idea of the unity between heaven and man of the ancient Chinese philosophy I ching (Book of Changes), combines the Bagua (eight trigrams) of the I ching with multidimensional data and multimedia, and uses an immersive interactive environment to present a novel form of narrative visualization. The main theme of this project is the &quot;Unity between Heaven and Man,&quot; namely the harmony of nature and humans. It systematically expounds the relationship between man and nature that man must follow the law of the universe, to respect and protect nature, to have an insight into the truth that harmony can produce all things. According to the main theme, we design this project under the form of a virtual reality environment by integrating personal data, environmental data, and media materials.</td>
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<th>449. Chain API</th>
<th>Joseph A. Paradiso, Gershon Dublon, Brian Mayton, Spencer Russell</th>
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<td>RESTful services and the Web provide a framework and structure for content delivery that is scalable, not only in size but, more importantly, in use cases. As we in Responsive Environments build systems to collect, process, and deliver sensor data, this project serves as a research platform that can be shared between a variety of projects both inside and outside the group. By leveraging hyperlinks between sensor data clients can browse, explore, and discover their relationships and interactions in ways that can grow over time.</td>
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<tr>
<th>450. ChainFORM</th>
<th>Hiroshi Ishii, Joseph A. Paradiso, Artem Dementyev, Ken Nakagaki</th>
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<td>ChainFORM is a modular hardware system for designing linear shape-changing interfaces. Each module is developed based on a servo motor with added flexible circuit board, and is capable of touch detection, visual output, angular sensing, and motor actuation. Moreover, because each module can communicate with other modules linearly, it allows users and designers to adjust and customize the length of the interface. Using the functionality of the hardware system, we propose a wide range of applications, including line-based shape changing display, reconfigurable stylus, rapid prototyping tool for actuated crafts, and customizable haptic glove. We conducted a technical evaluation and a user study to explore capabilities and potential requirements for future improvement.</td>
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<th>451. ChromoSkin</th>
<th>Joseph A. Paradiso, Chris Schmandt, Cindy Hsin-Liu Kao, Manisha Mohan, Katia Vega</th>
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<td>Makeup has long been used as a body decoration process for self-expression and for the transformation of one’s appearance. While the material composition and processes for creating makeup products have evolved, they still remain static and non-interactive. But our social contexts demand different representations of ourselves; thus, we propose ChromoSkin, a dynamic color-changing makeup system that gives the wearer ability to alter seamlessly their appearance. We prototyped an interactive eye shadow tattoo composed of thermochromic pigments activated by electronics or ambient temperature conditions. We present the design and fabrication of these interactive cosmetics, and the challenges in creating skin interfaces that are seamless, dynamic, and fashionable.</td>
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<td>Currently, the manufacturing of self-actuating and self-sensing robots requires non-standard manufacturing techniques and assembly steps to integrate electrical and mechanical systems. In this work, we developed a novel manufacturing technique, where such robots can be produced at a flexible electronics factory. We developed the technique using standard industrial machines, processes, and materials. Using a lamination process, we were able to integrate air pouches or shape memory alloy (SMA) inside a polyamide-based flexible circuit to produce bending actuators. The bend angle of the actuators is sensed with a chain of inertial measurement units integrated on the actuator. Air-pouch actuators can produce a force of a 2.24N, and a maximum bend angle of 74 degrees. To demonstrate, we manufactured a five-legged robot with the developed actuators and bend sensors, with all the supporting electronics (e.g., microcontrollers, radio) directly integrated into the flexible printed circuit. Such robots are flat and lightweight (15 grams) and thus conveniently compact for transportation and storage. We believe that our technique can allow inexpensive and fast prototyping and deployment of self-actuating and self-sensing robots.</td>
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Circuit Stickers is a toolkit for crafting electronics using flexible and sticky electronic pieces. These stickers are created by printing traces on flexible substrates and adding conductive adhesive. These lightweight, flexible, and sticky circuit boards allow us to begin sticking interactivity onto new spaces and interfaces such as clothing, instruments, buildings, and even our bodies.

Circuit Stickers Activity Book is a primer for using circuit stickers to create expressive electronics. Inside are explanations of the stickers, and circuits and templates for building functional electronics directly on the pages of the book. The book covers five topics, from simple LED circuits to crafting switches and sensors. As users complete the circuits, they are also prompted with craft and drawing activities to ensure an expressive and artistic approach to learning and building circuits. Once completed, the book serves as an encyclopedia of techniques to apply to future projects.

Circuit Storybook is an interactive picture book that explores storytelling techniques through paper-based circuitry. Sensors, lights, and microcontrollers embedded into the covers, spine, and pages of the book add electronic interactivity to the traditional physical picture book, allowing us to tell new stories in new ways. The current book, "Ellie," tells the adventures of an LED light named Ellie who dreams of becoming a star, and of her journey up to the sky.

Cognition-driven audio summarization as we move towards an increasingly IoT-enabled ecosystem, we find that it is easier than ever before to capture vast amounts of audio data. However, there are many scenarios in which we may seek a "compressed" representation of an audio stream, consisting of an intentional curation of content to achieve a specific presentation—a background soundtrack for studying or working; a summary of salient events over the course of a day; or an aesthetic soundscape that evokes nostalgia of a time and place. In this work, we present a novel, automated approach to the task of content-driven "compression," built upon the tenets of auditory cognition, attention, and memory. We expand upon our previous experimental findings, which demonstrate the relative importance of higher-level gestalt and lower level spectral principles in determining auditory memory, to design corresponding computational implementations enabled by auditory saliency models, deep neural networks for audio classification, and spectral feature extraction. We demonstrate the approach by generating a number of 30 second binaural mixes from eight-hour recordings captured in three contrasting locations at the Media Lab, and conduct a qualitative evaluation illustrating the relationship between our feature space and a user's perception of the resulting presentations. Through this work, we suggest rethinking traditional paradigms of compression in favor of an approach that is goal-oriented and modulated by human perception.

When we form memories, not everything that we perceive is noticed; not everything that we notice is remembered. Humans are excellent at filtering and retaining only the most important parts of their experience—what if our audio compression had the same ability? Our goal is to understand what makes sound memorable. With this work, we hope to gain insight into the cognitive processes that drive auditory perception and predict the memorability of sounds in the world around us more accurately than ever before. Ultimately, these models will give us the ability to generate and manipulate the sounds that surround us to be more or less memorable. We envision this research introducing new paradigms into the space of audio compression, attention-driven user interactions, and auditory AR, amongst others.

Homes and offices are being filled with sensor networks to answer specific queries and solve predetermined problems, but no comprehensive visualization tools exist for fusing these disparate data to examine relationships across spaces and sensing modalities. DoppelLab is a cross-reality virtual environment that represents the multimodal sensor data produced by a building and its inhabitants. Our system encompasses a set of tools for parsing, databasing, visualizing, and sonifying these data; by organizing data by the space from which they originate, DoppelLab provides a platform to make both broad and specific queries about the activities, systems, and relationships in a complex, sensor-rich environment.
**Doppelmarsh: Cross-reality environmental sensor data browser**  
Joseph A. Paradiso, Gershon Dublon, Don Derek Haddad, Evan Lynch, Brian Mayton, Spencer Russell  
Doppelmarsh is a cross-reality sensor data browser built for experimenting with presence and multimodal sensory experiences. Built on evolving terrain data from a physical wetland landscape, the software integrates real-time data from an environmental sensor network with real-time audio streams and other media from the site. Sensor data is rendered in the scene in both visual representations and as 3D sonification. Users can explore this data by walking on the virtual terrain in a first person view, or flying high above it. This flexibility allows Doppelmarsh to serve as an interface to other research platforms on the site, such as Quadrasense, an augmented reality UAV system that blends a flying live camera view with a virtual camera from Doppelmarsh. We are currently investigating methods for representing subsurface data, such as soil and water temperatures at depth, as well as automation in scene and terrain painting.

**Envirome Monitoring with CRISPR Biosensors**  
Devora Najjar  
Microbial monitoring plays a critical role in informing governments, researchers, and locals on the health of their ecosystem. Unfortunately, common methods of microbial detection and identification for human and environmental health require specialized equipment that provide results on the order of days. As an alternative to these bottlenecks, this project translates novel CRISPR biological sensing platforms meant for low-resource (out-of-lab) diagnostics to be used for waterborne pathogen monitoring in low-resource contexts.

This project will serve as the proof of concept for an on-demand, low-cost, and quick environmental monitoring biotechnology to deliver results in hours. Experiments are being run to test the applicability both within local communities as well as in microgravity. Field trials are set to begin Summer 2020. This project is funded in part by the SEI-TRISH Seed Grant Program and National Geographic.  
Collaborators:  
Collins Lab, MIT; Space Exploration Initiative, MIT Media Lab; Open Ocean Initiative, MIT Media Lab.

**Experiential Lighting: New user interfaces for lighting control**  
Joseph A. Paradiso, Matthew Aldrich, Nan Zhao  
The vision of pervasive computing is now mainstream. These connected devices permeate every aspect of our lives. Yet, we remain tethered to arcane user interfaces. Unlike consumer devices, building appliances and utilities perpetuate this outdated vision. Lighting control is a prime example. Here, we show how a data-driven methodology—using people and sensors—enables an entirely new method of lighting control.

We are evaluating new methods of interacting and controlling solid-state lighting based on our findings of how participants experience and perceive architectural lighting in our new lighting laboratory (E14-548S). This work, aptly named “Experiential Lighting,” reduces the complexity of modern lighting controls (intensity/color/space) into a simple mapping, aided by both human input and sensor measurement. We believe our approach extends beyond general lighting control and is applicable in situations where human-based rankings and preference are critical requirements for control and actuation. We expect our foundational studies to guide future camera-based systems that will inevitably incorporate context in their operation (e.g., Google Glass).

**FabricKeyboard**  
Joseph A. Paradiso, Irmandy Wicaksono  
Multimodal textile sensate media as an expressive and deformable musical interface  
In the area of intelligent textiles, we are exploring a multi-modal, fabric-based, stretchable sensate surface for physical interaction media, specifically as deformable musical interface.

The fabric keyboard consists of multi-layer textile sensors machine-sewn in a keyboard pattern, and it detects different stimuli such as touch, pressure, stretch, proximity, and electric field. This allows users to explore physical and non-contact gestures for expressive on-body and on-surface musical performance. We’ve also developed additional textile-based inputs such as ribbon controller, trackpad, and fur for more expressive control. This soft sensate surface contributes toward developing seamless, self-aware, and washable media.
**463. FingerSynth: Wearable transducers for exploring the environment through sound**

**Joseph A. Paradiso, Gershon Dublon**

The FingerSynth is a wearable musical instrument made up of a bracelet and set of rings that enables its players to produce sound by touching nearly any surface in their environments. Each ring contains a small, independently controlled audio exciter transducer. The rings sound loudly when they touch a hard object, and are silent otherwise. When a wearer touches their own (or someone else’s) head, the contacted person hears sound through bone conduction, inaudible to others. A microcontroller generates a separate audio signal for each ring, and can take user input through an accelerometer in the form of taps, flicks, and other gestures. The player controls the envelope and timbre of the sound by varying the physical pressure and the angle of their finger on the surface, or by touching differently resonant surfaces. The FingerSynth encourages players to experiment with the materials around them and with one another.

**464. Grappler: Arrays of bistable elements for landing distributed sensor networks on low gravity bodies**

**Juliana Cherston, Paul Strohmeier, Paul Strohmeier, University of Copenhagen**

Can a modified snap bracelet be used to land infrastructure on an asteroid?

It is notoriously difficult to stick a landing on a low gravity body, particularly if locomotion across the body is desired. We have been studying the use of arrays of bistable pinching elements for grappling onto the unpredictable contours of asteroids and other distant low gravity bodies. Each pinching element is mechanically actuated via an impact force, much like a snap bracelet. By coupling together arrays of such elements, we seek to demonstrate that the chain can conform with added precision to the topological structure of the body, as well as grapple more effectively.

This mechanism can ultimately be used to land large-scale structures like nets and tethers across the body, which then serve as infrastructure for crawling distributed sensors or sensory membranes, among other possibilities.

Additionally, we completed a study on a candidate low cost spectral imager payload for determining iron content in rock samples.

A concept paper on the broader work was published by the 31st Annual AIAA/USU Conference on Small Satellites. A prototype was deployed on a microgravity flight and results summarized at AIAA Scitech 2019.

There may also be compelling uses for the technology on Earth for adhering sensors to terrain that is erratic and difficult to access, like the roof of a cave, or structures at the bottom of the sea floor.

Two prototypes—one equipped with sensors—were tested on a microgravity flight by throwing them at a rocky target object. Data from the flight will be used to characterize the behavior of chains of one vs three bistable elements in order to inform future design decisions.

**465. Hacking the Sketchbook**

**Joseph A. Paradiso, Jie Qi**

In this project we investigate how the process of building a circuit can be made more organic, like sketching in a sketchbook. We integrate a rechargeable power supply into the spine of a traditional sketchbook, so that each page of the sketchbook has power connections. This enables users to begin creating functioning circuits directly onto the pages of the book and to annotate as they would in a regular notebook. The sequential nature of the sketchbook allows creators to document their process for circuit design. The book also serves as a single physical archive of various hardware designs. Finally, the portable and rechargeable nature of the book allows users to take their electronic prototypes off of the lab bench and share their creations with people outside of the lab environment.

**466. Halo: Wearable Lighting**

**Joseph A. Paradiso, Nan Zhao**

Imagine a future where lights are not fixed to the ceiling, but follow us wherever we are. In this colorful world we enjoy lighting that is designed to go along with the moment, the activity, our feelings, and our outfits. Halo is a wearable lighting device created to explore this scenario. Different from architectural lighting, this personal lighting device aims to illuminate and present its user. Halo changes the wearer’s appearance with the ease of a button click, similar to adding a filter to a photograph. It can also change the user’s view of the world, brightening up a rainy day or coloring a gray landscape. Halo can react to activities and adapt based on context. It is a responsive window between the wearer and his or her surroundings.
We only perceive a tiny sliver of the world around us. We are constrained by what our senses can process. These senses evolved to react to what is immediately important for our survival. Our technological development has outstripped the pace at which our physical senses evolve. We do not have access to things such as the electromagnetic spectrum at 2.5 GHz, even though it is relevant to the day-to-day life of most of us. We are poor at perceiving things such as changes in the chemical composition of the air we breathe, even though it is critical for our long-term survival as a species.

Can we augment a stroll through nature with sensory experiences usually outside the range of our perception? Haptic Footprints explore using vibrotactile rendering for this purpose.

With our Ubiquitous Sonic Overlay, we are working to place virtual sounds in the user’s environment, fixing them in space even as the user moves. We are working toward creating a seamless auditory display, indistinguishable from the user’s actual surroundings. Between bone-conduction headphones, small and cheap orientation sensors, and ubiquitous GPS, a confluence of fundamental technologies is in place. However, existing head-tracking systems either limit the motion space to a small area (e.g., Oculus Rift), or sacrifice precision for scale using technologies like GPS. We are seeking to bridge the gap to create large outdoor spaces of sonic objects.

ListenTree is an audio-haptic display embedded in the natural environment. Visitors to our installation notice a faint sound emerging from a tree. By resting their heads against the tree, they are able to hear sound through bone conduction. To create this effect, an audio exciter transducer is weatherproofed and attached to the tree’s roots, transforming it into a living speaker, channeling audio through its branches, and providing vibrotactile feedback. In one deployment, we used ListenTree to display live sound from an outdoor ecological monitoring sensor network, bringing a faraway wetland into the urban landscape. Our intervention is motivated by a need for forms of display that fade into the background, inviting attention rather than requiring it. We consume most digital information through devices that alienate us from our surroundings; ListenTree points to a future where digital information might become enmeshed in material.

Living Observatory is an initiative for documenting and interpreting ecological change that will allow people, individually and collectively, to better understand relationships between ecological processes, human lifestyle choices, and climate change adaptation. As part of this initiative, we are developing sensor networks that document ecological processes and allow people to experience the data at different spatial and temporal scales. Low-power sensor nodes capture climate and other data at a high spatiotemporal resolution, while other stream audio. Sensors on trees measure transpiration and other cycles, while fiber-optic cables in streams capture high-resolution temperature data. At the same time, we are developing tools that allow people to explore this data, both remotely and onsite. The remote interface allows for immersive 3D exploration of the terrain, while visitors to the site will be able to access data from the network around them directly from wearable devices.

We demonstrate an always-available, on-body gestural interface. Using an array of pressure sensors worn around the wrist, it can distinguish subtle finger pinch gestures with high accuracy (> 80%). We demonstrate that it is a complete system that works wirelessly in real time. The device is simple and lightweight in terms of power consumption and computational overhead. Prototype’s sensor power consumption is 89uW, allowing the prototype to last more than a week on a small lithium polymer battery. Also, device is small and non-obtrusive, and can be integrated into a wristwatch or a bracelet. Custom pressure sensors can be printed with off-the-shelf conductive inkjet technology. We demonstrate that number of gestures can be greatly extended by adding orientation data from an accelerometer. Also, we explore various usage scenarios with the device.
Tidmarsh is a 600-acre former cranberry farm near Plymouth, MA that has undergone a restoration to wetland. We have instrumented the site with an extensive network of custom low-power environmental sensor nodes, microphones, and cameras. The data from the network is made available in real time and has enabled a number of explorations into the ways that people can experience and learn from large-scale, long-term sensor installations.

See sensor data, listen to live audio, and watch live camera feeds on the Tidmarsh website.

Valentina Sumini, Siranush Babakhanova, Sheila Baber, Eric Hinterman, Jeffrey Hoffman, Joseph Kusters, George Lordos, Hans Nowak, Tajana Schneiderman, Sara Seager, Samantha Seaman, Thomas Smith, Natasha Stamler, Zhuchang Zhan | Massachusetts Institute of Technology, Franco Bernelli Zazzera, Jana Lukic, Aldo Moccia | Politecnico di Milano, Fabio Maffia, Paolo Maggiore, Laura Mainini, Samuele Sciarretta | Politecnico di Torino

This work was supported by the Space Architecture for Extra-planetary Exploration (SAEEX) Project under the Alta Scuola Politecnica Program of Politecnico di Torino and Politecnico di Milano, and by the 2019 Breakthrough, Innovative and Game-changing (BIG) Idea Challenge under the NASA Game Changing Development (GCD) Program awarding the second place to the Biosphere Engineered Architecture for Viable Extraterrestrial Residence (BEAVER) project team. Additional acknowledgments to Confaritigianato di Vicenza and Digital Innovation Hub for the support to Dr. Valentina Sumini and to the Visiting Professor Program of Politecnico di Torino for the support to Dr. Laura Mainini.

As global interest in deep space exploration rises, new mission architectures and new dwelling solutions must be sought for to accomplish longer and safer permanence in space.

Less dependency from Earth supplies, better psychological and physical conditions for the astronauts, higher safety, and lower energy and resources consumption are the main requirements for such missions, and must be matched and experimented from the very beginning of human deep space exploration. To address this same need for higher feasibility and sustainability, this research explores a novel design for a greenhouse module that can supply 100% of the food required for a crew of four astronauts on an extended mission to Mars, while also providing physical and mental health benefits for the crew members.

The module accomplishes this by maximizing space and minimizing mass with a novel spiral system within an inflatable, cylindrical shell designed to protect astronauts from harmful radiation. Crops, which supply the food for the crew, grow in modular hydroponic trays that descend from the top floor of the module along six spiral tracks. The lighting, temperature, nutrient supply, track length, and vertical separation of each spiral is matched to plants growth patterns and needs, thereby maximizing volume for growth, optimizing growing conditions, and providing isolation in case of disease.
When materials sciences meet HCI and e-textiles, for custom sensors and actuators

In this project we explore the process of polymerization to add electrical functionalities to everyday materials such as fabrics, or feathers, and transform them as sensors.

Creating one’s own sensitive textiles provides a plethora of opportunities: for example, it means the freedom from constraints of store bought materials. Polymerization broadens the range of interactive objects which can be created. One might augment an existing and loved item, or create unique new materials and sensors by polymerizing items with unique properties such as tape or zippers.

Existing piezoresistive materials (pressure sensitive) also act as a black box in designs; it means that entrepreneurs, tailors, researchers, and hackers are dependent on a specific manufacturer. If this manufacturer changes their production process, this might make entire designs obsolete, which can make it tricky to reproduce work or create products.

PolySense, our CHI publication, highlights how—by framing polymerization as a dyeing process—polymerization is a versatile and easy-to-deploy tool for creating fabric with custom electrical properties. We also show how to use etching on existing functional fabric to customize it. The resulting custom fabrics might be used as sensors or conductors, and even whole circuits including sensing elements can be implemented in fabric only.

Other publications highlight specific pieces and technologies which are implemented using the process described in PolySense. For example, we demonstrate rapid prototyping of on-skin interaction, and showcase a hybrid art piece which features polymerized feathers.

Credits

The project is a collaboration with members of Datapaulette, the Saarland University HCI Lab, and various other friends and colleagues. The materials research behind this project was conducted with Ana C Baptista of Nova University Lisbon (CENIMAT-i3N). The CHI publication was developed over a series of visits at the Saarland HCI Lab by Hannah Perner-Wilson and Cedric Honnet.

More

CounterChemists.github.io

In the knowledge economy, worker satisfaction is paramount to retention and productivity. Recent studies have identified a decline in workplace satisfaction. Our research demonstrates how Mediated Atmosphere address this growing need. We created a workspace prototype equipped with a modular real-time control infrastructure, integrating biosignal sensors, controllable lighting, projection, and sound.

Credits

The Mediated Atmosphere project envisions a smart office that is capable of dynamically transforming itself to enhance occupants’ work experience.

More

MediatedAtmosphere.github.io
Meet the Ganimals

New generative AI technologies (such as the Generative Adversarial Network, or GAN) can allow us to imagine new species. Hidden within the neural network, there are millions of these “ganimals” that no one has ever seen before. These ganimals occupy a digital landscape not unlike our own, where attention is short, and engagement is necessary to survive.

Meet the Ganimals is a collaborative social experiment to discover new species, breed your own, and feed the ones you love. The data you provide about the ganimals is their “food.” Unfed ganimals are quickly forgotten, so ganimals you engage with have a genetic advantage, and breed more often. Thus, to withstand the harsh conditions of the attention economy, ganimals adapt to the crowd’s opinions and preferences. So the question remains, which ganimals do you want to thrive?

We built Meet the Ganimals to showcase how artificial intelligence can not only generate images of realistic animals, but also images of believable hybrid animals. These hybrid animals are created with a Generative Adversarial Network (GAN), which we baked into their name: ganimals. When we combine a Goldfish with a Golden Retriever, the result is a combination of the most striking features of both animals: a bright orange, big-eyed, mopey-eared underwater canine. What the AI features is based on the idiosyncrasies of an animal relative to the pool of animals that we have selected. For ganimals, the striking and transferrable morphological features are stripes on a zebra, eyes on dogs, the shape of a great white shark, the color of goldfish, the feathers of an owl, and many more. One could argue that the biodiversity of ganimals rivals that of the natural world. Artificial evolution is not constrained by the laws of the physical world and fitness but instead the limits of our imagination and our aesthetic tastes. We can curate ganimals by adapting the AI model or adding and removing images of species on which to train the model.

The Meet the Ganimals website is an online social experiment to see what happens when we allow our aesthetic interests to guide evolution. Our goal is to direct thousands of people to the website in order to see how these new artificial life forms evolve, and what dynamics emerge. This number of people is critical for us to properly understand how aesthetic interests guide evolution.

Mindful Photons: Context-Aware Lighting

Light enables our visual perception. It is the most common medium for displaying digital information. Light regulates our circadian rhythms, affects productivity and social interaction, and makes people feel safe. Yet despite the significance of light in structuring human relationships with their environments on all these levels, we communicate very little with our artificial lighting systems. Occupancy, ambient illuminance, intensity, and color preferences are the only input signals currently provided to these systems. With advanced sensing technology, we can establish better communication with our devices. This effort is often described as context-awareness. Context has typically been divided into properties such as location, identity, affective state, and activity. Using wearable and infrastructure sensors, we are interested in detecting these properties and using them to control lighting. The Mindful Photons Project aims to close the loop and allow our light sources to “see” us.

Moments

Moments is a prototype designed for users to save special moments and to experience those moments in the future. Firstly, a multi-sensor equipment is designed to collect environment data in user’s daily life. Secondly, the data integration system can collect relevant information based on both photos and user data from an open data platform. At last, an immersive virtual reality environment is provided for the user to explore his or her past experiences.
Moon Village

Claudie Haignere, Piero Messina | European Space Agency, Paris, France

Sponsors: Confartigianato di Vicenza and Digital Innovation Hub

In 2015, the director general of the European Space Agency (ESA), Jan Wörner, introduced the concept of the “Moon Village.” Inspired by the unparalleled level of cooperation achieved by the International Space Station, the Moon Village represents an extension of this paradigm of deep space activities. It is a vision to apply international cooperative principles to exploration beyond low Earth orbit.

The Massachusetts Institute of Technology, in collaboration with Skidmore, Owings & Merrill and the European Space Agency, are investigating concepts for the first permanent human settlement on the lunar surface. This collaboration aims to demonstrate the potential of an international private-public partnership to advance human space exploration through cross-disciplinary cooperation.

The Moon Village project presents a holistic approach to the planning of a lunar development, centering on the need for habitation systems, designed as adaptive space environments to enable versatile surface operations. The team has proposed a design located near the South Pole where there is a convergence of resources such as near perpetual light, as well as water ice in the nearby permanently shaded craters, in order to maximize in-situ resource utilization.

NailO

Joseph A. Paradiso, Chris Schmandt, Artem Dementyev, Cindy Hsin-Liu Kao

NailO is a wearable input device in the form of a commercialized nail art sticker. It works as a miniaturized trackpad the size and thickness of a fingernail that can connect to your mobile devices; it also enables wearers to customize the device to fit the wearer’s personal style. NailO allows wearers to perform different functions on a phone or PC with different gestures, and the wearer can easily alter its appearance with a nail art design layer, creating a combination of functionality and aesthetics. From the fashion-conscious, to techies, and anyone in between, NailO can make a style, art, or a design statement; for example attracting minimal attention when you are in a meeting but need to reply to an urgent text message. Mimicking the form of a cosmetic extension, NailO blends into and decorates one’s body when attached, yet remains removable at the wearer’s discretion, giving the wearer power and control over the level of intimacy of the device to one’s body.

Persian Domes for Human Space Exploration on Mars

Joseph A. Paradiso, Valentina Sumini, Mahsa Moghimi Esfandabadi | MIT Media Lab Space Exploration Initiative + Sasakawa International Center for Space Architecture (SICSA) | Cullen College of Engineering | University of Houston

Sponsors: Confartigianato di Vicenza and Digital Innovation Hub

The Lut Desert of Iran is one of the most similar regions to Mars. Close to that area, there are vernacular adobe architectures that are hundreds of years old which were built by primitive construction methods, but with interesting and complex geometry.

Among all city structures, bathhouses represent the unique example of an introvert architecture that has a deep commonality with greenhouse closed-systems. A bathhouse not only isolates active interior life from the outer world, but also insulates the temperature and humidity from the extreme environment of the Lut Desert. It usually also has a closed clean water system, open-air water flow circulation, and water reservoir and safe power access, all features that should be present in a greenhouse design concept for Mars.

The main architectural feature of the Persian bathhouse architecture is the presence of one or more domes as a roof system. These masonry domes, named Karbandi, are characterized by ease of construction and use of local materials, absolutely consistent with the In Situ Resources Utilization requirements for building on Mars. Indeed, this research focuses on exploring the structural performance of bathhouse architecture for designing a 3D printed regolith dome—a shelter to provide micrometeoroid and radiation shielding for a greenhouse infrastructure on Mars.

Programmable Paintings

Joseph A. Paradiso, Leah Buechley, Jie Qi

Programmable Paintings are a series of artworks that use electronic elements such as LED lights and microphone sensors as “pigments” in paintings. The goal is to blend traditional elements of painting—color, texture, composition—with these electronic components to create a new genre of time-based and interactive art.
Project Captivate

Patrick Chwalek, David Ramsay

Project Captivate have been designed to serve as an easy and reliable platform to measure physiology in the real world. We’ve designed it to be a tool for researchers, a means to understand attention and engagement, and a scalable means to control responsive ecosystems.

A Tool for Researchers

Smartglasses are increasingly popular because the face is an ideal location for continuous monitoring of environmental and physiological signals. Unfortunately, no standard smartglasses platforms offer easy access to physiological data. That leaves researchers constrained by their own quick—and usually bulky—designs that make people self-conscious and uncomfortable, altering their behavior and preventing long-term naturalistic studies. The Captivate platform addresses these concerns; it saves researchers design time and gives them easy access to data in a form factor that doesn’t stand out. We spent a summer in Shenzhen, China, learning from eyeglass manufacturers on how best to integrate sensors that track physiology events across your face, head movements, and location in a form-factor that is similar to a traditional pair of glasses.

Measuring Attention Across Contexts

We are using the Captivate platform study a user’s cognitive state, specifically cognitive loading and overall attention. Many lab-based behavioral studies fail to replicate in real-world contexts. Because of the deep engineering work behind these glasses, we are capable of studying people naturally—all day long, in their real lives. Combined with new probabilistic modeling tools, we can make much more reliable predictions about a user’s cognitive state in real scenarios.

Driving IoT Ecosystems at Scale

The glasses also talk to each other over a mesh network, allowing them to scale to large events and concerts, as well as to serve as one integral part of IoT ecosystems at home and at work. We envision the insights Captivate glasses can capture about users in these environments as a crucial first step towards responsive, immersive environments that support user goals.

Prosthetic Sensor Networks: Factoring attention, proprioception, and sensory coding

Joseph A. Paradiso, Gershon Dublon

Sensor networks permeate our built and natural environments, but our means for interfacing to the resultant data streams have not evolved much beyond HCI and information visualization. Researchers have long experimented with wearable sensors and actuators on the body as assistive devices. A user’s neuropsychology can, under certain conditions, transcend sensory substitution to enable perceptual-level cognition of “extrasensory” stimuli delivered through existing sensory channels. But there remains a huge gap between data and human sensory experience. We are exploring the space between sensor networks and human augmentation, in which distributed sensors become sensory prostheses. In contrast, user interfaces are substantially unincorporated by the body, our relationship to them never fully pre-attentive. Attention and proprioception are key, not only to moderate and direct stimuli, but also to enable users to move through the world naturally, attending to the sensory modalities relevant to their specific contexts.

Rovables

Joseph A. Paradiso, Chris Schmandt, Deborah Ajilo, Artem Dementyev, Cindy Hsain-Liu Kao, Stanford University (Intrak Choi, Maggie Xu, Sean Follmer)

We introduce Rovables, a miniature robot that can move freely on unmodified clothing. The robots are held in place by magnetic wheels, and can climb vertically. The robots are untethered and have an onboard battery, microcontroller, and wireless communications. They also contain a low-power localization system that uses wheel encoders and IMU, allowing Rovables to perform limited autonomous navigation on the body. In the technical evaluations, we found that Rovables can operate continuously for 45 minutes and can carry up to 1.5N. We propose an interaction space for mobile on-body devices spanning sensing, actuation, and interfaces, and develop application scenarios in that space. Our applications include on-body sensing, modular displays, tactile feedback and interactive clothing and jewelry.

Saving Face

Fadel Adib, Kevin Esvelt, Pattie Maes, Joseph A. Paradiso, Guadalupe Babio Fernandez, Eyal Perry, Camilo Rojas, Irmandy Wicaksono, Cedric Honnet (visiting scientist, Responsive Environments); Niels Poulsen (visiting student, Fluid Interfaces); Nicolas Ayoub (visiting student, City Science); Zhi Wei Gan (MIT undergraduate); Korrawat (James) Pruegsanusak (MIT EECS); Franklin Zhang (MIT EECS); Aaron Stinnett (MIT IDM).
| 488. | SensorChimes: Musical mapping for sensor networks | Joseph A. Paradiso, Evan Lynch<br>SensorChimes aims to create a new canvas for artists leveraging ubiquitous sensing and data collection. Real-time data from environmental sensor networks are realized as musical composition. Physical processes are manifested as musical ideas, with the dual goal of making meaningful music and rendering an ambient display. The Tidmarsh Living Observatory initiative, which aims to document the transformation of a reclaimed cranberry bog, provides an opportunity to explore data-driven musical composition based on a large-scale environmental sensor network. The data collected from Tidmarsh are piped into a mapping framework, which a composer configures to produce music driven by the data. |
| 489. | SensorKnits: Architecting textile sensors with machine knitting | Hiroshi Ishii, Joseph A. Paradiso, Don Derek Haddad, Daniel Oran, Jifei Ou<br>Digital machine knitting is a highly programmable manufacturing process that has been utilized to produce apparel, accessories, and footwear. Our research presents three classes of textile sensors exploiting the resistive, piezoresistive, and capacitive properties of various textile structures enabled by machine knitting with conductive yarn. |
| 490. | SensorNets | Joseph A. Paradiso, Elena Chong Loo, Artem Dementyev, Irmandy Wicaksano<br>SensorNets: Towards Reconfigurable Multifunctional Fine-grained Soft and Stretchable Electronic Skins.<br>SensorNets is a bioinspired electronic skin integrated with multimodal sensor networks for interactive media applications, from wearables, self-aware objects, to intelligent environments. It is developed by connecting miniaturized flexible printed circuit boards as two-dimensional sensor arrays with stretchable interconnects. The system is embedded in between soft deformable layers, such as textiles or rubbers. The result is a soft sensate surface that can be distributed and conformally wrap and adapt to curved structures. Each node contains a microprocessor together with a collection of nine sensors and a light-emitting diode, providing multimodal data that can be used to detect various deformation, proxemic, tactile, and environmental changes. We show that the electronic skin can sense and respond to a variety of stimuli simultaneously, as well as open up a possibility for sensor-rich virtual and augmented reality-based visualization and interaction. |
| 491. | SensorTape: Modular and programmable 3D-aware dense sensor network on a tape | Joseph A. Paradiso, Artem Dementyev, Cindy Hsin-Liu Kao<br>SensorTape is a modular and dense sensor network in a form factor of a tape. SensorTape is composed of interconnected and programmable sensor nodes on a flexible electronics sub-strate. Each node can sense its orientation with an inertial measurement unit, allowing deformation self-sensing of the whole tape. Also, nodes sense proximity using time-of-flight infrared. We developed network architecture to automatically determine the location of each sensor node, as SensorTape is cut and rejoined. We also made an intuitive graphical interface to program the tape. Our user study suggested that SensorTape enables users with different skill sets to intuitively create and program large sensor network arrays. We developed diverse applications ranging from wearables to home sensing, to show low-deployment effort required by the user. We showed how SensorTape could be produced at scale and made a 2.3-meter long prototype. |
| 492. | SkinBot: A wearable, skin-climbing robot | Joseph A. Paradiso, Artem Dementyev, Sean Follmer, Javier Hernandez, Inrak Choi<br>We introduce SkinBot: a lightweight robot that moves over the skin’s surface with a two-legged suction-based locomotion mechanism and captures a wide range of body parameters with an exchangeable multipurpose sensing module. We believe that robots that live on our skin, such as SkinBot, will enable a more systematic study of the human body and offer great opportunities to advance our knowledge in many areas such as telemedicine, human-computer interfaces, body care, and fashion. |
| 493. | SoundSignaling | Ishwarya Ananthabhotla<br>Drawing inspiration from the notion of cognitive incongruence associated with Stroop’s famous experiment, from musical principles, and from the observation that music consumption on an individual basis is becoming increasingly ubiquitous, we present the SoundSignaling system—a software platform designed to make real-time, stylistically relevant modifications to a personal corpus of music as a means of conveying information or notifications. From the substantial body of HCI research demonstrating the negative attentional implications of a daily inundation of notifications, we highlight two challenges associated with standard audio notifications—a “switch cost” that impedes productivity, and a lack of awareness of a user’s cognitive load—that have the potential to be addressed by such a system without active activity estimation. Through this work, we suggest a re-evaluation of the age-old paradigm of binary notifications in favor of a system designed to operate upon the relatively unexplored medium of a user’s musical preferences. |
Joseph A. Paradiso, Ariel Ekblaw, Manuel Muccillo, Valentina Sumini, Thanks to Prof. Dava Newman, Gui Trotti and all the astronauts who helped during each design phase: Cady Coleman, Prof. Jeffrey Hoffman, Leland Melvin and Paolo Nespoli. Thanks also to all collaborators: Kyung Yun Choi, Prof. Lorenzo Imbesi, Jamie Milliken and John Rao.

Sponsors: Confartigianato di Vicenza and Digital Innovation Hub, Shima Seiki Inc. and Empatica Inc.

SpaceHuman is a soft robotics device designed to facilitate the exploration of environments with reduced gravity in a view of democratization and openness towards access to space and its exploration. It is based on the idea that one day, people who have not received a long preparation and training, as happens today with the astronauts, will be able to have access to the space having a type of conformation and physical configuration that is not adapted to this kind of setting.

The analysis of the unique seahorse’s tail structure became the insight of the overall biomimetic design process. In fact, seahorse tail movement, gripping and protection to the seahorse while floating. Moreover, seahorses do not use their tails to swim; instead, they use them to grasp objects in their environment while they camouflage to hide from predators and hunts for prey. Flexibility and resiliency are key features that enable these behaviours.

SpaceHuman is an additive prosthesis or otherwise definable as a “supernumerary robot.” SpaceHuman will facilitate the use of space in zero gravity or reduced gravity restoring the right motion and balance of our body and assigning a new function to a part of our body that until now has not been fully exploited except for the transport of loads, our back. Users will thus be able to build a new poetics of the body and its movements within this radically different space through SpaceHuman, creating new scenarios of its application. Through air chambers specifically designed to be able to change their shape and bend along a reinforcing rib of the material, the people who will use SpaceHuman will be able to cling to useful surfaces inside orbital housing or in lunar or martian villages.

Juliana Cherston, Valentina Sumini

The outermost skin of a space-based structure is designed using materials known to protect against the harsh elements of space. Simultaneously, the skin provides a unique opportunity to characterize the environment proximate to a spacecraft and to perform real-time damage detection. Thus, we propose developing an aerospace-grade fabric that simultaneously senses and protects, emulating the dual protective and sensory capabilities of biological skin. Aerospace-grade sensory skins will serve a key role in next generation haptic feedback systems for spacesuits (see SpaceTouch application area), as well as next generation thermal blankets for distributed detection of high velocity debris impact.

For example, Beta Cloth—the outermost layer of the International Space Station—is particularly resilient to atomic oxygen erosion and extended UV radiation exposure. It is also regularly exposed to high velocity debris impact. We draw from recent advances in functional fibers and electronic textiles in order to weave and coat sensors directly into the teflon-coated fiberglass that comprises Beta Cloth, enabling the skin to detect and characterize impact events. We seek to demonstrate that the well-characterized, protective properties of aerospace-grade woven materials can be preserved even when modified to include sensory functionality.

Our work begins by examining integrated piezoelectric yarns and piezoelectric ink coatings for vibration sensing. We will also consider state-of-the-art manufacturing methods (e.g., device-in-fiber technology [1]) and intriguing high velocity impact sensing modalities; e.g., detection of impact plasma RF emission [2]. Other possibilities include the use of free-flying external optical sensors that collaborate with the skin to assess damage (“Skin and Eyes”), as well as work towards making the sensory skin robust to cutting, sewing, and wrapping.

Overview:
How will we build the coming generations of Space Architecture—the modules, space ships, and space stations that will enshrine our space-faring species? Can we move beyond the 20th century paradigm of cylindrical tubes in orbit, to geodesic dome habitats, to microgravity concert halls, to space cathedrals? The next generation of space architecture should delight, inspire, and protect humanity for our future in the near, and far, reaches of space.

The future of human habitation in space lies in self-assembling, adaptive, and reconfigurable structures. Rather than transporting fixed, rigid habitation modules and risking astronaut Extravehicular Activities (EVAs) during construction, we can lower payload weight, reduce assembly complexity, and revolutionize space-structure modularity by relying on reconfigurable, self-assembly.

This project proposes a multi-year research effort to study, characterize, prototype and test "TESSERAE": Tessellated Electromagnetic Space Structures for the Exploration of Reconfigurable, Adaptive Environments. Each TESSERAE structure is made from a set of tiles. These tiles are tuned to self-assemble into a particular geometry—in our initial prototypes, we have focused on the buckminsterfullerene (20 hexagonal tiles, 12 pentagonal tiles). Each tile at minimum includes a rigid outer shell, responsive sensing for bonding diagnosis, electro-permanent magnets for dynamically controllable bonding actuation, and an on-board power harvesting and power management system. Habitat-scale TESSERAE tiles will also include clamping and sealing for pressurization. Tiles are released in microgravity testing environments to quasi-stochastically self assemble.

The "TESSERAE" name and multi-tile structure hearken to the small, colored tiles used in Roman mosaics, where many standard pieces, or "tesserae," interlock to form a larger creation. We make this reference to ancient history, when designing an artifact of our space exploration future, to tie architectural elements together across scales and across millennia.

TESSERAE will function as multi-use, low-cost orbiting modules that supply a critical space infrastructure for the next generation of zero gravity habitats, science labs, staging areas for on-surface exploration, and more. Unlike large-scale habitats proposed for entire space colonies, the TESSERAE should be thought of as flexible and reconfigurable modules to aid in agile mission operations. Our mission concept focuses on supporting LEO, Lunar and Mars operations, with dual-use orbit and surface capability:

Tiles are packed flat and condensed for launch

Tiles are released after orbit insertion to quasi-stochastically self-assemble into the target geometry, while floating in microgravity

Once assembled, the structure can be reconfigured on demand (e.g., where a berthing port tile was needed yesterday, a cupola tile can be replaced tomorrow)

Tiles can be disassembled entirely, packed flat again in an EDL (Entry, Descent and Landing) vehicle, and then deployed and "snap-assembled" with astronaut assists on the lunar or martian surface

Multiple, interlocking TESSERAE can serve as a larger volume orbiting base (e.g., "MOSAIC": Mars Orbiting Self-Assembling Interlocking Chambers), in addition to supporting the coming waves of space tourists and space hotels in low Earth orbit.
The Tidmarsh Living Observatory Portal is a research project that focuses on the design and fabrication of a pavilion that will generate an immersive physical telepresence experience of this enchanting natural wetland.

The Tidmarsh site has been restored from a former cranberry farm to natural wetland and, through extensive Responsive Environments research that lasted decades, it has been possible to retrieve several environmental live data thanks to the networked and outdoor installed instrumentation.

The portal will generate a real-time telepresence by recreating visuals and sounds representative of the site, streaming live data as well as past recorded data, allowing also a travel across time. The overall experience, for maximizing its immersion, is tailored for a single user and lasts about three to five minutes. The user will interact by selecting a location of the Tidmarsh map and a specific time.

**Architectural design**

The architectural design of the pavilion is inspired by the idea of recreating an individual Tidmarsh ecosystem wherever the Portal is going to be located. Therefore, the bio-inspired egg shape enclosure represents the optimal metaphor of a micro-ecosystem within a macro-ecosystem.

The research explored different ways of geometrically describing an egg shape using computational techniques to allow a parametric design flow while considering a user-centered design approach.

Some of the variables are the overall dimensions of the Portal and the different mathematical approaches to define a spatial egg geometry. The coded Rhino-Grasshopper algorithms allowed us to define a set of possible design solutions that respect some physical boundary conditions and optimize the visual experience.

**Towards a Perceptual Loss:** Using a neural network codec approximation as a loss for generative audio models

Generative audio models based on neural networks have led to considerable improvements across fields including speech enhancement, source separation, and text-to-speech synthesis. These systems are typically trained in a supervised fashion using simple element-wise $l_1$ or $l_2$ losses. However, because they do not capture properties of the human auditory system, such losses encourage modeling perceptually meaningless aspects of the output, wasting capacity and limiting performance. Additionally, while adversarial models have been employed to encourage outputs that are statistically indistinguishable from ground truth and have resulted in improvements in this regard, such losses do not need to explicitly model perception as their task; furthermore, training adversarial networks remains an unstable and slow process.

In this work, we investigate an idea fundamentally rooted in psychoacoustics. We train a neural network to emulate an MP3 codec as a differentiable function. Feeding the output of a generative model through this MP3 function, we remove signal components that are perceptually irrelevant before computing a loss. To further stabilize gradient propagation, we employ intermediate layer outputs to define our loss, as found useful in image domain methods. Our experiments using an autoencoding task show an improvement over standard losses in listening tests, indicating the potential of psychoacoustically motivated models for audio generation.
Junsu Jang

Biological Carbon Pump (BCP), which refers to the transport of particulate organic carbon (POC) from the ocean’s surface to the bottom, directly impacts the global climate. However, predicting ocean carbon sequestration remains highly uncertain due to the complexity of the BCP, observation methodology differences, and temporal and spatial aliasing. Therefore, mass-deployable (i.e. low-cost) sensors that directly observe the transport of organic particles are crucial.

We set out to build an underwater stereo-imaging system to remotely measure the sinking POC in the ocean. The hardware design is primarily restricted by the depth (pressure), particle size (resolution) and sinking rate (framerate), deployment duration (battery) and cost (mass-deployment). Upon obtaining time-lapse images of the POC, 3D particle tracking velocimetry algorithm is applied to analyze the particle sinking rate. Ultimately, this will be attached to a Lagrangian float with other sensors to reliably measure various factors that affect the BCP.

Joseph A. Paradiso, Ishwarya Ananthabhotla

We present VisualSoundtrack, a system designed as a tool for soundtrack composers to experiment with original musical content in differing musical “styles.” The system allows a user to rapidly prototype musical ideas with respect to the target media (such as a film or podcast) by having him/her input original musical motifs, capitalizing on a corpus of existing soundtrack samples to source various styles, and allowing the user to identify the most appropriate style sources for the target media by visually architecting a path through a highly abstracted feature space.
Alex 'Sandy' Pentland: Human Dynamics
Exploring how social networks can influence our lives in business, health, governance, and technology adoption and diffusion

Active Fairness in Algorithmic Decision Making
Alex 'Sandy' Pentland, Michiel Bakker, Alejandro Noriega Campero, Bernardo Garcia-Bulle, visiting student, Human Dynamics group
Algorithmic Fairness
Society increasingly relies on machine learning models for automated decision making. Yet, efficiency gains from automation have come paired with concern for algorithmic discrimination that can systematize inequality. Substantial work in algorithmic fairness has surged, focusing on either post-processing trained models, constraining learning processes, or pre-processing training data. Recent work has proposed optimal post-processing methods that randomize classification decisions on a fraction of individuals in order to achieve fairness measures related to parity in errors and calibration. These methods, however, have raised concerns due to the information inefficiency, intra-group unfairness, and Pareto sub-optimality they entail.

Active Fairness
The present work proposes an alternative active framework for fair classification, where, in deployment, a decision maker adaptively acquires information according to the needs of different groups or individuals towards balancing disparities in classification performance. We propose two such methods where information collection is adapted to group- and individual-level needs, respectively. We show on real-world datasets that these can achieve: 1) calibration and single error parity (e.g., equal opportunity) and 2) parity in both false positive and false negative rates (e.g., equal odds). Moreover, we show that, by leveraging their additional degree of freedom, active approaches can outperform randomization-based classifiers previously considered optimal, while also avoiding limitations such as intra-group unfairness.

Augmented Eternity and Swappable Identities
Hossein Rahnama
Have you ever wondered what a friend would do if she was in your decision-making situation? Or thought about where a family member might go if he was visiting a travel destination with you? In many cases, you can only guess what a person would do if they were in your shoes. But now you may be able to securely “borrow their identity” and ask a question with the confidence of receiving a relevant and valuable answer.

Can software agents become our digital heirs? Can a head of state, a scientist, or a business owner leverage machine intelligence to complement succession planning? What if you could select the digital identity of a deceased person from a social network and activate it as a pluggable ontology into your iPhone’s Siri and ask a question?

Our digital identity has become so rich and intrinsic that without it, it may feel like a part of us is missing. The number of sensors we carry daily and the digital footprints we leave behind have given us enough granular patterns and data clusters that we can now use them for prediction and reasoning on behalf of an individual. We believe that by enabling our digital identity to perpetuate, we can significantly contribute to global expertise and enable a new form of an intergenerational collective intelligence.

Alex 'Sandy' Pentland, Yves-Alexandre de Montjoye
bandicoot provides a complete, easy-to-use environment for researchers using mobile phone metadata. It allows them to easily load their data, perform analysis, and export their results with a few lines of code. It computes 100+ standardized metrics in three categories: individual (number of calls, text response rate), spatial (radius of gyration, entropy of places), and social network (clustering coefficient, assortativity). The toolbox is easy to extend and contains extensive documentation with guides and examples.
Autonomous vehicles (AVs), drones, and other types of robots will revolutionize our way of traveling and understanding urban space. In order to operate, all of these devices are expected to collect, analyze, and share sensitive data about our daily activities. However, current approaches of handling these datasets relies on centralized models (e.g., corporate databases, cloud-based services, etc.). Recently, it has been shown that the security and privacy-preserving capabilities of these centralized models present significant challenges for future deployments. For this reason, this project proposes BASIC, the Blockchained Agent-based Simulator for Cities. This tool aims to verify the feasibility of using blockchain as a communication layer between agents (e.g., citizens, robots, etc.) in simulated urban scenarios. In order to test the proposed tool, we propose a car-sharing scenario populated with AVs within the city of Cambridge (Massachusetts, USA).

Swarms of robots will revolutionize many applications, from targeted material delivery to farming. However, the characteristics that make them ideal for certain future applications, such as robot autonomy or decentralized control, can also be an obstacle when transferring this technology from academia to real-world problems. Blockchain, an emerging technology, demonstrates that by combining peer-to-peer networks with cryptographic algorithms, a group of agents can reach agreements without the need for a controlling authority. The combination of blockchain with other distributed systems, such as robotic swarm systems, can provide the necessary capabilities to make robotic swarm operations more secure, autonomous, flexible, and even profitable.

Participants in cryptocurrency markets are in constant communication with each other about the latest coins and news releases. Do these conversations build hype through the contagiousness of excitement, help the community process information, or play some other role? Using a novel dataset from a major cryptocurrency forum, we conduct an exploratory study of the characteristics of online discussion around cryptocurrencies. We find that coins with more information available and higher levels of technical innovation are associated with higher quality discussion. People who talk about serious coins tend to participate in discussion displaying signatures of collective intelligence and information processing, while people who talk about less serious coins tend to display signatures of hype and naïvety. Interviews with experienced forum members also confirm these quantitative findings. These results highlight the varied roles of discussion in the cryptocurrency ecosystem and suggest that discussion of serious coins may be oriented towards earnest, perhaps more accurate, attempts at discovering which coins are likely to succeed.

As of August 2019, Ring has active partnerships with over 400 law enforcement agencies across the US. These partnerships allow law enforcement agencies to use the “Neighbors Portal,” an extension of Ring’s surveillance-as-a-social-network Neighbors App. The portal gives law enforcement the ability to make posts and comment on videos that users share to the app, but it also allows them to “submit requests for video recordings.” The partnerships also give law enforcement the ability to offer subsidized ring cameras to residents, and training on how to successfully solicit videos from Ring users.

If Ring is part of “the new neighborhood watch,” shouldn’t we know where they’re looking? Beyond knowing which law enforcement agencies have partnered with Ring, researchers, policymakers, and activists have very little information about how Amazon’s growing surveillance network is spreading.

To answer questions about Ring’s spread and its presence in neighborhoods around the US, we’re using the API that Ring uses to deliver data to its Neighbors smartphone app to pull all the alerts that have been posted to their “social network” since the beginning of 2017.

To understand what makes a neighborhood more or less likely to use Ring’s surveillance service, we are using spatial modeling techniques at the county level to predict Ring camera density from demographic and crime data.

To test Ring’s claims that their service helps public safety, we are using point-level data to test the effects of adoption and use of Ring cameras on crime solve rates in certain cities.

We are also making tools that provide policymakers and activists with crucial information about neighborhood surveillance spread to inform policymaking and direct action.
The COVID-19 pandemic is having a tremendous socioeconomic impact around the world, the scale of which is still hard to assess.

A unique team of computer scientists, social scientists, and business leaders are being gathered to extract insights from massive datasets from the private sector, in order to provide live and actionable insights for other researchers, policymakers, and the general public, while respecting privacy.

Our objective will be to provide a rapid assessment of the impact of social-distancing policies aimed at mitigating the spread of the COVID-19 pandemic, and to quantify the extent to which changes in mobility, social interactions, and purchasing patterns relate to health and economic outcomes at a very high resolution.

Our immediate contribution will be an interactive dashboard that will produce actionable insights for policymakers. This collaboration will be guided by our key privacy principles, and will build on our team’s rich experience in developing and deploying numerous privacy-preserving research projects, pipelines, and algorithms.

**Research Goals**

**Social Distance**

Given that we do not yet have pharmaceutical solutions (e.g. vaccines) for the COVID-19 pandemic, the social engineering of our lifestyle is our only current response to the pandemic. It is therefore crucial to understand how we can improve local, national, and global policy decisions regarding how to implement social distancing to minimize infection rates. This will necessitate:

- Careful and precise measurements of social distance and interaction, and how these respond -- causally and empirically -- to different implementations of social distancing policies.

Using these measurements, we are working with epidemiologists, public health officials and modeling experts to understand how to dynamically optimize social distancing policies for optimal health outcomes.

**Economic Impact**

Various local and national governments are considering a vast spectrum of economic relief decisions ranging from freezing rent payments for individuals to interest-free loans for businesses. In order to inform these policy decisions, it is critical to understand which demographics of people and what types of businesses are most at risk by studying changes in spending patterns.

Using the economic data from our data partners, we will more precisely measure the impact of the pandemic on individual and business financial health.

By integrating financial impact into our epidemiological models, we will more thoroughly understand the trade-off between health and economic outcomes.

**Privacy**

Our team is highly experienced in developing and deploying numerous privacy-preserving research, pipelines and algorithms such as OPAL: Open Algorithms and Secure Multi-Party Computation using Blockchain.

We are deeply committed to preserving the privacy and security of the data we will be using. Our principles are:

- We will only use anonymized data with no personal identifiers.
- We will use data at the highest level of time, space and group aggregation that still allows us to gather useful insights.
- Working with public health practitioners and policy makers, we will only run analysis that has a net positive benefit to society.
- The use of data will be in compliance with existing laws and ethical standards.
- We will elect not to receive data from our data partners when possible, but instead elect to run our models on our data partner’s premises and we will only transfer high-level statistics outside of their data clouds.
We will use state-of-the-art privacy and infosec techniques and protocols.

We will dedicate a significant portion of our effort into researching techniques that allow for the use of sensitive data while maintaining privacy.

Website: https://c19observatory.media.mit.edu/

511. Crowdsourcing the detection and evaluation of misinformation

Ziv Epstein
This strand of work seeks to develop new interventions to reduce the spread of information, and deploy those interventions towards a crowdsourcing framework for detecting and evaluating misinformation on social media.

Design interventions
Crowdsourcing Results

512. Data for Refugees

Alex ‘Sandy’ Pentland, Michiel Bakker, Jose Balsa Barreiro, Yan Leng, Alfredo Morales-Guzman, Vivek K. Singh
Data for refugees is a big data challenge whereby Turk Telekom opens a large dataset of anonymized mobile phone records to research groups for the purpose of providing better living conditions to Syrian refugees in Turkey.

We introduce different measures extracted from mobile phone metadata to study the integration of refugees along three dimensions: (1) social integration, (2) spatial integration, and (3) economic integration through signatures of employment activity. We use these measures to compare integration across different regions in Turkey and find striking differences both in the distributions of these dimensions and the relations between them.

The paper is currently under review but will be shared soon.

513. Data-Pop Alliance

Alex ‘Sandy’ Pentland, Harvard Humanitarian Initiative, Overseas Development Institute
Data-Pop Alliance is a joint initiative on big data and development with a goal of helping to craft and leverage the new ecosystem of big data—new personal data, new tools, new actors—to improve decisions and empower people in a way that avoids the pitfalls of a new digital divide, de-humanization, and de-democratization. Data-Pop Alliance aims to serve as a designer, broker, and implementer of ideas and activities, bringing together institutions and individuals around common principles and objectives through collaborative research, training and capacity building, technical assistance, convening, knowledge curation, and advocacy. Our thematic areas of focus include official statistics, socio-economic and demographic methods, conflict and crime, climate change and environment, literacy, and ethics.

514. DeepShop: Understanding purchase patterns via deep learning

Alex ‘Sandy’ Pentland, Xiaowen Dong, Yoshihiko Suhara
The recent availability of quantitative behavioral data provides an opportunity to study human behavior at unprecedented scale. Using large-scale financial transaction data, we propose a novel deep learning framework for understanding human purchase patterns and testing the link between them and the existence of individual financial troubles. Our work opens new possibilities in studying human behavioral traits using state-of-the-art machine learning techniques, without the need for hand-engineered features.

515. Enigma

Alex ‘Sandy’ Pentland, Guy Zyskind, Oz Nathan
A peer-to-peer network, enabling different parties to jointly store and run computations on data while keeping the data completely private. Enigma’s computational model is based on a highly optimized version of secure multi-party computation, guaranteed by a verifiable secret-sharing scheme. For storage, we use a modified distributed hashtable for holding secret-shared data. An external blockchain is utilized as the controller of the network, manages access control and identities, and serves as a tamper-proof log of events. Security deposits and fees incentivize operation, correctness, and fairness of the system. Similar to Bitcoin, Enigma removes the need for a trusted third party, enabling autonomous control of personal data. For the first time, users are able to share their data with cryptographic guarantees regarding their privacy.
Alex 'Sandy' Pentland, Yves-Alexandre de Montjoye, Eaman Jahani, Pål Sundsøy, Johannes Bjelland, Linus Bengtsson

Mobile phones are one of the fastest growing technologies in the developing world with global penetration rates reaching 90%. Mobile phone data, also called CDR, are generated every time phones are used and recorded by carriers at scale. CDR have generated groundbreaking insights in public health, official statistics, and logistics. However, the fact that most phones in developing countries are prepaid means that the data lacks key information about the user, including gender and other demographic variables. This precludes numerous uses of this data in social science and development economic research. It furthermore severely prevents the development of humanitarian applications such as the use of mobile phone data to target aid towards the most vulnerable groups during crisis.

We developed a framework to extract more than 1,400 features from standard mobile phone data and used them to predict useful individual characteristics and group estimates. We here present a systematic cross-country study of the applicability of machine learning for dataset augmentation at low cost. We validate our framework by showing how it can be used to reliably predict gender and other information for more than half a million people in two countries. We show how standard machine learning algorithms trained on only 10,000 users are sufficient to predict individual's gender with an accuracy ranging from 74.3 to 88.4% in a developed country and from 74.5 to 79.7% in a developing country using only metadata. This is significantly higher than previous approaches and, once calibrated, gives highly accurate estimates of gender balance in groups. Performance suffers only marginally if we reduce the training size to 5,000, but significantly decreases in a smaller training set. We finally show that our indicators capture a large range of behavioral traits using factor analysis and that the framework can be used to predict other indicators of vulnerability such as age or socio-economic status. Mobile phone data has a great potential for good and our framework allows this data to be augmented with vulnerability and other information at a fraction of the cost.

Alex 'Sandy' Pentland, Dhaval Adjodah, David Shrier

Cooperation in a large society of self-interested individuals is notoriously difficult to achieve when the externality of one individual’s action is spread thin and wide. This leads to the "tragedy of the commons," with rational action ultimately leaving everyone worse off. Traditional policies to promote cooperation involve Pigouvian taxation or subsidies that make individuals internalize the externality they incur. We introduce a new approach to achieving global cooperation by localizing externalities to one’s peers in a social network, thus leveraging the power of peer pressure to regulate behavior. The mechanism relies on a joint model of externalities and peer-pressure. Surprisingly, this mechanism can require a lower budget to operate than the Pigouvian mechanism, even when accounting for the social cost of peer pressure. Even when the available budget is very low, the social mechanisms achieve greater improvement in the outcome.

Alex 'Sandy' Pentland, Dhaval Adjodah, Alejandro Noriega Campero

We believe that the narrative of only listening to experts or trusting the wisdom of the crowd blindly is flawed. Instead we have developed a system that weighs experts and lay-people differently and dynamically and show that a good balance is required. We show that our methodology leads to a 15 percent improvement in mean performance, 15 percent decrease in variance, and almost 30 percent increase in Sharpe-type ratio in a real online market.

Cynthia Breazeal, Alex 'Sandy' Pentland, Iyad Rahwan, Manuel Cebrian, Nick Obradovich

Machines powered by artificial intelligence (AI) increasingly mediate our social, cultural, economic, and political interactions. Understanding the behavior of AI systems is essential to our ability to control their actions, reap their benefits, and minimize their harms. We argue this necessitates a broad scientific research agenda to study machine behavior that incorporates but expands beyond the discipline of computer science and requires insights from across the sciences. Here we first outline a set of questions fundamental to this emerging field. We then explore the technical, legal, and institutional constraints facing the study of machine behavior.
Meet the Ganimals

New generative AI technologies (such as the Generative Adversarial Network, or GAN) can allow us to imagine new species. Hidden within the neural network, there are millions of these “ganimals” that no one has ever seen before. These ganimals occupy a digital landscape not unlike our own, where attention is short, and engagement is necessary to survive.

Meet the Ganimals is a collaborative social experiment to discover new species, breed your own, and feed the ones you love. The data you provide about the ganimals is their “food.” Unfed ganimals are quickly forgotten, so ganimals you engage with have a genetic advantage, and breed more often. Thus, to withstand the harsh conditions of the attention economy, ganimals adapt to the crowd’s opinions and preferences. So the question remains, which ganimals do you want to thrive?

We built Meet the Ganimals to showcase how artificial intelligence can not only generate images of realistic animals, but also images of believable hybrid animals. These hybrid animals are created with a Generative Adversarial Network (GAN), which we baked into their name: ganimals. When we combine a Goldfish with a Golden Retriever, the result is a combination of the most striking features of both animals: a bright orange, big eyed, mopey-eared underwater canine. What the AI features is based on the idiosyncrasies of an animal relative to the pool of animals that we have selected. For ganimals, the striking and transferrable morphological features are stripes on a zebra, eyes on dogs, the shape of a great white shark, the color of goldfish, the feathers of an owl, and many more. One could argue that the biodiversity of ganimals rivals that of the natural world. Artificial evolution is not constrained by the laws of the physical world and fitness but instead the limits of our imagination and our aesthetic tastes. We can curate ganimals by adapting the AI model or adding and removing images of species on which to train the model.

The Meet the Ganimals website is an online social experiment to see what happens when we allow our aesthetic interests to guide evolution. Our goal is to direct thousands of people to the website in order to see how these new artificial life forms evolve, and what dynamics emerge. This number of people is critical for us to properly understand how aesthetic interests guide evolution.

Managing Travel Demand: Location recommendation for system efficiency

Alex ’Sandy’ Pentland, Yan Leng, Larry Rudolph, Jinhua Zhao

Growth in leisure travel has become increasingly significant economically, socially, and environmentally. However, flexible but uncoordinated travel behaviors exacerbate traffic congestion. Mobile phone records not only reveal human mobility patterns, but also enable us to manage travel demand for system efficiency. We propose a location recommendation system that infers personal preferences while accounting for constraints imposed by road capacity in order to manage travel demand. We first infer unobserved preferences using a machine learning technique from phone records. We then formulate an optimization method to improve system efficiency. Coupling mobile phone data with traffic counts and road network infrastructures collected in Andorra, this study shows that uncoordinated travel behaviors lead to longer average travel delay, implying opportunities in managing travel demand by collective decisions. The interplay between congestion relief and overall satisfied location preferences observed in extensive simulations indicate that moderate sacrifices of individual utility lead to significant travel time savings. Specifically, the results show that under full compliance rate, travel delay fell by 52 percent at a cost of 31 percent less satisfaction. Under 60 percent compliance rate, 41 percent travel delay is saved with a 17 percent reduction in satisfaction. This research highlights the effectiveness of the synergy among collective behaviors in increasing system efficiency.

Measuring and reducing social segregation in cities

Dan Calacci, Xiaowen Dong, Esteban Moro Egido

We use high-resolution geospatial data collected from mobile phones to measure social segregation at an unprecedented resolution in cities across the United States. Social segregation happens when people of varying socioeconomic groups in a city have little opportunity to be exposed to people different than them.

To construct this measure, we aggregate high-resolution data from over 4.5 million users in the principal metro areas in the US to characterize places in the city by how mixed their visitors are by income. Using this measure, rather than traditional residential metrics, reveals that social exposure in third places is crucial to understanding economic segregation patterns in cities. In fact, the social segregation of different economic groups is dependent on an extremely small proportion of overall venues in a city.

We also look at how much individual citizens would need to change their behavior in order to make their patterns of exposure more integrated. Surprisingly, small changes in the amount of time people spend in different categories of places—changes as low as 2-5%—can reduce their social segregation by half.

We’re currently working on finalizing these results and exploring how we might translate these findings into policy.
The Mobile Territorial Lab (MTL) aims at creating a "living" laboratory integrated in the real life of the Trento territory in Italy, open to manifold kinds of experimentations. In particular, the MTL is focused on exploiting the sensing capabilities of mobile phones to track and understand human behaviors (e.g., families’ spending behaviors, lifestyles, mood, and stress patterns); on designing and testing social strategies aimed at empowering individual and collective lifestyles through attitude and behavior change; and on investigating new paradigms in personal data management and sharing. This project is a collaboration with Telecom Italia SKIL Lab, Foundation Bruno Kessler, and Telefonica I+D.

Even when real names and other personal information are stripped from metadata datasets, it is often possible to use just a few pieces of information to identify a specific person. Here, we study three months of credit card records for 1.1 million people and show that four spatiotemporal points are enough to uniquely reidentify 90 percent of individuals. We show that knowing the price of a transaction increases the risk of reidentification by 22 percent, on average. Finally, we show that even data sets that provide coarse information at any or all of the dimensions provide little anonymity, and that women are more reidentifiable than men in credit card metadata.

We present Open Badges, an open-source framework and toolkit for measuring and shaping face-to-face social interactions using either custom hardware devices or smart phones, and real-time web-based visualizations. Open Badges is a modular system that allows researchers to monitor and collect interaction data from people engaged in real-life social settings.

In a world where sensors, data storage, and processing power are too cheap to meter, how do you ensure that users can realize the full value of their data while protecting their privacy? openPDS is a field-tested, personal metadata management framework that allows individuals to collect, store, and give fine-grained access to their metadata to third parties. SafeAnswers is a new and practical way of protecting the privacy of metadata at an individual level. SafeAnswers turns a hard anonymization problem into a more tractable security one. It allows services to ask questions whose answers are calculated against the metadata, instead of trying to anonymize individuals’ metadata. Together, openPDS and SafeAnswers provide a new way of dynamically protecting personal metadata.

Markets are notorious for bubbles and bursts. Other research has found that crowds of lay-people can replace even leading experts to predict everything from product sales to the next big diplomatic event. In this project, we leverage both threads of research to see how prediction markets can be used to predict business and technological innovations, and use them as a model to fix financial bubbles. For example, a prediction market was rolled out inside of Intel and the experiment was very successful, and led to better predictions than the official Intel forecast 75 percent of the time. Prediction markets also led to as much as a 25 percent reduction in mean squared error over the prediction of official experts at Google, Ford, and Koch industries.

Location prediction is a critical building block in many location-based services and transportation management. This project explores the issue of next-location prediction based on the longitudinal movements of the locations individuals have visited, as observed from call detail records (CDR). In a nutshell, we apply recurrent neural network (RNN) to next-location prediction on CDR. RNN can take in sequential input with no restriction on the dimensions of the input. The method can infer the hidden similarities among locations and interpret the semantic meanings of the locations. We compare the proposed method with Markov and a Naive Model proving that RNN has better accuracy in location prediction.
Rhythm: Open measurement and feedback tools for human interaction

Dan Calacci, Oren Lederman, Akshay Mohan

Rhythm is a collection of open-source tools to make it easier for researchers to examine, analyze, and augment human interaction. Rhythm includes hardware to measure face to face interaction, software platforms to quantify social dynamics from online videoconferencing, and analysis and visualization tools to craft interventions that affect social behavior. For more information, visit rhythm.mit.edu, or our main github repository.

RoboChain: A secure data-sharing framework for human-robot interaction

Alex 'Sandy' Pentland, Eduardo Castello Ferrer, Ognjen (Oggi) Rudovic, Dr. Thomas Hardjono

A learning framework for secure, decentralized, computationally efficient data and model sharing among multiple robot units installed at multiple sites.

RoboChain has potential to revolutionize the way we interact with the world around us. One of their greatest potentials is in the domain of mobile health, where they can be used to facilitate clinical interventions. However, to accomplish this, robots need to have access to our private data in order to learn from these data and improve their interaction capabilities. To enhance this learning process, knowledge sharing among multiple robot units is the natural step forward. However, to date, there is no well-established framework which allows for such data sharing while preserving the privacy of the users, such as hospital patients. To this end, we introduce RoboChain: the first learning framework for secure, decentralized, computationally efficient data and model sharing among multiple robot units installed at multiple sites such as hospitals. RoboChain builds upon and combines the latest advances in open data access, blockchain technologies, and machine learning. We illustrate this framework using the example of a clinical intervention conducted in a private network of hospitals. Specifically, we lay down the system architecture that allows multiple robot units, conducting the interventions at different hospitals, to perform efficient learning without compromising the data privacy.

Secure Sharing of Wildlife Data

Alex 'Sandy' Pentland, Remo Frey

Leveraging the power of platforms, big data, and advanced analytics for species protection and the public good in a privacy-preserving, scalable, and sustainable manner.

Modern tracking technology enables new ways of mining data in the wild. It allows wildlife monitoring centers to permanently collect geospatial data in a non-intrusive manner and in real time. Unfortunately, such sensible data is exposed to fraud and misuse and there is already a first reported case of "cyber-poaching." Based on stolen geospatial data, poachers can easily track and kill animals. Meanwhile, cautious monitoring centers limited data access for research and public use. We propose a novel privacy-preserving system to allow these monitoring centers to securely answer questions from the research community and the public while the raw data is protected against unauthorized third parties. Based on the core system, several new applications are conceivable, such as a mobile app for preventing conflicts between human and wildlife or for engaging people in wildlife donation. Besides providing a solution and working on specific use cases, the intention of this project is to start a discussion about the need for data protection in the animal world.

Social AI and Extended Intelligence

Alex 'Sandy' Pentland, Dhaval Adjodah, Peter Krafft, Esteban Moro Egido

There is a deep fear that human jobs will be replaced by AI. Rather than racing against the machines, our aim is to show that a human-AI combination will perform better than humans and AI working alone. Although no man is better than a machine for some tasks, “no machine is better than a man with a machine” (Paul Tudor Jones). Thus, by building “bots” that are compatible with human behavior, and specifically leverage the manner in which humans use social information, we have been able to build bots that extend human intelligence capabilities. In a large-scale financial trading experiment, we have shown that groups of humans and “socially compatible” AI bots can successfully incorporate human intuition into their decisions and consequently not only do better than humans alone, but also do better than similar AI bots that use only objective information.

Social Bridges in Community Purchase Behavior

Alex 'Sandy' Pentland, Xiaowen Dong, Vivek K. Singh, Yoshihiko Suhara

The understanding and modeling of social influence on human economic behavior in city environments can have important implications. In this project, we study human purchase behavior at a community level and argue that people who live in different communities but work at similar locations could act as “social bridges” that link their respective communities and make the community purchase behavior similar through the possibility of social learning through face-to-face interactions.

Social Capital Accounting

Alex 'Sandy' Pentland, Takeo Nishikata, Thomas Hardjono, MIT Connection Science

To better understand and improve the quality of our lives, there has been a need for measuring non-economic capital such as social capital and natural capital in addition to economic capital. Quantifying non-economic capital, however, is not easy and has not been widespread. In this project, we propose a system where individuals can start measuring their social capital, turning them into a real-world asset that enables the improvement their economic wellbeing, while preserving individual privacy and security.
We build recommender bots that use machine learning and network analytics to create personalized recommendations for users on various social and financial platforms. We show that bots that work not just on the raw user data, but instead build on human intuition, do far better. We are in the process of live testing these bots on various platforms.

Earlier studies proved that behavior is highly shaped and constrained by one's social networks, and demonstrated ways in which individuals can manipulate these networks to achieve specific goals. A great example is the much-studied “strength of weak ties” hypothesis, which states that the strength of a tie between A and B increases with the overlap of their friendship circles, resulting in an important role for weak ties in connecting communities. Mark Granovetter first proposed this idea in a study that emphasized the nature of the tie between job changers in a Boston suburb and the contacts who provided the necessary information for them to obtain new employment. Basically, although people with whom the job seekers had strong ties were more motivated to provide information, the structural position of weak ties played a more important role. The implication is that those to whom one is weakly tied are more likely to move in different circles, and will thus have access to different information than the people to whom you are tied more strongly.

Much of our knowledge about how mobility, social networks, communication, and education affect the economic status of individuals and cities has been obtained through complex and costly surveys, with an update rate ranging from fortnights to decades. However, recent studies have shown the value of mobile phone data as an enabling methodology for demographic modeling and measurement. Many of our daily routines are driven by activities either afforded by our economic status or related to maintaining or improving it, from our movements around the city, to our daily schedules, to our communication with others. As such, we expect to be able to measure passive patterns and behavioral indicators, using mobile phone data, that could describe local unemployment rates. To investigate this question, we examined anonymized mobile phone metadata combined with beneficiaries' records from an unemployment benefit program. We found that aggregated activity, social, and mobility patterns strongly correlate with unemployment. Furthermore, we constructed a simple model to produce accurate reconstructions of district-level unemployment from mobile communication patterns alone.

Our results suggest that reliable and cost-effective indicators of economic activity could be built based on passively collected and anonymized mobile phone data. With similar data being collected every day by telecommunication services across the world, survey-based methods of measuring community socioeconomic status could potentially be augmented or replaced by such passive sensing methods.

Segregation is hurting our societies and especially our cities. But economic inequality isn't just limited to neighborhoods. The restaurants, stores, and other places we visit in cities are all unequal in their own way.

The Atlas of Inequality shows the income inequality of people who visit different places in the Boston metro area. It uses aggregated anonymous location data from digital devices to estimate people's incomes and where they spend their time. Using that data, we've made our own place inequality metric to capture how unequal the incomes of visitors to each place are. Economic inequality isn't just limited to neighborhoods; it's part of the places you visit every day.

Try it yourself here:

The Atlas of Inequality

The Atlas of Inequality is a project from the Human Dynamics group at the MIT Media Lab and the Department of Mathematics at Universidad Carlos III de Madrid.

It is part of a broader initiative to understand human behavior in our cities and how large-scale problems like transportation, housing, segregation, or inequality depend in part on the emergent patterns of people's individual opportunities and choices.
The well-known “small-world” phenomenon indicates that an individual can be connected with any other in the world through a limited number of personal acquaintances. Furthermore, Nicholas and Fowler show that not only are we connected to each other, but we could also shape the behavior of our friends’ friends. In this project, we are interested in understanding how social influence propagates and triggers behavioral change in social networks. Specifically, we analyze a large-scale, one-month international event held in the European country of Andorra using country-wide mobile phone data, and investigate the change in the likelihood of attending the event for people that have been influenced by and are of different social distances from the attendees.

Our results suggest that social influence exhibits the ripple effect, decaying across social distances from the source but persisting up to six degrees of separation. We further show that influence decays as communication delay increases and intensity decreases. Such ripple effect in social communication can lead to important policy implications in applications where it is critical to trigger behavior change in the population.

Modern cities have to respond to the growing demands of more efficient and sustainable urban development, as well as an increased quality of life. In this context, the cities of the future will need the ability to gain insight about current urban conditions and react dynamically to them. According to this view, “smart cities” can be seen as cybernetic urban environments in which different agents (e.g., citizens) and actuators (e.g., robots) exploit the city-wide infrastructure as a medium to operate synergistically. Urban Swarms explores the feasibility of swarm robotics systems in urban environments. By using bio-inspired methods, a swarm of robots is able to handle important urban systems and infrastructures, improving their efficiency and autonomy. A diverse set of simulation experiments were designed and conducted using real-world GIS data. Results show that the proposed combination is able to outperform current approaches. Urban Swarms not only aims to show the efficiency of our proposed solution, but also to give insights about how to design and customize these systems. CityScope Volpe ABM model has been customized to integrate Swarm behavior using the Gama Platform as an open source project.
Rosalind W. Picard: Affective Computing

Advance human wellbeing by developing new ways to communicate, understand, and respond to emotion

541. Adaptive Music for Affect Improvement
Rosalind W. Picard, David Su, Yan Liu (Harvard GSD)
Adaptive Music for Affect Improvement (AMAI) is a music generation and playback system with the goal of steering the listener toward a state of more positive affect. AMAI utilizes techniques from game music in order to adjust elements of the music being heard; such adjustments are made adaptively in response to the valence levels of the listener as measured via facial expression and emotion detection.

542. Affective Network
Rosalind W. Picard, Deb Roy, Belen Saldias Fuentes
Try Affective Network!
Emotional contagion in online social networks has been of great interest over the past years. Previous studies have mainly focused on finding evidence of affection contagion in homophilic atmospheres. However, these studies have overlooked users’ awareness of the sentiments they share and consume online. In this work, we present an experiment with Twitter users that aims to help them better understand which emotions they experience on this social network. We introduce Affective Network (Aff-Net), a Google Chrome extension that enables Twitter users to filter and make explicit (through colored visual marks) the emotional content in their news feed.

The extension is powered by machine learning algorithms that classify tweets into different sentiment categories: positive posts tend to use happy or surprising language; negative posts tend to use sad, angry, or disgusting language; and posts without strong emotional language are classified as neutral. Affective Network aims to help social media users better understand which emotions they tend to consume on social media, and how these emotions can spread through their social networks. It was built by researchers at the Laboratory for Social Machines and the Affective Computing group at the MIT Media Lab.

Note that Affective Network does not necessarily reflect the official position of the MIT Media Lab regarding the benefits and drawbacks of filtering out specific emotional content.

Try Affective Network!

543. Affective Response to Haptic Signals
Rosalind W. Picard, Grace Leslie, Suranga Nanayakkara, Singapore University of Technology and Design
This study attempts to examine humans’ affective responses to superimposed sinusoidal signals. These signals can be perceived either through sound, in the case of electronically synthesized musical notes, or through vibro-tactile stimulation, in the case of vibrations produced by vibrotactile actuators. This study is concerned with the perception of superimposed vibrations, whereby two or more sinusoidal signals are perceived simultaneously, producing a perceptual impression that is substantially different than of each signal alone, owing to the interactions between perceived sinusoidal vibrations that give rise to a unified percept of a sinusoidal chord. The theory of interval affect was derived from systematic analyses of Indian, Chinese, Greek, and Arabic music theory and tradition, and proposes a universal organization of affective response to intervals organized using a multidimensional system. We hypothesize that this interval affect system is multi-modal and will transfer to the vibrotactile domain.

544. An EEG and motion-capture based expressive music interface for affective neurofeedback
Rosalind W. Picard, Grace Leslie, Singapore University of Technology and Design, Simon Lui
This project examines how the expression granted by new musical interfaces can be harnessed to create positive changes in health and wellbeing. We are conducting experiments to measure EEG dynamics and physical movements performed by participants who are using software designed to invite physical and musical expression of the basic emotions. The present demonstration of this system incorporates an expressive gesture sonification system using a Leap Motion device, paired with an ambient music engine controlled by EEG-based affective indices. Our intention is to better understand affective engagement, by creating both a new musical interface to invite it, and a method to measure and monitor it. We are exploring the use of this device and protocol in therapeutic settings in which mood recognition and regulation are a primary goal.
<table>
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<tr>
<th>545. Automated Tongue Analysis</th>
<th>Rosalind W. Picard, Weixuan 'Vincent' Chen, Craig Ferguson, Javier Hernandez, Akane Sano</th>
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<td>A common practice in Traditional Chinese Medicine (TCM) is visual examination of the patient’s tongue. This study will examine ways to make this process more objective and to test its efficacy for understanding stress- and health-related changes in people over time. We start by developing an app that makes it comfortable and easy for people to collect tongue data in daily life together with other stress- and health-related information. We will obtain assessment from expert practitioners of TCM, and also use pattern analysis and machine learning to attempt to create state-of-the-art algorithms able to help provide better insights for health and prevention of sickness.</td>
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<th>546. Behavioral Indications of Depression Severity</th>
<th>Rosalind W. Picard, Szymon Fedor, Asma Ghandeharioun</th>
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<td>In collaboration with Massachusetts General Hospital, we are conducting a clinical trial exploring objective methods for assessing depression and its severity. We are challenging the assessment methods that were created decades ago and which rely mostly on self-reported measures. We are including information from wearable sensors and regular sensors in mobile phones to collect information about sleep, social interaction, and location changes to find behavioral patterns that are associated with depressive symptoms.</td>
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<td>Can we sonify calming breathing and passively influence a state of calm? Deep breathing has been scientifically proven to affect the heart, brain, digestive system, and the immune system. We believe designing a technology to promote deep breathing can facilitate transition into a calm state. Nowadays, many people are spending a significant amount of time listening to music while working or studying. This makes music a good means for providing auditory breathing cues. While it has been shown that liminal auditory cues can be effective in encouraging a healthy breathing pattern, we are examining the use of subliminal encouragement of breathing modulation using music. Auditory ambient feedback has long been studied and is proved to be effective. It has been explored in concert settings, interactive installations, and smartphone applications. However, our aim is to design an intervention that is unobtrusive and doesn’t keep people from doing their primary work. In order to find the best auditory feedback design, we have designed a controlled study comparing an interactive rhythmic ambient music track that responds to a user’s current breathing patterns to a fixed rate music track whose speed of playback is pegged to a rate slightly below the user’s natural resting breathing rate. A control condition with no music is also included. We will compare the resulting breathing patterns, heart rate, EEG signals, and self-reported measures to determine if the ambient music feedback has any effect on the user’s state of mind and body. If successful, a musical system to subliminally encourage calming breathing patterns may be integrated into workplace environments, hospitals, and other places where it is necessary to promote less stressful and healthy environments. Our preliminary results significant shift in multiple physiological measures that indicate a state of calmness.</td>
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<tr>
<th>548. BrightBeat: Effortlessly influencing breathing for cultivating calmness and focus</th>
<th>Rosalind W. Picard, Asma Ghandeharioun</th>
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<td>The relationship between breathing and self-reported stress is bidirectional. Respiration pattern is an indicator of stress, but it can also be manipulated to induce calmness. In this project we explore this relationship via novel means of interaction. BrightBeat is a set of seamless visual, auditory, and tactile interventions that mimic a calming breathing oscillation, with the aim of influencing physiological syncing and consequently bringing a sense of focus and calmness. The animation above shows an exaggerated version of BrightBeat. These interventions are designed to run easily on commonplace personal electronic devices, respect the user’s privacy, and not to require constant focus or attention in order to be effective.</td>
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<th>549. Building the Just-Right-Challenge in Games and Toys</th>
<th>Rosalind W. Picard, Elliott Hedman</th>
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<td>With the LEGO Group and Hasbro, we looked at the emotional experience of playing with games and LEGO bricks. We measured participants’ skin conductance as they learned to play with these new toys. By marking the stressful moments, we were able to see what moments in learning should be redesigned. Our findings suggest that framing is key: how can we help children recognize their achievements? We also saw how children are excited to take on new responsibilities but are then quickly discouraged when they aren’t given the resources to succeed. Our hope for this work is that by using skin conductance sensors, we can help companies better understand the unique perspective of children and build experiences fit for them.</td>
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Kristy Johnson, Lindsey Epstein, Violet Killy, Laura Yenchesky

Cube Puzzles: A tangible platform for dynamic assessment of cognitive and psychomotor skills

Cognitive and psychomotor assessments are a vital scientific tool; however, they are resource intensive, can be biased by examiner presence and interaction, and can disadvantage individuals with neurodevelopmental differences such as autism or ADHD. We present a new tangible user interface, Cube Puzzles, that dynamically tracks placement and orientation of colored wooden blocks. The system not only automates data acquisition and captures real-time learning progressions, but it also enables customizable, motivating feedback and synchronization with biosensors.

We highlight the potential of the system with two user studies involving 22 participants. The first study (n=10) validates and visualizes the dynamic data capture of real-time user activity. The second study (n=12) explores Cube Puzzles as a gamified cognitive assessment platform by examining the effects of reinforcement on user performance, engagement, and physiological arousal. Our work has broad applications within educational and assessment domains, particularly for neurodiverse and elderly individuals.

Part of the SPRING system

Cube Puzzles is a new game-play module for SPRING. In this module, children move and orient colored blocks in order to match a displayed design. This module is inspired by the Block Design activity in the Wechsler Intelligence Scales (e.g., WAIS), quantifying visual-spatial orientation and motor skills. In free-play mode, Cube Puzzles also encourages open-ended design and play with geometric shapes and colors.

Rosalind W. Picard, Daniel Lopez Martinez

Deep Reinforcement Learning for Pain Management

Opioid therapy is the cornerstone of management of pain in the ICU. However, opioids present numerous side effects and are highly addictive. In fact, it is estimated that over 130 Americans die every day from an opioid overdose. Adequate opioid therapy, personalized to each patient's needs, is therefore essential. Unfortunately, ICUs are frenetic environments and clinicians are often unable to make optimal decisions or to continuously adapt therapy in real time based on the evolving patient physiological state.

To address many of these issues and augment physicians' decision making with information about what an optimal therapeutic approach may look like, we propose to leverage the latest advancements in artificial intelligence. Specifically, we focus on deep reinforcement learning, which can learn optimal state-action policies using training data that does not represent optimal behaviors. We are therefore able to train the machine learning model to recommend optimal opioid interventions using training data that does not contain optimal decisions.

Opioid analgesia in the ICU is a complex decision problem influenced by multiple factors, and extensive work will be required to develop systems that can be deployed in real clinical environments.

Rosalind W. Picard, Weixuan 'Vincent' Chen, Szymon Fedor, Natasha Jaques, Akane Sano, Sara Taylor, Victoria Xia

Electrodermal Activity Explorer

Electrodermal Activity (EDA) is a physiological indicator of stress and strong emotion. While an increasing number of wearable devices can collect EDA, analyzing the data to obtain reliable estimates of stress and emotion remains a difficult problem. We have built a graphical tool that allows anyone to upload their EDA data and analyze it. Using a highly accurate machine learning algorithm, we can automatically detect noise within the data. We can also detect skin conductance responses, which are spikes in the signal indicating a “fight or flight” response. Users can visualize these results and download files containing features calculated on the data to be used in their own analysis. Those interested in machine learning can also view and label their data to train a machine learning classifier. We are currently adding active learning, so the site can intelligently select the fewest possible samples for the user to label.

Daniel Lopez Martinez

Electrocardiogram collection in noisy ambulatory environments with Android smartphone devices

The explosion of mHealth in both abundant and resource-constrained countries is both a cause for celebration and for concern. While mHealth clearly has the potential to deliver information and diagnostic decision support to the poorly trained, it is not appropriate to simply translate the technologies which the trained clinician uses into the hands of non-experts. In particular, it is important that the explosion of access does not lead to a flooding of the medical system with low quality data and false negatives. Clearly for mHealth to expand, a paradigm shift in how data is analysed must occur. Data must be vetted at the front end, using automated algorithms, to provide robust filtering of low quality data.

This project addresses the specific problem of vetting the quality of electrocardiograms (ECGs) collected by an untrained user in ambulatory scenarios using smartphone devices.
ELSA: Empathy learning, socially-aware agents

Rosalind W. Picard, Craig Ferguson, Asma Ghandeharioun, Natasha Jaques, Noah Jones, Agata Lapedriza Garcia, Judy Hanwen Shen

What is ELSA?
ELSA is an AI-powered chatbot that acts as an empathetic companion, encouraging users to talk about their day through a form of interactive journaling.

You can try some of the current ELSA bots in this online demo.

How does ELSA work?
Our project goal is to build a more empathetic neural network conversational AI by incorporating a deeper understanding of both the affective content of the conversation and the topic. More specifically, we build hierarchical recurrent neural network models that can converse like people and use transfer learning of topic and emotional tone recognition models to improve our final model.

What are the applications of ELSA?
Beyond the development of chatbots that act as an empathetic companion, we have a more ambitious and longer term goal: deploy the empathetic companion bots to support mental health. In particular, we aim to make ELSA useful for:

- Eliciting journaling
- Suggesting behaviour interventions
- Using Cognition Behavioral Therapy
- Detecting individuals at risk of depression or suicide

Work in progress
ELSA is a recently started project in the Affective Computing group. You can see an example of ELSA bot conversations below. You can also try our online demo.

EMMA: An emotionally intelligent personal assistant for improving wellbeing

Asma Ghandeharioun, Daniel McDuff/Mary Czerwinski

The delivery of mental health interventions via ubiquitous devices has shown a lot of promise. A natural conversational interface that allows longitudinal symptom tracking and appropriate just-in-time interventions would be extremely valuable. However, the task of designing emotionally aware agents is still poorly understood. Furthermore, the feasibility of automating the delivery of just-in-time mHealth interventions via such an agent has not been fully studied. In this project, we explore the design and evaluation of EMMA (EMotion-Aware mHealth Agent).

EMMA conducts experience sampling in an empathetic manner and provides emotionally appropriate micro-activities. We show the system can be extended to detect a user’s mood purely from smartphone sensor data.

We have conducted a three-week user study (N=58). Our results show that extroverts preferred EMMA significantly more, and that our personalized machine learning model was effective, as was relying on ground-truth emotion samples from users.

Emotion Navigation


Before automobiles were invented and widely adopted, animals like horses were the most common mode of transportation. While this change brought significant improvements in terms of reliability and efficiency, it also removed a core component: the emotional relationship that existed between the person and the animal.

While largely ignored, the emotional states of drivers are quite important, as they influence not only driving behavior but also the safety of all road users. For instance, driving can be quite an emotionally stressful experience and, while certain amounts of stress help the driver to remain alert and attentive, too much or too little can negatively impact driving performance and safety. Furthermore, stress in large doses has been linked to a large array of adverse health conditions such as depression and various forms of cardiovascular disease.

The Emotion Navigation special interest group is led by Dr. Javier Hernandez with the goal of stimulating research efforts at the intersection of Automotive and Affective Computing.
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<tr>
<th>Project Title</th>
<th>Authors</th>
<th>Description</th>
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<tbody>
<tr>
<td>Emotion Recognition in Scene Context                                         Rosalind W. Picard, Agata Lapedriza Garcia, Ronak Kosti (UOC), Jose Alvarez (NVIDIA), Adrià Recasens (CSAIL, MIT)</td>
<td>The goal of this project is providing machines with the ability of understanding what a person is experiencing from her frame of reference, taking into account the scene context: where is this person, what is this person doing, how does this person look, etc. You can find more information about this project on this website.</td>
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<td>Emotion/wellbeing x skincare cosmetics                                         Akane Sano</td>
<td>The project aims to investigate the relationships between emotion, wellbeing, skin, and skincare cosmetics. In our first study, we measured emotion/wellbeing, heart rate, and respiration using a mobile phone and a wearable sensor during consumer in-use test.</td>
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<td>Fathom: Probabilistic graphical models to help mental health counselors       Henry A. Lieberman, Rosalind W. Picard, Karthik Dinakar, MIT EECS, Jackie Chen</td>
<td>We explore advanced machine learning and reflective user interfaces to scale the national Crisis Text Line. We are using state-of-the-art probabilistic graphical topic models and visualizations to help a mental health counselor extract patterns of mental health issues experienced by participants, and bring large-scale data science to understanding the distribution of mental health issues in the United States.</td>
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<td>FEEL: A cloud system for frequent event and biophysiological signal labeling  Rosalind W. Picard, Yadid Ayzenberg</td>
<td>The wide availability of low-cost, wearable, biophysiological sensors enables us to measure how the environment and our experiences impact our physiology. This creates a new challenge: in order to interpret the collected longitudinal data, we require the matching contextual information as well. Collecting weeks, months, and years of continuous biophysiological data makes it unfeasible to rely solely on our memory for providing the contextual information. Many view maintaining journals as burdensome, which may result in low compliance levels and unusable data. We present an architecture and implementation of a system for the acquisition, processing, and visualization of biophysiological signals and contextual information.</td>
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<td>Image Sentiment Analysis                                                     Agata Lapedriza Garcia</td>
<td>In this project we explore how to recognize and localize affect in images.</td>
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<td>Improving RNN Sequence Generation with RL                                    Natasha Jaques</td>
<td>This project investigates a general method for improving the structure and quality of sequences generated by a recurrent neural network (RNN) using deep reinforcement learning (RL).Our method, which we call Sequence Tutor, allows models to improve sequence quality with RL, while maintaining information originally learned from data, as well as sample diversity. An RNN is first pre-trained on data using maximum likelihood estimation (MLE), and the probability distribution over the next token in the sequence learned by this model is treated as a prior policy. Another RNN is then trained using reinforcement learning (RL) to generate higher-quality outputs that account for domain-specific incentives while retaining proximity to the prior policy of the MLE RNN. To formalize this objective, we derive novel off-policy RL methods for RNNs from KL-control. The effectiveness of the approach is demonstrated on two applications: 1) generating novel musical melodies, and 2) computational molecular generation for drug discovery. For both problems, we show that the proposed method improves the desired properties and structure of the generated sequences, while maintaining information learned from data.</td>
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<td>Improving Wellbeing for Office Workers                                       Rosalind W. Picard, Akane Sano, Sara Taylor, Terumi Umematsu</td>
<td>Excessive stress can decrease office workers’ productivity and negatively impact overall health. This project aims to predict office workers’ stress levels using physiological and behavioral markers based on heart rate, skin conductance, skin temperature, and acceleration. Building on knowledge and models developed for student populations in the SNAPSHOT study and collecting new data from worker populations, we plan to improve stress-level prediction performance for office workers. Furthermore, we will also study how to improve productivity by decreasing stress. In order to accomplish this, we will look for causal factors that increase stress and possible interventions that can be deployed to office workers to decrease these factors.</td>
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<td>Improving wellbeing prediction performance using temporal machine learning models</td>
<td>Rosalind W. Picard, Akane Sano, Sara Taylor, Terumi Umematsu</td>
<td>This project aims to improve the prediction accuracy of wellbeing (stress, mood, and health levels) using temporal machine learning models. We extend our previous approach using Long Short-Term Memory models and time series data from the SNAPSHOT study. In addition, we consider adaptive methods to fill in missing data with time series information. We also develop the model using modifiable behavioral features such as bedtime, and examine how these contribute to wellbeing, so that people can get better control over how to improve their personal well-being.</td>
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Many drugs, such as monoclonal antibodies, are administrated using parenteral delivery devices via subcutaneous injections. Unfortunately, needle phobia, anxiety before and during needle insertion and pain during injections are key aspects that lead to poor therapeutic compliance and prevent wider applicability and acceptance of this technology across patient groups. Therefore, in order to improve patient experience, traditional pain scores using a visual analog scale (VAS) or other similar techniques have been used to compare and investigate different subcutaneous injection methodologies. However, they are subjective and it is difficult to power a clinical study to show significant differences in pain.

In this study, we propose to use electrodermal activity (EDA), heart rate variability (HRV), and facial expression analysis as potential endpoints to determine quantitative pain scores during the injection process, together with other secondary endpoints such as wellness aspects of patients (e.g. sleep quality). Therefore, the objective of this study is to evaluate these endpoints in subcutaneous injections for different injection methodologies (consisting of different dose volumes, flow rates, needle gauges and injectate viscosity) in a clinical setting in humans. The data will be used to understand pain upon injection and see if there is any correlation between traditional pain scores (e.g. visual analog scale) and our proposed endpoints.

We have designed a novel system to promote kindness and gratitude. We leverage pervasive technologies to naturally embed gratitude inspiration in everyday life. Mobile sensor data is utilized to infer optimal moments for stimulating contextually relevant thankfulness and appreciation. We analyze the interplay between mood, contextual cues, and gratitude expressions.

In the quest towards general artificial intelligence (AI), researchers have explored developing loss functions that act as intrinsic motivators in the absence of external rewards. This paper argues that such research has overlooked an important and useful intrinsic motivator: social interaction. We posit that making an AI agent aware of implicit social feedback from humans can allow for faster learning of more generalizable and useful representations, and could potentially impact AI safety. We collect social feedback in the form of facial expression reactions to samples from Sketch RNN, an LSTM-based variational autoencoder (VAE) designed to produce sketch drawings. We use a Latent Constraints GAN (LC-GAN) to learn from the facial feedback of a small group of viewers, and then show in an independent evaluation with 76 users that this model produced sketches that lead to significantly more positive facial expressions. Thus, we establish that implicit social feedback can improve the output of a deep learning model.
Depressive disorders are ranked as the single largest contributor to non-fatal health loss (7.5% of all Years Lived with Disability), affecting an estimated 300 million people[1]. Evidence-based treatments are available and measurement-based care has been described as the gold standard. Monitoring of depressive symptoms is currently performed with self-administered and interview-based assessment methods conducted by clinicians in their offices. However, the shortage of mental health specialists and the limited resources available to primary care physicians who often manage patients with depression prevent close monitoring of symptoms, delaying optimal treatment, and potentially prolonging suffering. Passive recording of behavioral data (gathering information without an individual’s direct input) has been identified as a potentially feasible method for long-term monitoring of depression.

During the past decade, along with the development of wearable sensors, we have seen the progressive use of machine learning, which has allowed for the development of complex models. The combination of sensor technology and machine learning enables detailed measurement in real time of a wealth of behaviors predicting variation of depression. Our interdisciplinary team, including one of the leading labs on depression research at the Massachusetts General Hospital and the Affective Computing group at the MIT Media Lab, has conducted a study applying machine learning analytics to create a model combining wristband sensor data and phone-based passive measurements to assess depression. In our pilot study with chronically depressed patients monitored over eight weeks, we found that an algorithm based on biological and behavioral sensor data could estimate depression severity evaluated by a clinician with high accuracy, comparable to the inter-rater reliability.

In this project, we build from our pilot study and develop an objective, passive, sensor-based algorithm able to detect depression and early response as well as predict response. We will monitor for 12 weeks 100 adults with Major Depression Disorder who just started treatment. The identification of reliable, objective, passive assessment of depression with biosensors will have significant ramifications for the monitoring of depression, early detection of response, and ultimately contribute to the advancement of precision medicine.


Rosalind W. Picard, Daniel Lopez Martinez, Ognjen (Oggi) Rudovic

Pain is a subjective experience commonly measured through patients’ self reports. Unfortunately, self-report measures only work when the subject is sufficiently alert and cooperative, and hence they lack utility in multiple situations (such as during drowsiness) and patient populations (such as patients with dementia or paralysis). To circumvent the limitations of pain self-reports, in this project we are developing automatic methods for pain estimation based on physiological signals and/or facial expressions.

Rosalind W. Picard, Elliott Hedman

Receiving a shot or discussing health problems can be stressful, but does not always have to be. We measure participants’ skin conductance as they use medical devices or visit hospitals and note times when stress occurs. We then prototype possible solutions and record how the emotional experience changes. We hope work like this will help bring the medical community closer to their customers.
Meet the Ganimals

Oceane Boulais, Abhimanyu Dubey, Ziv Epstein, Matthew Groh

New generative AI technologies (such as the Generative Adversarial Network, or GAN) can allow us to imagine new species. Hidden within the neural network, there are millions of these “ganimals” that no one has ever seen before. These ganimals occupy a digital landscape not unlike our own, where attention is short, and engagement is necessary to survive.

Meet the Ganimals is a collaborative social experiment to discover new species, breed your own, and feed the ones you love. The data you provide about the ganimals is their “food.” Unfed ganimals are quickly forgotten, so ganimals you engage with have a genetic advantage, and breed more often. Thus, to withstand the harsh conditions of the attention economy, ganimals adapt to the crowd’s opinions and preferences. So the question remains, which ganimals do you want to thrive?

We built Meet the Ganimals to showcase how artificial intelligence can not only generate images of realistic animals, but also images of believable hybrid animals. These hybrid animals are created with a Generative Adversarial Network (GAN), which we baked into their name: ganimals. When we combine a Goldfish with a Golden Retriever, the result is a combination of the most striking features of both animals: a bright orange, big eyed, mopey-eared underwater canine. What the AI features is based on the idiosyncrasies of an animal relative to the pool of animals that we have selected. For ganimals, the striking and transferrable morphological features are stripes on a zebra, eyes on dogs, the shape of a great white shark, the color of goldfish, the feathers of an owl, and many more. One could argue that the biodiversity of ganimals rivals that of the natural world. Artificial evolution is not constrained by the laws of the physical world and fitness but instead the limits of our imagination and our aesthetic tastes. We can curate ganimals by adapting the AI model or adding and removing images of species on which to train the model.

The Meet the Ganimals website is an online social experiment to see what happens when we allow our aesthetic interests to guide evolution. Our goal is to direct thousands of people to the website in order to see how these new artificial life forms evolves, and what dynamics emerge. This number of people is critical for us to properly understand how aesthetic interests guide evolution.

Mobile health interventions for drug addiction and PTSD

Rosalind W. Picard, Richard R. Fletcher

We are developing a mobile phone-based platform to assist people with chronic diseases, panic-anxiety disorders, or addictions. Making use of wearable, wireless biosensors, the mobile phone uses pattern analysis and machine learning algorithms to detect specific physiological states and perform automatic interventions in the form of text/images plus sound files and social networking elements. We are currently working with the Veterans Administration drug rehabilitation program involving veterans with PTSD.

Modulating peripheral and cortical arousal using a musical motor response task

Rosalind W. Picard, Grace Leslie, Annabel Chen, Singapore University of Technology and Design, Nanyang Technological University, Simon Lui

We are conducting EEG studies to identify the musical features and musical interaction patterns that universally impact measures of arousal. We hypothesize that we can induce states of high and low arousal using electrodermal activity (EDA) biofeedback, and that these states will produce correlated differences in concurrently recorded skin conductance and EEG data, establishing a connection between peripherally recorded physiological arousal and cortical arousal as revealed in EEG. We also hypothesize that manipulation of musical features of a computer-generated musical stimulus track will produce changes in peripheral and cortical arousal. These musical stimuli and programmed interactions may be incorporated into music technology therapy, designed to reduce arousal or increase learning capability by increasing attention. We aim to provide a framework for the neural basis of emotion-cognition integration of learning that may shed light on education and possible applications to improve learning by emotion regulation.

Onsite Stress Measurement

Rosalind W. Picard, Judith Amores Fernandez, Marc Exposito Gomez, Szymon Fedor, Javier Hernandez, Daniel McDuff, Robert R. Morris

Occupational stress can be described as a harmful emotional and physical response that occurs when high demanding job conditions cannot be met by the resources of the worker. This type of stress is usually associated with feelings of frustration, anger, and fear and can lead to dissatisfaction and lack of motivation in the long-term. Furthermore, high levels of stress can impair decision making, decrease productivity, and lead to high amounts of accidents and job absenteeism. Despite the well-studied negative outcomes, workplace stress is still considered a necessary evil by many people as it helps us keep up with the pace of modern society. Leveraging state-of-the-art sensing technologies and AI, this project seeks to advance the measurement, understanding, and management of stress in real-life settings.

Open-Source SPRING

Kristy Johnson

Open-Source Instructions for Building SPRING System
Panoply is a crowdsourcing application for mental health and emotional wellbeing. The platform offers a novel approach to computer-based psychotherapy, targeting accessibility without stigma, engagement, and therapeutic efficacy. A three-week randomized-controlled trial with 166 participants showed Panoply conferred greater or equal benefits for nearly every therapeutic outcome measure compared to an active control task (online expressive writing). Panoply significantly outperformed the control task also on all measures of engagement, and is now being commercialized at itskoko.com.

Storytelling is a fundamental way in which human beings understand the world. Imagine watching a movie telling the story of your life, how would you respond to it and how would it change your perception of your own memories? Personalized animated movies are generated from Unity, customized to each user’s mood and behavior data collected through self-reports. Our study shows that personalized animations can elicit strong emotional responses from participants and lengthier writing of self-reflection compared to a non-personalized control. Moving forward, we’re looking at using personalized animation to encourage cognitive reappraisal and positive thinking.

EngageME is a project aimed at building new technology to enable automatic monitoring of affect and engagement of children with ASC (Autism Spectrum Conditions) in communication-centered activities. This work has been published in Science Robotics, June 2018.

The view on Alzheimer’s Disease (AD) diagnosis has shifted towards a more dynamic process in which clinical and pathological markers evolve gradually before diagnostic criteria are met. Given the wide variability in data available per subject, inherent per-person differences, and the slowly changing nature of the disease, accurate prediction of AD progression is a significant, difficult challenge. The goal of this project is to devise novel Personalized Machine Learning Models that can accurately capture future changes in the key biomarkers and cognitive scores related to AD and other neurological conditions. As the basis for our framework, we use the Alzheimer’s Disease Neuroimaging Initiative (ADNI) dataset—the largest publicly available dataset for AD research. These data are highly heterogeneous and multi-modal, and include imaging (MRI, PET), cognitive scores, CSF biomarkers, genetics, and demographics (e.g. age, gender, race). The developed models are the breakthrough in machine learning for health-care as they allow personalized forecasting of the diseases’ progression— in contrast to the traditional “one-size-fits-all” approaches. This capability is of great importance to both clinicians and those at risk of AD since it is critical to early identification of at-risk subjects, construction of informative clinical trials, and timely detection of AD.

In the Affective Computing group, we have actively been working on the development of personalized machine learning models for future forecasting of ADAS-Cog13 - a significant predictor of Alzheimer’s Disease(AD) in the cognitive domain – over the future 6, 12, 18, and 24 months, using the data of participants in the ADNI database. Specifically, in our latest work to be presented on August 09 in the premiere conference on Machine Learning for Healthcare (ML4HC), we introduced a modeling framework based on Gaussian Processes (GPs) that leverages the notion of “meta-learning” (learning how to learn). This approach learns automatically from previous participants’ data what is the best forecasting model to apply to a new participant: the population-level or personalized model. This is important in cases when the participants’ data are highly noisy or missing, in which case the population-level GP models are suboptimal. Conversely, when we have a good-quality past data of the target participants, these are used to effectively personalize the target model to a new participant, largely outperforming the population-level model on the future data of that participant. This has important implications for the design of clinical trials and also in gauging decisions of medical practitioners, allowing them to use smart and personalized AI when deciding what treatment to prescribe to their patients (by informing them of potential future outcomes for those patients, based on the medical history of the target patient but also large source of knowledge available from previous/other patients). For more details about this approach, check our paper (“Meta-Weighted Gaussian Process Experts for Personalized Forecasting of AD Cognitive Changes”) that is provided below.
Rosalind W. Picard, Szymon Fedor, Natasha Jaques, Kristy Johnson, Sara Taylor

This project seeks to examine the effects of altered gravity on an individual's physiology during parabolic flight. Specifically, we will collect flight participants' heart rate, heart rate variability, breathing rate, skin temperature, and skin conductance measurements using wearable, wireless sensors in order to determine the response of these biosignals to zero/hyper/microgravity and feelings of nausea.

The results of this research will have both significant scientific and civilian value. To our knowledge, this experiment will be the first to investigate the new Multiple Arousal Theory in the context of motion sickness, as well as altered gravity. This theory was developed in the Affective Computing group at the MIT Media Lab and examines asymmetry in skin conductance signals from right and left wrists as differing metrics of emotional arousal and intensity. The parabolic flight configuration provides an inimitable circumstance to systematically analyze the evolution of these signals over the course of the repeated parabolic flight path. For example, we expect to see globally heightened stress and emotional arousal on the first pass, with maximal skin conductance peaks from both wrists just before the first moment of weightlessness. We expect these peaks to monotonically decrease over time with each pass, but to remain more elevated (relative to an individual’s baseline) for participants experiencing more self-reported nausea during flight. For individuals not experiencing extreme nausea, we expect to see a much higher skin conductance signal from their right wrists compared to their left (for right-handed participants) during the first few passes, with this difference decreasing steadily as the participant habituates to the flight pattern and sensations.

Note that NASA and other researchers—including the Boston-local scientists at the Ashton Graybiel Spatial Orientation Lab at Brandeis University—have investigated spatial orientation and motion sickness, but they are just beginning to add the use of physiological sensors to their work. Not only does this demonstrate that the proposed experiment is at the forefront of scientific inquiry, but it also facilitates potential collaboration with world-renowned experts in the Boston area!

In addition to sensor data, we intend to collect pre- and post-flight surveys recording participant reactions to different levels of gravity, including points at which they experienced nausea or discomfort. Pre-flight surveys will include nausea sensitivity metrics, designed to determine how likely a person is to feel nausea (i.e., separating those who feel carsick on a drive through town versus those who approach rollercoasters without hesitation). It will also ask about each participant’s feelings of anxiety, nausea, and excitement in anticipation of flying. Note that while these feelings may be experienced simultaneously, each one has a different effect on one’s physiology.

After the flight, we will ask participants to rank which sections of the flight (e.g., beginning, middle, end) prompted the greatest sensations of anxiety, nausea, and excitement and to what degree. We will also annotate the flight video recordings to denote periods of high anxiety, nausea, or excitement.

Then, we will use the survey, annotation, and sensor information to build a model that predicts when an individual might experience distress in altered gravity environments. This aspect of the study will leverage our research group’s unique expertise building machine learning algorithms for physiological data, but the results could have widespread impact. For example, such a system could be deployed to space travelers to help them monitor their physiology and anticipate or prevent feelings of discomfort during flight. As access to space travel becomes more pervasive, it is critical to understand the physiological effects of altered gravity on a population that does not solely include astronauts or specially trained individuals. Our models, along with the use of low-cost, commercially available sensors, would enable “space hacking” by tourists and other non-technical personnel, allowing them to measure and track their biosignals to achieve optimal wellness during space travel.

Agata Lapedriza Garcia, Bolei Zhou, Aditya Khosla, Aude Oliva, Antonio Torralba (CSAIL,MIT)

The Places dataset (website) is designed following principles of human visual cognition. Our goal is to build a core of visual knowledge that can be used to train artificial systems for high-level visual understanding tasks, such as scene context, object recognition, action and event prediction, emotion recognition, or theory-of-mind inference.

You can try our online demo.
Rosalind W. Picard, Natasha Jaques

We show that using thin slices (~1 minute) of facial expression and body language data, we can train a deep neural network to predict whether two people in a conversation will bond with each other. Bonding is measured using the Bonding subscale of the Working Alliance Inventory. We show that participants who experience bonding perceive their conversational partner as interesting, charming, and friendly, and do not perceive them as distant or annoying.

The data are collected from a user study of naturalistic conversations, in which participants were asked to interact for 20 minutes, and were recorded using cameras, microphones, and Microsoft Kinects. To ensure participants did not become self-conscious of their non-verbal cues, they were told the purpose of the study was to train machine learning algorithms to read lips.

We show that not only can we accurately predict bonding from participants' personality, disposition, and traits, but that we can predict whether the participant will experience bonding up to 20 minutes later, using only one-minute thin slices of facial expression and body language data. This ability could be extremely useful to an intelligent virtual agent, because if it could detect at one-minute intervals whether it was bonding with its user, it could make course corrections to promote enjoyment and foster bonding. We provide an analysis of the facial expression and body language cues associated with higher bonding, and show how this information could be used by an agent to synthesize the appropriate non-verbal cues during conversation.

Rosalind W. Picard, Weixuan ‘Vincent’ Chen

Animated GIFs are widely used on the Internet to express emotions, but automatic analysis of their content is largely unexplored. To help with the search and recommendation of GIFs, we aim to predict how their emotions will be perceived by humans based on their content. Since previous solutions to this problem only utilize image-based features and lose all the motion information, we propose to use 3D convolutional neural networks (CNNs) to extract spatiotemporal features from GIFs. We evaluate our methodology on a crowdsourcing platform called GIFGIF with more than 6,000 animated GIFs, and achieve better accuracy than any previous approach in predicting crowdsourced intensity scores of 17 emotions. We have also found that our trained model can be used to distinguish and cluster emotions in terms of valence and risk perception.

Rosalind W. Picard, Asaph Azaria, Asma Ghandeharioun, Natasha Jaques, Ehi Nosakhare, Akane Sano, Sara Taylor

The goal of this project is to apply machine learning methods to model the wellbeing of MIT undergraduate students. Extensive data is obtained from the SNAPSHOT study, which monitors participating students on a 24/7 basis, collecting data on their location, sleep schedule, phone and SMS communications, academics, social networks, and even physiological markers like skin conductance, skin temperature, and acceleration.

We extract features from this data and apply a variety of machine learning algorithms, including Gaussian mixture models and Multi-task Multi-Kernel Learning; we are currently working to apply Bayesian hierarchical multi-task learning and Deep Learning as well.

Interesting findings include: when participants visit novel locations they tend to be happier; when they use their phones or stay indoors for long periods they tend to be unhappy; and when several dimensions of wellbeing (including stress, happiness, health, and energy) are learned together, classification accuracy improves. The biggest classification accuracy improvements come when we use multi-tasking algorithms to leverage group data while customizing a model for each participant.

Rosalind W. Picard, Craig Ferguson, Akshay Mohan, Akane Sano, Sara Taylor

Unlike traditional randomized controlled trials that generalize relationships in large groups of people, single-case experiments seek to quantify an individual’s reaction to an intervention by measuring an independent variable’s effect on a dependent variable (i.e., an intervention’s effect on an outcome behavior). These single-case experiments are then combined back together using Bayesian Statistics methods in order to learn more general patterns about a population. We are interested in single-case experiments that test the causal relationships between behaviors that have been observed to be correlated with higher wellbeing.

Thus, instead of using an RCT to find what works for the imaginary “average” person, we can learn what works for each individual and then carefully combine data to generalize the results to other real individuals.

To our knowledge, single-case experiments have not been implemented in a smartphone app format. We believe that a successful app will allow researchers to dramatically scale the number of participants in these studies.

Code available on GitHub!
### 586. Real-time assessment of suicidal thoughts and behaviors
Rosalind W. Picard, Szymon Fedor, Massachusetts General Hospital, Harvard

Depression correlated with anxiety is one of the key factors leading to suicidal behavior, and is among the leading causes of death worldwide. Despite the scope and seriousness of suicidal thoughts and behaviors, we know surprisingly little about what suicidal thoughts look like in nature (e.g., How frequent, intense, and persistent are they among those who have them? What cognitive, affective/physiological, behavioral, and social factors trigger their occurrence?). The reason for this lack of information is that historically researchers have used retrospective self-report to measure suicidal thoughts, and have lacked the tools to measure them as they naturally occur. In this work we explore use of wearable devices and smartphones to identify behavioral, affective, and physiological predictors of suicidal thoughts and behaviors.

### 587. SkinBot: A wearable, skin-climbing robot
Joseph A. Paradiso, Artem Dementyev, Sean Follmer, Javier Hernandez, Inrak Choi

We introduce SkinBot: a lightweight robot that moves over the skin’s surface with a two-legged suction-based locomotion mechanism and captures a wide range of body parameters with an exchangeable multipurpose sensing module. We believe that robots that live on our skin, such as SkinBot, will enable a more systematic study of the human body and offer great opportunities to advance our knowledge in many areas such as telemedicine, human-computer interfaces, body care, and fashion.

### 588. SNAPSHOT Study
Rosalind W. Picard, Weixuan 'Vincent' Chen, Asma Ghandeharioun, Natasha Jaques, Daniel Lopez Martinez, Ehi Nosakhare, Fengjiao Peng, Ognjen (Oggi) Rudovic, Akane Sano, Sara Taylor, Terumi Umematsu, Harvard Medical School, Brigham and Women's Hospital

The SNAPSHOT study seeks to measure Sleep, Networks, Affect, Performance, Stress, and Health using Objective Techniques. It is an NIH-funded collaborative research project between the Affective Computing and Collective Learning groups, and Harvard Medical School’s Brigham & Women’s hospital. Since fall 2013, we’ve run this study to collect one month of data every semester from 50 undergraduate students who are socially connected. We have collected data from about 250 participants, totaling over 7,500 days of data. We measure physiological, behavioral, environmental, and social data using mobile phones, wearable sensors, surveys, and lab studies. We investigate how daily behaviors and social connectivity influence sleep behaviors and health, and outcomes such as mood, stress, and academic performance. Using this multimodal data, we are developing models to predict onsets of sadness and stress. This study will provide insights into behavioral choices for wellbeing and performance.

### 589. SPRING: A Smart Platform for Research, Intervention, and Neurodevelopmental Growth
Rosalind W. Picard, Kristy Johnson

SPRING is a custom-built hardware and software platform for children with neuro-differences. The system automates data acquisition, optimizes learning progressions, and encourages social, cognitive, and motor development in a positive, personalized, child-led play environment. The quantitative data and developmental trajectories captured by this platform enable systematic, multi-modal, long-term studies of different therapeutic and educational approaches to autism and other developmental disorders, as well as a better understanding of motivation, engagement, and learning for the general population.

### 590. StoryScape
Rosalind W. Picard, Micah Eckhardt, Craig Ferguson

Stories, language, and art are at the heart StoryScape. While StoryScape began as a tool to meet the challenging language learning needs of children diagnosed with autism, it has become much more. StoryScape was created to be the first truly open and customizable platform for creating animated, interactive storybooks that can interact with the physical world. Download the android app and make your own amazing stories at https://storyscape.io.

### 591. The Challenge
Pattie Maes, Rosalind W. Picard, Niaja Farve, Natasha Jaques

Mental wellbeing is intimately tied to both social support and physical activity. The Challenge is a tool aimed at promoting social connections and decreasing sedentary activity in a workplace environment. Our system asks participants to sign up for short physical challenges and pairs them with a partner to perform the activity. Social obligation and social consensus are leveraged to promote participation. Two experiments were conducted in which participants’ overall activity levels were monitored with a fitness tracker. In the first study, we show that the system can improve users’ physical activity, decrease sedentary time, and promote social connection. As part of the second study, we provide a detailed social network analysis of the participants, demonstrating that users’ physical activity and participation depends strongly on their social community.
The Guardians Project aims to use the same game design principles used in mobile games to help people with depression. People are motivated by video games just as much as other people are motivated by other things. We propose a new way to collect data on how caregivers and their children, with and without autism, affect and are affected by each other (i.e., how they “sync up” with one another), both in their behavior and in their physiology. We also introduce a customizable digital-physical smart toy platform that will allow us to test hypotheses and collect data about patterns of caregiver-child synchrony in a naturalistic and engaging environment. MIT and Northeastern are forging a new collaboration between smart toy technology and autism research that will help uncover how the social brain develops.

The Guardians

Rosalind W. Picard, Craig Ferguson, Fengjiao Peng, Sara Taylor

The Guardians Project aims to use the same game design principles used in mobile games to help people form beneficial long-term habits and improve their overall wellbeing.

Forming positive health habits can be difficult. Whether it’s getting enough sleep, sticking to a diet, or going for a run, it’s tough to commit to a new schedule long enough to make it stick. This process is even harder when the habit focuses on long-term goals with no immediate noticeable benefits. Mobile video games, on the other hand, use common design techniques and mechanics to produce a loop that draws players to return on a regular schedule and encourages them to watch ads or pay a fee for special rewards within the game.

We have already used these same design principals to show that embedding a daily Patient Reported Outcome within a mobile game can drastically increase response rate and data quality in adolescents.

Now we are shifting our focus to show that games can be a beneficial therapeutic tool for those suffering from depression and anxiety. Oftentimes, people with depression struggle to find motivation to do even the most basic tasks. And yet, people with depression are motivated by video games just as much as anyone else. We aim to leverage this fact to use in-game rewards to motivate people to stick to therapeutic interventions.

We are launching The Guardians, a new mobile game that provides immediate and gratifying rewards for using a therapeutic technique known as behavioral activation. Behavioral activation is a therapy that asks people to choose and perform a meaningful and positive task, then reflect on it. By rewarding players for completing and reflecting on these real-life activities, we hope The Guardians will help people handle depression and live more fulfilling lives through the power of mobile games.

The behavioral activation techniques used within The Guardians were developed in collaboration with Chelsey Wilks, a postdoc at Harvard University and soon-to-be assistant professor at University of Missouri-St Louis. She is a member of the Nock Lab, where she studies the use of technology to treat people at risk for suicide. As such, she has a uniquely suited background to not only deeply understand behavioral activation therapy, but how to modify it to be effectively embedded within a video game.

Chelsey advised the Guardians team on which aspects of behavioral activation therapy are most effective and why, what types of activities are the most effective, and how to maximize both engagement and benefits from within the unique context of a mobile game.

Gameplay, rewards, and behavioral activation

The Guardians is a strategy/resource management game focused on collecting and training pets. Evil villains have imprisoned the Guardian of each of many Realms, sending the Realms’ cute little animals into hiding. It’s up to you to inspire these animals and send them on missions to learn skills they can use to fight back and reclaim their Realm. You have missions that your pets can complete, each of which requires certain types of skills; completing a mission rewards experience points in a given skill. It’s your task to decide which pet goes on which missions in order to best train them into an elite team. Along the way you need to collect spirit gems, pet activities, cosmetic outfits, gold, and items you can use to make missions easier. Once the pets are strong enough, you can send a team to fight back against the villain attacking their Realm, which will unlock more features and rewards. Eventually, when you’ve assembled an elite enough team, you can free the Guardian and save its Realm once and for all.

When you open the game, you’ll be shown a cutscene explaining the backstory, then you’ll be led through a gameplay tutorial. During the tutorial sequence, you’ll be guided to choose a meaningful adventure to complete in real life (i.e, behavioral activation), then you’ll be given time to complete it. After you’ve completed your adventure, you are asked to reflect on it and how it has affected your mood. Once you’ve completed that, you get in-game rewards including new pets, spirit gems, and gold coins. You are free to play the game as much as you want while your adventure is in progress. Every day, you’ll get a notification that a new adventure is available, allowing you to choose and complete a new adventure for that day. And every time you complete your daily adventure, you’ll earn new in-game rewards!
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<td>Traditional Chinese medicine-inspired pulse analysis</td>
<td>Rosalind W. Picard, Weixuan 'Vincent' Chen, Javier Hernandez, Akane Sano</td>
<td>This study aims to bring objective measurement to the multiple &quot;pulse&quot; and &quot;pulse-like&quot; measures made by practitioners of traditional Chinese medicine (TCM). The measurements are traditionally made by manually palpitating the patient’s inner wrist in multiple places, and relating the sensed responses to various medical conditions. Our project brings several new kinds of objective measurement to this practice, compares their efficacy, and examines the connection of the measured data to various other measures of health and stress. Our approach includes the possibility of building a smartwatch application that can analyze stress and health information from the point of view of TCM.</td>
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<tr>
<td>595</td>
<td>Tributary</td>
<td>Rosalind W. Picard, Yadid Ayzenberg</td>
<td>The proliferation of smartphones and wearable sensors is creating very large data sets that may contain useful information. However, the magnitude of generated data creates new challenges as well. Processing and analyzing these large data sets in an efficient manner requires computational tools. Many of the traditional analytics tools are not optimized for dealing with large datasets. Tributary is a parallel engine for searching and analyzing sensor data. The system utilizes large clusters of commodity machines to enable in-memory processing of sensor time-series signals, making it possible to search through billions of samples in seconds. Users can access a rich library of statistics and digital signal processing functions or write their own in a variety of languages.</td>
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<tr>
<td>596</td>
<td>UncNet: Modeling uncertainty in deep learning for inherently subjective tasks</td>
<td>Rosalind W. Picard, Asma Ghandeharioun, Brian Eoff, Brendan Jou</td>
<td>Automatic emotion recognition has become a well-established machine learning task in recent years. The sensitive and subjective nature of emotions may give rise to societal challenges manifesting from incorrect or misinterpreted predictions. In this work, we make the argument that emotion recognition models have an obligation to quantify their uncertainty (or similarly, provide confidence bounds). We provide demonstrations of how classical network architectures can be altered to give measures of epistemic and aleatoric uncertainty using established probabilistic inference techniques. We also explore what these uncertainties explain about the data and predictions and how it can reveal a lack of diversity in training data. We demonstrate how difficult and subjective training samples can be identified using these learned uncertainty measures.</td>
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<tr>
<td>598</td>
<td>Valinor: Mathematical models to understand and predict self-harm</td>
<td>Rosalind W. Picard, Karthik Dinakar, Matthew Nock (Harvard), Eric Horvitz (Microsoft Research)</td>
<td>We are developing statistical tools for understanding, modeling, and predicting self-harm by using advanced probabilistic graphical models and fail-soft machine learning in collaboration with Harvard University and Microsoft Research.</td>
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<tr>
<td>599</td>
<td>Wavelet-based motion artifact removal for electrodermal activity</td>
<td>Rosalind W. Picard, Weixuan 'Vincent' Chen, Szymon Fedor, Natasha Jaques, Akane Sano, Sara Taylor</td>
<td>Electrodermal activity (EDA) recording is a powerful, widely used tool for monitoring psychological or physiological arousal. However, analysis of EDA is hampered by its sensitivity to motion artifacts. We propose a method for removing motion artifacts from EDA, measured as skin conductance (SC), using a stationary wavelet transform (SWT). We modeled the wavelet coefficients as a Gaussian mixture distribution corresponding to the underlying skin conductance level (SCL) and skin conductance responses (SCRs). The goodness-of-fit of the model was validated on ambulatory SC data. We evaluated the proposed method in comparison with three previous approaches. Our method achieved a greater reduction of artifacts while retaining motion-artifact-free data.</td>
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Can we modulate the way we hear the world around us to make it more calming or to induce focus?

While technology is usually associated with causing stress, technology also has the potential to bring about calm. In particular, breathing usually speeds up with higher stress, but it can be slowed through a manipulation, and in so doing, it can help the person calm down. We are exploring a range of interventions to influence breathing without requiring any focused attention in order to be effective. In multiple projects, we have looked at dynamic composition of music, modulation of screen brightness, and headphone volume to create a seamless pulsating behavior, similar to breathing biofeedback, to indirectly influence breathing. Our preliminary analyses show promising results that such seamless modulation indeed have an influence on breathing rate and pattern.

In this project, we explore modulating insertion gain on a headphone in harmony with affective signals, particularly breathing rate. We study the influence of this dynamic change between “inside” and “outside” sources of sound to induce a sense of calmness. We experiment in simulated environments that resemble different situations such as a library, a busy street, and a fireplace.

We would like to thank Dan Gauger for giving us equipment and his thoughtful suggestions, including the project name. We would also like to thank Bose for making this project happen.
Iyad Rahwan: Scalable Cooperation
Reimagining human cooperation in the age of social media and artificial intelligence

Iyad Rahwan, Manuel Cebrian, Morgan Ryan Frank, Matthew Groh, Esteban Moro Egido, Alex Rutherford, Hyejin Youn, David Autor, James E. Bessen, Erik Brynjolfsson, David J. Deming, Maryann Feldman, Jose Lobo, Dashun Wang

Should workers worry about automation and AI?

Many workers, policy makers, and researchers are asking themselves exactly this question. But the answer has proven elusive using traditional tools and methods. While some fear the end of employment and rising wealth inequality, others celebrate rising productivity and new frontiers for innovation and investment. The confusion between these perspectives arises from several barriers that inhibit today’s study of AI, technology, and the future of work.

Matthew Groh

Media manipulation technologies have the power to vanish people from photographs. Yet their souls live on in the deep memory of these algorithms of omission.


The problem of ethical decision making presents a grand challenge for modern AI research. Arguably the main obstacle to automating ethical decisions is the lack of a formal specification of ground-truth ethical principles, which have been the subject of debate for centuries among philosophers (e.g., trolley problem). We present an algorithm to automate ethical decisions; using machine learning and computational social choice (new theory of swap-dominance efficient voting rules), we propose to learn a model of societal preferences, and, when faced with a specific ethical dilemma at runtime, efficiently aggregate those preferences to identify a desirable choice. Finally, we implement and evaluate a system for ethical decision making in the autonomous vehicle domain, using preference data collected from 1.3 million voters through the Moral Machine website. Our proof of concept shows that the decision the system takes is likely to be the same as if we could go to each of the 1.3 million voters, ask for their opinions, and then aggregate their opinions into a choice that satisfies mathematical notions of social justice.

Iyad Rahwan, Lorenzo Coviello

There is a wide cultural belief in the power of the Internet and social media as enablers of collective intelligence. They help us spread information rapidly, and learn useful information from each other. But there are fundamental limits to the capabilities of those networks. Understanding these limits is essential to improving social media and allowing society to make the most of it.

Iyad Rahwan, Manuel Cebrian

The Internet has unleashed the capacity for planetary-scale collective problem solving (also known as crowdsourcing). However, the very openness of crowdsourcing makes it vulnerable to sabotage by rogue or competitive actors. To explore the effect of errors and sabotage on the performance of crowdsourcing, we analyze data from the DARPA Shredder Challenge, a prize competition for exploring methods to reconstruct documents shredded by a variety of paper shredding techniques.
Deep Angel: The AI behind the aesthetics of absence

Iyad Rahwan, Manuel Cebrian, Abhimanyu Dubey, Ziv Epstein, Matthew Groh, Nick Obradovich, Niccolo Pescetelli, Julian KellyMicah Epstein

Deep Angel is an artificial intelligence that erases objects from photographs. The algorithm is hosted on http://deepangel.media.mit.edu, which enables anyone to interact with the AI and explore what it can disappear.

Part philosophy, part technology, and part art, Deep Angel is designed to spark a series of conversations on technology in our daily lives and AI and media manipulation.

Deep Angel draws from Walter Benjamin’s description of Paul Klee’s Angelus Novus, the angel of history who has clairvoyance into the dark side of what appears to be progress. The angel sees the unravelling of all that matters in the world and would like to alert the world about his vision, but he’s caught in the storm of progress and can’t communicate any messages. The images that Deep Angel generates are intended to deliver the message that Angelus Novus would have sent if he could.

The algorithm applies computer vision techniques to automatically (1) detect and outline objects in images, (2) remove the outlined object from the image, and (3) imagine what the image would look like if that outlined object were removed from the image. Any image uploaded and transformed by Deep Angel can be published on the Deep Angel website by clicking the “Publish to Deep Angel” button.

The AI’s performance varies across photographs. Sometimes, it’s impossible to tell what has been disappeared. Other times, the images appear similar to the images from Adrian Piper’s Everything series. The more people interact with the algorithm, the more attuned people will be to the potential and limitations of modern AI to manipulate the media. It’s now possible to automate the vanishing commissar in Soviet photography, but the AI is not yet perfect. Below are two examples of the Deep Angel AI effect: (1) a gif generated by Deep Angel showing a father and daughter disappearing in the wilderness and (2) two images showing the before and after of Deep Angel peering into a photo of a professional surfer.

DeepMoji

Iyad Rahwan, Bjarke Felbo, Nick Obradovich, Alan Mislove, Anders Søgaard, Sune Lehmann, Holly Shablack, Kristen Lindquist, Max Lever

Emotional content is an important part of language. There are many use cases now showing that natural language processing is becoming an increasingly important part of consumer products. We are attempting to learn more about human emotions.

In his 2006 book The Emotion Machine, legendary computer scientist Marvin Minsky (co-founder of the field of Artificial Intelligence and one of the founding faculty members of the MIT Media Lab) wrote about the central role of emotions in reasoning—reminding us that AI will only be capable of true commonsense reasoning once it has understood emotions. To Minsky, emotions are not the opposite of rational reason, something to be weeded out before we can think clearly; rather, emotions are just a different way of thinking.

TRY DEEPMOJI HELP TEACH OUR AI ABOUT EMOTIONS

But this is hardly helpful to a computer scientist trying to construct an emotional machine by programming a concrete set of rules. If you ask two people to explain what makes a particular sentence happy, sad, serious, or sarcastic, you will likely get at least two different opinions. Much of what determines emotional content is context-specific, culturally constructed, and difficult to describe in an explicit set of rules.

Evolution of the Social Contract

Iyad Rahwan, Manuel Cebrian, Alex Rutherford, Yonatan Lupu, Brad LeVeck, Manuel Garcia-Herranz

Political constitutions describe the fundamental principles by which nation-states are governed, the political and legal state institutions, the powers, procedures, and duties of those institutions, and the rights and responsibilities of individuals. How do these constitutions develop over long periods of time? What is the interplay between colonial history and global, time varying trends in determining the characteristics of a country’s constitution? We explore these questions using new techniques of computational social science.

Global Cooperation

Iyad Rahwan, Morgan Ryan Frank, Nick Obradovich, Lijun Sun

Measuring Cooperation at Scale
Iyad Rahwan, Lorenzo Coviello, Morgan Ryan Frank, Lijun Sun, NICTA, Manuel Cebrian

The Honest Crowds project addresses shortcomings of traditional survey techniques in the modern information and big data age. Web survey platforms, such as Amazon's Mechanical Turk and CrowdFlower, bring together millions of surveys and millions of survey participants, which means paying a flat rate for each completed survey may lead to survey responses that lack desirable care and forethought. Rather than allowing survey takers to maximize their reward by completing as many surveys as possible, we demonstrate how strategic incentives can be used to actually reward information and honesty rather than just participation. The incentive structures that we propose provide scalable solutions for the new paradigm of survey and active data collection.

Iyad Rahwan

Since Alan Turing envisioned Artificial Intelligence (AI), a major driving force behind technical progress has been competition with human cognition (e.g. beating humans in Chess or Jeopardy!). Less attention has been given to developing autonomous machines that learn to cooperate with humans. Cooperation does not require sheer computational power, but relies on intuition, and pre-evolved dispositions toward cooperation, common-sense mechanisms that are difficult to encode in machines. We develop state-of-the-art machine-learning algorithms that cooperate with people and other machines at levels that rival human cooperation in two-player repeated games.

Scientific writings:

Iyad Rahwan, Manuel Cebrian, Bjarke Felbo, Esteban Moro Egido, Nick Obradovich, Pinar Yanardag

Climate change is going to alter the environments that we depend on in myriad ways. We’re using data to identify and quantify these potential human impacts.

Cynthia Breazeal, Alex ‘Sandy’ Pentland, Iyad Rahwan, Manuel Cebrian, Nick Obradovich

Machines powered by artificial intelligence (AI) increasingly mediate our social, cultural, economic, and political interactions. Understanding the behavior of AI systems is essential to our ability to control their actions, reap their benefits, and minimize their harms. We argue this necessitates a broad scientific research agenda to study machine behavior that incorporates but expands beyond the discipline of computer science and requires insights from across the sciences. Here we first outline a set of questions fundamental to this emerging field. We then explore the technical, legal, and institutional constraints facing the study of machine behavior.

Edmond Awad, Sohan Dsouza, Iyad Rahwan, Azim Shariff, Jean-Francois Bonnefon

The Moral Machine is a platform for gathering a human perspective on moral decisions made by machine intelligence, such as self-driving cars. We generate moral dilemmas, where a driverless car must choose the lesser of two evils, such as killing two passengers or five pedestrians. As an outside observer, people judge which outcome they think is more acceptable. They can then see how their responses compare with other people. If they are feeling creative, people can also design their own scenarios, for others to view, share, and discuss.

Visit the Moral Machine.

Iyad Rahwan, Edmond Awad, Zoe Rahwan, Erez Yoeli

There are over one million registered charities in the United States alone, and many more worldwide. How do you choose among them?

MyGoodness is a simple game that helps you understand how you give. In the game, you will make 10 giving decisions. Each decision is between two choices, and you tell us which you prefer.

At the end of the game, we give you a summary of your ‘goodness’ and how it compares to others. You can share that feedback with whomever you would like.

Iyad Rahwan, Manuel Cebrian, Nick Obradovich, Pinar Yanardag

For centuries, across geographies, religions, and cultures, people try to innovate ways of scaring each other. Creating a visceral emotion such as fear remains one of the cornerstones of human creativity. This challenge is especially important in a time when we wonder what the limits of Artificial Intelligence are: Can machines learn to scare us? Towards this goal, we present you Haunted Faces and Haunted Places: computer generated scary imagery powered by deep learning algorithms!
Iyad Rahwan, Manuel Cebrian, Pinar Yanardag

We present Norman, world's first psychopath AI. Norman was inspired by the fact that the data used to teach a machine learning algorithm can significantly influence its behavior. So when people say that AI algorithms can be biased and unfair, the culprit is often not the algorithm itself, but the biased data that was fed to it. The same method can see very different things in an image, even "sick" things, if trained on the wrong (or, the right!) data set. Norman suffered from extended exposure to the darkest corners of Reddit, and represents a case study on the dangers of artificial intelligence gone wrong when biased data is used in machine learning algorithms.

Norman is an AI that is trained to perform image captioning; a popular deep learning method of generating a textual description of an image. We trained Norman on image captions from an infamous subreddit (its name is redacted due to its graphic content) that is dedicated to documenting and observing the disturbing reality of death. Then, we compared Norman's responses with a standard image-captioning neural network (trained on MSCOCO dataset) on Rorschach inkblots—a test that is used to detect underlying thought disorders. Visit norman-ai.mit.edu to explore what Norman sees!

Iyad Rahwan, Edmond Awad

Opinion aggregation on social media uses various mechanisms, such as "Likes" or thumbs-up/-down, which handle a single item at a time. In many domains (e.g., political discussion), we need to consider the relationships between different claims, and how they rebut one another through complex webs of arguments and counter-arguments. We study methods for aggregating opinions about such complex argument networks, the quality of the outcomes of different methods of opinion aggregation, and whether strategic agents can manipulate those outcomes.

Iyad Rahwan, Edmond Awad, Jean-Francois Bonnefon, Sohan Dsouza, Sydney Levine

When an automated car harms someone, who is blamed by those who hear about it? In this project, we asked participants to consider hypothetical cases in which a pedestrian was killed by a car operated under shared control of a primary and a secondary driver, and to indicate how blame should be allocated. We find that when only one driver makes an error, that driver is blamed more, regardless of whether that driver is a machine or a human. However, when both drivers make errors in cases of human-machine shared-control vehicles, the blame attributed to the machine is reduced. This finding portends a public under-reaction to the malfunctioning AI components of automated cars and therefore has a direct policy implication: allowing the de-facto standards for shared-control vehicles to be established in courts by the jury system could fail to properly regulate the safety of those vehicles; instead, a top-down scheme (through federal laws) may be called for.

Iyad Rahwan

Cooperation in a large society of self-interested individuals is notoriously difficult to achieve when the externality of one individual's action is spread thin and wide on the whole society (e.g., in the case of pollution). We introduce a new approach to achieving global cooperation by localizing externalities to one's peers in a social network, thus leveraging the power of peer-pressure to regulate behavior. Global cooperation becomes more like local cooperation.

Iyad Rahwan, Manuel Cebrian, Pinar Yanardag

Project website: shelley.ai

Human-AI collaborated stories: stories.shelley.ai

Follow @shelley_ai to collaborate with Shelley!

For centuries, across geographies, religions, and cultures, people have innovated ways of scaring each other. Creating a visceral emotion such as fear remains one of the cornerstones of human creativity. This challenge is especially important at a time when we are exploring the limits of artificial intelligence: Can machines learn to scare us?

In Halloween 2016 we presented the Nightmare Machine—computer-generated scary imagery powered by deep learning algorithms. This Halloween, we present Shelley: Human-AI Collaborated Horror Stories! Shelley is a deep-learning powered AI who was raised reading eerie stories coming from r/nosleep. Now, as an adult—and not unlike Mary Shelley, her Victorian idol—she takes a bit of inspiration in the form of a random seed, or a short snippet of text, and starts creating stories emanating from her creepy creative mind. But what Shelley truly enjoys is working collaboratively with humans, learning from their nightmarish ideas, creating the best scary tales ever. If you want to work with her, respond to the stories she'll start every hour on her Twitter account, and she will write with you the first AI-human horror anthology ever put together!
Recent rapid advances in Artificial Intelligence (AI) and Machine Learning have raised many questions about the regulatory and governance mechanisms for autonomous machines. This is not about individual gadgets, but about complex, networked systems of humans and algorithms making decisions in business, government, and the media. We need conceptual frameworks for designing new governance architectures for these human-machine social systems. In doing so, it is helpful to learn lessons about human cooperation and governance from political philosophy and cultural anthropology. Read more here.

We must proactively tackle the economic, social, and societal implications that accompany the widespread deployment of AI technology. In service to this goal, examining the evolution of AI research itself could provide a valuable input into models of AI’s impact (e.g., models of the future of work).
Ramesh Raskar: Camera Culture
Making the invisible visible—inside our bodies, around us, and beyond—for health, work, and connection

Ramesh Raskar, Nikhil Naik
Is it possible to create passive displays that respond to changes in viewpoint and incident light conditions? Holograms and 4D displays respond to changes in viewpoint. 6D displays respond to changes in viewpoint as well as surrounding light. We encode the 6D reflectance field into an ordinary 2D film. These displays are completely passive and do not require any power. Applications include novel instruction manuals and mood lights.

Ramesh Raskar, Shantanu Sinha
Eye exams via a slit lamp are critical in early diagnosis of diseases such as cataracts, corneal injury, and pterygia, in order to avert vision loss. The slit lamp is one of the most versatile tools in an ophthalmologist’s clinic, but is big, expensive, and is designed with specialized ophthalmic clinics in mind. AnEye is a suite of portable, computationally driven solutions that leverage modern optics and commercially available consumer electronics to extend the reach of examinations of the anterior segment of the eye well beyond large hospitals and clinics, into resource-constrained settings such as rural mass-screening camps, mobile ophthalmology clinics, and even primary care.

Otkrist Gupta
We introduce MetaQNN, a meta-modeling algorithm based on reinforcement learning to automatically generate high-performing CNN architectures for a given learning task. The learning agent is trained to sequentially choose CNN layers using Q-learning with an $\epsilon$-greedy exploration strategy and experience replay. The agent explores a large but finite space of possible architectures and iteratively discovers designs with improved performance on the learning task. On image classification benchmarks, the agent-designed networks (consisting of only standard convolution, pooling, and fully-connected layers) beat existing networks designed with the same layer types and are competitive against the state-of-the-art methods that use more complex layer types. We also outperform existing meta-modeling approaches for network design on image classification tasks.

Ramesh Raskar, Barmak Heshmat Dehkordi, Gurmukh Bhasin
This concept gallery shows the chain of startups and ideas that will follow after the emergence of self-driving cars.

Ramesh Raskar, Ayush Bhandari, Commonwealth School, Christopher Barsi
Fluorescence lifetime imaging is a significant bio-imaging tool that finds important applications in life-sciences. Widely known applications include cancer detection and DNA sequencing. To that end, fluorescence microscopy which is at the heart of bio-imaging is an electronically and optically sophisticated device which is prohibitively expensive. Our work is demonstrates the fluorescence microscopy like functionality can be achieved by a simple, consumer sensor such as the Microsoft Kinect which costs about $100. This is done by trading-off the precision in optics and electronics for sophistication in computational methods. Not only this allows for massive cost reduction but leads to several advances in the area. For example, our method is calibration-free in that we do not assume sample’s relative placement with respect to the sensor. Furthermore, our work opens new pathways of interaction between bio-imaging, optics and computer vision communities.
Ramesh Raskar, Otkrist Gupta, Barmak Heshmat Dehkordi, Guy Satat, Matthew Tancik
Object Classification through Scattering Media with Deep Learning

A method for classifying objects hidden behind a scattering layer with a neural network. Training on synthetic data with variations in calibration parameters allows the network to learn a model that doesn’t require calibration during lab experiments.

Traditional techniques to see through scattering media rely on a physical model that needs to be precisely calibrated. Computationally overcoming the scattering relies heavily on accurately calibrated physical models. Thus, such systems are extremely sensitive to a precise and lengthy calibration process.

In this work we overcome this bottleneck by utilizing neural networks and their ability to learn models that are invariant to data transformation. In our case, the transformations are variations in the imaging system calibration parameters. To that end, we create a synthetic dataset that contains variations in all calibration parameters (we use a Monte Carlo forward model to render the measurements). The system is then tested on actual lab experiments without specific calibration or tuning.

Ramesh Raskar, Nikhil Naik
Computational photography is an emerging multi-disciplinary field at the intersection of optics, signal processing, computer graphics and vision, electronics, art, and online sharing in social networks. The first phase of computational photography was about building a super-camera that has enhanced performance in terms of the traditional parameters, such as dynamic range, field of view, or depth of field. We call this Epsilon Photography. The next phase of computational photography is building tools that go beyond the capabilities of this super-camera. We call this Coded Photography. We can code exposure, aperture, motion, wavelength, and illumination. By blocking light over time or space, we can preserve more details about the scene in the recorded single photograph.

Anshuman Das
Computation photography applied to imaging the middle ear for infections.

Ramesh Raskar, Guy Satat, Matthew Tancik
Lensless imaging with compressive ultrafast sensing

Traditional cameras require a lens and a mega-pixel sensor to capture images. The lens focuses light from the scene onto the sensor. We demonstrate a new imaging method that is lensless and requires only a single pixel for imaging. Compared to previous single pixel cameras our system allows significantly faster and more efficient acquisition. This is achieved by using ultrafast time-resolved measurement with compressive sensing. The time-resolved sensing adds information to the measurement, thus fewer measurements are needed and the acquisition is faster. Lensless and single pixel imaging computationally resolves major constraints in imaging systems design. Notable applications include imaging in challenging parts of the spectrum (like infrared and THz), and in challenging environments where using a lens is problematic.

Anshuman Das
We demonstrate a smartphone based spectrometer design that is standalone and supported on a wireless platform. The device is inherently low-cost and the power consumption is minimal making it portable to carry out a range of studies in the field. All essential components of the device like the light source, spectrometer, filters, microcontroller and wireless circuits have been assembled in a housing of dimensions 88 mm x 37 mm x 22 mm and the entire device weighs 48 g. The resolution of the spectrometer is 15 nm, delivering accurate and repeatable measurements. The device has a dedicated app interface on the smartphone to communicate, receive, plot and analyze spectral data. The performance of the smartphone spectrometer is comparable to existing bench-top spectrometers in terms of stability and wavelength resolution. Validations of the device were carried out by demonstrating non-destructive ripeness testing in fruit samples. Ultra-Violet (UV) fluorescence from Chlorophyll present in the skin was measured across various apple varieties during the ripening process and correlated with destructive firmness tests. A satisfactory agreement was observed between ripeness and fluorescence signals. This demonstration is a step towards possible consumer, bio-sensing and diagnostic applications that can be carried out in a rapid manner.
Ramesh Raskar, Anshuman Das

We believe that tough global health problems require an innovation pipeline. We must bring together the people and providers facing health challenges to form what we call an innovation continuum: inventors building new low-cost technologies; developers capable of rapidly iterating on these inventions for use in the real world; clinicians and end users to validate our creations; and entrepreneurs, philanthropists, and development agencies to scale our solutions. We are asking big questions such as: what billion-dollar ideas could impact a billion lives in health, education, transportation through digital interfaces, digital opportunities, and applications for physical systems? Using machine learning, computer vision, big data, sensors, mobile technology, diagnostics, and crowdsourcing, we are conducting research at the Media Lab, and also collaborating with innovators in three centers in India and in other centers worldwide. Innovations like this launched the effort to create the Emerging Worlds initiative.

Ramesh Raskar, Achuta Kadambi

Time of Flight 3D cameras like the Microsoft Kinect are prevalent in computer vision and computer graphics. In such devices, the power of an integrated laser is amplitude modulated at megahertz (MHz) frequencies and demodulated using a specialized imaging sensor to obtain sub-cm range precision. To use a similar architecture and obtain micron range precision, this paper incorporates beat notes. To bring telecommunications ideas to correlation ToF imaging, we study a form of “cascaded Time of Flight” that uses a Hertz-scale intermediate frequency to encode high-frequency pathlength information. We show synthetically and experimentally that a bulk implementation of opto-electronic mixers offers: (a) robustness to environmental vibrations; (b) programmability; and (c) stability in frequency tones. A fiberoptic prototype is constructed, which demonstrates three micron range precision over a range of two meters. A key contribution of this paper is to study and evaluate the proposed architecture for use in machine vision.

Ramesh Raskar, Anshuman Das

We believe that tough global health problems require an innovation pipeline. We must bring together the people and providers facing health challenges to form what we call an innovation continuum: inventors building new low-cost technologies; developers capable of rapidly iterating on these inventions for use in the real world; clinicians and end users to validate our creations; and entrepreneurs, philanthropists, and development agencies to scale our solutions. We are asking big questions such as: What billion-dollar ideas could impact a billion lives in health, education, transportation through digital interfaces, digital opportunities, and applications for physical systems? Using machine learning, computer vision, big data, sensors, mobile technology, diagnostics, and crowdsourcing, we are conducting research at the Media Lab, and also collaborating with innovators in three centers in India and in other centers worldwide. Innovations like this launched the effort to create the Emerging Worlds initiative.

Ramesh Raskar, Nikhil Naik, Guy Satat

Asthma is the most common chronic illness among children. The skills required to diagnose it make it an even greater concern. Our solution is a child-friendly wearable device that allows in-home diagnosis of asthma. The device acquires simultaneous measurements from multiple stethoscopes. The recordings are then sent to a specialist who uses assistive diagnosis algorithms that enable auscultation (listening to lung sounds with a stethoscope). Sound refocusing algorithms enable the specialist to listen to any location in the lungs. The specialist also has access to a sound “heat map” that shows the location of sound sources in the lungs.

Ramesh Raskar, Barmak Heshmat Dehkordi

Locating and classifying fluorescent tags behind turbid layers using time-resolved inversion

Using time resolved and sparse optimization framework to locate and classify fluorescent markers hidden behind turbid layer: The use of fluorescent probes and the recovery of their lifetimes allow for significant advances in many imaging systems, in particular medical imaging systems. Here, we propose and experimentally demonstrate reconstructing the locations and lifetimes of fluorescent markers hidden behind a turbid layer. This opens the door to various applications for non-invasive diagnosis, analysis, flowmetry, and inspection. The method is based on a time-resolved measurement which captures information about both fluorescence lifetime and spatial position of the probes. To reconstruct the scene, the method relies on a sparse optimization framework to invert time-resolved measurements. This wide-angle technique does not rely on coherence, and does not require the probes to be directly in line of sight of the camera, making it potentially suitable for long-range imaging.

More details:
http://web.media.mit.edu/~guysatat/project_scattering.html
http://web.media.mit.edu/~guysatat/tf/

634. Health-tech innovations with Tata Trusts, Mumbai

635. High-frequency LIDAR using beat notes

636. Hyderabad eye health collaboration with LVP

637. Identi-Wheez: A device for in-home diagnosis of asthma

638. Imaging Behind Diffusive Layers
Ramesh Raskar, Nikhil Naik
We use time-resolved information in an iterative optimization algorithm to recover reflectance of a three-dimensional scene hidden behind a diffuser. We demonstrate reconstruction of large images without relying on knowledge of diffuser properties.

Ramesh Raskar, Barmak Heshmat Dehkordi, Guy Satat
How to see through tissue
We demonstrate a new method to image through scattering materials like tissue and fog. The demonstration includes imaging an object hidden behind 1.5cm of tissue; it’s like imaging through the palm of a hand. Our optical method is based on measuring and using all photons in the signal (as opposed to traditional methods, which use only part of the signal). Specifically, we use a time-resolved method that allows us to distinguish between photons that travel different paths in the tissue. Combining this unique measurement process with novel algorithms allows us to recover the hidden objects. This technique can be used in biomedical imaging, as well as imaging through fog and clouds.

Ramesh Raskar, Ayush Bhandari, Achuta Kadambi
We are exploring mathematical modeling of time-of-flight imaging problems and solutions.

Ramesh Raskar, Nikhil Naik, Wei-Chao Chen
With networked cameras in everyone’s pockets, we are exploring the practical and creative possibilities of public imaging. LensChat allows cameras to communicate with each other using trusted optical communications, allowing users to share photos with a friend by taking pictures of each other, or borrow the perspective and abilities of many cameras.

Ramesh Raskar, Ayush Bhandari, Anshuman Das
CNF: Sharing photos with strangers
We believe that tough global health problems require an innovation pipeline. We must bring together the people and providers facing health challenges to form what we call an innovation continuum: inventors building new low-cost technologies; developers capable of rapidly iterating on these inventions for use in the real world; clinicians and end users to validate our creations; and entrepreneurs, philanthropists, and development agencies to scale our solutions. We are asking big questions such as: What billion-dollar ideas could impact a billion lives in health, education, transportation through digital interfaces, digital opportunities, and applications for physical systems? Using machine learning, computer vision, Big Data, sensors, mobile technology, diagnostics, and crowdsourcing, we are conducting research at the Media Lab, and also collaborating with innovators in three centers in India and in other centers worldwide. Innovations like this launched the effort to create the Emerging Worlds initiative.

Ramesh Raskar, Nikhil Naik
Can a person look at a portable display, click on a few buttons, and recover his or her refractive condition? Our optometry solution combines inexpensive optical elements and interactive software components to create a new optometry device suitable for developing countries. The technology allows for early, extremely low-cost, mobile, fast, and automated diagnosis of the most common refractive eye disorders: myopia (nearsightedness), hypermetropia (farsightedness), astigmatism, and presbyopia (age-related visual impairment). The patient overlaps lines in up to eight meridians, and the Android app computes the prescription. The average accuracy is comparable to the traditional method—and in some cases, even better. We propose the use of our technology as a self-evaluation tool for use in homes, schools, and at health centers in developing countries, and in places where an optometrist is not available or is too expensive.

Ramesh Raskar, Ayush Bhandari, Anshuman Das, Micha Feigin-Almon, Achuta Kadambi
New methods in time-of-flight imaging
Time-of-flight (ToF) cameras are commercialized consumer cameras that provide a depth map of a scene, with many applications in computer vision and quality assurance. Currently, we are exploring novel ways of integrating the camera illumination and detection circuits with computational methods to handle challenging environments, including multiple scattering and fluorescence emission.
647. **Optical Brush: Enabling deformable imaging interfaces**
Ramesh Raskar, Barmak Heshmat Dehkordi

Our deformable camera exploits new, flexible form factors for imaging in turbid media. In this study we enable a brush-like form factor with a time-of-flight camera. This has enabled us to reconstruct images through a set of 1100 optical fibers that are randomly distributed and permuted in a medium.

648. **PhotoCloud: Personal to shared moments with angled graphs of pictures**
Ramesh Raskar, Otkrist Gupta, Nikhil Naik

We present a near-real-time system for interactively exploring a collectively captured moment without explicit 3D reconstruction. Our system favors immediacy and local coherency to global consistency. It is common to represent photos as vertices of a weighted graph. The weighted angled graphs of photos used in this work can be regarded as the result of discretizing the Riemannian geometry of the high dimensional manifold of all possible photos. Ultimately, our system enables everyday people to take advantage of each others’ perspectives in order to create on-the-spot spatiotemporal visual experiences similar to the popular bullet-time sequence. We believe that this type of application will greatly enhance shared human experiences, spanning from events as personal as parents watching their children’s football game to highly publicized red-carpet galas.

649. **Portable Retinal Imaging**
Ramesh Raskar, Everett Lawson, Nikhil Naik, Alex Olwal, Gordon Wetzstein

The major challenge in preventing blindness is identifying patients and bringing them to specialty care. Diseases that affect the retina, the image sensor in the human eye, are particularly challenging to address, because they require highly trained eye specialists (ophthalmologists) who use expensive equipment to visualize the inner parts of the eye. Diabetic retinopathy, HIV/AIDS-related retinitis, and age-related macular degeneration are three conditions that can be screened and diagnosed to prevent blindness caused by damage to retina. We exploit a combination of two novel ideas to simplify the constraints of traditional devices, with simplified optics and clever illumination in order to capture and visualize images of the retina in a standalone device easily operated by the user. Prototypes are conveniently embedded in either a mobile hand-held retinal camera, or wearable eyeglasses.

650. **Reading Through a Closed Book**
Barmak Heshmat Dehkordi

Terahertz time-gated spectral imaging for content extraction through layered structures.

651. **Reflectance acquisition using ultrafast imaging**
Ramesh Raskar, Nikhil Naik

We demonstrate a new technique that allows a camera to rapidly acquire reflectance properties of objects “in the wild” from a single viewpoint, over relatively long distances and without encircling equipment. This project has a wide variety of applications in computer graphics, including image relighting, material identification, and image editing.
Kevin Esvelt, Alex ‘Sandy’ Pentland, Ramesh Raskar, Input from experts from Harvard University, Stanford University, and SUNY Buffalo; clinical input from Mayo Clinic and Massachusetts General Hospital; and mentors from the World Health Organization, the US Department of Health and Human Services, and the Graduate Institute of International and Development Studies. A number of leaders and personnel from the global company EY are volunteering their time across many disciplines, including strategy and inclusion on the core initiative leadership team. Numerous additional companies are also participating in this way, including TripleBlind, Public Consulting Group, and Earned Media Consultants. Experts from government agencies and academic institutes in Canada, Germany, India, Italy, the United Kingdom, and Vietnam are also helping to guide the platform’s development.

Safe Paths is an MIT-led, free, open source technology that enables jurisdictions and individuals to maximize privacy, while also maximizing the effectiveness of contact tracing in the case of a positive diagnosis. The Safe Paths platform, currently in beta, comprises both a smartphone application, PrivateKit, and a web application, Safe Places. The PrivateKit app will enable users to match the personal diary of location data on their smartphones with anonymized, redacted, and blurred location history of infected patients. The digital contact tracing uses overlapped GPS and Bluetooth trails that allow an individual to check if they have crossed paths with someone who was later diagnosed positive for the virus. Through Safe Places, public health officials are equipped to redact location trails of diagnosed carriers and thus broadcast location information with privacy protection for both diagnosed patients and for local businesses.

Context

Fast containment is key to halting an epidemic outbreak. But with the long incubation period of a virus like COVID-19, it is extremely difficult to identify individuals who may have been in contact with carriers of the virus and are thus at risk of contagion. Across the globe, the use of smartphones has been tested to track location and solve this problem, raising concerns about mass surveillance. However, with our privacy-first method, the user remains in control of their data—providing a fundamentally different approach to app-based epidemic analytics.

Resilience requires citizens and organizations to self-organize so that they can predict and respond to challenges (e.g., climate change) and disruptions (e.g., COVID-19). Such orchestration would be easy if everyone involved shared data about their past activities and future intentions openly, and responded to scientific evidence in ways that supported long term resilience, fairness, inclusiveness and accountability. This is, however, is challenging due to the need to maintain privacy, consent, trade secrets and compatible incentives.

The current epidemic highlights this challenge. A “big brother” system in some countries has made a big difference in public health intervention via contact tracing, quarantine adherence verification, health verification, as well as tools for health officials such as spread analysis, resource allocation and incentive methods.

Unfortunately, network analysis of social activities leads to a surveillance state. Thus, there are several big challenges to capture, analyze and act in a closed loop: (i) population scale understanding of a fast or slow moving threat without coercing an individual to reveal anything identifiable about themselves, (ii) analyze and providing precise guidance to an individual without the orchestration system knowing to who and what message is delivered and (iii) incentivize and verify the action while maintaining a sense of agency and privacy for the individual.

These seemingly impossible problems can now be addressed thanks to: (i) deep penetration of smartphones and IoT which can act to capture, compute, disseminate and act on information, (ii) the data sources associated with these devices (iii) practical and scalable privacy preserving algorithms and (iv) incentive mechanisms for networks of people and agents which act to guide individuals to support not only themselves but the society as a whole.

Transparent, accountable, and inclusive ecosystems that can simultaneously address the privacy and utility of data in building resilient societal systems are key to humanity’s future. In the short run, digital tracing and infection spread analysis, monitoring of logistics and service chains, and simulation to help policy makers will help the current public health challenges. In the medium term, such systems will be critical in restarting socio-economic activities and get the society on track to more perm

For upcoming version releases, Private Kit: Safe Paths will deploy the following capabilities:

V1 - Log location history

V2 - Match personal location history with infected patient anonymous redacted trace files provided by public health officials

V3 - Match personal location history with encrypted anonymous redacted infected patient trace files provided by city officials
As noted, Private Kit: Safe Paths works in conjunction with the MIT-developed GIS web app, Safe Places. Safe Places will be used by public health officials to:

- Collect time-stamped location data from one of the three sources, Private Kit: Safe Paths, Google location history, and patient interviews
- Produce partially obscured trace files that meet jurisdiction legal requirements for anonymity that can be posted openly on the web and utilized for contact tracing in Private Kit: Safe Paths
- By enabling contact tracing, Private Kit: Safe Paths will help to reduce panic and “flatten the curve” of Coronavirus spread by enabling those who have been exposed and are showing symptoms to make more informed decisions on when to seek testing and self-quarantine—without losing individual privacy and while reducing the fear of unknown exposure.

Ramesh Raskar, Nikhil Naik

We have created a 3D motion-tracking system with automatic, real-time vibrotactile feedback and an assembly of photo-sensors, infrared projector pairs, vibration motors, and a wearable suit. This system allows us to enhance and quicken the motor learning process in a variety of fields such as healthcare (physiotherapy), entertainment (dance), and sports (martial arts).

Ramesh Raskar, Guy Satat, Matthew Tancik

Seeing through dense, dynamic, and heterogeneous fog conditions. The technique, based on visible light, uses hardware that is similar to LIDAR to recover the target depth and reflectance. The system relies on ultrafast measurements, used to computationally remove inclement weather conditions such as fog, and produce a photo and depth map as if the fog weren’t there (with contrast improved by 6.5x in dense fog conditions).

**Applications**
- Autonomous and augmented driving in challenging weather.
- Airplanes and helicopters take off, landing and low level flight in dense fog conditions.
- Trains traveling at normal speeds during inclement weather conditions.

Ramesh Raskar, Nikhil Naik

We present a new method for scanning 3D objects through a single-shot, shadow-based method. We decouple 3D occluders from 4D illumination using shield fields: the 4D attenuation function which acts on any light field incident on an occluder. We then analyze occluder reconstruction from cast shadows, leading to a single-shot light-field camera for visual hull reconstruction.

Ramesh Raskar, Barmak Heshmat Dehkordi

The ability to record images with extreme temporal resolution enables a diverse range of applications, such as time-of-flight depth imaging and characterization of ultrafast processes. Here we present a demonstration of the potential of single-photon detector arrays for visualization and rapid characterization of events evolving on picosecond time scales. The single-photon sensitivity, temporal resolution, and full-field imaging capability enables the observation of light-in-flight in air, as well as the measurement of laser-induced plasma formation and dynamics in its natural environment. The extreme sensitivity and short acquisition times pave the way for real-time imaging of ultrafast processes or visualization and tracking of objects hidden from view.
### 658. Skin Perfusion Photography

Ramesh Raskar, Guy Satat

Skin and tissue perfusion measurements are important parameters for diagnosis of wounds and burns, and for monitoring plastic and reconstructive surgeries. In this project, we use a standard camera and a laser source in order to image blood-flow speed in skin tissue. We show results of blood-flow maps of hands, arms, and fingers. We combine the complex scattering of laser light from blood with computational techniques found in computer science.

### 659. Smartphone spectrometer for food sensing

Ramesh Raskar, Anshuman Das

A smartphone based spectrometer design that is standalone and supported on a wireless platform. The device is low-cost and the power consumption is minimal making it portable to perform a range of studies in the field. Essential components of the device like the light source, spectrometer, filters, microcontroller and wireless circuits have been assembled in a housing that fits into a pocket and the entire device weighs 48 g. The device has a dedicated app on the smartphone to communicate, receive, plot and analyze spectral data. Validations of the device were carried out by demonstrating non-destructive ripeness testing in fruits. Ultra-Violet fluorescence from Chlorophyll present in the skin was measured across various apple varieties during the ripening process and correlated with destructive firmness tests. This demonstration is a step towards possible consumer, bio-sensing and diagnostic applications that can be carried out in a rapid manner.

### 660. Split Learning: Distributed and collaborative learning

Ramesh Raskar, Praneeth Vepakomma

**Split Learning: Distributed deep learning without sharing raw data**

**Project Page:** [https://splitlearning.github.io/](https://splitlearning.github.io/)

**Abstract:**
Can a server utilize deep learning models for training or inference without accessing raw data from clients? Split learning naturally allows for various configurations of cooperating entities to train (and infer from) machine learning models without sharing any raw data or detailed information about the model.

**Key idea:**
In the simplest of configurations of split learning, each client (for example, radiology center) trains a partial deep network up to a specific layer known as the cut layer. The outputs at the cut layer are sent to another entity (server/another client) which completes the rest of the training without looking at raw data from any client that holds the raw data. This completes a round of forward propagation without sharing raw data. The gradients are now back propagated again from its last layer until the cut layer in a similar fashion. The gradients at the cut layer (and only these gradients) are sent back to radiology client centers. The rest of back propagation is now completed at the radiology client centers. This process is continued until the distributed split learning network is trained without looking at each others raw data.

**Split learning’s computational and communication efficiency on clients:**

Client-side communication costs are significantly reduced as the data to be transmitted is restricted to initial layers of the split learning network (splitNN) prior to the split. The client-side computation costs of learning the weights of the network are also significantly reduced for the same reason. In terms of model performance, the accuracies of Split NN remained competitive to other distributed deep learning methods like federated learning and large batch synchronous SGD with a drastically smaller client side computational burden when training on a larger number of clients as shown below in terms of teraflops of computation and gigabytes of communication when split learning is used to train Resnet and VGG architectures over 100 and 500 clients with CIFAR 10 and CIFAR 100 datasets.

**Versatile plug-and-play configurations of split learning**

Versatile configurations of split learning configurations cater to various practical settings of i) multiple entities holding different modalities of patient data, ii) centralized and local health entities collaborating on multiple tasks, iii) learning without sharing labels, iv) multi-task split learning, v) multi-hop split learning and other hybrid possibilities to name a few as shown below and further detailed in our paper here (PDF)

**News stories about this work**

- Technology Review: A new AI method can train on medical records without revealing patient data
- Technology Review: A little-known AI method can train on your health data without threatening your privacy
- The Algorithm Newsletter: The privacy-preserving AI technique that will transform healthcare
- Les Echos: Medical secrecy, artificial intelligence and RGPD: irreconcilable? Not so sure...

### 661. Streetchange

Cesar A. Hidalgo, Ramesh Raskar, Nikhil Naik

Computer vision uncovers predictors of physical urban change
StreetScore is a machine learning algorithm that predicts the perceived safety of a streetscape. StreetScore was trained using 2,920 images of streetscapes from New York and Boston and their rankings for perceived safety obtained from a crowdsourced survey. To predict an image’s score, StreetScore decomposes this image into features and assigns the image a score based on the associations between features and scores learned from the training dataset. We use StreetScore to create a collection of map visualizations of perceived safety of street views from cities in the United States. StreetScore allows us to scale up the evaluation of streetscapes by several orders of magnitude when compared to a crowdsourced survey. StreetScore can empower research groups working on connecting urban perception with social and economic outcomes by providing high-resolution data on urban perception.

In this visual brainstorming, we present the next 30 years of VR in a set of concept designs.

This work focuses on bringing powerful concepts from wave optics to the creation of new algorithms and applications for computer vision and graphics. Specifically, ray-based, 4D lightfield representation, based on simple 3D geometric principles, has led to a range of new applications that include digital refocusing, depth estimation, synthetic aperture, and glare reduction within a camera or using an array of cameras. The lightfield representation, however, is inadequate to describe interactions with diffractive or phase-sensitive optical elements. Therefore we use Fourier optics principles to represent wavefronts with additional phase information. We introduce a key modification to the ray-based model to support modeling of wave phenomena. The two key ideas are "negative radiance" and a "virtual light projector." This involves exploiting higher dimensional representation of light transport.

Rethinking photography optics in the time dimension

Our architecture takes a hybrid approach to microwaves and treats them like waves of light. Most other work places antennas in a 2D arrangement to directly sample the RF reflections that return. Instead of placing antennas in a 2D arrangement, we use a single, passive, parabolic reflector (dish) as a lens. Think of every point on that dish as an antenna with a fixed phase-offset. This means that the lens acts as a fixed set of 2D antennas which are very dense and spaced across a large aperture. We then sample the focal-plane of that lens. This architecture makes it possible for us to capture higher resolution images at a lower cost.

A new method to detect and distinguish between different types of fluorescent materials. The suggested technique has provided a dramatically larger depth range compared to previous methods; thus it enables medical diagnosis of body tissues without removing the tissue from the body, which is the current medical standard. It uses fluorescent probes, which are commonly used in medical diagnosis. One of these parameters is the fluorescence lifetime, that is the average time the fluorescence emission lasts. The new method can distinguish between different fluorescence lifetimes, which allows diagnosis of deep tissues. Locating fluorescence probes in the body using this method can, for example, indicate the location of a tumor in deep tissue, and classify it as malignant or benign according to the fluorescence lifetime, thus eliminating the need for X-ray or biopsy.

We have developed a camera system that captures movies at an effective rate of approximately one trillion frames per second. In one frame of our movie, light moves only about 0.6 mm. We can observe pulses of light as they propagate through a scene. We use this information to understand how light propagation affects image formation and to learn things about a scene that are invisible to a regular camera.

Traditional medical ultrasound assumes that we are imaging ideal liquids. We are interested in imaging muscle and bone as well as measuring elastic properties of tissues, all of which are places where this assumption fails quite miserably. Interested in cancer detections, Duchenne muscular dystrophy, and prosthetic fitting, we use tomographic techniques as well as ideas from seismic imaging to deal with these issues.
Unbounded high dynamic range photography using a modulo camera

Ramesh Raskar, Nikhil Naik, Boxin Shi, Hang Zhao, Sai-Kit Yeung, Christy Fernandez-Cull

We present a novel framework to extend the dynamic range of images called Unbounded High Dynamic Range (UHDR) photography with a modulo camera. A modulo camera could theoretically take unbounded radiance levels by keeping only the least significant bits. We show that with limited bit depth, very high radiance levels can be recovered from a single modulus image with our newly proposed unwrapping algorithm for natural images. We can also obtain an HDR image with details equally well preserved for all radiance levels by merging the least number of modulus images. Synthetic experiments and experiments with a real modulo camera show the effectiveness of the proposed approach.

VisionBlocks

Ramesh Raskar, Nikhil Naik

VisionBlocks is an on-demand, in-browser, customizable, computer-vision application-building platform for the masses. Even without any prior programming experience, users can create and share computer vision applications. End-users drag and drop computer vision processing blocks to create their apps. The input feed could be either from a user’s webcam or a video from the Internet. VisionBlocks is a community effort where researchers obtain fast feedback, developers monetize their vision applications, and consumers can use state-of-the-art computer vision techniques. We envision a Vision-as-a-Service (VaaS) over-the-web model, with easy-to-use interfaces for application creation for everyone.
Mitchel Resnick: Lifelong Kindergarten
Engaging people in creative learning experiences

672. **Agent-based programming interfaces for children**

Tina Quach, Andrew Sliwinski
A conversational, voice-based interface for creating and playing Scratch projects makes Scratch accessible to children regardless of visual ability. Just as Scratch’s visual language lowers the barrier to entry for sighted children, the conversational interface lowers the barrier for children with visual impairments. The screenless interface is inspired by voice assistants and demonstrates the potential for programming through conversation.

673. **Bricoleur**

Sean Hickey
Bricoleur allows makers of all ages to explore the creative possibilities of video and audio as programmable media on mobile devices. Using hand-drawn gestures and a Scratch Blocks-based interface, makers can quickly create complex interactive stories, animations, and artworks by capturing and programming images and sounds from the world around them.

674. **Clubhouse Teen Summit**

Mitchel Resnick, Natalie Rusk, Jaleesa Trapp, The Clubhouse Network
Teen Summit is a biennial week-long Youth Leadership event that brings Clubhouse youth together from each of the 100 Clubhouses internationally. Youth leaders explore issues relevant to them and propose solutions through the creative use of innovative, high-end technologies. The 2018 Teen Summit will take place in late July at Boston University, featuring a college and career fair, collaborative cross-cultural activities, and many other opportunities for educational, career, and personal growth.

675. **Computational Tinkering**

Mitchel Resnick, Carmelo Presicce, Natalie Rusk
As children tinker with materials in the world, they are constantly putting things together and taking them apart. They are learning through play—trying out new ideas, exploring alternate paths, making adjustments, imagining new possibilities, expressing themselves creatively. In the process, they learn about the creative process and develop as creative thinkers.

As digital technologies enter the lives of children, there is risk that they will crowd out tinkering, with children spending more time watching screens than tinkering with materials. Yet, in our work, we have seen how digital technologies can also be used to open up new opportunities for tinkering.

Working in collaboration with the Tinkering Studio at the Exploratorium, Fondazione Reggio Children and the LEGO Foundation, we are developing a new generation of tools, activities, and spaces to support playful investigation and experimentation, integrating digital and physical materials.

The new activities will enable children to engage in new types of inquiry into light, sound, motion, and storytelling. In the initial set of activities, called “light play,” children can program colored lights and moving objects to make dynamic patterns of shadows.
The Lifelong Kindergarten group develops technologies and activities that engage people in creative learning. We're exploring a few directions with our work in Africa:

1. Supporting creative learning across contexts

Instruction-focused learning and an emphasis on narrow outcomes continue to dominate formal and informal environments. As school systems seek to adapt to changes in technology, we're exploring ways to support school systems, educators, and informal learning organizations in reconstructing outcomes and pedagogy that better prepare young people for lifelong, creative learning.

2. Creative Learning Communities

We're exploring two kinds of communities in particular: (a) a maker-focused community that connects makers with employers while helping makers document and translate their skills to professional contexts and (b) supporting the development of creative learning communities—connecting individuals and organizations working to support creative learning in formal and informal learning environments.

Building on the work of Aprendizagem Criativa no Brasil (Creative Learning in Brazil—a decentralized network of educators, designers, systems leaders, foundations, and companies all involved in or hoping to support creative learning) and other initiatives, we hope to first gather stories of educators across a range of contexts, connect them with one another (including at the 2019 Africa Scratch conference), support co-development of resources, and hopefully engage in movement building.

3. Creative vocational learning

Vocational, 21st-century skills trainings are in high demand across the world—and especially in areas with high unemployment. Trainings tend to be dominated by traditional instruction and often limited to a particular set of skills. Moreover, while some of these trainings might help a student get a specific job or progress on a particular skill, they don't prepare students for lifelong, creative learning—and the world that students will be entering.

In this environment, we're exploring how to bring creative learning principles to the design and facilitation of "vocational trainings"—with the aspiration to create a model for more open-ended, playful, passionate, and peer-driven vocational learning that provides a springboard for lifelong learning.

We're piloting this work with the Mekatilili Initiative in Nairobi, Kenya.

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Mitchel Resnick, Leo Burd

The Lemann Creative Learning Program is a collaboration between the MIT Media Lab and the Lemann Foundation to foster creative learning in Brazilian public education.

Established in February 2015, the program designs new technologies, support materials, and innovative initiatives to engage Brazilian public schools, afterschool centers, and families in learning practices that are more hands-on, creative, and centered on students' interests and ideas.

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O Programa Lemann de Aprendizagem Criativa é uma colaboração entre o MIT Media Lab e a Fundação Lemann visando incentivar a aprendizagem criativa na educação pública do Brasil.

Criado em fevereiro de 2015, o programa cria novas tecnologias, materiais de apoio e iniciativas que ajudem escolas públicas, organizações de educação não formal, e famílias a implementar práticas de aprendizagem que sejam mais mão na massa, criativas e centradas nos interesses dos alunos.

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Mitchel Resnick, Leo Burd

O Desafio de Aprendizagem Criativa Brasil é o programa de fellowship da Rede Brasileira de Aprendizagem Criativa. Ele tem como objetivo fomentar a implementação de soluções inovadoras que ajudem a tornar a educação brasileira mais criativa, prazerosa, relevante, colaborativa e inclusiva para crianças e jovens de todo o Brasil.

Com o apoio da Fundação Lemann e do MIT Media Lab, o Desafio 2020 busca propostas que desenvolvem especificamente ações aprofundadas de aprendizagem criativa em sala de aula com o apoio de múltiplos níveis decisórios no ecossistema escolar.

Neste ano, estamos procurando equipes formadas por gestores, diretores e professores já empenhados em tornar as escolas de sua região mais criativas e relevante para todos.

Cada equipe selecionada receberá R$10.000,00 para a realização do seu projeto, visitará o MIT Media Lab e participará de encontros presenciais dos Fellows em eventos no Brasil com todas as despesas de transporte e hospedagem custeadas pelo DAC.

As inscrições começam no dia 25/11!

Informações: https://www.desafioaprendizagemcriativa.com/
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<tr>
<td>679. Duct Tape Network</td>
<td>Leo Burd, Alisha Panjwani, Rachel Garber</td>
<td>The Duct Tape Network (DTN) is a series of fun, hands-on maker clubs that encourage young children (ages 7-10) to use cardboard, tape, wood, fabric, LED lights, motors, and more to bring their stories and inventions to life. We are designing an educational framework and toolkit to engage kids in the creation of things that they care about before they lose their curiosity or get pulled in by more consumer-oriented technology. Work on DTN started in 2014 as part of a collaboration with Autodesk and is now expanding to communities all around the world.</td>
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<td>680. Festival of Invention and Creativity</td>
<td>Leo Burd</td>
<td>The Festival of Invention and Creativity (FIC) is a great celebration of the inventive, collaborative, and hands-on spirit of Brazilian education. In it, children, young people, their families and educators have opportunity to explore high and low tech tools and materials, participate in interactive workshops and learn in a stimulating and relaxed way. The Festival aims to disseminate, inspire and facilitate the implementation of creative learning activities in schools and non-formal educational environments. In 2018, the Brazilian Creative Learning Network, with support from the MIT Media Lab and the Lemann Foundation, facilitated the organization of more than 15 regional Festivals throughout the country.</td>
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<td>681. Getting Started with Scratch</td>
<td>Shruti Dhariwal, Natalie Rusk</td>
<td>Every day, young people around the world use the Scratch programming language to create and share thousands of interactive projects on the Scratch website. Yet many students aren’t sure how to get started coding their own projects. To address this, we have launched a new set of free resources to help students learn to create with code. The Things to Try page offers a variety of project ideas, such as creating an animated story, making a pong game, or designing a virtual pet. For each theme, students can use step-by-step tutorials or printable activity cards. In addition, the site offers educator guides you can use to organize a class or workshop based on the theme. The Scratch Activity Cards is a collection of more than 80 colorful cards with 11 project themes. The front of each card illustrates an activity students can do with Scratch, such as animating a character or keeping score in a game. The back of the card shows how to snap together blocks of code to make their projects come to life. These resources are designed to let students learn at their own pace and personalize their projects. Students can work individually or pair up to make projects together.</td>
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<td>682. Learning Creative Learning</td>
<td>Mitchel Resnick, Yusuf Ahmad, Shruti Dhariwal, Lily Gabaree, Sean Hickey, Katherine McConachie, Yumiko Murai, Marian Muthui, Carmelo Presicce, Carolina Rodeghiero, Natalie Rusk, Eric Schilling, J. Philipp Schmidt, Srishti Sethi, Andrew Sliwinski, Jaleesa Trapp, Moran Tsur, Kiyah WillisGrif Peterson</td>
<td>Learning Creative Learning is an online course and community of educators, designers, technologists, and tinkerers exploring creative learning. Participants create hands-on projects based on their interests, explore new technologies, and share ideas with peers from more than 100 countries. The course is organized by the Lifelong Kindergarten group at the MIT Media Lab. The course is free, and open to everyone. Participants can use the materials at their own pace at any time, or participate with a cohort each fall. <strong>The Spring 2020 session starts on Monday, April 13th.</strong> Sign up to receive more information!</td>
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Learning through Digital Play (LtDP) is a collaboration with the LEGO Foundation to explore how characteristics of learning through play—experiences that are active, social, iterative, meaningful, joyful—can be extended to digital environments. It looks at platforms like Scratch, LEGO Mindstorms, Minecraft, and others that can afford children with a sense of agency and opportunities for guidance from others (peers, parents, teachers, etc.) while creating something shareable. We are also interested in evidence of learning outcomes (academic and life skills), and insights on related topics like enabling factors (e.g., what facilitates use in schools or community settings), along with opportunities and challenges to scaling. The primary product will be a white paper, blog post, and related publications.

Let's Chance: Playful Probabilistic Programming for Children

Probabilistic thinking has been one of the most powerful ideas in the history of science, and it is rapidly gaining even more relevance as it lies at the core of artificial intelligence (AI) systems and machine learning (ML) algorithms that are increasingly pervading our everyday lives. Let’s Chance is designed as a new computational microworld that extends the Scratch Programming Language with new types of code blocks and representations that make it accessible for children to encounter and tinker with the rich ideas and sophisticated concepts of probabilistic modeling and learning. Using the tool, children can imagine and code their own expressive, playful, and personally meaningful probabilistic projects, such as—generative art, music, or text; chance-based games and stories; interactive visualizations; and even advanced projects for making a computer learn from input data using simple Markov models of probabilistic learning, among many other creative possibilities. Constructing and developing ideas and better intuitions about probabilistic thinking will not only help children better understand, critique, appreciate, and create with AI technologies, but also, more importantly, provide them with a powerful lens to think about their own thinking, and about the world around them.

Mekatilili Fellowship Program

Mekatilili is a learning initiative that provides a platform for African youth to enhance technical skills through creative learning approaches that strive to empower learners and enable access to broader job opportunities and meaningful work. Founded in 2016, the program has reached over 400 young people whose average age demographic ranges from 14 – 25 years. The program is conducted through hands on, interactive workshops focusing on human-centered design, rapid prototyping, electronics, computer science, and professional development. Mekatilili Fellowship Program In 2019, the initiative launched the Mekatilili Fellowship Program (MFP), which is an annual gathering of African innovators that aims to foster open ended, playful, and peer-driven learning to promote the development of appropriate and sustainable local technical solutions.

Microworlds

The MIT Scratch Team is exploring ways to make it easier for newcomers to get started creating with coding. We are designing "microworlds" — customized versions of the Scratch editor that contain a small set of blocks for making projects based on a theme. Microworlds offer a more creative entry point to coding. While many introductory coding experiences focus on engaging children in puzzles with one right answer, microworlds provide an open-ended experience, enabling children to explore, experiment, and create, while still providing a more simplified and scaffolded entry point into coding. Each microworld includes subset of the Scratch programming blocks that are most relevant and useful for the particular interest area, along with specialized graphical assets related to the interest area. In addition to aligning with a particular interest area, each microworld highlights how coding can enable young people to create projects and express ideas with code. For example, by tinkering with the music microworld, young people can see how they can use code to make musical melodies and beats; by tinkering with the soccer microworld, young people can see how they can use coding to make objects move and start building their own game.

The project is part of the Coding for All project. The Coding for All project brings together an interdisciplinary research team from the MIT Media Lab, the Digital Media and Learning Hub at University of California Irvine, and Harvard University’s Berkman Center for Internet and Society to develop new online tools and activities to engage more young people in developing computational fluency, particularly youth from groups currently underrepresented in computing.
**Paper Circuits**

Jie Qi

Paper circuitry blends conductive craft materials with electronics components to engage learners in circuit building and programming through making arts and crafts. Learners can take advantage of the expressive richness of paper to create artifacts that are technically functional, aesthetically unique and personally meaningful. Chibitronics circuit stickers are a toolkit designed for paper circuits that transforms flexible circuit boards into interactive stickers for crafting circuits.

**Rede Brasileira de Aprendizagem Criativa**

Leo Burd

Somos uma rede de educadores, artistas, pesquisadores, empreendedores, alunos e outros interessados na implementação de ambientes educacionais mais mão-na-massa, criativos e interessantes nas escolas, universidades, espaços não-formais de aprendizagem e residências de todo o Brasil.

A Rede Brasileira de Aprendizagem Criativa surgiu em 2015 a partir de uma parceria entre o Programa (uma colaboração da Fundação Lemann com a Fundação Telefônica Vivo) e o Lifelong Kindergarten Group do MIT Media Lab. Atualmente, contamos com centenas de participantes de todo o Brasil.

**RemixEd: Creative Learning Design Tools**

Yusuf Ahmad, Luciana Bueno, Annie Liu, and Trinity Gao

While text-editors (e.g., Google Docs, MS Word) might be useful for writing a lecture, they’re not an intuitive medium for designing experiences that are open-ended, challenging, and exciting to both students and educators. This project explores how educators might design learning experiences using alternative tools, including a tool that we’re developing.

In response to the Coronavirus, we’re also exploring ways to support online collaboration among educators and students. This includes efforts to co-design and facilitate extended project based learning using a digital medium that acts both as a tool to think with and a tool for making thinking visible.

Our inspiration comes from the design world, where tools like Sketch or Figma help designers bring ideas to life. From the creative computing movement (think Scratch, Logo, and Glitch) and HCI pioneers like Alan Kay and Bret Victor. From organizers advocating for multiple ways of knowing and thinking (like bell hooks or Sherry Turkle) and the countless educators and young people we have and continue to work with.

You can learn more on our project website.

**Scratch**


Scratch is a programming language and online community that makes it easy to create your own interactive stories, games, and animations — and share your creations online. As young people create and share Scratch projects, they learn to think creatively, reason systematically, and work collaboratively, while also learning important mathematical and computational ideas. Young people around the world have shared more than 40 million projects on the Scratch website, with tens of thousands of new projects shared every day. (For information on who has contributed to Scratch, see the Scratch Credits page.)

**Scratch 3.0**

Carl Bowman, Kasia Chmielinski, Timothy Mickel, Eric Rosenbaum, Ray Schamp, Andrew Sliwinski, Christopher Willis-Ford

Since the release of Scratch in 2007, young people around the world have programmed and shared more than 15 million Scratch projects. The first generation of Scratch was an application that kids downloaded to local machines. With Scratch 2.0, the second and current generation of Scratch, kids create and share their interactive stories, games, and animations directly in web browsers.

Scratch 3.0 is the next generation of Scratch which takes this experience further by empowering children to create with technology on their mobile devices. In addition, Scratch 3.0 puts a special emphasis on creating with a wide variety of mediums including sound, data, and even the physical world by seamlessly integrating with IoT and digitally enhanced construction kits.
ScratchBit is an effort to enable children to create more seamlessly in both the physical and digital world by creating a dedicated physical interface for the Scratch programming language and environment. Designed to be rugged, low cost, and highly composable, the ScratchBit allows children to take the materials around them—such as cardboard, clothes, skateboards, and trees—and transform them into inputs to their digital creations on Scratch. Unlike the Makey Makey which was designed to make these connections electronically, the ScratchBit is designed to create these connections through motion and mechanism.

Scratch BlockArt is an experimental visualization tool designed to let children discover their own computational patterns on Scratch. Existing methods often utilize data about the types of programming blocks used in children’s projects to generate a quantitative assessment of a project’s computational complexity based on limited criteria. BlockArt presents an alternative approach for revealing this data to young creators themselves. Rather than datafying children’s creations, BlockArt is designed to transform the data about their code into creative objects that can spark children’s curiosity and enable them to reflect on their own styles and choices.

For a given username, the tool dynamically generates colorful visualizations representing the number and diversity of programming blocks used in each of their shared projects over time. Children can also click to see the project behind the visualization. The idea is not to evaluate whether they use more or less ‘complex’ blocks, but to reveal how the types of blocks children use are based on their motivations and interests behind creating a specific project. It also shows how looking at the diversity of code in all their projects is a better representation of their learning trajectory than providing a quantitative assessment on individual projects without additional context.

Facilitating opportunities for non-dominant youth to learn how to use technology as a tool to engage civically, and create positive change in their communities is both powerful and revolutionary. Through this curriculum we are developing, we explore activities that allow underrepresented youth to understand computer science as an accessible field of exploration that can be used to develop learners’ understandings of identity, race, and power. Additionally, we’ll examine how allowing underrepresented youth to explore issues in their communities and propose solutions (or create awareness) while enhancing their abilities and understanding of computer science is life-changing, and leads to an increase in participation in STEM and helps students develop as creative thinkers. This curriculum builds off the work of Seymour Papert, Mitch Resnick, and Karen Brennan, emphasizing constructionism, creative learning, and developing computational creators. Additionally, this work builds off of the many, and often unnamed, community organizers and activists in marginalized communities that continue to fight for better lives for all people—emphasizing the right importance of civic engagement and creating positive change in our own communities. This curriculum uses an anti-racist framework, with the belief that everyone has the right to have access to computer science education.

Scratch Community Blocks is an NSF-funded project that extends the Scratch programming language to enable youth to analyze and visualize their own learning and participation in the Scratch online community. With Scratch Community Blocks, youth in the Scratch community can easily access, analyze, and represent data about the ways they program, share, and discuss Scratch projects.

Scratch Day (day.scratch.mit.edu) is a network of face-to-face local gatherings, on the same day in all parts of the world, where people can meet, share, and learn more about Scratch, a programming environment that enables people to create their own interactive stories, games, animations, and simulations. We believe that these types of face-to-face interactions remain essential for ensuring the accessibility and sustainability of initiatives such as Scratch. In-person interactions enable richer forms of communication among individuals, more rapid iteration of ideas, and a deeper sense of belonging and participation in a community. The first Scratch Day took place in 2009. In 2015, there were 350 events in 60 countries.
The Scratch extension system enables anyone to extend the Scratch programming language through custom programming blocks written in JavaScript. The extension system is designed to enable innovating on the Scratch programming language itself, in addition to innovating with it through projects. With the extension system, anyone can write custom Scratch blocks that enable others to use Scratch to program hardware devices such as the LEGO WeDo, get data from online web-services such as weather.com, and use advanced web-browser capabilities such as speech recognition.

Scratch in Practice (SiP) shares stories, strategies, and resources from the Scratch Team and educators around the world. The SiP website features new themes to explore and discuss, and the team hosts conversations on social media to connect with educators using the hashtag #scratchinpractice.

SiP is developed by the Scratch Team and the Lifelong Kindergarten group at the MIT Media Lab. The goal of SiP is to help more educators integrate Scratch into their practice in a way that supports a creative learning approach.

ScratchJr makes coding accessible to younger children (ages 5-7), enabling them to program their own interactive stories, games, and animations. To make ScratchJr developmentally appropriate for younger children, we revised the interface and provided new structures to help young children learn relevant math concepts and problem-solving strategies. ScratchJr is available as a free app for iPads, Android, and Chromebook. ScratchJr is a collaboration between the MIT Media Lab, Tufts University, and Playful Invention Company.

Scratch Memories is a web-based visualization tool that empowers children to celebrate and reflect on their creative journey with Scratch. The system dynamically generates personalized visualizations in the form of a video, highlighting a user’s key moments, diverse creations, and collaborative experiences in the online community.

Existing tools for visualizing children’s progress in computational learning are primarily designed for educators, and often focus exclusively on evaluating predefined concepts in individual projects. The goal of Scratch Memories is to present a new approach towards designing positive reflective experiences that value the full range of children’s contributions as members of a creative community.

The tool engages young people to reflect on their personal growth over time—starting from their first experiments with code to seeing the increasing diversity and complexity of their projects over time; and from their initial interactions in the community to seeing how their projects have inspired others around the world. Such reflective experiences can not only help young creators feel proud about how far they have come, but also to feel inspired by their own trajectories to continue exploring new possibilities.
Scratch Mondays is an initiative to share the Scratch Day spirit to schools in Brazil. After having a big Scratch Day event in 2018 in my hometown, the year after I decided that it would be more interesting to support schools and teachers on their own effort to organize their own events. In April 2019, I experimented together with collaborators in Brazil what I call the Scratch Mondays (Segundas de Scratch), gathering school teachers who want to learn about Scratch and organize a Scratch Day in their own school. For more than six weeks, these educators were spending every Monday night together, experimenting Scratch, organizing their events and sharing ideas on how to practice creative computing with their students.

After almost two months, I thought it was time to share with these educators something that could inspire them to keep exploring Scratch in many ways, even after the Scratch Mondays. So I prepared what I call the Scratch Day kit: a kit full of resources and materials that can inspire people to organize and create activities for a Scratch Day. The kit was homemade and pretty simple, but it was prepared with lots of love, paying attention to details: the materials in the box are things that they've experimented on Scratch Mondays. Others were complementary for the event and based on their interests along our meetings, making the kit not only inspiring but meaningful for these educators.

Here are photos of the box and of the simple and happy night we had sharing it with teachers during a Scratch Monday.

This is the list of items for its first version. You're very welcome to make comments and suggestions.

NEXT EDITION
In 2020, Scratch Mondays will be organized nationwide, as part of the "Scratch & Creative Computing" program lead by the Brazilian Creative Learning Network.

HOW ABOUT YOU?
Do you lead or know any initiative to promote and support schools in their Scratch Days?
What do you think it would be useful in a Scratch Day kit?

Scratch Online Community
Mitchel Resnick, Christian Balch, Sarah Otts, Natalie Rusk, Eric Schilling
Launched in 2007, the Scratch Online Community enables children, primarily between the ages of 8 and 16, to share interactive media such as games, stories, and animations created with the Scratch programming environment. As of September 2016, Scratch members had shared more than 16.3 million projects, and had exchanged over 87.4 million project comments.

The Clubhouse Network
Mitchel Resnick, Leo Burd, Chris Garrity, Sean Hickey, Natalie Rusk, Elisabeth Sylvan, Jaleesa Trapp, Claudia Urrea
The Clubhouse provides a creative and safe out-of-school learning environment where young people from underserved communities around the world work with adult mentors to explore their own ideas, develop new skills, and build confidence in themselves through the use of technology.

The first Clubhouse was established in 1993, as a collaboration between the Lifelong Kindergarten group and The Computer Museum (now part of the Boston Museum of Science). Four guiding principles were created to empower youth from all backgrounds to become more capable, creative, and confident learners. The four principles are: learning by designing, following one’s interests, building a community, and fostering respect and trust. Since then the network has expanded to more than 100 centers in 19 countries, serving more than 25,000 young people annually.

The Lifelong Kindergarten group continues to develop new technologies, introduce new educational approaches, and lead professional-development workshops for Clubhouses around the world.

Learn more: https://theclubhousenetwork.org/
Rosalind W. Picard, Deb Roy, Belen Saldias Fuentes

Try Affective Network!

Emotional contagion in online social networks has been of great interest over the past years. Previous studies have mainly focused on finding evidence of affection contagion in homophilic atmospheres. However, these studies have overlooked users’ awareness of the sentiments they share and consume online. In this work, we present an experiment with Twitter users that aims to help them better understand which emotions they experience on this social network. We introduce Affective Network (Aff-Net), a Google Chrome extension that enables Twitter users to filter and make explicit (through colored visual marks) the emotional content in their news feed.

The extension is powered by machine learning algorithms that classify tweets into different sentiment categories: positive posts tend to use happy or surprising language; negative posts tend to use sad, angry, or disgusting language; and posts without strong emotional language are classified as neutral. Affective Network aims to help social media users better understand which emotions they tend to consume on social media, and how these emotions can spread through their social networks. It was built by researchers at the Laboratory for Social Machines and the Affective Computing group at the MIT Media Lab.

Note that Affective Network does not necessarily reflect the official position of the MIT Media Lab regarding the benefits and drawbacks of filtering out specific emotional content.

Try Affective Network!

Deb Roy, Sarah Ballinger, Susan Blumenthal, MD, Russell Stevens, McKinsey & Company; The Simpsons writers, Creative Artists Agency

Grounded in science, #BeatTheVirus aims to raise awareness of the behaviors we all must adopt to collectively defeat COVID-19.

This effort began in early March 2020 in a conversation between members of the MIT Media Lab and public health experts. They realized the urgent need to bring together fast evolving scientific knowledge of COVID-19 with state-of-the-art social media practices and media analytics to communicate essential information to all. This led to a partnership with McKinsey. Now a growing network of partners have come together to launch #BeatTheVirus, a campaign to raise awareness of the behaviors we all must adopt to collectively defeat COVID-19

Learn more at https://beatthevirus.org/

Eric Chu

Speech synthesis in tutor mode. Using phones for literacy learning is an empowering application of mobile technology, but there are elements of the human tutor that have yet to be replicated in current apps. Namely, when reading a story, a tutor is likely to be more expressive and colorful in tone. When encountering a new word, a tutor might emphasize the vowel phoneme or stress a consonant pair the child has yet to master. By modeling speech with deep neural networks, our speech synthesizer will be able to interpolate between speaking styles, switching from ‘normal’ mode to ‘tutor’ mode as needed.

Ann Yuan

On Collective Debate, users take a test of their morality, then debate an artificial agent regarding a controversial claim: that differences in professional outcomes between men and women arise from bias as opposed to biology. Users indicate how much they agree with the claim, then they exchange arguments with the agent (who assumes the opposite position). After the debate, users are asked to re-evaluate their position. The artificial agent is trained to select arguments that nudge the user to become more moderate.
Loneliness is becoming a global epidemic. As many as 33 percent of Americans report being chronically lonely, with similar percentages being reported in countries around the world. Additionally, this percentage has risen in recent years. Many are turning to online forums as a way to connect with others about their feelings of loneliness and to begin to reduce these feelings. However, oftentimes, posts go unresponded to and online conversations do not take place, perhaps because those conversing did not find a connection with each other, potentially leaving the poster feeling even more lonely. This research explores the how health of conversation should be defined in online support conversations and analyzes the characteristics of conversation that contribute to healthier conversation.

What is Cortico and the Local Voices Network?

Cortico, a non-profit 501(c)(3) in cooperation with MIT’s Laboratory for Social Machines, seeks to foster constructive public conversation in communities and in the media to improve our understanding of one another. To this end, we’re developing a public conversation network called the Local Voices Network (LVN), designed to bring under-heard community voices, perspectives and stories to the center of a healthier public dialogue.

LVN combines in-person and digital listening to host, analyze and connect community conversations at scale. Launching in Wisconsin, New York, and Alabama in 2019 with ambitions to scale nationally, the Local Voices Network is designed around three core efforts:

- Facilitating in-person community dialogue that enables participants to listen, learn, and be heard
- Connecting facilitators and conversations digitally across boundaries
- Opening a new listening channel for journalists, leaders, and the community at large

Why is this work important?

Our media environment prioritizes national perspectives and our politics reinforce divisive tribalism. Local citizenries, however, share a lived community experience. And those local voices, be they from red counties or blue cities, go unheard in the current media environment, drowned out by hyperpartisan noise and toxic dialogue. Social media, designed to connect us, has also divided us into insular “tribes” hostile toward outside views and ripe for the spread of false news, hateful discourse, and extremism. We need to create a new civic space for local voices to be heard in civil, empathic public conversation that heals divisions from the inside of communities out.

FlipFeed is a Google Chrome Extension that enables Twitter users to replace their own feed with that of another real Twitter user. Powered by deep learning and social network analysis, feeds are selected based on inferred political ideology (“left” or “right”) and served to users of the extension. For example, a right-leaning user who uses FlipFeed may load and navigate a left-leaning user’s feed to observe the news stories, commentary, and other content they consume. The user can then decide to flip back to their own feed or repeat the process with another feed. We hope tools like FlipFeed will enable us to explore how social media platforms can be used to mitigate, rather than exacerbate, ideological polarization by helping people explore and empathize with different perspectives.
INSPIRE

Deb Roy, Eric Chu, Nabeel Gillani, Maggie Hughes, Sneha Priscilla Makini, Belen Saldias Fuentes

INSPIRE: Intelligence Never Seeks Perfection, Instead Requires Effort.

Stories help us expand our sense of what’s possible: by hearing from others like us who have overcome personal and societal obstacles in order to become activists, spoken word poets, and game designers (for example), we become more confident and hopeful in our ability to do the same. Unfortunately, many children grow up in environments with little exposure to these stories, and subsequently pursue pathways through their education and careers that could have been very different had they received this exposure early on.

INSPIRE is a program in partnership with a local middle school that seeks to expose students to stories of triumph and hope that they find personally meaningful. A key part of the program is a mobile application that delivers short video stories of professionals talking about their life journeys. Stories are sourced from our content partner Roadtrip Nation, and delivered through a virtual coach (“Jo Jo”). Jo Jo personalizes video recommendations for students and prompts them to reflect after they watch videos. The program also includes in-person community building and engagement initiatives developed in collaboration with the school to supplement and extend what the mobile application can offer on its own.

Ultimately, the goal of INSPIRE is to help students enhance their metacognitive traits and academic outcomes in ways that help them positively and productively shape their own unfolding narratives.

Instrumentation of Montessori Learning Materials

Nazmus Saquib

The Montessori Method is an educational approach that emphasizes independence and respect for a child’s natural development process. Montessori materials are a hallmark of the Montessori Method. These self-teaching tools encourage exploration of concepts in the areas of mathematics, language, sensorial development, and practical life, and allow children to direct their own learning with the light guidance of teachers and peers.

We envision a novel framework of unobtrusive sensor networks to understand and reflect on a child’s learning progress, by instrumenting existing Montessori learning materials using distributed sensing techniques.

Language Simplification

Eric Chu, Marc Exposito Gomez, Nabeel Gillani

The Language Simplification project is developing automatic methods to simplify complex texts to be more easily read and understood by a broader audience, such as children and non-native English speakers. Using neural networks, complex words and phrases can be substituted, the sentence can be split and rephrased, and the overall text can be summarized and compressed. These capabilities can be wrapped into a reading assistance tool for end users, or as a pre-processing step for other NLP tasks.

Learning Loops

Sarah Ballinger, David Bonner, Jim Gray, Sneha Priscilla Makini, Juliana Nazare, Anneli Woolf

Developed as part of the Playful Words research project at the MIT Media Lab’s Laboratory for Social Machines, Learning Loops aims to make literacy learning—both on and off the screen—a family experience. We create small-scale coach-family networks centered around children’s play on custom-built, open-ended literacy learning apps. Building Coach-family networks helps to empower children as authors and facilitate their narrative development.

StoryBlocks, a Learning Loops app, aims to promote literacy and social-emotional development through storytelling for children ages 6-10. StoryBlocks allows children to create and customize their own comic-style stories. These stories are analyzed using tools developed by the Learning Loops team to document children’s narrative development, and support Coaches as they provide personalized scaffolding for children’s narratives.

How does the Learning Loop work?

Data captured from a child’s use of StoryBlocks is streamed via the internet to cloud servers, and can immediately be accessed from a remote location by the child’s Coach. We have developed a Coach’s dashboard, called the Coach Console, powered by play analytics which enables a Coach to rapidly inspect play traces collected from a child’s activity and pull out their salient achievements, or meaningful moments. The Coaches then translate these moments into short personalized messages for the caregiver to inform them on their child’s narrative progress and provide suggestions for how to encourage new activities using StoryBlocks, together with background knowledge about their child’s path to literacy. Caregivers communicate with Coaches via text messages. Coaches can also help the children expand their sphere of learning and exploration by providing feedback on children’s stories and suggesting new story starters directly to the child’s device that are based on trends in the child’s play data.

More info is available on the Learning Loops website.
716. **Play Analytics**

Eric Chu, Juliana Nazare, Mina Soltangheis, Ivan Sysoev, Anneli Woolf

Analyzing detailed data from SpeechBlocks to understand how kids engage with constructionist literacy learning technologies, with the goal of empowering caregivers (e.g. parents, older siblings, tutors) with these insights.

717. **Playful Words**

Preeta Bansal, Eric Chu, Sneha Priscilla Makini, Juliana Nazare, Deb Roy, Nazmus Saquib, Mina Soltangheis, Ivan Sysoev, Anneli Woolf

While there are a number of literacy technology solutions developed for individuals, the role of social—or networked—literacy learning is less explored. We believe that literacy is an inherently social activity that is best learned within a supportive community network including peers, teachers, and parents.

By designing an approach that is child-driven and machine-guided, we hope to empower human learning networks in order to establish an engaging and effective medium for literacy development while enhancing personal, creative, and expressive interactions within communities. We aim to create a network of learners to engage students from different communities in socially collaborative, self-expressive, and playful literacy learning opportunities via mobile devices.

To learn more about this project, please check out: [http://playfulwords.org/](http://playfulwords.org/)

718. **RadioTalk**

Deb Roy, Doug Beeferman, William Brannon

The RadioTalk corpus includes speech recognition transcripts sampled from talk radio broadcasts in the United States between October of 2018 and March of 2019. The corpus is intended for use by researchers in the fields of natural language processing, conversational analysis, and the social sciences. The corpus encompasses approximately 2.8 billion words of automatically transcribed speech from 284,000 hours of radio, together with metadata about the speech, such as geographical location, speaker turn boundaries, gender, and radio program information. The paper introducing it summarizes why and how we prepared the corpus, gives some descriptive statistics on stations, shows and speakers, and carries out a few high-level analyses.

719. **ShapeBlocks**

Deb Roy, Nazmus Saquib

ShapeBlocks is a play analytics observatory that tracks, remembers, and aids players in building traditional LEGO-style structures. As players build a structure using these blocks, an underlying geometry engine analyzes the players’ moves and suggests next steps (if a target structure is provided). The players can see real-time updates of what they are building in 3D. Instead of only suggesting, the AI learns from the players’ moves and corrects itself through reinforcement learning. This essentially gives an opportunity for children and machines to learn shapes and geometry together.

Other use cases include urban design, and interactive strategy games and/or storytelling experiences that fuse the physical and virtual world together.

This is a work in progress. The hardware is complete, and the AI tool and games are currently being built.

720. **Social Mirror**

Deb Roy, Nabeel Gillani, Ann Yuan

Social Mirror is a web application that helps Twitter users interactively explore the politically active parts of their social network. Worsening political polarization over the past several years has exacerbated ideological echo chambers, which in turn have further fueled polarization by widening knowledge and empathy gaps between disparate groups. We hope digital tools like Social Mirror can help inspire self-reflection, and ultimately, intellectual humility by providing people with a new view of their social media ecosystems and helping them form new network connections.

721. **SpeechBlocks**

Jim Gray, Sneha Priscilla Makini, Ivan Sysoev, Anneli Hershman (former contributor), Juliana Nazare (former contributor), Susan Fine (Assistant Clinical Instructor, Department of Communication Sciences and Disorders, Northeastern University)

SpeechBlocks is a medium that allows children (4-5 years old) to engage in open-ended play with writing. They can build arbitrary compositions out of words and associated images, which can become cards, signs, stories, and “books.” We hypothesize that such creative, self-expressive play can foster development of basic literacy skills, like phonological awareness. However, because users of SpeechBlocks are not yet in command of writing, it is necessary for the system to scaffold and guide them. We study a variety of ways to accomplish this.
StoryBlocks aims to promote creative expression, literacy development, and social-emotional development through storytelling for children ages six to ten. In this app, children create personally generated, comic-style stories by inserting characters, setting emotions, typing dialogue, using words to insert images that customize scenes, and recording their voices to narrate their unique stories. With StoryBlocks, we can collect a corpus of children’s stories in order to build analysis tools that can document children’s narrative development over time, and support coaches in providing personalized scaffolding for children’s narratives.

Deb Roy, Bridgit Mendler, Prashanth Vijayaraghavan

The ability to automatically understand and infer characters’ goals and their emotional states is key towards better narrative comprehension. Reasoning about mental representations of various characters in a narrative has been referred to as Theory of Mind (ToM) reasoning. In this work, we propose an unsupervised neural network that exploits the personal stories on social media and incorporates commonsense knowledge about characters’ motivations and reactions to generate interpretable trajectories of characters’ mental states. We find that our model is capable of learning coherent mental representations from characters’ actions and their affect states. We evaluate our model using a publicly available dataset for mental state tracking of characters in short commonsense stories.

The Electome: Where AI meets political journalism

The Electome is a machine-driven mapping and analysis of public sphere content and conversation associated with the 2016 presidential election campaign. Through its unprecedented view of the national election conversation, LSM aims to shift some of our collective focus from who’s winning/losing (traditional “horse race” polls and projections) to the issues the campaign is being fought over (the “Horse Race of Ideas”). The Electome is fueled by two primary data streams: the entire Twitter archive and daily output (the so-called 500m Tweet per day “fire hose”) as well as a sample of daily content from 30 digital news sites (5k-6k stories per day). A series of machine learning algorithms identify those Tweets and stories specifically about the election, then classify them by topic, candidate, organization and a number of other filters. The classified data is then run through various semantic and network analytics that continuously measure and visualize:

- the share of conversation or coverage that any given issue or candidate commands on Twitter and in the news media, respectively—and how the two platforms are aligned
- which issues are most closely associated with each candidate on Twitter (via co-occurrence candidate/issue references in single Tweets)
- how much of the public sphere conversation and coverage is about substantive issues as compared to politics (polls, projections, process) and the candidates’ character and personality
- specific sub-topics and representative Tweets within broader conversations about specific issues or candidates
- the level of “incivility” (profanity, insults, violence, ethnic/sexual slurs) within the public Twitter conversation about any given issue or candidate
- who is influencing the public sphere election conversation (via a composite Twitter/media influence metrics)

LSM’s deployment of Electome analytics has been supported by the Knight Foundation, with the goal of fueling news coverage that is more responsive to what matters most to the public. To that end, LSM has:
- provided customized analysis to several Electome media outlets—including the Washington Post, Bloomberg News, CNN Politics and Fusion—as well as publishing its own analysis in Medium
- collaborated with the Commission on Presidential Debates to offer Electome analysis to the general election debates’ moderators and credentialed journalists
- also collaborated with the Roper Center for Public Opinion Research at Cornell University for integration of the Center’s polling in Electome analytics/dashboard
- and built a self-service dashboard featuring several Electome analytic tools for journalists and analysts to produce their own issue-driven analyses and visualizations.

Looking beyond the 2016 election, LSM sees Electome technology as enabling new forms—and, importantly, creators—of investigative and explanatory journalism by democratizing access to powerful data mapping, analysis and visualization tools.

Deb Roy, Eric Chu, Russell Stevens, Prashanth Vijayaraghavan, Soroush Vosoughi

The Story Learning Machine

The Storytelling project uses machine-based analytics to identify the qualities of engaging and marketable media. By developing models with the ability to “read” emotional arcs and semantic narrative video content, our researchers aim to map video story structure across many story types and formats.

To complement this content-based analysis, our researchers are also developing methods to analyze how emotional and semantic narratives affect viewer engagement with these stories. By tracking “referrals” of video URLs on social media networks, our researchers hope to identify how stories of different types and genres diffuse across networks, who influences this spread, and how video story distribution might be optimized. Given this project’s two-pronged strategy, our hope is to develop a robust story learning machine that uniquely maps the relationship between story structure and engagement across networks.
Danielle Wood, Christine Joseph

For decades, the International Space Station (ISS) has operated as a bastion of international cooperation and a unique testbed for microgravity research. Beyond enabling insights into human physiology in space, the ISS has served as a microgravity platform for numerous science experiments. In recent years, private industry has also been affiliating with NASA and international partners to offer transportation, logistics management, and payload demands. As the costs of flying projects to the ISS decrease, the barriers limiting non-traditional partners, like emerging space nations and startups, from accessing the ISS as a platform also decrease.

However, the ISS in its current form cannot be sustained forever. As NASA looks towards commercialization of the low Earth orbit (LEO) space and the development of a cislunar station, concrete plans for shifting the public-private relationship of the ISS are unclear. With the consistent need to continue microgravity research—from governments and private industry—understanding the socio-technical and policy issues that affect the marketplace for future microgravity platforms is essential to maintaining an accessible and sustainable space economy.

How will the US and other governments design public-private partnerships to pursue economic and social goals in the LEO microgravity ecosystem? What governance structures will influence who is eligible to operate platforms for activities including tourism, research, manufacturing, and outreach? How will international collaboration occur in the future LEO microgravity ecosystem?

This project contributes to progress on these questions by offering technology policy insight using methods from Systems Engineering. Through case study research and numerous expert interviews, this project examines the stakeholders, needs, objectives, system functions and forms for the ISS and microgravity research platforms now and in the future. Particular attention is paid towards explaining the market dynamics that affect the administrative and economic barriers to entry for emerging space nations and non-traditional spaceflight participants.

Javier Stober

Paraffin wax (common candlewax) shows promise as a high-performing hybrid rocket propellant for chemical propulsion systems. Its inherent safety and simplicity advantages and low cost (less than $4/kg) make it well-suited for widespread adoption for launch and in-space applications. Its benign nature compared to the toxicity and carcinogenicity which characterize currently-used propellants, such as hydrazine and nitrogen tetroxide, make paraffin an especially strong candidate for new entrants to the propulsion community.

The Space Enabled research group is focused on the use of paraffin wax for small satellite missions. Specifically, we are investigating the centrifugal casting of paraffin into annular geometries on Earth as well as in microgravity. The research group envisions the repurposing of paraffin thermal insulation at end of life for deorbit maneuvers. However, such a mission would require centrifugal casting of paraffin in orbit—a task which has never been done before. The microgravity environment is expected to reduce rotation rate demands for uniform casting, and the overall experimental investigation aims to quantify the differences between 1-g and microgravity centrifugal casting.
The space environment will likely produce authoritarian social relations. How might engineered and social technologies and create democratic counterweights?

How do you quit your job when you work in outer space?

The physical features of the space environment (big, and lethal, absent capital-intensive technological mediation) will likely create authoritarian patterns of social relations among humans living and working in space. It is difficult for a free society of equals to take root in a context in which surveillance is total, government is private, and noncompliance with authorities is lethal.

What might a democracy agenda look like in this environment? Sociotechnical systems such as law and economies offer the potential for democratic counterweights. By building out the architectures for systems of philosophy, law, economics, and technology design that center relational equality, we can lay the groundwork for democratic relations in space and other extreme environments, such as an Earth increasingly marked by climate change.

This project is my effort to outline the stakes and frame the challenges of building systems that can accommodate democratic social relations in future space habitations and economies. I am incubating several projects and collaborations across philosophy, law, market design and development economics, science and technology studies (STS), and technology design that will collectively offer a vision of justice in our space futures.

Antarctica is a unique and beautiful continent that is key to the global ecosystem and climate. Research based in Antarctica is helping scientists explore cutting-edge questions in oceanography, physics, climate science, ecology, and more. To most members of the public, however, Antarctica appears to be a cold and inhospitable place with little relevance to daily life. This project asks if combining a citizen science campaign and an immersive museum experience can increase a sense of stewardship to care for Antarctica within people around the world.

For this project, the Space Enabled research group designed a concept for an interactive, room-scale multi-sensory presentation providing education regarding the Antarctic. This presentation is designed to be placed in an informal education venue such as an aquarium or science museum. The immersive presentation helps participants understand this dynamic region through an experience that combines photos, video, sound, smell, and temperature changes. The information draws on multiple types of data from earth science satellites (i.e., ICESAT), airborne science platforms (i.e., IceBridge), and in-situ sensors (i.e., underwater video cameras and photographs). As participants go through the experience, they hear vignettes about specific research areas in Antarctica, including studies on penguin colonies, ice cores, meteorite searches, and ocean food chains.

In addition to the physical, interactive presentation, the second aspect of the project involves a companion Citizen Science campaign. Specifically, citizen scientists and students located in countries near the Southern Ocean (including Chile, South Africa, New Zealand, and Australia) are invited to participate in a data collection campaign about their part of the Southern Ocean. A proposed mobile application in both English and Spanish could invite participants to submit photographs of the shoreline on the Southern Ocean. Our team is prototyping a small, low-cost kit that allows citizen scientists to take measurements such as temperature, salinity and pH measurements from coastal areas facing the Southern Ocean. Information from these citizen scientists could be incorporated into the physical presentation in the museum. Meanwhile, the visual aspects of the presentation may be provided online as photo or video files that could be downloaded to host on their own platforms.
In December of 1968, the first human voyage to the moon catapulted the population of Earth into a new era of space exploration and self-reflection. It was during this voyage that astronauts Bill Anders and Jim Lovell recognized a familiar pale blue dot in the distance and snapped a photo, providing us with the first view of Earth from this distant vantage point. Since its release, this image has been the subject of various works of art and literature. After having seen the Earth from space, some astronauts reported a cognitive shift in awareness about the planet. This shift helped them recognize the fragility of Earth and has inspired feelings of global citizenship. Thanks to the writings of author Frank White, we now call this shift, “The Overview Effect.”

The Media Lab’s Space Enabled research group asks if it is possible to create a similar cognitive shift in Earthlings through an experiential installation piece meant to inspire global citizenship as well as universal citizenship. “Earthrise: A 50 Year Contemplation” will celebrate the original Earthrise photo by creating a meditative space of reflection where participants are transported to the surface of Earth’s moon to reflect on themselves, Earth, and the solar system. The viewer will be immersed in the sensory experience that surrounds them. Through artificially creating “The Overview Effect,” and altering our perspective, might we also inspire a more sustainable approach in our exploration of the solar system?

Frank White, author of The Overview Effect: Space Exploration and Human Evolution, is launching “The Human Space Program” through his new book, The Cosma Hypothesis: Implications of the Overview Effect (Emergent Media; February 2019). The goal of the Human Space Program is to create a comprehensive, sustainable, and inclusive plan for exploring and developing the solar system. It is built around White’s “Cosma Hypothesis,” which addresses the question, “What is the purpose of human space exploration? Why has the evolutionary process brought humanity to the brink of becoming a spacefaring species?” White’s surprising conclusion: Homo sapiens have a very significant role to play in the evolution of the universe (Cosma). Space Enabled appreciates the opportunity to dialogue with Frank about these fundamental questions shaping the moral compass of human exploration beyond earth.

By Lizbeth B. De La Torre, Rachael Petersen, Frank White and Danielle Wood

One of the six research methods used by the Space Enabled research group is creating models of complex systems by drawing on techniques from systems engineering, social science, and earth science. The environment, human vulnerability and societal impact, human decision-making, and technology design are four domains with complex interactions that can be simulated in computer models. Environmental models use physics-based simulations to estimate the behavior of natural features in the atmosphere, water, or vegetation. Human vulnerability and societal impact models estimate how people are impacted by environmental hazards, such as hurricanes, or ecosystems services, such as the benefits of forests, using physics-based simulations or economic regressions. Human decision-making models, which can be decentralized agent-based or centralized decision-logic, simulate the actions taken by humans in response to environmental features. The technology design model allows humans to explore options for technical systems (such as earth observation satellites) to improve awareness of the state of the environment.

While significant benefit has come from addressing each domain individually in existing models, and yet more from considering certain groupings (such as the economic valuations that combine both decision-making and societal impact), capturing all four together in an integrated software model can enable us to overcome important challenges that lie at the intersections of these domains.

Work is underway to make such integrated models a reality. We are developing applications aimed at facilitating the targeted harvesting of water hyacinth in southern Benin and at assisting the city of Rio de Janeiro with the conservation of their mangrove forests (see the images below). Once complete, these models will accomplish the dual objectives of improving remote observation-informed decision-making and to enable the exploration of remote observation system options, including specifying the architecture of a custom satellite.

The Space Enabled research group aims to develop an open-source standard for software model interfaces and begin to build an open-source library of new and existing computational models for use in a variety of applications. Hopefully this library will be used to facilitate the use of remote sensing data, craft policy here on Earth, and design new remote sensing platforms. As we progress and work towards version 1.0, we hope others will join us in this endeavor.
Danielle Wood, Ufuoma Ovienmhada

All over Africa, experts use satellite Earth Observation (EO) data for applications such as monitoring crop health or assessing the risk of disease vectors. These applications are often done at a national scale meaning there is a challenge to ensure that end users such as small companies, rural communities or otherwise marginalized groups benefit from EO systems. This project explores an EO application with the enterprise Green Keeper Africa (GKA) based in Cotonou, Benin, that addresses the management of an invasive plant species that is threatening local economic activities such as fishing. GKA helps control the infestation of the water hyacinth on Lake Nokoue by repurposing the plant into a product that absorbs oil-based waste. The EO application is an online Environmental Observatory that utilizes satellite, aerial and ground data to map the location of the water hyacinth over time, providing valuable information for government, private and public users. The research outcomes presented in this project address processes that (i) outline the steps for a small company in Benin to setup and operate a new EO technological capability, and (ii) enable low cost data collection of parameters describing the coastal water ecosystem.

In the observatory, the technique Normalized Difference Vegetation Index (NDVI) is applied to free satellite data to identify likely locations of the hyacinth in the target region of Lake Nokoue.
Joy Buolamwini

Algorithmic auditing has emerged as a key strategy to expose systematic biases embedded in software platforms, yet scholarship on the impact of algorithmic audits on increasing algorithmic fairness and transparency in commercial systems is nascent. To analyze the impact of publicly naming and disclosing performance results of biased AI systems, we investigate the commercial impact of Gender Shades, the first algorithmic audit of gender and skin type performance disparities in commercial facial analysis models. This paper 1) outlines the audit design and structured disclosure procedure used in the Gender Shades study; 2) presents new performance metrics from targeted companies IBM, Microsoft, and Megvii (Face+++) on the Pilot Parliaments Benchmark (PPB) as of August 2018; 3) provides performance results on PPB by non-target companies Amazon and Kairos; and 4) explores differences in company responses as shared through corporate communications that contextualize differences in performance on PPB. Within seven months of the original audit, we find that all three targets released new API versions.

All targets reduced accuracy disparities between males and females and darker and lighter-skinned subgroups, with the most significant update occurring for the darker-skinned female subgroup that underwent a 17.7% - 30.4% reduction in error between audit periods. Minimizing these disparities led to a 5.72% to 8.3% reduction in overall error on the Pilot Parliaments Benchmark (PPB) for target corporation APIs. The overall performance of non-targets Amazon and Kairos lags significantly behind that of the targets, with error rates of 8.66% and 6.60% overall, and error rates of 31.37% and 22.50% for the darker female subgroup, respectively.

While algorithmic fairness may be approximated through reductions in subgroup error rates or other performance metrics, algorithmic justice necessitates a transformation in the development, deployment, oversight, and regulation of facial analysis technology. Consequently, the potential for weaponization and abuse of facial analysis technologies cannot be ignored, nor the threats to privacy or breaches of civil liberties diminished even as accuracy disparities decrease. More extensive explorations of policy, corporate practice, and ethical guidelines are thus needed to ensure vulnerable and marginalized populations are protected and not harmed as this technology evolves.

Arwa Michelle Mboya

Definition:
combining form
Prefix: allo-
other; different.
“allopatric”
imagi-nation
noun: imagination; plural noun: imaginations

the faculty or action of forming new ideas, or images or concepts of external objects not present to the senses.

allo-“is” is a project exploring alternative imaginations through the use of interactive, immersive experiences.

How can we leverage new technologies in low-cost environments to create location based experiences similar to theme-parks? Arwa is developing a mixed reality tool kit that can be used by creators to create immersive location based experiences at a low cost. She plays with projection mapping, AR/VR/XR, sensor technologies, theatre design, and narrative/story structures.

We further investigate the socio-economic and mental health impact of immersive spaces in low income communities across Africa.
Cindy Bishop, Lorrie LeJeune

As we know from our ‘maker’ classes and workshops, different capabilities and approaches can yield remarkable projects. Let’s facilitate a ‘smart’ building that is at least as much about the people as the tech.

Because the walls and halls of E14 and E15 are subject to building codes and approvals, we decided to create our own walls that can contain and display, conceal or reveal, and in the true MIT innovative spirit, move. As a result, our ArtCube was born. Once we gather the remaining materials to finish construction, we will open for submissions (beginning of 2019).

Ethan Zuckerman, Anushka Shah

Civic Entertainment is a project based at the Center for Civic Media that explores the intersection of civic engagement with film, television, radio, theatre, literature, and digital entertainment. The project aims to study the modes in which entertainment can create greater knowledge of public institutions, motivate citizens towards democratic duties, and present effective strategies of social and political change.

The research focuses on studying the ways in which fiction media can affect change in thought and behavior, develops case studies of past and existing films and television shows that reflect or carry elements of civic engagement, explores the representation of protest and activism in popular culture, and experiments with techniques to balance civic education with humor or drama within entertainment.

The project has a key focus on Indian entertainment and works with Civic Studios (www.civicstudios.com), a Mumbai-based production firm, on creating civic entertainment content for young people across India.

Ethan Zuckerman, J Nathan Matias, Merry Mou

The CivilServant project supports online communities to run their own experiments on the effects of moderation practices on antisocial behavior, harassment, discrimination, and community well-being online. All results are published to an open repository of collective knowledge on practices that contribute to fair, flourishing social life online.

The first experiment, in a 13.2 million subscriber community, showed that posting rules at the top of conversations prevents problems and increases engagement.

Ethan Zuckerman, Joy Buolamwini

Code4Rights promotes human rights through technology education. By facilitating the development of rights-focused mobile applications in workshops and an online course, Code4Rights enables participants to create meaningful technology for their communities in partnership with local organizations. For example, Code4Rights, in collaboration with It Happens Here, a grassroots organization focused on addressing sexual violence, created the First Response Oxford App to address sexual violence at Oxford University. Over 30 young women contributed to the creation of the app, which provides survivors of sexual violence and friends of survivors with information about optional ways to respond, essential knowledge about support resources, critical contact details, and answers to frequently asked questions.

DataBasic is a suite of web-based tools that give people fun and relevant ways learn how to work with data. Existing tools focus on operating on data quickly to create some output, rather than focusing on helping learners understand how to work with data. This fails the huge population of data literacy learners, who are trying to build their capacity in various ways. Our tools focus on the user as learner. They provide introductory activities, connect to people with fun sample datasets, and connect to other tools and techniques for working with data. We strongly believe in building tools focused on learners, and are putting those ideas into practice on these tools and activities. Visit databasic.io today to try it out!

Rahul Bhargava

Struggling to build your organization’s ability to work with data? Use our hands-on learning program to kickstart your data culture.

databasic.io
741. **Data Therapy**  
Ethan Zuckerman, Rahul Bhargava  
As part of our larger effort to build out a suite of tools for community organizers, we are helping to build their capacity to do their own creative data visualization and presentation. New computer-based tools are lowering the barriers of entry for making engaging and creative presentations of data. Rather than encouraging partnerships with epidemiologists, statisticians, or programmers, we see an opportunity to build capacity within small community organizations by using these new tools. This work involves workshops, webinars, and writing about how to pick more creative ways to present their data stories.  
datatherapy.org

742. **dataVisionaRi**  
Arwa Michelle Mboya  
dataVisionaRi is an exploration of big data visualizations techniques in VR. The research generates new taxonomy and structures around data visualization in the relatively unexplored space of Virtual Reality. The first demonstration, NodeitAll, is a Media Cloud link map that experiments with various ways to present edges and nodes, playing with interaction and manipulability. Developed in Unity, the scripting is open source so that anyone may input their own CSV files and have a randomly generated network graph.

743. **DeepStream**  
Ethan Zuckerman, Gordon Mangum, Vivian Diep, David Anderton  
Citizens and journalists are increasingly choosing to live stream civic events. But live streams are currently hard to find and lack in-depth information about the events being documented. DeepStream seeks to increase participation in this emergent form of media by creating tools for live stream curation. Users can add relevant news stories, images, tweets, and other media to almost any live or on-demand video to create more informative and engaging viewing experiences. To help find relevant videos, Deepstream includes a search engine that lets you find live streams across multiple platforms with a single search query.  
By lowering the technical barriers to creating enhanced live and on-demand videos, Deepstream makes it possible for newsrooms or individuals to curate the chaos of live streams from major global events, add media to video in real-time like fact-checking live political debates, or create enhanced version of documentaries with extra footage and related stories that appear at specific times. Our goal is to connect viewers to global events in a way that emphasizes local perspectives and deeper engagement, while maintaining the experience of immediacy and authenticity that is an essential part of live streaming.
Ishaan Grover, Adam Haar Horowitz, Abhinandan Jain, Pedro Reynolds-Cuellar, Oscar Rosello, Tomas Vega Galvez, Eyal Perry, Matthew Ha

Inspiration

Sleep is a forgotten country of the mind. A vast majority of our technologies are built for our waking state, even though a third of our lives are spent asleep. Current technological interfaces miss an opportunity to access the unique, imaginative, elastic cognition ongoing during dreams and semi-lucid states. In turn, each of us misses an opportunity to use interfaces to influence our own processes of memory consolidation, creative insight generation, gist extraction, and emotion regulation that are so deeply sleep-dependent. In this project, we explore ways to augment human creativity by extending, influencing, and capturing dreams in Stage 1 sleep. It is currently impossible to force ourselves to be creative because so much creative idea association and creative incubation happens in the absence of executive control and directed attention. Sleep offers an opportunity for prompting creative thought in the absence of directed attention, if only dreams can be controlled.

Scientific Background

During sleep onset, a window of opportunity arises in the form of hypnagogia, a semi-lucid sleep state where we all begin dreaming before we fall fully unconscious. Hypnagogia is characterized by phenomenological unpredictability, distorted perception of space and time, and spontaneous, fluid idea association. Edison, Tesla, Poe, and Dalí each accessed this state by napping with a steel ball in hand to capture creative ideas generated in hypnagogic microdreams when it dropped to the floor below.

Engineering and Experimentation

In this project we modernize this technique, using an interactive social robot accompanied with a custom sleep stage tracking system, and auditory biofeedback. We are able to influence, extract information from, and extend hypnagogic microdreams for the first time: we found that active use of hypnagogia with the system can augment human creativity. This system enables future research into sleep, an underutilized and understudied state of mind vital for memory, learning, and creativity. This system is a tested prototype. Dormio has a published study in alt.CHI (see publications section), a second publication under review, and is being used in four independent labs for ongoing sleep research. We’re actively presenting and testing the work in varied settings, like the McLean Technology in Psychiatry Summit and the International Sleep Replay Workshop, to gain information about sleep interventions in various conditions. We’ve just completed a second study (with 50 participants) on dream incubation and creativity augmentation. But sleep onset is still poorly understood, and dreams are still really a mystery—we’re learning! Please reach out if anything seems off, or just to chat.

This work has been hugely collaborative. The following people, in alphabetical order by first name, have all made it possible: Abhinandan Jain, Adam Haar Horowitz, Christina Chen, Eyal Perry, Ishaan Grover, Kathleen Esfahany, Matthew Ha, Oscar Rosello, Pattie Maes, Pedro Reynolds-Cuellar, Robert Stickgold, and Tomás Vega. For an in-depth dive, see the FAQ below and see more on this website.

If you want all the details, please read this thesis and offer any feedback!
Dressing Audio Technologies: In/Visibility and Civic Resistance in the Age of Surveillance Capitalism

Rubez Chong Lu Ming

The fourth industrial revolution has brought new meanings to surveillance in the digital age. In recent years, we have seen the rise of state and enterprise-driven surveillance—from the tracking of our digital footprint, to piloting facial recognition CCTVs, to eavesdropping on our private conversations—the panopticon is more ubiquitous than ever. Governments and corporations are increasingly data-hungry, arguing that more data beget better services, greater convenience, and higher levels of security. Convenience, however, has come at the cost of personal privacy. User data have been mined, analyzed, profiled in the name of “free services” and “personalized experiences”. Whilst researchers, artists, and activists have drawn attention to the threats posed by camera and video surveillance technologies, lesser attention has been given to audio surveillance technologies. These technologies, however, are often more covert and less visible than a CCTV. The hidden networks of audio surveillance obscure and yet fuels the reach of surveillance capitalism. In the past year alone, we have witnessed a myriad of privacy breaches and violations in the voice technology space. With the smart speaker market projected to outnumber the human population by 2021, I argue that a thorough and critical analysis of privacy, surveillance and their relationship to voice technologies is pressing.

I am particularly interested in the dynamics of the seen/unseen, the visible/invisible, surface/subterranean, public/private of surveillance and counter-surveillance. Surveillance, I argue, operates in duo-realms, serving different purposes and goals. While overt surveillance acts as a means of control, covert surveillance obscures the mechanisms of the loss of privacy and agency. My research aims to uncover, unpack and expose these multi-dimensions of surveillance/counter-surveillance and their manifestations. I am interested in the aesthetic of control and subversion, asking: “what does civic resistance look/feel/sound like in the age of surveillance capitalism?” My research has 3 key contributions: i) employing critical design as a medium for reflecting on the cultural, social, and ethical implications of emerging technologies; ii) making hyper-visible the aesthetics of surveillance and counter-surveillance via DressKit, a hardwear kit for voice technologies; iii) amplifying camp as a methodology of subversion. DressKit is a low to high-tech hardwear kit for voice technologies that uses ultrasonic jamming and sound masking to reclaim users’ privacy in the age of surveillance capitalism.

Each kit comes with a range of visual metaphors of sound jamming and masking, employing camp as a visual aesthetic i.e., “earplugs”, “earmuffs”, “plunger”, “hat”, “phone case. The kit is a play on “wearable technologies” by questioning who (or what) is doing the wearing. Use camp as an analytical framework to make hyper-visible the invisible, emerging technologies of surveillance capitalism given its historical roots in subversion and performance of heteronormativity in black queer communities.

The research will culminate with 3 outputs: i) DressKit: a hardwear kit for audio surveillance technologies; ii) an exhibit of DressKit, placing surveillance on (literal) display; iii) a visual ethnography of the aesthetics of surveillance and counter-surveillance in non-Western contexts, particularly in Singapore. Success will be determined by a panel critique of the exhibit, feedback from participants in the visual ethnographic piece, and the extent to which conversations can be masked via jamming and masking. Further, I am interested in surveilling audio surveillance by conducting a short experiment investigating the extent to which Facebook (and Instagram) are listening in on our conversations. I will conduct several engineered conversations along key trigger words with a set of participants where they will self-monitor the types and number of related ads that show up on their feed after the conversation.

Ultimately, my work is about the de-centering and re-centering of power, de-centering power by exposing and unveiling the aesthetics of surveillance in order to re-center and reclaiming civic privacy and agency in the age of surveillance capitalism.

First Upload

Ethan Zuckerman, Matthew Carroll, Joe Goldbeck, Cynthia Fang

First Upload is a tool for verifying the authenticity of news imagery. It helps find the first upload of imagery, particularly videos. Finding the person who uploaded a video is a key to determining authenticity, because often it is necessary to contact that person directly. It is being developed with input from YouTube and Bloomberg. Currently we have a working prototype, built for the YouTube site.

FOLD

Matthew Carroll, Cesar A. Hidalgo, Ethan Zuckerman, Alexis Hope, Kevin Zeng Hu, Joe Goldbeck, Nathalie Huynh

Some readers require greater context to understand complex stories. FOLD (fold.cm) is an open publishing platform with a unique structure that lets writers link media cards to the text of their stories. Media cards can contain videos, maps, tweets, music, interactive visualizations, and more. FOLD is used by journalists, educators, and storytellers around the world.
Ethan Zuckerman, Joy Buolamwini
The Gender Shades project pilots an intersectional approach to inclusive product testing for AI.

Algorithmic Bias Persists

Gender Shades is a preliminary excavation of the inadvertent negligence that will cripple the age of automation and further exacerbate inequality if left to fester. The deeper we dig, the more remnants of bias we will find in our technology. We cannot afford to look away this time, because the stakes are simply too high. We risk losing the gains made with the civil rights movement and women’s movement under the false assumption of machine neutrality. Automated systems are not inherently neutral. They reflect the priorities, preferences, and prejudices—the coded gaze—of those who have the power to mold artificial intelligence.

Ethan Zuckerman, Rahul Bhargava, Neil Gaikwad, Alexis Hope, Dennis Jen, Yasmine (Jasmin) Rubinovitz, Belen Saldias Fuentes

Your social media. Your rules.

Gobo is an experiment, not a startup. We’re building it to change the conversation on social media and imagine a better version of it. This is a technology-to-think-with—a tool we want you to play with and push against. Gobo is being built by a small team at MIT Media Lab’s Center for Civic Media, where we work on technologies for social change.

For questions, feedback, and musings, you can reach the Gobo team at gobo@media.mit.edu.

Control your own feed
Social media companies use algorithms to control what we see on our feeds, but we don’t know how these algorithms work. As a result, we’re often unaware why certain posts show up in our feed while others don’t. Gobo allows you to control the algorithms, or a set of “rules,” so you can decide what gets shown on your feed and know why.

Connect multiple platforms
We believe that multiple social media platforms should exist to serve different purposes. However, it’s not easy to keep up with all these platforms, especially when your data can’t be easily shared between them. Gobo allows you to connect up to three platforms, so you can view all of your feeds in one place.

See what gets hidden
We believe that transparency can help you better understand what you see on social media and keep platforms accountable for algorithmic bias. Gobo tells you why certain posts are hidden based on the rules you set. It also shows you how many posts are hidden, so you can understand the overall impact of the rules you set.

Expand your perspective
Social media companies make assumptions about what we want to see based on what we read and click on. They tend to show us content we’re already engaging with, reinforcing our echo chambers. Instead of assuming what you want to see, Gobo allows you to add unfamiliar perspectives into your feed, so you can better understand the range of opinions that are shared online.

J Nathan Matias
How do people who lead communities on online platforms join together in mass collective action to influence platform operators? Going Dark analyzes a protest against the social news platform reddit by moderators of 2,278 communities in July of 2015. These moderators collectively disabled their communities, preventing millions of readers from accessing major parts of reddit and convincing the company to negotiate over their demands. This study reveals social factors—including the work of moderators, relations among moderators, relations with platform operators, factors within communities, and the isolation of a community—that can lead to participation in mass collective action against a platform.
Ethan Zuckerman, Rubez Chong Lu Ming, Victoria Palacin

LinkedOut aims to define and build solutions to facilitate societal reentry for formerly incarcerated individuals.

In collaboration with the Office of Returning Citizens (ORC), an office under the City of Boston that facilitates reentry, LinkedOut is working to design a reentry infrastructure to shut the revolving door of incarceration and reincarceration.

Our work seeks to break down the structural and societal barriers to successful reentry. At the structural level, we are building technologies to develop richer data biographies of the lives of returning citizens, and in doing so provide policymakers with the robust data required for effective reentry programs. Importantly, our goal is to embed values in technology design to humanize the reentry process. On the societal level, we have begun to expose holes in the moral fabric of society as we draw attention to the dehumanization and stigmatization of returning citizens. These invisible societal norms disempower returning citizens from rebuilding their lives. Thus, our work demands a reimagination of our current justice system—one that rehabilitates rather than retributes, that embraces rather than excludes—to design for a successful reentry journey.

**Ongoing Project**

**Pathfinder: How it works**

Pathfinder is a personalized case management platform that helps case managers design and keep track of returning citizens’ transition back into society. It makes real-time recommendations in the categories of healthcare, housing, employment, education, financial health, and community engagement based on the unique needs of each returning citizen. Beyond tracking the reentry journey of returning citizens, Pathfinder helps service providers identify and track community service gaps in meeting the needs of their clients.

In summary, Pathfinder has three key aims:

- Develop individualized case management plans for returning citizens
- Streamline work process for service providers to improve efficacy of services
- Capture community-level determinants of reentry for more informed reentry policies and programs

**Collaborators**

Pathfinder is a collaboration between, with, and for returning citizens. We are partnering with Coders Beyond Bars, a non-profit that teaches returning citizens to code; through this partnership, returning citizens will co-design and co-develop Pathfinder with the MIT Media Lab.

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Ethan Zuckerman, Tal Achituv, Catherine D’Ignazio, Alexis Hope, Taylor Levy, Che-Wei Wang, Alexandra Metral

In September 2014, 150 parents, engineers, designers, and healthcare practitioners gathered at the MIT Media Lab for the "Make the Breast Pump Not Suck!" Hackathon. As one of the midwives at our first hackathon said, "Maternal health lags behind other sectors for innovation." This project brought together people from diverse fields, sectors, and backgrounds to take a crack at making life better for moms, babies, and new families.
Catherine D'Ignazio, Alexis Hope
A Case for Breastfeeding Innovation

Breastfeeding saves lives.

If women globally were able to meet the WHO's public health goal to exclusively breastfeed for the first six months, we would prevent 823,000 infant deaths. For every 597 women who optimally breastfeed, one maternal or child death is prevented.

Breastfeeding promotes long-term wellness for mother and baby.

Breastfeeding protects against child infections and malocclusion, increases intelligence, and reduces the risk of obesity and diabetes for children¹. Breastfeeding decreases mothers' risk of breast cancer and optimal breastfeeding would lead to 20,000 fewer cases every year¹. It may also protect against ovarian cancer and diabetes¹. Women who are supported to successfully establish breastfeeding in early months have a lower risk for postpartum depression.

Breastfeeding saves healthcare costs.

If women in the US were able to meet the WHO's public health goal to exclusively breastfeed for the first six months, we would save $17.2 billion dollars in annual costs treating preventable events, including infant and maternal deaths, SIDS, ear infections and necrotizing enterocolitis in babies, and heart attacks, diabetes and breast cancer in mothers.

Work environments and policies in the US are hostile to breastfeeding.

The US is one of only three nations worldwide without paid parental leave. The other countries in this club are Papua New Guinea and Lesotho⁴. Women's return to work outside the home is the leading factor for early weaning⁵. Most US work environments do not provide material or policy-based support for breastfeeding women, including parental leave, flexible schedules, on-site daycare, breaks and spaces for nursing and pumping.

The Hackathon

Our team is thrilled to produce a weekend with the leading innovators in breastfeeding and postpartum health, along with many mamas, papas, babies, students, and newcomers. This time around we have a focus on equity and inclusive innovation in breastfeeding. We want to catalyze the development of tech, products, spaces, clothing, programs and services that have an eye on affordability and access as well as cultural diversity.

REFERENCES:


https://en.wikipedia.org/wiki/Parental_leave


Ethan Zuckerman, Rahul Bhargava, Sands Fish, Natalie Gyenes, Alexis Hope, Anushka Shah, David LaRochelle, Hal Roberts

Media Cloud is a platform for studying media ecosystems. By tracking millions of stories published online, the system allows researchers to track the spread of memes, media framings, and the tone of coverage of different stories.

We aggregate data from over 50,000 news sources from around the world and in over 20 languages including Spanish, French, Hindi, Chinese, and Japanese. Our tools help analyze, deliver, and visualize information about media conversations on three primary levels: attention and coverage peaks of issues, network analysis, and clustered language use.

The platform is open source and open data, designed to be a substrate for a wide range of communications research efforts. Media Cloud is a collaboration between Civic Media and the Berkman Klein Center for Internet and Society at Harvard Law School.

To learn more or register for a free account, check out www.mediacloud.org.
Ethan Zuckerman, Adrienne Debigare, Dalia Othman
Recent years have witnessed a surge in online digital storytelling tools, enabling users to more easily create engaging multimedia narratives. Increasing Internet access and powerful in-browser functionality have laid the foundation for the proliferation of new online storytelling technologies, ranging from tools for creating interactive online videos to tools for data visualization. While these tools may contribute to diversification of online storytelling capacity, sifting through tools and understanding their respective limitations and affordances poses a challenge to storytellers. The NetStories research initiative explores emergent online storytelling tools and strategies through a combination of analyzing tools, facilitating story-hack days, and creating an online database of storytelling tools.

Ethan Zuckerman, Matthew Carroll, Catherine D'Ignazio, Catherine D'Ignazio, Emerson College Engagement Lab, Jay Vachon
NewsPix is a simple news-engagement application that helps users encounter breaking news in the form of high-impact photos. It is currently a Chrome browser extension (mobile app to come) that is customizable for small and large news organizations. Currently, when users open a new, blank page in Chrome, they get a new tab with tiles that show recently visited pages. NewsPix replaces that view with a high-quality picture from a news site. Users interested in more information about the photo can click through to the news site. News organizations can upload photos ranging from breaking news to historic sporting events, with photos changing every time a new tab is clicked.

Ethan Zuckerman, Catherine D'Ignazio, Don Blair, Adrienne Debigare, Public Lab Community
The Open Water Project aims to develop and curate a set of low-cost, open source tools enabling communities everywhere to collect, interpret, and share their water quality data. Traditional water monitoring uses expensive, proprietary technology, severely limiting the scope and accessibility of water quality data. Homeowners interested in testing well water, watershed managers concerned about fish migration and health, and other groups could benefit from an open source, inexpensive, accessible approach to water quality monitoring. We’re developing low-cost, open source hardware devices that will measure some of the most common water quality parameters, using designs that makes it possible for anyone to build, modify, and deploy water quality sensors in their own neighborhood.

Ethan Zuckerman, Rahul Bhargava, Edward Platt
Newspaper front pages are a key source of data about our media ecology. Newsrooms spend massive time and effort deciding what stories make it to the front page. PageOneX makes coding and visualizing newspaper front page content much easier, democratizing access to newspaper attention data. Communication researchers have analyzed newspaper front pages for decades, using slow, laborious methods. PageOneX simplifies, digitizes, and distributes the process across the net and makes it available for researchers, citizens, and activists.

Ethan Zuckerman, J Nathan Matias, Andres Monroy Hernandez, Emma Spiro
Organizations are deploying gratitude-tracking systems to encourage appreciation, promote pro-sociality, and monitor employee wellbeing. We present the case study of one such system, called Gratia, adopted by a Fortune 500 company for over four years. We analyzed 422,209 messages of thanks and examined temporal patterns of appreciation, reciprocity, and repeated interactions. We also compared the formal organizational chart to the informal network expressed through the system. We found that gratitude is strongly reciprocated, that time between thanks is relatively long, and that it is predominantly given to peers outside one’s immediate team.
Promise Tracker
Ethan Zuckerman, Rahul Bhargava, Joy Buolamwini, Alexis Hope, Jude Mwenda Ntabathia, Emilie Reiser
Promise Tracker is a citizen-monitoring platform designed to help communities track issues they care about and use that information to advocate for change with local government, institutions or the press. Using a simple web application, community groups can design a mobile phone-based survey, distribute the survey to community members’ phones, collect data using a mobile app, visualize it on a map, and use the resulting data to advocate for change. We are currently partnering with civil society groups, universities, and government oversight agencies in Brazil who are implementing Promise Tracker as part of multi-sector alliances to monitor public spending and services. Key collaborators include:

University of São Paulo’s CoLaboratory for Development and Participation
Ministry of Transparency, Oversight and the Comptroller-General
Federal University of Pará’s Laboratory for Innovation and Oversight in the Public Sector
Social Observatory of Belém
Project SOL
Humanitas360

Scanner Grabber
Pattie Maes, Ethan Zuckerman, Tal Achituv, Luke Berndt (OpenMhz)
Scanner Grabber is a digital police scanner that enables reporters to record, playback, and export audio, as well as archive public safety radio (scanner) conversations. Like a TiVo for scanners, it’s an update on technology that has been stuck in the last century. It’s a great tool for newsrooms. For instance, a problem for reporters is missing the beginning of an important police incident because they have stepped away from their desk at the wrong time. Scanner Grabber solves this because conversations can be played back. Also, snippets of exciting audio, for instance a police chase, can be exported and embedded online. Reporters can listen to files while writing stories, or listen to older conversations to get a more nuanced grasp of police practices or long-term trouble spots. Editors and reporters can use the tool for collaborating, or crowdsourcing/public collaboration.

Space/Craft
Alexis Hope, Tim Savas
Space/Craft explores sculpting in zero gravity. Making artistic works by hand is a fundamentally human act, but how will it transform in space? What non-existent forms of artistic expression does different gravity enable?

Prior work has explored the adaptation of mark-making techniques, like painting, in zero gravity (e.g., Frank Pietronigro’s creativity chamber for drift painting, 1998). Less explored in zero gravity are sculptural works, although 3D printing has been shown to work normally in space (NASA technical publication, 2017).

Digital modeling tools allow us to break the laws of physics as we create, but we can’t replicate those processes on Earth. Space/Craft will explore the artistic processes and possibilities enabled by zero gravity by using a hot glue gun to “draw in 3D.” During each cycle of microgravity, the artist will use the mark-making tool to sculpt shapes inside of a containment cube. The thin strings of glue will float into forms that could not be created on Earth by the same process, and then cool in order to “freeze” in that position. The containment cube will be video recorded as the works are created, to be shared after the flight with communities of craft and design. The cooled sculptures will also be preserved so they can be exhibited after the flight. This project will inform reflective writing about the evolving nature of hand-craft in new environments that humans will likely inhabit in the future.
Pedro Reynolds-Cuellar

IAP 2020 applications are open!

This course is open to all MIT students?

Online application: bit.ly/mitcoffee2

Application Deadline: December 1st, 2019

In the Civic Media group, we are exploring new theoretical frameworks for design, and novel design education methodologies that serve a future celebrating the pluriversal, rather than the universal.

The “Technology Design for Coffee Production in Colombia” is a program exploring this concept. This IAP course convened 16 participants from seven countries to explore technological, social, and business solutions for small-scale coffee production along with coffee growers in rural Colombia. The course was a unique, multidisciplinary, multicultural design experience in which people came together to co-design technologies and to connect with rural coffee growers inventive practices in rural Colombia.

The course immersed participants into different agricultural practices, primarily coffee growing, as well as in the ontologies traditional to these practices. In an effort to expose participants to non-mainstream design methods and mechanisms of invention, our research team focused on surfaced local knowledge through research materials and hands-on activities.

Ethan Zuckerman, Catherine D’Ignazio

The Babbling Brook

The Babbling Brook is an unnamed neighborhood creek in Waltham, MA, that winds its way to the Charles River. With the help of networked sensors and real-time processing, the brook constantly tweets about the status of its water quality, including thoughts and bad jokes about its own environmental and ontological condition. Currently, the Babbling Brook senses temperature and depth and cross-references that information with real-time weather data to come up with extremely bad comedy. Thanks to Brian Mayton, the Responsive Environments group, and Tidmarsh Farms Living Observatory for their support.

Jia Zhang

The Constant Atlas

An interactive atlas of census data for direct consumption by individual citizens.