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 are:

**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**
Thirty years ago, 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 (Open AG)**
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.

The most current information about our research is available on the MIT Media Lab website, at http://www.media.mit.edu/research.
The Lab has also organized the following special interest groups (SIGs), which deal with particular subject areas.

**Advancing Wellbeing**

In contributing to the digital revolution, the Media Lab helped fuel a society where increasing numbers of people are obese, sedentary, and glued to screens. Our online culture has promoted meaningfulness in terms of online fame and numbers of viewers, and converted time previously spent building face-to-face relationships into interactions online with people who may not be who they say they are. What we have helped to create, willingly or not, often diminishes the social-emotional relationships and activities that promote physical, mental, and social health. Moreover, our workplace culture escalates stress, provides unlimited caffeine, distributes nutrition-free food, holds back-to-back sedentary meetings, and encourages overnight hackathons and unhealthy sleep behavior. Without being dystopian about technology, this effort aims to spawn a series of projects that leverage the many talents and strengths in the Media Lab in order to reshape technology and our workplace to enhance health and wellbeing.

With support from the Robert Wood Johnson Foundation (RWJF), Cisco, Deloitte, LKK Health Products Group, and Steelcase, the Media Lab’s Advancing Wellbeing initiative addresses the role of technology in shaping our health, and explores new approaches and solutions to wellbeing. The program is built around education and student mentoring; prototyping tools and technologies that support physical, mental, social, and emotional wellbeing; and community initiatives that will originate at the Media Lab, but be designed to scale.

Thanks to the Carson Reynolds Memorial Fund for generously funding the video lectures and making them freely accessible around the planet.

**Autism & Communication Technology Initiative**

The Autism & Communication Technology Initiative utilizes the unique features of the Media Lab to foster the development of innovative technologies that can enhance and accelerate the pace of autism research and therapy. Researchers are especially invested in creating technologies that promote communication and independent living by enabling non-autistic people to understand the ways autistic people are trying to communicate; improving autistic people’s ability to use receptive and expressive language along with other means of functional, non-verbal expression; and providing telemetric support that reduces reliance on caregivers’ physical proximity, yet still enables enriching and natural connectivity as wanted and needed.

**CE 2.0**

Most of us are awash in consumer electronics (CE) devices: from cellphones, to TVs, to dishwashers. They provide us with information, entertainment, and communications, and assist us in accomplishing our daily tasks. Unfortunately, most are not as helpful as they could and should be; for the most part, they are dumb, unaware of us or our situations, and often difficult to use. In addition, most CE devices cannot communicate with our other devices, even when such communication and collaboration would be of great help. The Consumer Electronics 2.0 Initiative (CE 2.0) is a collaboration between the Media Lab and its sponsor companies to formulate the principles for a new generation of consumer electronics that are highly connected, seamlessly interoperable, situation-aware, and radically simpler to use. Our goal is to show that as computing and communication capability seep into more of our everyday devices, these devices do not have to become more confusing and complex, but rather can become more intelligent in a cooperative and user-friendly way.

**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.

Center for Mobile Learning
The Center for Mobile Learning invents and studies new mobile technologies to promote learning anywhere anytime for anyone. The Center focuses on mobile tools that empower learners to think creatively, collaborate broadly, and develop applications that are useful to themselves and others around them. The Center’s work covers location-aware learning applications, mobile sensing and data collection, augmented reality gaming, and other educational uses of mobile technologies. The Center’s first major activity will focus on App Inventor, a programming system that makes it easy for learners to create mobile apps by fitting together puzzle piece-shaped ‘blocks’ in a web browser.

City Science
The world is experiencing a period of extreme urbanization. In China alone, 300 million rural inhabitants will move to urban areas over the next 15 years. This will require building an infrastructure equivalent to the one housing the entire population of the United States in a matter of a few decades. In the future, cities will account for nearly 90 percent of global population growth, 80 percent of wealth creation, and 60 percent of total energy consumption. Developing better strategies for the creation of new cities, is therefore, a global imperative. Our need to improve our understanding of cities, however, is pressed not only by the social relevance of urban environments, but also by the availability of new strategies for city-scale interventions that are enabled by emerging technologies. Leveraging advances in data analysis, sensor technologies, and urban experiments, City Science will provide new insights into creating a data-driven approach to urban design and planning. To build the cities that the world needs, we need a scientific understanding of cities that considers our built environments and the people who inhabit them. Our future cities will desperately need such understanding.

Code Next
Code Next, a Media Lab collaboration with Google, aims to create a new generation of computer scientists, innovators, and inventors and have them emerge from the underserved 8-12th grade Black and Latino populations. The pilot launched in January 2016 with two laboratories, one in NYC and one in Oakland. Curricula is being developed by the Media Lab. Code Next’s first year of tutorials and maker activities are focusing on several domains: fabrication and design, digital music and interactive media, and game design. Our toolbox includes laser cutters, 3D printers, Scratch, Makey Makey, and Arduino. In the second year, we will introduce Python, Raspberry Pi, BeagleBone, and emphasize making code to make things that make things. Learning domains will emphasize computational design, mechatronics, robotics, web design, web technology, and 2D and 3D design. In addition, we teach parents technology and provide academic enrichment to our students. We will have four successive cohorts of freshmen (2016, 2017, 2018, 2019).

Communications Futures Program
The Communications Futures Program conducts research on industry dynamics, technology opportunities, and regulatory issues that form the basis for communications endeavors of all kinds, from telephony to RFID tags. The program operates through a series of working groups led jointly by MIT researchers and industry collaborators. It is highly participatory, and its agenda reflects the interests of member companies that include both traditional stakeholders and innovators. It is jointly directed by Dave Clark (CSAIL), Charles Fine (Sloan School of Management), and Andrew Lippman (Media Lab).

Connection Science
As more of our personal and public lives become infused and shaped by data from sensors and computing devices, the lines between the digital and the physical have become increasingly blurred. New possibilities arise, some promising, others alarming, but both with an inexorable momentum that is supplanting time honored practices and institutions. MIT Connection Science is a cross-disciplinary effort drawing on the strengths of faculty, departments and researchers across the Institute, to decode the meaning of this
dynamic, at times chaotic, new environment. The initiative will help business executives, investors, entrepreneurs and policymakers capitalize on the multitude of opportunities unlocked by the new hyperconnected world we live in.

**Emerging Worlds**
The Emerging Worlds SIG is focused on emerging opportunities to address pressing challenges, and leapfrog existing solutions. Emerging Worlds are vibrant ecosystems where we are rolling out new and innovative citizen-based technologies using a framework that supports the wide-ranging needs of urban populations. It is a co-innovation initiative to solve problems in areas such as health, education, financial inclusion, food and agriculture, housing, transportation, and local business.

**Ethics**
The mission of MIT Media Lab’s new Ethics Initiative is to foster multi-disciplinary program designs and critical conversations around ethics, wellbeing, and human flourishing. The initiative seeks to create collaborative platforms for scientists, engineers, artists, and policy makers to optimize designing for humanity.

**Future of News**
The Future of News is designing, testing, and making creative tools that help newsrooms adapt in a time of rapid change. As traditional news models erode, we need new models and techniques to reach a world hungry for news, but whose reading and viewing habits are increasingly splintered. Newsrooms need to create new storytelling techniques, recognizing that the way users consume news continues to change. Readers and viewers expect personalized content, deeper context, and information that enables them to influence and change their world. At the same time, newsrooms are seeking new ways to extend their influence, to amplify their message by navigating new paths for readers and viewers, and to find new methods of delivery. To tackle these problems, we will work with Media Lab students and the broader MIT community to identify promising projects and find newsrooms across the country interested in beta-testing those projects.

**Future Storytelling**
The Future Storytelling working group at the Media Lab is rethinking storytelling for the 21st century. The group takes a new and dynamic approach to how we tell our stories, creating new methods, technologies, and learning programs that recognize and respond to the changing communications landscape. The group builds on the Media Lab’s more than 25 years of experience in developing society-changing technologies for human expression and interactivity. By applying leading-edge technologies to make stories more interactive, improvisational, and social, researchers are working to transform audiences into active participants in the storytelling process, bridging the real and virtual worlds, and allowing everyone to make and share their own unique stories. Research also explores ways to revolutionize imaging and display technologies, including developing next-generation cameras and programmable studios, making movie production more versatile and economic.

**Pixel Factory**
Data is ubiquitous in a world where our understanding of it is not. The Pixel Factory is a special interest group working to help people understand their data by making tools to transform data into stories. The Pixel Factory is led by the Macro Connections group, a group experienced in the creation of data visualization engines including: The Observatory of Economic Complexity (atlas.media.mit.edu), Immersion (immersion.media.mit.edu), and Pantheon (pantheon.media.mit.edu).

**Terrestrial Sensing**
The deeply symbiotic relationship between our planet and ourselves is increasingly mediated by technology. Ubiquitous, networked sensing has provided the earth with an increasingly sophisticated electronic nervous system. How we connect with, interpret, visualize, and use the geoscience information shared and gathered is a deep challenge, with transformational potential. The Center for Terrestrial Sensing aims to address this challenge.

**Ultimate Media**
Visual media has irretrievably lost its lock on the audience but has gained unprecedented opportunity to evolve the platform by which it is communicated and to become integrated with the social and data worlds in which we live. Ultimate Media is creating a platform for the invention, creation, and realization of new ways to explore and participate in the media universe. We apply extremes of access, processing, and interaction to build new media experiences and explorations that permit instant video blogging, exploration of the universe of news and narrative entertainment, and physical interfaces that allow people to collaborate around media.
# Table of Contents

**Fadel Adib: Signal Kinetics** .......................................................... 1
1. Cyber-Physical Security and Privacy (System & Network Security) ........................................ 1
2. Health Sensing (Human-Computer Interaction) ..................................................................... 1
3. Programming Wireless Networks (Computer Networks) .................................................... 1
4. Seeing Through Walls (Computer Vision) ........................................................................... 1
5. Wireless Sensing for Drones & Agile Robots (Robotics) ..................................................... 1

**V. Michael Bove: Object-Based Media** .................................................. 2
6. 3D Telepresence Chair .................................................................................. 2
7. 4K/8K Comics ............................................................................................. 2
8. 8K Time Machine ......................................................................................... 2
9. Aerial Light-Field Display ............................................................................ 2
10. BigBarChart .............................................................................................. 2
11. Bottles&Boxes: Packaging with Sensors .................................................................. 2
12. Callope ...................................................................................................... 2
13. Consumer Holo-Video ............................................................................... 3
14. Dressed in Data .......................................................................................... 3
15. DUSK ........................................................................................................ 3
16. Emotive Materials ....................................................................................... 3
17. EmotiveModeler: An Emotive Form Design CAD Tool ............................................ 3
18. Everything Tells a Story .............................................................................. 3
19. Free-Space Haptic Feedback for 3D Displays ...................................................... 3
20. Guided-Wave Light Modulator for Holographic Video ........................................... 3
21. Infinity-by-Nine .......................................................................................... 4
22. ListenTree: Audio-Haptic Display in the Natural Environment .................................. 4
23. Live Objects .............................................................................................. 4
24. Narratarium ............................................................................................... 4
25. Networked Playscapes: Dig Deep ...................................................................... 4
26. Pillow-Talk ................................................................................................. 4
27. Printed Wearable Holographic Display .................................................................. 4
28. Programmable Synthetic Hallucinations ................................................................... 5
30. QuiE Sense: Distributed Context-Awareness System for WIFI Enabled Mobile Devices .................................................. 5
31. ShAir: A Platform for Mobile Content Sharing .................................................... 5
32. Smell Narratives ......................................................................................... 5
33. SurroundVision .......................................................................................... 5
34. Thermal Fishing Bob: In-Place Environmental Data Visualization .............................. 5

**Edward Boyden: Synthetic Neurobiology** ............................................ 6
35. Cognitive Integration: The Nature of the Mind ..................................................... 6
36. Optogenetics: Molecules Enabling Neural Control by Light .................................. 6
37. Prototype Strategies for Treating Brain Disorders ............................................... 6
38. Tools for Mapping the Molecular Structure of the Brain ......................................... 6
39. Tools for Recording High-Speed Brain Dynamics ............................................... 7
40. Understanding Normal and Pathological Brain Computations ............................... 7

**Cynthia Breazeal: Personal Robots** ....................................................... 7
41. AIDA: Affective Intelligent Driving Agent .......................................................... 7
42. Animal-Robot Interaction ............................................................................... 7
43. Children Use Nonverbal Cues to Learn from Robots ................................ ........ 8
44. Cloud-HRI ................................................................................................. 8
45. Computational Trust ..................................................................................... 8
46. Curious Learning: Understanding Learning Behaviors for Early Literacy ............. 8
47. DragonBot: Android Phone Robots for Long-Term HRI .................................... 8
48. Global Literacy Tablets .................................................................................. 8
49. Huggable: A Robotic Companion for Long-Term Health Care, Education, and Communication .................................................. 9
50. Huggable: A Social Robot for Pediatric Care .................................................... 9
51. Human-Robot Trust ...................................................................................... 9
52. Interactive Inference of Mental States .................................................................. 9
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hiroshi Ishii: Tangible Media</td>
<td>19</td>
</tr>
<tr>
<td>108. aeroMorph</td>
<td>19</td>
</tr>
<tr>
<td>109. bioLogic</td>
<td>19</td>
</tr>
<tr>
<td>110. ChainFORM</td>
<td>19</td>
</tr>
<tr>
<td>111. Cilias: 3D-Printed Micro Pillar Structures for Surface Texture,</td>
<td>19</td>
</tr>
<tr>
<td>Actuation and Sensing</td>
<td></td>
</tr>
<tr>
<td>112. HydroMorph</td>
<td>20</td>
</tr>
<tr>
<td>113. Inflated Appetite</td>
<td>20</td>
</tr>
<tr>
<td>114. inFORCE</td>
<td>20</td>
</tr>
<tr>
<td>115. inFORM</td>
<td>20</td>
</tr>
<tr>
<td>116. jamSheets: Interacting with Thin Stiffness-Changing Material</td>
<td>20</td>
</tr>
<tr>
<td>117. LineFORM</td>
<td>20</td>
</tr>
<tr>
<td>118. Material</td>
<td>20</td>
</tr>
<tr>
<td>119. MirrorFugue</td>
<td>21</td>
</tr>
<tr>
<td>120. Pneudino</td>
<td>21</td>
</tr>
<tr>
<td>121. Pneumatic Shape-Changing Interfaces</td>
<td>21</td>
</tr>
<tr>
<td>122. Radical Atoms</td>
<td>21</td>
</tr>
<tr>
<td>123. S.C.A.L.E.</td>
<td>21</td>
</tr>
<tr>
<td>124. TRANSFORM</td>
<td>21</td>
</tr>
<tr>
<td>125. TRANSFORM: Adaptive and Dynamic Furniture</td>
<td>21</td>
</tr>
<tr>
<td>Joseph M. Jacobson: Molecular Machines</td>
<td>22</td>
</tr>
<tr>
<td>126. Evolutron: Deep Learning for Protein Design</td>
<td>22</td>
</tr>
<tr>
<td>127. Scaling Up DNA Logic and Structures</td>
<td>22</td>
</tr>
<tr>
<td>128. Synthetic Genome Engineering</td>
<td>22</td>
</tr>
<tr>
<td>Sepandar Kamvar: Social Computing</td>
<td>23</td>
</tr>
<tr>
<td>129. A Multi-Sensor Wearable Device for Analyzing Stress Response in</td>
<td>23</td>
</tr>
<tr>
<td>Preschool Classrooms</td>
<td></td>
</tr>
<tr>
<td>130. Big Data for Small Places</td>
<td>23</td>
</tr>
<tr>
<td>131. Boundaries Drawings</td>
<td>23</td>
</tr>
<tr>
<td>132. Computational Scope and Sequence for a Montessori Learning</td>
<td>23</td>
</tr>
<tr>
<td>Environment</td>
<td></td>
</tr>
<tr>
<td>133. Microculture</td>
<td>23</td>
</tr>
<tr>
<td>134. Motivation and Mobility: Bicycles and Sensors in the City</td>
<td>23</td>
</tr>
<tr>
<td>135. Narrative Visualization for Distributed Urban Interventions</td>
<td>24</td>
</tr>
<tr>
<td>136. New Learning Materials for Computational Thinking</td>
<td>24</td>
</tr>
<tr>
<td>137. Proximity Networks</td>
<td>24</td>
</tr>
<tr>
<td>138. Storyboards</td>
<td>24</td>
</tr>
<tr>
<td>139. The Dog Programming Language</td>
<td>24</td>
</tr>
<tr>
<td>140. Wildflower Montessori</td>
<td>25</td>
</tr>
<tr>
<td>141. You Are Here</td>
<td>25</td>
</tr>
<tr>
<td>Kent Larson: Changing Places</td>
<td>25</td>
</tr>
<tr>
<td>142. Cities Network</td>
<td>25</td>
</tr>
<tr>
<td>143. CityScope</td>
<td>25</td>
</tr>
<tr>
<td>144. FlickInk</td>
<td>26</td>
</tr>
<tr>
<td>145. Mobility on Demand</td>
<td>26</td>
</tr>
<tr>
<td>146. Places</td>
<td>26</td>
</tr>
<tr>
<td>Andrew Lippman: Viral Communications</td>
<td>26</td>
</tr>
<tr>
<td>147. 8K Time into Space</td>
<td>26</td>
</tr>
<tr>
<td>148. As You Need It</td>
<td>26</td>
</tr>
<tr>
<td>149. Captions++</td>
<td>26</td>
</tr>
<tr>
<td>150. DnDo</td>
<td>27</td>
</tr>
<tr>
<td>151. GIFGIF</td>
<td>27</td>
</tr>
<tr>
<td>152. IoT Recorder</td>
<td>27</td>
</tr>
<tr>
<td>153. MedRec</td>
<td>27</td>
</tr>
<tr>
<td>154. NewsClouds</td>
<td>27</td>
</tr>
<tr>
<td>155. News Graph</td>
<td>27</td>
</tr>
<tr>
<td>156. Perspectives</td>
<td>27</td>
</tr>
<tr>
<td>157. PubPub</td>
<td>28</td>
</tr>
<tr>
<td>158. Solar Micro-Mining</td>
<td>28</td>
</tr>
<tr>
<td>159. Super Cut Notes</td>
<td>28</td>
</tr>
<tr>
<td>160. SuperGlue</td>
<td>28</td>
</tr>
<tr>
<td>161. This Is How</td>
<td>28</td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Tod Machover: Opera of the Future</td>
<td>29</td>
</tr>
<tr>
<td>Ambisonic Surround-Sound Audio Compression</td>
<td>29</td>
</tr>
<tr>
<td>Breathing Window</td>
<td>29</td>
</tr>
<tr>
<td>...but not simpler...</td>
<td>29</td>
</tr>
<tr>
<td>City Symphonies: Massive Musical Collaboration</td>
<td>29</td>
</tr>
<tr>
<td>Death and the Powers: Global Interactive Simulcast</td>
<td>30</td>
</tr>
<tr>
<td>Empathy and the Future of Experience</td>
<td>30</td>
</tr>
<tr>
<td>Fablur</td>
<td>30</td>
</tr>
<tr>
<td>Fensadense</td>
<td>30</td>
</tr>
<tr>
<td>Hyperinstruments</td>
<td>31</td>
</tr>
<tr>
<td>Hyperproduction: Advanced Production Systems</td>
<td>31</td>
</tr>
<tr>
<td>Hyperscore</td>
<td>31</td>
</tr>
<tr>
<td>Media Scores</td>
<td>31</td>
</tr>
<tr>
<td>Music Visualization via Musical Information Retrieval</td>
<td>31</td>
</tr>
<tr>
<td>Remote Theatrical Immersion: Extending &quot;Sleep No More&quot;</td>
<td>32</td>
</tr>
<tr>
<td>SfDR: Deep Learning-Based Real-Time Speaker Identification</td>
<td>32</td>
</tr>
<tr>
<td>Sound Cycles</td>
<td>32</td>
</tr>
<tr>
<td>Using the Voice As a Tool for Self-Reflection</td>
<td>32</td>
</tr>
<tr>
<td>Vocal Vibrations: Expressive Performance for Body-Mind Wellbeing</td>
<td>32</td>
</tr>
<tr>
<td>Patti Maes: Fluid Interfaces</td>
<td>33</td>
</tr>
<tr>
<td>A Flying Pantograph</td>
<td>33</td>
</tr>
<tr>
<td>Augmented Airbrush</td>
<td>33</td>
</tr>
<tr>
<td>BrainVR: A Neuroscience Learning Experience in Virtual Reality</td>
<td>33</td>
</tr>
<tr>
<td>CocoVerse: A Playground for Cocreation and Communication in Virtual Reality</td>
<td>33</td>
</tr>
<tr>
<td>Dermal Abyss: Interfacing with the Skin by Tattooing Biosensors</td>
<td>33</td>
</tr>
<tr>
<td>Enlight</td>
<td>33</td>
</tr>
<tr>
<td>Express</td>
<td>34</td>
</tr>
<tr>
<td>EyeRing: A Compact, Intelligent Vision System on a Ring</td>
<td>34</td>
</tr>
<tr>
<td>FingerReader</td>
<td>34</td>
</tr>
<tr>
<td>Food Attack</td>
<td>34</td>
</tr>
<tr>
<td>GlassProv Improv Comedy System</td>
<td>34</td>
</tr>
<tr>
<td>HandsOn: A Gestural System for Remote Collaboration Using Augmented Reality</td>
<td>34</td>
</tr>
<tr>
<td>HRQ</td>
<td>35</td>
</tr>
<tr>
<td>Invisibilia: Revealing Invisible Data as a Tool for Experiential Learning</td>
<td>35</td>
</tr>
<tr>
<td>Jual!: Remote Language Learning in Shared Virtual Space</td>
<td>35</td>
</tr>
<tr>
<td>KickOut: A Wearable System for Foot Interactions with Digital Devices</td>
<td>35</td>
</tr>
<tr>
<td>LuminAR</td>
<td>35</td>
</tr>
<tr>
<td>MARS: Manufacturing Augmented Reality System</td>
<td>35</td>
</tr>
<tr>
<td>Move Your Glass</td>
<td>35</td>
</tr>
<tr>
<td>Oasis</td>
<td>35</td>
</tr>
<tr>
<td>Open Hybrid</td>
<td>36</td>
</tr>
<tr>
<td>PsychicVR</td>
<td>36</td>
</tr>
<tr>
<td>Reality Editor</td>
<td>36</td>
</tr>
<tr>
<td>Remot-IO: A System for Reaching into the Environment of a Remote Collaborator</td>
<td>36</td>
</tr>
<tr>
<td>Robotic Symbionts</td>
<td>36</td>
</tr>
<tr>
<td>Scanner Grabber</td>
<td>36</td>
</tr>
<tr>
<td>ScreenSpire</td>
<td>36</td>
</tr>
<tr>
<td>ShowMe: Immersive Remote Collaboration with 3D Hand Gestures</td>
<td>37</td>
</tr>
<tr>
<td>Skrin</td>
<td>37</td>
</tr>
<tr>
<td>SmileCatcher</td>
<td>37</td>
</tr>
<tr>
<td>STEM Accessibility Tool</td>
<td>37</td>
</tr>
<tr>
<td>TagMe</td>
<td>37</td>
</tr>
<tr>
<td>The Challenge</td>
<td>37</td>
</tr>
<tr>
<td>TreeSense</td>
<td>37</td>
</tr>
<tr>
<td>WATCH</td>
<td>37</td>
</tr>
<tr>
<td>WordSense</td>
<td>38</td>
</tr>
<tr>
<td>Project</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>Neri Oxman: Mediated Matter</td>
<td>38</td>
</tr>
<tr>
<td>221. 3D Printing of Functionally Graded Materials</td>
<td>38</td>
</tr>
<tr>
<td>222. Additive Manufacturing in Glass: Electrospinning and Spark Gap Glass Blowing</td>
<td>38</td>
</tr>
<tr>
<td>223. Anthozoa</td>
<td>38</td>
</tr>
<tr>
<td>224. Beast</td>
<td>39</td>
</tr>
<tr>
<td>225. Bots of Babel</td>
<td>39</td>
</tr>
<tr>
<td>226. Building-Scale 3D Printing</td>
<td>39</td>
</tr>
<tr>
<td>227. Carpal Skin</td>
<td>39</td>
</tr>
<tr>
<td>228. CNSILK: Computer Numerically Controlled Silk Cocoon Construction</td>
<td>39</td>
</tr>
<tr>
<td>229. DCP: Digital Construction Environment</td>
<td>39</td>
</tr>
<tr>
<td>230. Digital Construction Platform v.1</td>
<td>40</td>
</tr>
<tr>
<td>231. Digital Construction Platform v.2</td>
<td>40</td>
</tr>
<tr>
<td>232. Digitally Reconfigurable Surface</td>
<td>40</td>
</tr>
<tr>
<td>233. FABRICOLYTIC: Variable-Property 3D Printing as a Case for Sustainable Fabrication</td>
<td>40</td>
</tr>
<tr>
<td>234. FitSocket: Measurement for Attaching Objects to People</td>
<td>40</td>
</tr>
<tr>
<td>235. Functionally Graded Filament-Wound Carbon-Fiber Prosthetic Sockets</td>
<td>41</td>
</tr>
<tr>
<td>236. G3P</td>
<td>41</td>
</tr>
<tr>
<td>237. G3P 2.0</td>
<td>41</td>
</tr>
<tr>
<td>238. Gemini</td>
<td>41</td>
</tr>
<tr>
<td>239. Lichtenberg 3D Printing</td>
<td>41</td>
</tr>
<tr>
<td>240. Living Mushhari</td>
<td>41</td>
</tr>
<tr>
<td>241. Meta-Mesh: Computational Model for Design and Fabrication of Biomimetic Scaled Body Armors</td>
<td>42</td>
</tr>
<tr>
<td>242. MonoCoque</td>
<td>42</td>
</tr>
<tr>
<td>243. PCB Origami</td>
<td>42</td>
</tr>
<tr>
<td>244. Printing Living Materials</td>
<td>42</td>
</tr>
<tr>
<td>245. Printing Multi-Material 3D Microfluidics</td>
<td>42</td>
</tr>
<tr>
<td>246. Rapid Craft</td>
<td>43</td>
</tr>
<tr>
<td>247. Raycounting</td>
<td>43</td>
</tr>
<tr>
<td>248. Rotflace</td>
<td>43</td>
</tr>
<tr>
<td>249. Silk Pavilion</td>
<td>43</td>
</tr>
<tr>
<td>250. SpiderBot</td>
<td>43</td>
</tr>
<tr>
<td>251. Synthetic Apairy</td>
<td>43</td>
</tr>
<tr>
<td>252. Vesper</td>
<td>44</td>
</tr>
<tr>
<td>253. Water-Based Additive Manufacturing</td>
<td>44</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sputnikol: Design Fiction</td>
<td>45</td>
</tr>
<tr>
<td>254. Egristrogen Farms</td>
<td>45</td>
</tr>
<tr>
<td>255. Estrofem Lab</td>
<td>45</td>
</tr>
<tr>
<td>256. Forget Me Not: The Botany of Desire &amp; Loss</td>
<td>45</td>
</tr>
<tr>
<td>257. Hormone Microperfomance</td>
<td>46</td>
</tr>
<tr>
<td>258. Human Perfume</td>
<td>46</td>
</tr>
<tr>
<td>259. (Im)possible Baby</td>
<td>46</td>
</tr>
<tr>
<td>260. I want to become a cephalopod</td>
<td>46</td>
</tr>
<tr>
<td>261. Open Source Estrogen</td>
<td>46</td>
</tr>
<tr>
<td>262. Pop Roach</td>
<td>46</td>
</tr>
<tr>
<td>263. Red Silk of Fate-Tamaki’s Crush</td>
<td>46</td>
</tr>
<tr>
<td>264. Teshima 8 Million Lab</td>
<td>47</td>
</tr>
<tr>
<td>265. Tranceflora: Amy’s Glowing Silk</td>
<td>47</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Project</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joseph A. Paradiso: Responsive Environments</td>
<td>47</td>
</tr>
<tr>
<td>266. Chain API</td>
<td>47</td>
</tr>
<tr>
<td>267. ChainFORM</td>
<td>47</td>
</tr>
<tr>
<td>268. ChromoSkin</td>
<td>47</td>
</tr>
<tr>
<td>269. Circuit Stickers</td>
<td>48</td>
</tr>
<tr>
<td>270. Circuit Stickers Activity Book</td>
<td>48</td>
</tr>
<tr>
<td>271. Circuit Storybook</td>
<td>48</td>
</tr>
<tr>
<td>272. DoppelLab: Experiencing Multimodal Sensor Data</td>
<td>48</td>
</tr>
<tr>
<td>273. Doppelmarsh: Cross-Reality Environmental Sensor Data Browser</td>
<td>48</td>
</tr>
<tr>
<td>274. Experiential Lighting: New User Interfaces for Lighting Control</td>
<td>48</td>
</tr>
<tr>
<td>275. FingerSynth: Wearable Transducers for Exploring the Environment through Sound</td>
<td>49</td>
</tr>
<tr>
<td>276. Hack the Sketchbook</td>
<td>49</td>
</tr>
<tr>
<td>277. Halo Flex</td>
<td>49</td>
</tr>
<tr>
<td>278. Halo: Wearable Lighting</td>
<td>49</td>
</tr>
<tr>
<td>279. Hear There: Ubiquitous Sonic Overlay</td>
<td>49</td>
</tr>
<tr>
<td>280. KickSoul: A Wearable System for Foot Interactions with Digital Devices</td>
<td>49</td>
</tr>
<tr>
<td>261.</td>
<td>ListenTree: Audio-Haptic Display in the Natural Environment</td>
</tr>
<tr>
<td>262.</td>
<td>Living Observatory: Sensor Networks for Documenting and Experiencing Ecology</td>
</tr>
<tr>
<td>263.</td>
<td>Low-Power Gesture Input with Wrist-Worn Pressure Sensors</td>
</tr>
<tr>
<td>264.</td>
<td>Low-Power Wireless Environmental Sensor Node</td>
</tr>
<tr>
<td>265.</td>
<td>MedRec</td>
</tr>
<tr>
<td>266.</td>
<td>Mindful Photonic: Context-Aware Lighting</td>
</tr>
<tr>
<td>267.</td>
<td>NaiO</td>
</tr>
<tr>
<td>268.</td>
<td>Prosthetic Sensor Networks: Factoring Attention, Proprioception, and Sensory Coding</td>
</tr>
<tr>
<td>269.</td>
<td>Quantizer: Sonification Platform for High-Energy Physics Data</td>
</tr>
<tr>
<td>270.</td>
<td>SensorChimes: Musical Mapping for Sensor Networks</td>
</tr>
<tr>
<td>271.</td>
<td>Sensor Tape: Modular and Programmable 3D-Aware Dense Sensor Network on a Tape</td>
</tr>
<tr>
<td>272.</td>
<td>Skin</td>
</tr>
<tr>
<td>273.</td>
<td>StretchyKeyboard: Multi-sensory Fabric as Deformable Musical Interface</td>
</tr>
<tr>
<td>274.</td>
<td>TidZam</td>
</tr>
</tbody>
</table>

**Alex 'Sandy' Pentland: Human Dynamics**

| 296. | bandicoot: A Python Toolbox for Mobile Phone Metadata | 52 |
| 297. | Data-Pop Alliance | 52 |
| 298. | DeepShop: Understanding Purchase Patterns via Deep Learning | 53 |
| 299. | Enigma | 53 |
| 300. | Incentivizing Cooperation Using Social Pressure | 53 |
| 301. | Leveraging Leadership Expertise More Effectively in Organizations | 53 |
| 302. | Managing Travel Demand: Location Recommendation for System Efficiency | 53 |
| 303. | Mobile Territorial Lab | 53 |
| 304. | On the Reidentifiability of Credit Card Metadata | 54 |
| 305. | Open Badges | 54 |
| 306. | openPDS/ SaferAnswers: Protecting the Privacy of Metadata | 54 |
| 307. | Prediction Markets: Leveraging Internal Knowledge to Beat Industry Prediction Experts | 54 |
| 308. | Recurrent Neural Network in Context-Free Next-Location Prediction | 54 |
| 309. | Rhythm: Open measurement and feedback tools for human Interaction | 54 |
| 310. | Social Bridges in Community Purchase Behavior | 55 |
| 311. | Social Physics of Unemployment | 55 |
| 312. | The Ripple Effect: You Are More Influential Than You Think | 55 |

**Rosaid W. Picard: Affective Computing**

<p>| 313. | Affective Response to Haptic Signals | 56 |
| 314. | An EEG and Motion-Capture Based Expressive Music Interface for Affective Neurofeedback | 56 |
| 315. | Automated Tongue Analysis | 56 |
| 316. | Automatic Stress Recognition in Real-Life Settings | 56 |
| 317. | Autonomic Nervous System Activity in Epilepsy | 56 |
| 318. | BrightBeat: Effortlessly Influencing Breathing for Cultivating Calmness and Focus | 57 |
| 319. | Building the Just-Right-Challenge in Games and Toys | 57 |
| 320. | EDA Explorer | 57 |
| 321. | EngageME | 57 |
| 322. | Fathom: Probabilistic Graphical Models to Help Mental Health Counselors | 57 |
| 323. | FEEL: A Cloud System for Frequent Event and Biophysiological Signal Labeling | 57 |
| 324. | IDA: Inexpensive Networked Digital Stethoscope | 57 |
| 325. | &quot;Kind and Grateful&quot;: Promoting Kindness and Gratitude with Pervasive Technology | 58 |
| 326. | Lering: Cardiolinguistics for Atypical Angina | 58 |
| 327. | Mapping the Stress of Medical Visits | 58 |
| 328. | Measuring Arousal During Therapy for Children with Autism and ADHD | 58 |
| 329. | Mobile Health Interventions for Drug Addiction and PTSD | 58 |
| 330. | Modulating Peripheral and Cortical Arousal Using a Musical Motor Response Task | 58 |
| 331. | Objective Assessment of Depression and its Improvement | 58 |
| 332. | Panoply | 59 |
| 333. | Predicting Bonding in Conversations | 59 |
| 334. | Predicting Perceived Emotions in Animated GIFs with 3D Convolutional Neural Networks | 59 |
| 335. | Predicting Students’ Wellbeing from Physiology, Phone, Mobility, and Behavioral Data | 59 |
| 336. | QuantifyMe | 60 |
| 337. | Real-Time Assessment of Suicidal Thoughts and Behaviors | 60 |
| 338. | SNAPSHOT Expose | 60 |
| 339. | SNAPSHOT Study | 60 |
| 340. | SPRING: A Smart Platform for Research, Intervention, &amp; Neurodevelopmental Growth | 60 |
| 341. | StoryScape | 60 |</p>
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>Traditional Chinese Medicine-Inspired Pulse Analysis</td>
</tr>
<tr>
<td>68</td>
<td>The Core Study</td>
</tr>
<tr>
<td>67</td>
<td>Cognitive Limits of Social Networks</td>
</tr>
<tr>
<td>66</td>
<td>Crowdsourcing Under Attack</td>
</tr>
<tr>
<td>65</td>
<td>Ethics of Autonomous Vehicles</td>
</tr>
<tr>
<td>64</td>
<td>Honest Crowds</td>
</tr>
<tr>
<td>63</td>
<td>Human-Machine Cooperation</td>
</tr>
<tr>
<td>63</td>
<td>Moral Machine</td>
</tr>
<tr>
<td>63</td>
<td>Nightmare Machine</td>
</tr>
<tr>
<td>63</td>
<td>Promoting Cooperation through Peer Pressure</td>
</tr>
<tr>
<td>62</td>
<td>Iyad Rahwan: Scalable Cooperation</td>
</tr>
<tr>
<td>62</td>
<td>Cognitive Limits of Social Networks</td>
</tr>
<tr>
<td>62</td>
<td>Crowdsourcing Under Attack</td>
</tr>
<tr>
<td>62</td>
<td>Ethics of Autonomous Vehicles</td>
</tr>
<tr>
<td>62</td>
<td>Honest Crowds</td>
</tr>
<tr>
<td>63</td>
<td>Human-Machine Cooperation</td>
</tr>
<tr>
<td>63</td>
<td>Moral Machine</td>
</tr>
<tr>
<td>63</td>
<td>Nightmare Machine</td>
</tr>
<tr>
<td>63</td>
<td>Promoting Cooperation through Peer Pressure</td>
</tr>
<tr>
<td>61</td>
<td>The Challenge</td>
</tr>
<tr>
<td>61</td>
<td>The Core Study</td>
</tr>
<tr>
<td>61</td>
<td>Traditional Chinese Medicine-Inspired Pulse Analysis</td>
</tr>
<tr>
<td>61</td>
<td>Tributary</td>
</tr>
<tr>
<td>61</td>
<td>Unlocking Wellbeing</td>
</tr>
<tr>
<td>61</td>
<td>ValiNor: Mathematical Models to Understand and Predict Self-Harm</td>
</tr>
<tr>
<td>62</td>
<td>Wavelet-Based Motion Artifact Removal for Electrodermal Activity</td>
</tr>
<tr>
<td>62</td>
<td>Iyad Rahwan: Scalable Cooperation</td>
</tr>
<tr>
<td>62</td>
<td>Cognitive Limits of Social Networks</td>
</tr>
<tr>
<td>62</td>
<td>Crowdsourcing Under Attack</td>
</tr>
<tr>
<td>62</td>
<td>Ethics of Autonomous Vehicles</td>
</tr>
<tr>
<td>62</td>
<td>Honest Crowds</td>
</tr>
<tr>
<td>63</td>
<td>Human-Machine Cooperation</td>
</tr>
<tr>
<td>63</td>
<td>Moral Machine</td>
</tr>
<tr>
<td>63</td>
<td>Nightmare Machine</td>
</tr>
<tr>
<td>63</td>
<td>Promoting Cooperation through Peer Pressure</td>
</tr>
</tbody>
</table>

**Ramesh Raskar: Camera Culture**

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>6D Display</td>
</tr>
<tr>
<td>68</td>
<td>AnEye: Extending the Reach of Anterior Segment Ophthalmic Imaging</td>
</tr>
<tr>
<td>65</td>
<td>Beyond the Self-Driving Car</td>
</tr>
<tr>
<td>64</td>
<td>Blind and Reference-Free Fluorescence Lifetime Estimation via Consumer Time-of-Flight Sensors</td>
</tr>
<tr>
<td>64</td>
<td>Bokode: Imperceptible Visual Tags for Camera-Based Interaction from a Distance</td>
</tr>
<tr>
<td>64</td>
<td>Coded Computational Photography</td>
</tr>
<tr>
<td>64</td>
<td>Computation Ear Imaging</td>
</tr>
<tr>
<td>64</td>
<td>Food sensing on smartphones</td>
</tr>
<tr>
<td>64</td>
<td>Health-Tech Innovations with Tata Trusts, Mumbai</td>
</tr>
<tr>
<td>65</td>
<td>Hyderabad Eye Health Collaboration with LVP</td>
</tr>
<tr>
<td>65</td>
<td>Identi-Wheez: A Device for In-home Diagnosis of Asthma</td>
</tr>
<tr>
<td>65</td>
<td>Imaging Behind Diffusive Layers</td>
</tr>
<tr>
<td>65</td>
<td>Imaging through Scattering Media Using Femtophotography</td>
</tr>
<tr>
<td>65</td>
<td>Imaging with All Photons</td>
</tr>
<tr>
<td>65</td>
<td>Inverse Problems in Time-of-Flight Imaging</td>
</tr>
<tr>
<td>65</td>
<td>LensChat: Sharing Photos with Strangers</td>
</tr>
<tr>
<td>66</td>
<td>Looking Around Corners</td>
</tr>
<tr>
<td>66</td>
<td>Naahik Smart Citizen Collaboration with TCS</td>
</tr>
<tr>
<td>66</td>
<td>NETRA: Smartphone Add-On for Eye Tests</td>
</tr>
<tr>
<td>66</td>
<td>New Methods in Time-of-Flight Imaging</td>
</tr>
<tr>
<td>66</td>
<td>Optical Brush: Enabling Deformable Imaging Interfaces</td>
</tr>
<tr>
<td>66</td>
<td>PhotoCloud: Personal to Shared Moments with Angled Graphs of Pictures</td>
</tr>
<tr>
<td>67</td>
<td>Portable Retinal Imaging</td>
</tr>
<tr>
<td>67</td>
<td>Reading Through a Closed Book</td>
</tr>
<tr>
<td>67</td>
<td>Reflectance Acquisition Using Ultrafast Imaging</td>
</tr>
<tr>
<td>67</td>
<td>Second Skin: Motion Capture with Actuated Feedback for Motor Learning</td>
</tr>
<tr>
<td>67</td>
<td>Shield Field Imaging</td>
</tr>
<tr>
<td>67</td>
<td>Single Lens Off-Chip Cellphone Microscopy</td>
</tr>
<tr>
<td>67</td>
<td>Single-Photon Sensitive Ultrafast Imaging</td>
</tr>
<tr>
<td>67</td>
<td>Skin Perfusion Photography</td>
</tr>
<tr>
<td>67</td>
<td>Slow Display</td>
</tr>
<tr>
<td>67</td>
<td>Smartphone dermatoscope</td>
</tr>
<tr>
<td>68</td>
<td>SpeckleSense</td>
</tr>
<tr>
<td>68</td>
<td>SpecTrans: Classification of Transparent Materials and Interactions</td>
</tr>
<tr>
<td>68</td>
<td>StreetScore</td>
</tr>
<tr>
<td>68</td>
<td>The Next 30 Years of VR</td>
</tr>
<tr>
<td>68</td>
<td>Theory Unifying Ray and Wavefront Lightfield Propagation</td>
</tr>
<tr>
<td>68</td>
<td>Time-of-Flight Microwave Camera</td>
</tr>
<tr>
<td>69</td>
<td>Towards In-Vivo Biopsy</td>
</tr>
<tr>
<td>69</td>
<td>Trillion Frames Per Second Camera</td>
</tr>
<tr>
<td>69</td>
<td>Ultrasound Tomography</td>
</tr>
<tr>
<td>69</td>
<td>Unbounded High Dynamic Range Photography Using a Module Camera</td>
</tr>
<tr>
<td>69</td>
<td>VisionBlocks</td>
</tr>
</tbody>
</table>

**Andrew Lippman: Viral Communications**

<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>Andrew Lippman: Viral Communications</td>
</tr>
</tbody>
</table>

---

*Fall 2016 · MIT Media Lab*
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8K Time into Space</td>
<td>26</td>
</tr>
<tr>
<td>As You Need It</td>
<td>26</td>
</tr>
<tr>
<td>Captions++</td>
<td>26</td>
</tr>
<tr>
<td>DoDb</td>
<td>27</td>
</tr>
<tr>
<td>GIF/GIF</td>
<td>27</td>
</tr>
<tr>
<td>IoT Recorder</td>
<td>27</td>
</tr>
<tr>
<td>MedRec</td>
<td>27</td>
</tr>
<tr>
<td>NewsClouds</td>
<td>27</td>
</tr>
<tr>
<td>News Graph</td>
<td>27</td>
</tr>
<tr>
<td>Perspectives</td>
<td>27</td>
</tr>
<tr>
<td>Watch People Watch</td>
<td>28</td>
</tr>
<tr>
<td>Solar Micro-Mining</td>
<td>28</td>
</tr>
<tr>
<td>Super Cut Notes</td>
<td>28</td>
</tr>
<tr>
<td>SuperGlue</td>
<td>28</td>
</tr>
<tr>
<td>This Is How</td>
<td>28</td>
</tr>
<tr>
<td>Viralcasting</td>
<td>28</td>
</tr>
<tr>
<td>VR Codes</td>
<td>28</td>
</tr>
<tr>
<td>Wall of Now</td>
<td>28</td>
</tr>
<tr>
<td>Mitchel Resnick: Lifelong Kindergarten</td>
<td>72</td>
</tr>
<tr>
<td>Active Drawing</td>
<td>72</td>
</tr>
<tr>
<td>BioBricks</td>
<td>72</td>
</tr>
<tr>
<td>Computational Tinkering</td>
<td>73</td>
</tr>
<tr>
<td>Creative Learning in Brazil / Aprendizagem Criativa no Brasil</td>
<td>73</td>
</tr>
<tr>
<td>Desafio Aprendizagem Criativa Brasil</td>
<td>73</td>
</tr>
<tr>
<td>Duct Tape Network</td>
<td>74</td>
</tr>
<tr>
<td>Getting Started with Scratch</td>
<td>74</td>
</tr>
<tr>
<td>Learning Creative Learning</td>
<td>74</td>
</tr>
<tr>
<td>Lemann-MIT Creative Learning Challenge</td>
<td>74</td>
</tr>
<tr>
<td>Microworlds</td>
<td>75</td>
</tr>
<tr>
<td>Paper Circuits</td>
<td>75</td>
</tr>
<tr>
<td>Rede Brasileira de Aprendizagem Criativa</td>
<td>75</td>
</tr>
<tr>
<td>Scratch</td>
<td>75</td>
</tr>
<tr>
<td>Scratch 3.0</td>
<td>75</td>
</tr>
<tr>
<td>Scratch Community Blocks</td>
<td>76</td>
</tr>
<tr>
<td>Scratch Day</td>
<td>76</td>
</tr>
<tr>
<td>Scratch Extensions</td>
<td>76</td>
</tr>
<tr>
<td>ScratchJr</td>
<td>76</td>
</tr>
<tr>
<td>Scratch Online Community</td>
<td>76</td>
</tr>
<tr>
<td>Scratch Pad</td>
<td>76</td>
</tr>
<tr>
<td>Slap Snap Tap</td>
<td>76</td>
</tr>
<tr>
<td>Deb Roy: Social Machines</td>
<td>77</td>
</tr>
<tr>
<td>AINA: Aerial Imaging and Network Analysis</td>
<td>77</td>
</tr>
<tr>
<td>ChatterBox</td>
<td>77</td>
</tr>
<tr>
<td>Human Atlas</td>
<td>77</td>
</tr>
<tr>
<td>Play Analytics</td>
<td>77</td>
</tr>
<tr>
<td>Playful Words</td>
<td>77</td>
</tr>
<tr>
<td>ShapeBlocks</td>
<td>77</td>
</tr>
<tr>
<td>SpeechBlocks</td>
<td>78</td>
</tr>
<tr>
<td>StoryBlocks</td>
<td>78</td>
</tr>
<tr>
<td>The Electome: Measuring Responsiveness in the 2016 Election</td>
<td>78</td>
</tr>
<tr>
<td>The Foodome: Building a Comprehensive Knowledge Graph of Food</td>
<td>79</td>
</tr>
<tr>
<td>Visible Communities</td>
<td>79</td>
</tr>
<tr>
<td>Chris Schmandt: Living Mobile</td>
<td>79</td>
</tr>
<tr>
<td>Amphibian: Terrestrial SCUBA Diving Simulator Using Virtual Reality</td>
<td>79</td>
</tr>
<tr>
<td>CAPS: Curbing Assault to Protect Society</td>
<td>80</td>
</tr>
<tr>
<td>ChromoSkin</td>
<td>80</td>
</tr>
<tr>
<td>DooSkin</td>
<td>80</td>
</tr>
<tr>
<td>Living Jewelry</td>
<td>80</td>
</tr>
<tr>
<td>NailO</td>
<td>80</td>
</tr>
<tr>
<td>Sensor Tape: Modular and Programmable 3D-Aware Dense Sensor Network on a Tape</td>
<td>80</td>
</tr>
</tbody>
</table>
Kevin Slavin: Playful Systems ................................................................. 81

20 Day Stranger .............................................................................. 81
Automat .................................................................................................. 81
Case and Molly .................................................................................. 81
Cognitive Integration: The Nature of the Mind ................................... 81
Cordon Sanitaire .................................................................................. 82
Designing Immersive Multi-Sensory Eating Experiences ....................... 82
Dice++ .................................................................................................. 82
For Once In Your Life......................................................................... 82
GAMR .................................................................................................. 82
Hello, Operator! .................................................................................. 82
Holobiont Urbanism: Revealing the Microbiological World of Cities ....... 82
Homeostasis ....................................................................................... 83
MicroPipe: An Architecture for Motivated Cognition ............................... 83
radiO_o ............................................................................................... 83
Sneak: A Hybrid Digital-Physical Tabletop Game .................................. 83
Soft Exchange: Interaction Design with Biological Interfaces ................ 83
Storyboards ......................................................................................... 83
Troxes .................................................................................................. 83

Ethan Zuckerman: Civic Media ............................................................... 84

Action Path .......................................................................................... 84
Algorithmic Justice League .................................................................. 84
CivilServant: User-Led Randomized Trials Online .................................. 84
Code4Rights ....................................................................................... 84
DataBasic ............................................................................................ 84
Data Therapy ....................................................................................... 84
DeepStream ......................................................................................... 85
First Upload ......................................................................................... 85
FOLD .................................................................................................... 85
Going Dark: Collective Action in the reddit Blackout ................................. 85
"Make the Breast Pump Not Suck!" Hackathon ....................................... 85
Media Cloud ....................................................................................... 85
Mission Wildlife .................................................................................. 86
MoboWater .......................................................................................... 86
NetStories ............................................................................................ 86
NewsPix ................................................................................................. 86
Open Water Project .............................................................................. 86
PageOneX ............................................................................................ 86
Peer Appreciation in the Workplace ....................................................... 86
Promise Tracker ................................................................................... 87
Scanner Grabber .................................................................................. 87
Slap Snap Tap ...................................................................................... 87
The Babbling Brook ............................................................................. 87
**Fadel Adib: Signal Kinetics**

Extending human and computer abilities in sensing, communication, and actuation through signals and networks

1. **Cyber-Physical Security and Privacy (System & Network Security)**
   - **Fadel Adib**
   - In the age of ubiquitous connectivity and the internet-of-things, our security and privacy have taken new dimensions. For example, how can we ensure that our locations are not being tracked from our cellphones? And, how can we prevent an unauthorized user from hacking into our smart home systems? Our research aims at developing primitives that can address these challenges. To do so, we explore intrinsically new security mechanisms that operate across all the computing stack to secure not only the bits but also the integrity of the sensed signals and to protect the privacy of the sensed environment.

2. **Health Sensing (Human-Computer Interaction)**
   - **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.

3. **Programming Wireless Networks (Computer Networks)**
   - **Fadel Adib**
   - Wireless networks — consisting of WiFi, LTE, RFID, and millimeter-wave devices — have become integral parts of our everyday lives. Our research explores how we can make these networks more robust, faster, and seamlessly mobile. It also explores how we can use these networks for purposes other than communication such as localization, sensing, and control.

4. **Seeing Through Walls (Computer Vision)**
   - **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 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.

5. **Wireless Sensing for Drones & Agile Robots (Robotics)**
   - **Fadel Adib**
   - Can drones find objects which we’ve lost, even if those objects are hidden? Can agile industrial robots, like Baxter, use wireless sensing capabilities to identify objects inside closed boxes? Can personal robots, like Roombas, use their on-board WiFi to map indoor environments and feed this information to smart home automation tools? To answer these questions, our group explores placing wireless devices on robots to sense the wireless channel, extract RF reflections, and interpret them in the context of Computer Vision.
V. Michael Bove: Object-Based Media

Changing storytelling, communication, and everyday life through sensing, understanding, and new interface technologies

6. **3D Telepresence Chair**
   Daniel Novy
   An autostereoscopic (no glasses) 3D display engine is combined with a “Pepper’s Ghost” setup to create an office chair that appears to contain a remote meeting participant. The system geometry is also suitable for other applications, such as tabletop or automotive heads-up displays.

7. **4K/8K Comics**
   Daniel Novy, V. Michael Bove
   4K/8K Comics applies the affordances of ultra-high-resolution screens to traditional print media such as comic books, graphic novels, and other sequential art forms. The comic panel becomes the entry point to the corresponding moment in the film adaptation, while scenes from the film indicate the source frames of the graphic novel. The relationships among comics, films, social media, parodies, and other support materials can be navigated using native touch screens, gestures, or novel wireless control devices. Big data techniques are used to sift, store, and explore vast catalogs of long-running titles, enabling sharing and remixing among friends, fans, and collectors.

8. **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.

9. **Aerial Light-Field Display**
   Daniel Novy, V. Michael Bove
   Henry Holtzman (Samsung NE/xD Lab)
   Suitable for anywhere a “Pepper’s Ghost” display could be deployed, this display adds 3D with motion parallax, as well as optically relaying the image into free space such that gestural and haptic interfaces can be used to interact with it. The current version is able to display a person at approximately full-size.

10. **BigBarChart**
    Laura Perovich, V. Michael Bove
    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.

11. **Bottles&Boxes: Packaging with Sensors**
    Daniel Novy, V. Michael Bove
    We have added inexpensive, low-power, wireless sensors to product packages to detect user interactions with products. Thus, a bottle can register when and how often its contents are dispensed (and generate side effects, like causing a music player to play music when the bottle is picked up, or generating an automatic refill order when near-emptiness is detected). A box can understand usage patterns of its contents. Consumers can vote for their favorites among several alternatives simply by handling them more often.

12. **Calliope**
    Edwina Portocarrero, V. Michael Bove
    Ye Wang
    Calliope is the follow-up to the NeverEnding Drawing Machine. A portable, paper-based platform for interactive story making, it allows physical editing of shared digital media at a distance. The system is composed of a network of creation stations that seamlessly blend analog and digital media. Calliope documents and displays the creative process with no need to interact directly with a computer. By using
human-readable tags and allowing any object to be used as material for creation, it offers opportunities for cross-cultural and cross-generational collaboration among peers with expertise in different media.

13. **Consumer Holo-Video**

Bianca Datta, Nickolaos Savidis, Sunny Jolly, V. Michael Bove

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.

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**

Bianca Datta, V. Michael Bove

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 by 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.

16. **Emotive Materials**

Bianca Datta, V. Michael Bove

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.

17. **EmotiveModeler: An Emotive Form Design CAD Tool**

Philippa Mothersill, V. Michael Bove

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.

18. **Everything Tells a Story**

V. Michael Bove

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.

19. **Free-Space Haptic Feedback for 3D Displays**

V. Michael Bove, Ali Shtarbanov

What if you could not only see but also feel virtual objects as you interacted with them? This would enable richer and more realistic user experiences. We have designed a low-cost air-vortex generator to provide midair haptic feedback when a user touches virtual objects displayed on holographic, aerial, and other 3D displays. The system consists of a 3D-printed chamber and nozzle, five low-frequency transducers, and a custom-designed driver board. The air-vortex generator can provide localized haptic feedback to a range of over 100cm. With increased driving power and a more optimized nozzle design, this range could be extended to several meters.
We are developing inexpensive, efficient, high-bandwidth light modulators based on lithium niobate guided-wave technology. These full-color modulators support hundreds of thousands of pixels per scan line, making them suitable for fixed or wearable holographic displays.

**Guided-Wave Light Modulator for Holographic Video**

Bianca Datta, Nickolaos Savidis, Sunny Jolly, V. Michael Bove

Daniel Smalley (BYU)

We are developing inexpensive, efficient, high-bandwidth light modulators based on lithium niobate guided-wave technology. These full-color modulators support hundreds of thousands of pixels per scan line, making them suitable for fixed or wearable holographic displays.

**Infinity-by-Nine**

Daniel Novy, V. Michael Bove

We are expanding the home-video viewing experience by generating imagery to extend the TV screen and give the impression that the scene wraps completely around the viewer. Optical flow, color analysis, and heuristics extrapolate beyond the screen edge, where projectors provide the viewer's perceptual vision with low-detail dynamic patterns that are perceptually consistent with the video imagery and increase the sense of immersive presence and participation. We perform this processing in real time using standard microprocessors and GPUs.

**ListenTree: Audio-Haptic Display in the Natural Environment**

Joseph A. Paradiso, Edwina Portocarrero, Gershon Dublon, V. Michael Bove

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.

**Live Objects**

Arata Miyamoto, Valerio Panzica La Manna, V. Michael Bove

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.

**Narratarium**

Jie Qi, Catherine Havasi, V. Michael Bove, Kasia Hayden, Daniel Novy

Narratarium augments printed and oral stories and creative play by projecting immersive images and sounds. We are using natural language processing to listen to and understand stories being told, and analysis tools to recognize activity among sensor-equipped objects such as toys, then thematically augmenting the environment using video and sound. New work addresses the creation and representation of audiovisual content for immersive story experiences and the association of such content with viewer context.

**Networked Playscapes: Dig Deep**

Edwina Portocarrero, V. Michael Bove

Networked Playscapes re-imagine outdoor play by merging the flexibility and fantastical 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.

**Pillow-Talk**

Edwina Portocarrero, V. Michael Bove

Pillow-Talk is the first of a series of objects designed to aid creative endeavors through the unobtrusive acquisition of unconscious, self-generated content to permit reflexive self-knowledge. Composed of a seamless recording device embedded in a pillow, and a playback and visualization system in a jar, Pillow-Talk crystallizes that which we normally forget. This allows users to capture their dreams in a less mediated way, aiding recollection by priming the experience and providing no distraction for recall and capture through embodied interaction.

**Printed Wearable Holographic Display**

Bianca Datta, Nickolaos Savidis, Sunny Jolly, V. Michael Bove

Daniel Smalley (BYU)

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."

Daniel Novy, V. Michael Bove

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.

Everett Lawson

Our sensory mechanisms can be thought of as networked input controls responsible for encoding the natural world before us. Acting as go-between from environment to our ultimate perception of it, sensory organs themselves exhibit deep learning potentials that, if acted upon, could radically challenge the way we develop and experience future technologies and extant realities. If we consider neural plasticity as a form of temporary memory which can be written and rewritten, consciously or unconsciously, externally or internally, there is potential to biologically encode new sensing parameters directly onto receptive fields, re-scripting and filtering input data from natural scenes into new and unique outcomes in our perception. By generating tailored stimuli specific to adaptation mechanisms, there is an exciting opportunity to create novel environments of controlled perceptual phenomenon, programming inherent biological functions to facilitate more dynamic, immersive environments.

Ali Shtarbanov

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 WiFi and change their behavior accordingly, without requiring any handshake or internet connection. By leveraging the latest and most inexpensive WiFi 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.

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

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 WiFi 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

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

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.

Laura Perovich, V. Michael Bove

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. The thermal fishing bob seeks to visceralize rather than simply visualize data by creating a data experience that makes water pollution data present. The bob measures water temperature and displays that data 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.

---

**Edward Boyden: Synthetic Neurobiology**

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

Kevin Slavin, Edward Boyden, 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?

**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. These tools are also being evaluated as components of prototype optical neural control prosthetics for ultraprecise 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.

New technologies for recording neural activity, controlling neural activity, or building brain circuits, may be capable some day 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 neural circuit computation, through prosthesis means. High throughput molecular and physiological analysis methods may also open up new diagnostic possibilities. 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.

**Edward Boyden**

Brain circuits are large, 3D structures. However, the building blocks — proteins, signaling complexes, synapses — are organized with nanoscale precision. This presents a fundamental tension in neuroscience — to understand a neural 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 the brain, so that comprehensive taxonomies of cells, circuits, and computations might someday become possible, even in entire brains. One of the technologies we are developing enables large 3D objects to be imaged with...
nanoscale precision, by physically expanding the sample (in contrast to all previous microscopies, that magnify light from the sample via lenses), a tool we call expansion microscopy (ExM). 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.

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 activity of many neurons 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. And, ideally, it would be possible to understand how those neural codes and dynamics emerge from subcellular computational events within individual cells. Our lab and our collaborators are developing a number of innovations 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 tools as well as new kinds of advanced brain-repair prostheses.

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

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 activity of many neurons 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. And, ideally, it would be possible to understand how those neural codes and dynamics emerge from subcellular computational events within individual cells. Our lab and our collaborators are developing a number of innovations 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 tools as well as new kinds of advanced brain-repair prostheses.

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

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 activity of many neurons 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. And, ideally, it would be possible to understand how those neural codes and dynamics emerge from subcellular computational events within individual cells. Our lab and our collaborators are developing a number of innovations 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 tools as well as new kinds of advanced brain-repair prostheses.

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

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 activity of many neurons 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. And, ideally, it would be possible to understand how those neural codes and dynamics emerge from subcellular computational events within individual cells. Our lab and our collaborators are developing a number of innovations 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 tools as well as new kinds of advanced brain-repair prostheses.

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

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 activity of many neurons 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. And, ideally, it would be possible to understand how those neural codes and dynamics emerge from subcellular computational events within individual cells. Our lab and our collaborators are developing a number of innovations 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 tools as well as new kinds of advanced brain-repair prostheses.

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
Building socially engaging robots and interactive technologies to help people live healthier lives, connect with others, and learn better
interface, providing stimulation and exercise to pets when the owners are at work or otherwise cannot be present.

Children Use Nonverbal Cues to Learn from Robots

Sooyeon Jeong, Jacqueline M Kory Westlund, Cynthia Breazeal
Paul Harris (Graduate School of Education, Harvard University), David DeSteno (Dept. of Psychology, Northeastern University), Leah Dickens (Dept. of Psychology, Northeastern University)

When learning from human partners, infants and young children will pay attention to nonverbal signals, such as gaze and bodily orientation, to figure out what a person is looking at and why. They may follow gaze to determine what object or event triggered another’s emotion, or to learn about the goal of another’s ongoing action. They also follow gaze in language learning, using the speaker’s gaze to figure out what new objects are being referred to or named.

In this project, we examined whether young children will attend to the same social cues from a robot as from a human partner during a word learning task, specifically gaze and bodily orientation.

Cloud-HRI

Nick DePalma, Cynthia Breazeal
Sonia Chernova

Imagine opening your eyes and being awake for only half an hour at a time. This is the life that robots traditionally live. This is due to a number of factors, such as battery life and wear on prototype joints. Roboticists have typically muddled though this challenge by crafting handmade perception and planning models of the world, or by using machine learning with synthetic and real-world data, but cloud-based robotics aims to marry large distributed systems with machine learning techniques to understand how to build robots that interpret the world in a richer way. This movement aims to build large-scale machine learning algorithms that use experiences from large groups of people, whether sourced from a large number of tabletop robots or a large number of experiences with virtual agents. Large-scale robotics aims to change embodied AI as it changed non-embodied AI.

Computational Trust

Jin Joo Lee, Cynthia Breazeal
Dr. David DeSteno, Dr. Jolie B. Wormwood

A computational model predicts the degree of trust a person has toward their novel partner, and advances our scientific understanding about interpersonal trust.

Curious Learning: Understanding Learning Behaviors for Early Literacy

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

Early literacy plays an important role in a child’s future. However, the reality is that over 57 million children have no access to a school and another 100 million attend such inadequate schools that they will remain functionally non-literate.

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. 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 develop a personalized, adaptive learning platform.

DragonBot: Android Phone Robots for Long-Term HRI

Cynthia Breazeal

DragonBot is a new platform built to support long-term interactions between children and robots. The robot runs entirely on an Android cell phone, which displays an animated virtual face. Additionally, the phone provides sensory input (camera and microphone) and fully controls the actuation of the robot (motors and speakers). Most importantly, the phone always has an Internet connection, so a robot can harness cloud-computing paradigms to learn from the collective interactions of multiple robots. To support long-term interactions, DragonBot is a “blended-reality” character: if you remove the phone from the robot, a virtual avatar appears on the screen and the user can still interact with the virtual character on the go. Costing less than $1,000, DragonBot was specifically designed to be a low-cost platform that can support longitudinal human-robot interactions “in the wild.”

Global Literacy Tablets

Tinsley Galyean, David Nunez, Cynthia Breazeal
Robin Morris (GSU), Maryanne Wolf (Tufts)

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 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. The Huggable is being designed with a full-body sensitive skin with over 1,500 sensors, quiet back-drivable actuators, video cameras in the eyes, microphones in the ears, an inertial measurement unit, a speaker, and an embedded PC with 802.11g wireless networking. An important design goal for the Huggable is to make the technology invisible to the user. You should not think of the Huggable as a robot but rather as a richly interactive teddy bear.

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 are currently running 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 preliminarily 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 pediatric care.

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 are currently running 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 preliminarily 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 pediatric care.

Social robots take an active role in the cognitive estimation of children during educational activities.

We developed a smartphone application that detects users’ affect and provides personalized positive psychology interventions in order to enhance users’ psychological wellbeing. Users’ emotional states were measured by analyzing facial expressions and the sentiment of SMS messages. A virtual character in the application prompted users to verbally journal about their day by providing three positive psychology interventions. The system used a Markov Decision Process (MDP) model and a State-Action-Reward-State-Action (SARSA) algorithm to learn users’ preferences about the positive psychology interventions. Nine participants were recruited for an experimental study to test the application. They used it daily for three weeks. The interactive journaling activity increased participants’ arousal and valence levels immediately following each interaction, and we saw a trend toward improved self-acceptance levels over the three week period. The interaction duration increased significantly throughout the study as well. The qualitative analysis on journal entries showed that the application users explored and reflected on various aspects of themselves by looking at daily events, and found novel appreciation for and meanings in their daily routine.

Mind-Theoretic Planning (MTP) is a technique for robots to plan in social domains. This system takes into account probability distributions over the initial beliefs and goals of people in the environment that are relevant to the task, and creates a prediction of how they will rationally act on their beliefs to achieve their goals. The MTP system then proceeds to create an action plan for the robot that simultaneously takes relevant to the task, and creates a prediction of how they will rationally act on their beliefs to achieve their goals. The MTP system then proceeds to create an action plan for the robot that simultaneously takes advantage of the effects of anticipated actions of others and also avoids interfering with them.

Can robots collaboratively exchange stories with children and improve their language and storytelling skills? With our latest Tega robot platform, we aim to develop a deep personalization algorithm based on a long-term interaction with an individual user. Through robot interaction, we collect a corpus of each
A growing body of research also suggests that social robots have potential as learning companions and tutors for young children’s early language education. Social robots are new technologies that combine the adaptability, customizability, and scalability of technology with the embodied, situated world in which we operate.

In this project, we asked whether a social robot can effectively engage preschoolers in dialogic reading. Given that past work has shown that children can and do learn new words from social robots, we investigate what factors modulate their learning. In particular, we looked at whether the verbal expressiveness of the robot impacted children’s learning and engagement during a dialogic reading activity. This project was funded by an NSF Cyberlearning grant.

56. **Robot Expressiveness Affects Children’s Learning**  
Hae Won Park, Sooyeon Jeong, Jacqueline M Kory Westlund, Cynthia Breazeal  
Paul Harris (Graduate School of Education, Harvard University), Samuel Ronfard (Dept. of Psychology, Northeastern University)

Prior research with preschool children has established that book reading, especially when children are encouraged to actively process the story materials through dialogic reading, is an effective method for expanding young children’s vocabulary. A growing body of research also suggests that social robots have potential as learning companions and tutors for young children’s early language education. Social robots are new technologies that combine the adaptability, customizability, and scalability of technology with the embodied, situated world in which we operate.

In this project, we asked whether a social robot can effectively engage preschoolers in dialogic reading. Given that past work has shown that children can and do learn new words from social robots, we investigate what factors modulate their learning. In particular, we looked at whether the verbal expressiveness of the robot impacted children’s learning and engagement during a dialogic reading activity. This project was funded by an NSF Cyberlearning grant.

57. **Robotic Language Learning Companions**  
Sooyeon Jeong, Jacqueline M Kory Westlund, Cynthia Breazeal  
Paul Harris, Leah Dickens, Dave DeSteno

Young children learn language not through listening alone, but through active communication with a social actor. Cultural immersion and context are also key in long-term language development. We are developing robotic conversational partners and hybrid physical/digital environments for language learning. For example, the robot Sophie helped young children learn French through a food-sharing game. The game was situated on a digital tablet embedded in a cafe table. Sophie modeled how to order food and as the child practiced the new vocabulary, the food was delivered via digital assets onto the table’s surface. A teacher or parent can observe and shape the interaction remotely via a digital tablet interface to adjust the robot’s conversation and behavior to support the learner. More recently, we have been examining how social nonverbal behaviors impact children’s perceptions of the robot as an informant and social companion.

58. **Robotic Learning Companions**  
David Nunez, Jacqueline M Kory Westlund, Samuel Spaulding, Cynthia Breazeal

The language and literacy skills of young children entering school are highly predictive of their long-term academic success. Children from low-income families are particularly at risk. Parents often work multiple jobs, giving them less time to talk to and read with their children. Parents might be illiterate or not speak the language taught in local schools, and they may not have been read to as children, providing less experience of good co-reading practice to draw upon. We are currently developing a robotic reading companion for young children, trained by interactive demonstrations from parents and/or educational experts. We intend for this robot to complement parental interaction and emulate some of their best practices in co-reading, building language and literacy through asking comprehension questions, prompting exploration, and simply being emotionally involved in the child’s reading experience.

59. **Robot Learning from Human-Generated Rewards**  
Cynthia Breazeal  
Tom Walsh, Robert Radway

To serve us well, robots and other agents must understand our needs and how to fulfill them. To that end, our research develops robots that empower humans by interactively learning from them. Interactive learning methods enable technically unskilled end-users to designate correct behavior and communicate their task knowledge to improve a robot’s task performance. This research on interactive learning focuses on algorithms that facilitate teaching by signals of approval and disapproval from a live human trainer. We operationalize these feedback signals as numeric rewards within the machine-learning framework of reinforcement learning. In comparison to the complementary form of teaching by demonstration, this feedback-based teaching may require less task expertise and place less cognitive load on the trainer. Envisioned applications include human-robot collaboration and assistive robotic devices for handicapped users, such as myoelectrically controlled prosthetics.

60. **Robot Mindset and Curiosity**  
Hae Won Park, Cynthia Breazeal  
Goren Gordon (Tel Aviv)

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
Sociable robotic learning companions have the ability to sustain engagement and promote children’s curiosity and growth mindset for improved learning outcomes in an educational play context.

61. **SHARE: Understanding and Manipulating Attention Using Social Robots**

   **Nick DePalma, Cynthia Breazeal**

   SHARE is a robotic cognitive architecture focused on manipulating and understanding the phenomenon of shared attention during interaction. SHARE incorporates new findings and research in the understanding of nonverbal referential gesture, visual attention system research, and interaction science. SHARE’s research incorporates new measurement devices, advanced artificial neural circuits, and a robot that makes its own decisions.

62. **Socially Assistive Robotics: An NSF Expedition in Computing**

   **Samuel Spaulding, Jin Joo Lee, Michal Gordon, Goren Gordon, Edith K. Ackermann, Cynthia Breazeal, Sooyeon Jeong, Luke Plummer, Jacqueline M Kory Westlund, Catherine Havasi, Willow Garage, Tufts University, Yale University, Kasia Hayden (Stanford University) University of Southern California**

   Our mission is to develop the computational techniques that will enable the design, implementation, and evaluation of “relational” robots, in order to encourage social, emotional, and cognitive growth in children, including those with social or cognitive deficits. Funding for the project comes from the NSF Expeditions in Computing program. This expedition has the potential to substantially impact the effectiveness of education and healthcare, and to enhance the lives of children and other groups that require specialized support and intervention. In particular, the MIT effort is focusing on developing second-language learning companions for pre-school aged children, ultimately for ESL (English as a Second Language).

63. **Social Robot Toolkit**

   **Hae Won Park, Randi Williams, Edith K. Ackermann, Cynthia Breazeal, Michal Gordon**

   The Social Robot Toolkit aims to provide a platform for children to learn through playful interaction. The social robot (Soro) toolkit allows preschool children to experiment with computational concepts while teaching a social robot new rules. The toolkit also provides a platform for learning interpersonal skills through the use of storytelling that integrates interpersonal and computational concepts. This harnesses preschoolers’ natural interest in social interaction to familiarize them with new concepts.

64. **Storytelling Companion**

   **Jacqueline M Kory Westlund, Cynthia Breazeal**

   Children’s oral language skills in preschool can predict their academic success later in life. Helping children improve their language and vocabulary skills early on could help them succeed later, in middle and high school. Learning language is also a very social, interactive activity. Social robots could have great impact in this area, since they can leverage the same kinds of social cues and presence that people use. Learning language also takes time.

   In this work, we asked whether a sociable robotic learning/teaching companion could supplement children’s early long-term language education. Children played with the robot for two months. The robot was designed as a social character, engaging children as a peer, not as a teacher, within a relational, dialogic context. The robot targeted the social, interactive nature of language learning through a storytelling game that the robot and child played together. The game was on a tablet – the tablet showed a couple characters that the robot or child could move around while telling their story. During the game, the robot introduced new vocabulary words and modeled good story narration skills.

   Furthermore, because children may learn better when appropriately challenged, we asked whether a robot that matched the “level” or complexity of the language it used to the general language ability of the child might help children improve more. The robot told easier or harder stories based on an assessment of the child’s general ability. This work is supported by the NSF Expeditions in Computing award in Socially Assistive Robots.

65. **Tega: A New Platform for Socially Assistive Robotics**

   **Luke Plummer, Cynthia Breazeal, Jin Joo Lee**

   Fardad Faridi, Cooper Perkins Inc., IFRobots, Stacey Dyer

   Tega is a new robot platform designed to support long-term, in-home interactions with children, with applications in early-literacy education from vocabulary to storytelling.

66. **TinkRBook: Reinventing the Reading Primer**

   **David Nunez, Cynthia Breazeal**

   TinkRBook is a storytelling system that introduces a new concept of reading, called textual tinkerability. Textual tinkerability uses storytelling gestures to expose the text-concept relationships within a scene. Tinkerability prompts readers to become more physically active and expressive as they explore concepts in reading together. TinkRBooks are interactive storybooks that prompt interactivity in a subtle way, enhancing communication between parents and children during shared picture-book reading. TinkRBooks encourage positive reading behaviors in emergent literacy: parents act out the story to control the words onscreen, demonstrating print referencing and dialogic questioning techniques. Young children actively explore the abstract relationship between printed words and their meanings.
even before this relationship is properly understood. By making story elements alterable within a narrative, readers can learn to read by playing with how word choices impact the storytelling experience. Recently, this research has been applied in developing countries.

Canan Dagdeviren: Conformable Decoders
Converting the patterns of nature and the human body into beneficial signals and energy

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 the quality life of people and potentially provide environmentally friendly power.

Kevin Esvelt: Sculpting Evolution
Exploring evolutionary and ecological engineering

Erika Alden DeBenedictis, Kevin Esvelt, 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.
Who should decide whether, when, and how to alter the environment? It’s a hard question, especially when the decision 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. 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.

Erika Alden DeBenedictis, Kevin Esvelt, Jianghong Min

We are developing methods of controlling the genetic and cellular composition of microbial communities in the gut. Stably colonized microbes could be engineered to sense disease, resist pathogen invasion, and release appropriate therapeutics in situ.

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, Devora Najjar

The world uses an estimated 20 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. If successful, widespread adoption of these mice could drastically reduce animal suffering in laboratories worldwide.

Kevin Esvelt

How will gene drive systems evolve once released into the wild? Can they be reliably overwitten 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, Cody Gilleland, Jianghong Min

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
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.

**Hugh Herr: Biomechatronics**

*Enhancing human physical capability*

| 75. | An Osseointegrated Prosthesis with Bi-Directional Neural Communication | Anthony Nicholas Zorzos, Tyler Clites  
Matthew J Carty, MD (BWH), Rickard Branemark, MD, PhD, MS (UCSF) |
| 76. | Artificial Gastrocnemius | Hugh Herr |
| 77. | Biomimetic Active Prosthesis for Above-Knee Amputees | Luke Mooney, Hugh Herr, Matthew Carney |
| 78. | Control of Muscle-Actuated Systems via Electrical Stimulation | Hugh Herr |
| 79. | Effect of a Powered Ankle on Shock Absorption and Interfacial Pressure | David Hill, Hugh Herr |
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.

80. FitSocket: Measurement for Attaching Objects to People

Jean-Francois Duval, Neri Oxman, Arthur J Petron, Hugh Herr

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.

81. FlexSEA: Flexible, Scalable Electronics Architecture for Wearable Robotics Applications

Jean-Francois Duval, Hugh Herr

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.

82. Human Walking Model Predicts Joint Mechanics, Electromyography, and Mechanical Economy

Matt Furtney, Hugh Herr

Stanford Research Institute

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.

83. Load-Bearing Exoskeleton for Augmentation of Human Running

Hugh Herr

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.

84. Neural Interface Technology for Advanced Prosthetic Limbs

Anthony Nicholas Zorzos, Tyler Clites, Edward Boyden, Shriya Srinivasan, Hugh Herr, Ron Riso, Cameron Taylor

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.

85. Powered Ankle-Foot Prosthesis

Matthew Carney, Hugh Herr

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.

86. Revolutionizing Amputation Surgery for the Restoration of Natural Neural Sensation

Anthony Nicholas Zorzos, Tyler Clites, Shriya Srinivasan

Matthew J Carty, MD (BWH)

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 effenter 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.

87. Sensor-Fusions for an EMG Controlled Robotic Prosthesis

Hugh Herr

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.

88. Terrain-Adaptive Lower Limb Prosthesis

Roman Stolyarov, Hugh Herr

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 projects 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.

89. Tethered Robotic System for Understanding Human Movements

Jiun-Yih Kuan, Hugh Herr

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.

90. Ultrasound Imaging for Transstitial Prosthetic Interface Design

Bryan Ranger, Hugh Herr

Brian W. Anthony

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.

91. Variable-Impedance Prosthetic (VIPr) Socket Design

Bryan Ranger, David Moinina Sengeh, Arthur J Petron, Hugh Herr

Today, 100 percent of amputees experience some form of prosthetic socket discomfort. This project involves the design and production of a comfortable, variable impedance prosthetic (VIPr) socket using digital anatomical data for a transstitial amputee using computer-aided design and manufacturing (CAD/CAM). The VIPr socket uses multiple materials to achieve compliance, thereby increasing socket
comfort for amputees, while maintaining structural integrity. The compliant features are seamlessly integrated into the 3D-printed socket to achieve lower interface peak pressures over bony protuberances and other anatomical points in comparison to a conventional socket. This lower peak pressure is achieved through a design that uses anthropomorphic data acquired through surface scan and Magnetic Resonance Imaging techniques. A mathematical transformation maps the quantitative measurements of the human residual limb to the corresponding socket shape and impedance characteristics, spatially.

Oliver A Kannape, Hugh Herr

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.

Cesar A. Hidalgo: Macro Connections
Transforming data into knowledge

92. Volitional Control of a Powered Ankle-Foot Prosthesis

93. DataUSA

Cesar A. Hidalgo
DataWheel, Deloitte
DataUSA is the most comprehensive site visualizing public data for the United States. Through interactive profiles, DataUSA makes available data from a variety of public sources, including the American Community Survey, the Bureau of Economic Analysis, the Bureau of Labor and Statistics, the Department of Education (IPEDS), and the county health records from the University of Wisconsin in Madison.

94. DataViva

Cesar A. Hidalgo
FapeMIG, DataWheel
DataViva made available data for the entire economy of Brazil, including exports and imports for each municipality and product, and occupation data for every municipality, industry, and occupation.

95. DIVE

Cesar A. Hidalgo, Kevin Zeng Hu
DIVE is a new data exploration platform that enables users to build rich stories from any dataset using just a few clicks. By combining intelligent ontology detection, recommendation-based visualization and analysis, and dynamic story sharing, DIVE aims to lower the barrier-to-entry to work with data.

96. FOLD

Ethan Zuckerman, Kevin Zeng Hu, Alexis Hope, Matthew Carroll, Cesar A. Hidalgo, 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.

97. GIFGIF

Andrew Lippman, Kevin Zeng Hu, Travis Rich, Cesar A. Hidalgo
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 website with 200,000 users maps the
GIFs to an emotion space and lets you peruse them interactively.

98. **Immersion**
Daniel Smilkov and Deepak Jagdish
The current interface of emails is designed around time and messages, pushing people to focus on what
is more recent rather than important. Immersion is a design experiment that centers the email interface
on people and the networks that people form.

99. **Linking Economic Complexity, Institutions, and Income Inequality**
Manuel Aristaran, Cristian Ignacio Jara Figueroa, Dominik Hartmann, Cesar A. Hidalgo
Miguel Guevara
The mix of products that a country exports is a known predictor of income and economic growth, but
does this product mix also predict income inequality? Here we apply methods from statistics, network
science, and economic complexity to a dataset combining more than 50 years of international trade data
and income inequality. Our results document a robust and stable relationship between income inequality
and the mix of products that a country exports. In addition, we present the PINI index; a measure that
relates 773 different types of products to the levels of income inequality in their producer countries.
Combining the PINI information with the network of related products allows us to illustrate how changes
in a country's industrial structure are accompanied by changes in its level of income inequality.

100. **Opus**
Cesar A. Hidalgo
Opus is an online tool exploring the work and trajectory of scholars. Through a suite of interactive
visualizations, Opus help users explore the academic impact of a scholar’s publications, discover her
network of collaborators, and identify her peers.

101. **Pantheon**
Amy Yu, Kevin Zeng Hu
Shahar Ronan
Pantheon is an effort to map our species’ collective memory by focusing on globally famous biographies.

102. **Participie**
Ali Almossawi
Participie was a design experiment on direct participation for constrained choices (like budgets).

103. **Place Pulse**
Phil Salesses, Deepak Jagdish, Daniel Smilkov
Place Pulse is a crowdsourcing effort to map urban perception. By asking users to select images from a
pair, Place Pulse collects the data needed to evaluate people’s perceptions of urban environments. This
data is also the data used to train Streetscore. Place Pulse was developed by Phil Salesses as part of his
requirement to complete his master’s thesis. The present version of Place Pulse was re-engineered by
Daniel Smilkov and Deepak Jagdish.

104. **PubPub**
Thariq Shihijar, Andrew Lippman, Kevin Zeng Hu, Travis Rich, Cesar A. Hidalgo
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.

105. **Shout!**
Ambika Krishnamachar
Can I borrow your network? Shout! is a marketplace for retweets that allows people to exchange micro-
contracts for future retweets. Shout! facilitates the coordination of social media diffusion efforts by
groups.

106. **StreetScore**
Cesar A. Hidalgo, Ramesh Raskar, Nikhil Naik
Jade Phillpoom
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.
The Observatory of Economic Complexity (OEC)

Alexander Simoes
The Observatory of Economic Complexity (OEC) is the world’s leading data visualization tool for international trade data. The OEC makes more than 50 years of international trade data available through dozens of millions of interactive visualizations. Visit the OEC at: http://atlas.media.mit.edu

Hiroshi Ishii: Tangible Media
Seamlessly coupling the worlds of bits and atoms by giving dynamic physical form to digital information and computation

aeroMorph
Nikolaos Vlavianos, Jifei Ou, Hiroshi Ishii, Chinyi Cheng, Felix Heibeck
Melina Skouras, Nikolaos Vlavianos, Jannik Peters
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 3-axis CNC machines to precisely fabricate the designed transforming material is presented. We envision this technology could be used for designing interactive wearables, toys, and packaging industry.
http://tangible.media.mit.edu/project/aeromorph/
Honorable Mention Paper Award, UIST 2016

bioLogic
Wen Wang, Lining Yao, Jifei Ou, Hiroshi Ishii
MIT Architecture; Guanyun Wang, Chin-Yi Cheng, RCA; Oksana Anilionyte, RCA, Zhejiang University; Helene Steiner
BioLogic is our attempt to program living organisms and invent responsive and transformational interfaces of the future. Nature has engineered its own actuators, as well as the efficient material composition, geometry, and structure to utilize its actuators and achieve functional transformation. Based on the natural phenomenon of hygromorphic transformation, we introduce a specific type of living cells as nanoactuators that react to body temperature and humidity change. The living nanoactuator can be controlled by electrical signal and communicate with the virtual world as well. A digital printing system and design simulation software are introduced to assist the design of transformation structure.

ChainFORM
Ken Nakagaki, Joseph A. Paradiso, Artem Dementyev, Hiroshi Ishii
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
Hiroshi Ishii, Jifei Ou, Gershon Dublon
Felix Heibeck, Chin-Yi Chen, Liang Zhou
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.

Ken Nakagaki, Thariq Shihipar, Hiroshi Ishii
Anthony Stuart, Chantine Akiyama, Yin Shuang, Jim Peraino, Pasquale Totaro

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.

Wen Wang, Lining Yao, Jifei Ou, Hiroshi Ishii
Chin-Yi Cheng

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.

Hiroshi Ishii, Luke Vink
Rebecca Li, Daniel Mendelsohn

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.

Lining Yao, Hiroshi Ishii, Jifei Ou
Juergen Steimle, Ryuma Niiyama, Daniel Tauber

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.

Ken Nakagaki, Hiroshi Ishii

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.

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.

119. **MirrorFugue**

Xiao Xiao, Hiroshi Ishii

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.

120. **Pneuduino**

Felix Heibeck, Lining Yao, Jifei Ou, Hiroshi Ishii

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.

121. **Pneumatic Shape-Changing Interfaces**

Lining Yao, Hiroshi Ishii, Jifei Ou

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.

122. **Radical Atoms**

Xiao Xiao, Daniel Leithinger, Leonardo A. Bonanni, Jean-Baptiste (JB) Labrune, Hiroshi Ishii

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.

123. **S.C.A.L.E.**

Penelope Eugenia Webb, Hiroshi Ishii, Tal Achituv

S.C.A.L.E. is a system for detecting localization of an external object or agent, utilizing weight and pressure as a controlling constant for the detection of place and pressure. The system is designed for simple prototyping of interactive products.

124. **TRANSFORM**

Daniel Leithinger, Hiroshi Ishii

LEXUS International

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.

125. **TRANSFORM: Adaptive and Dynamic Furniture**

Ken Nakagaki, Daniel Leithinger, Viirj Kan, Luke Vink, Hiroshi Ishii

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.

Joseph M. Jacobson: Molecular Machines
Engineering at the limits of complexity with molecular-scale parts

126. **Evolutron: Deep Learning for Protein Design**
Thrasvoulos Karydis, Joseph M. Jacobson, Kfir Schreiber
Andreas Mershin, MIT Center for Bits and Atoms

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 the 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.

127. **Scaling Up DNA Logic and Structures**
Lisa Nip, Joseph M. Jacobson, Noah Jakimo

Our goals include novel gene logic and data logging systems, as well as DNA scaffolds that can be produced on commercial scales. State of the art in the former is limited by finding analogous and orthogonal proteins for those used in current single-layer gates and two-layered circuits. State of the art in the latter is constrained in size and efficiency by kinetic limits on self-assembly. We have designed and plan to demonstrate cascaded logic on chromosomes and DNA scaffolds that exhibit exponential growth.

128. **Synthetic Genome Engineering**
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.
A Multi-Sensor Wearable Device for Analyzing Stress Response in Preschool Classrooms

Gal Koren, Sepandar Kamvar

One of the fundamental goals of Montessori education is to create productive, stress-free educational environments for children. In addition to traditional methods of observation, we argue that teachers would benefit from tools that could provide supplemental data identifying stress responses in students using psychophysiological data. The child-suited wearable device we have designed incorporates sensors that track signs linked to emotional and sympathetic responses, such as heart rate variability and electro-dermal activity. Through these data points, teachers and parents can better understand the child’s emotional responses to activities and social interactions at school, and tailor programs to support wellbeing and stress reduction.

Big Data for Small Places

Elizabeth Christoforetti, Jia Zhang, Stephen Rife, Sepandar Kamvar, Nazmus Saquib, Caroline Jaffe

Big Data for Small Places is a quantitative study of the qualities that define our neighborhoods and our collective role in the production of local places over time. We are translating the potentials of big data from the scale of the city to the scale of the urban block, the scale at which we physically experience urban space, to gain a better understanding of the local patterns and social spaces that aggregate to form metropolitan identity. We hope that this study will improve our collective understanding of the urban environments we shape and the stories they generate, that it will allow us to more sensitively test and implement real change in our shared public realm and support the invisible narratives it generates.

Boundaries Drawings

Kimberly Smith, Sepandar Kamvar

These wall drawings are generated by a series of predesigned instructions that dictate their form. The instructions give both constraint and flexibility, so that the piece that unfolds has a clear structure and at the same time expresses the individual aesthetic preferences of the participants who contribute. Since each step depends on the previous steps, the result is a dynamic, collaborative piece, authored collectively by the artist and the exhibit visitors.

Computational Scope and Sequence for a Montessori Learning Environment

Yonatan Cohen, Sepandar Kamvar, Kimberly Smith, Sanjoy Mahajan

As part of our motivation to expand the classic Montessori curriculum and to address contemporary proficiencies, we are working closely with Montessori experts and computer scientists to develop a scope and sequence for computational thinking that will contribute to the Montessori classroom. This curriculum outlines the key concepts behind computer science, along with the corresponding materials and their lessons.

Microculture

Yonatan Cohen, Sepandar Kamvar

Kathryn Grantham, Lisa DePiano, Josh Sarantitis

Microculture gardens are a network of small-scale permaculture gardens that are aimed at reimagining our urban food systems, remediating our air supply, and making our streets more amenable to human-scale mobility. Microculture combines micro-gardening with the principles of permaculture, creatively occupying viable space throughout our communities for small-scale self-sustaining food forests. Microgardens have proven to be successful for the production of a broad range of species, including leafy vegetables, fruit, root vegetables, herbs, and more. Traditionally, container-based micro-gardens occupy approximately one meter of space or less and are made from found, up-cycled materials. Our innovations involve the combining of permaculture and micro-gardening principles, developing materials and designs that allow for modularity, mobility, easy replicability, placement in parking spots, and software that supports the placement, creation, and maintenance of these gardens.

Motivation and Mobility: Bicycles and Sensors in the City

Caroline Jaffe, Sepandar Kamvar

We are interested in investigating the motivations at play when an individual makes choices about mobility. How do factors like money, time, comfort, and habit impact how people choose to get around cities? And is it possible to disrupt these practices by nudging people in new directions?
In the first part of this study, we targeted individuals who live within five miles of their main workplace, but primarily use a car to get around. We lent these people a bicycle with the stipulation that they actually use it several times a week. This study is ongoing; we are investigating whether the act of giving somebody a bicycle will prompt them to change established commuting and transportation habits. We are assessing travel behavior through surveys and mobile location tracking app.

In the second part of this study, we are developing a Blockchain-based marketplace that allows cyclists to anonymously share their location data and receive financial compensation from organizations that would like to sponsor cycling activity. For example, an insurance company may want to reward its customers with lower premiums for partaking in healthy commuting behavior. An advertising company may wish to understand cycling activity in order to improve their advertisement targeting. A local business may sponsor bicycling activity in its vicinity to increase sales.

This marketplace uses GPS data from sensors embedded in bicycles frames and powered by the cyclists themselves. The use of Blockchain technology makes transactions in the marketplace secure, seamless, trustworthy, and transparent. Users are able to reveal "just enough" information about themselves to participate in the decentralized marketplace, instead of exposing their entire profile to a central entity. This market-driven system facilitates better incentive-matching, and in turn produces a scalable and stable solution for increasing the use of sustainable transportation in cities.

Through both these studies, we hope to develop a better understanding of individuals' travel behavior, the psychology of urban cyclists, and the benefits and challenges of city cycling.

Jia Zhang

Kimberly Smith, Sepandar Kamvar

Ayesha Bose, Nazmus Saquib, Sepandar Kamvar, Dwayne George

Nazmus Saquib, Shantell Martin, Jonathan Bobrow

Shantell Martin

Sepandar Kamvar

Fall 2016 · MIT Media Lab
Wildflower Montessori

Sepandar Kamvar

Wildflower is an open-source approach to Montessori learning. Its aim is to be an experiment in a new learning environment, blurring the boundaries between home-schooling and institutional schooling, between scientists and teachers, between schools and the neighborhoods around them. At the core of Wildflower are nine principles that define the approach. The Wildflower approach has been implemented by several schools, which serve as a research platform for the development of Montessori materials that advance the Montessori Method, software tools that enable Montessori research, and social software that fosters the growth and connection of such schools.

You Are Here

Pranav Ramkrishnan, Wesam Manassra, Jia Zhang, Stephen Rife, Sepandar Kamvar, Yonatan Cohen
Edward Faulkner, Kim Smith

You Are Here is an experiment in microurbanism. In this project, we are creating 100 maps each of 100 different cities. Each map gives a collective portrait of one aspect of life in the city, and is designed to give communities meaningful micro-suggestions of what they might do to improve their city. The interplay between the visualizations and the community work they induce creates a collective, dynamic, urban-scale project.

Kent Larson: Changing Places

Enabling dynamic, evolving places that respond to the complexities of life

We propose that fundamentally new strategies must be found for creating the places where people live and work, and the mobility systems that connect these places, in order to meet the profound challenges of the future.

*Click here for Cities Network website

Building on current work at the mit media lab, city science researchers will initially focus on the following project themes. Additional project themes will be added in response to the priorities of corporate members, mit researchers, and the city science advisory board. These six initial themes represent a cross section of the interdisciplinary research that will be undertaken to address the major challenges associated with global urbanization.

The world is experiencing a period of extreme urbanization. In China alone, 300 million rural inhabitants will move to urban areas over the next 15 years. This will require building an infrastructure equivalent to the one housing the entire population of the United States in a matter of a few decades.

In the future, cities will account for nearly 90% of global population growth, 80% of wealth creation, and 60% of total energy consumption. Developing better strategies for the creation of new cities, is therefore, a global imperative.

Our need to improve our understanding of cities, however, is pressed not only by the social relevance of urban environments, but also by the availability of new strategies for city-scale interventions that are enabled by emerging technologies. Leveraging advances in data analysis, sensor technologies, and urban experiments, City Science will provide new insights into creating a data-driven approach to urban design and planning. To build the cities that the world needs, we need a scientific understanding of cities that considers our built environments and the people who inhabit them. Our future cities will desperately need such understanding.

Changing Places 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.
Sheng-Ying (Aithne) Pao, Kent Larson

FlickInk is a gesture-sensing pen to support collaborative work and to augment the environment. With a quick “flick” of the pen toward a desired destination, analog written content on paper instantly transfers onto the corresponding physical object in the environment. The FlickInk gesture sensing module allows for wireless communication and directional gesture sensing. If multiple surfaces are present, the direction of the pen swing determines which screen the information is transferred to. Furthermore, multiple users can flick their written content to multiple devices, creating a personalized collaborative environment.

Andrew Lippman: Viral Communications

Creating scalable technologies that evolve with user inventiveness

Andrew Lippman, Hisayuki Ohmata

8K Time into Space is a user interface for a video exploration system with an 8K display. 8K is an ultra high-definition video system and it can present a huge amount of visual content on one display. In our system, video thumbnails with shifted playback time in chronological order are spaced out like tiles. The time range of a scene that a viewer wants to check can be adjusted with a touch interface, and resolution of the thumbnails is changed depending of the range. 8K Time into Space aims to provide responsive and intuitive experiences for video consumption.

Yasmine (Jasmin) Rubinovitz, Andrew Lippman

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.

Tomer Weller, Andrew Lippman

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.
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.

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

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 that 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.

Thariq Shihipar, Andrew Lippman

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.

Asaph Azaria, Andrew Lippman, Ariel Ekblaw, Joseph A. Paradiso, Thiago Vieira

We face a well-known need for innovation in electronic medical records (EMRs), but the technology is cumbersome and innovation is impeded by inefficiency and regulation. We demonstrate MedRec as a solution tuned to the needs of patients, the treatment community, and medical researchers. It is a novel, decentralized record management system for EMRs that uses blockchain technology to manage authentication, confidentiality, accountability, and data sharing. A modular design integrates with providers’ existing, local data-storage solutions, enabling interoperability and making our system convenient and adaptable. As a key feature of our work, we engage the medical research community with an integral role in the protocol. Medical researchers provide the “mining” necessary to secure and sustain the blockchain authentication log, in return for access to anonymized, medical metadata in the form of “transaction fees.”

Thariq Shihipar, Andrew Lippman

NewsClouds presents a visual exploration of how the news reporting of an event evolves over time. Each “cloud” represents a publication and each competing news organization usually emphasizes different aspects of that same story. Using the time sliders, that evolution becomes evident. In addition, each word or phrase can be expanded to show its links and context. We are building an archive of events associated with ongoing US election developments.

Yasmine (Jasmin) Rubinovitz, Andrew Lippman

This project aims to show a different picture of the data behind the news, looking at how we analyze, represent, and interact with it. Video content is constantly created and added to the public archives, but there is never time to watch it all. News Graph explores a new method for interacting with news media. By analyzing the words that are said, extracting entities that appear, and finding the connections between them, we are able to map connections between video segments. Each connection represents two entities that were mentioned in the same video segment, and a video segment can be mapped to a number of connections.

Yasmine (Jasmin) Rubinovitz, Andrew Lippman

The news is probably one of the first things people check in the morning, but how much does what you know and understand about the world depend on your news source? Will you view the world differently if you head over to CNN instead of BBC?

“Perspectives” is presenting top news stories from many points of view. The viewer can easily see the different perspectives and get the whole story.
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.

Andrew Lippman, Ariel Ekblaw, Tal Achituv, Jonathan Harvey-Buschel

Bitcoin generates net-new value from "mining" in a distributed network. In this work, we explore solar micro-mining rigs that transform excess energy capacity from renewable energy (hard to trade) into money (fungible). Each rig runs a small Bitcoin miner and produces Bitcoin dust for micropayments. We envision these micro-miners populating a highly distributed network, across rooftops, billboards, and other outdoor spaces. Where systematic or environmental restrictions limit the ability to freely trade the underlying commodity, micro-mining produces new economic viability. Renewable energy-based, micropayment mining systems can broaden financial inclusion in the Bitcoin network, particularly among populations that need a currency for temporary store of value and must rely on flexible electricity off the grid (e.g., unbanked populations in the developing world). This exploration seeds a longer-term goal to enable open access to digital currency via account-free infrastructure for the public good.

Tomer Weller, Andrew Lippman

A large portion of popular media is remixed: existing media content is spliced and re-ordered in a manner that serves a specific narrative. Super Cut Notes is a semi-comical content remix tool that allows a user to splice and combine the smallest bits of media: words. By tapping into the dataset of our group’s SuperGlue platform, it has access to a huge dictionary of words created by SuperGlue’s transcription module. Users are able to input a text of any length, choose video-bits of individual words that match their text, and create a video of their combination—in the style of cut-and-pasted ransom notes.

Tomer Weller, Andrew Lippman

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.

Tomer Weller, Andrew Lippman

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.

Andrew Lippman

Ditch the truck. Live, collaborative broadcasting through mixed-reality

Andrew Lippman

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.

Tomer Weller, Andrew Lippman

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.
Watch People Watch

Tomer Weller, Suzanne Wang, Andrew Lippman

Recording your reaction to a short video is becoming the new gossip; famous watchers get as many as 750,000 views. We attempt to transform this utterly useless and talentless event into a socially constructive alternative to simultaneous, synchronized, group viewing. Any user can opt in to be recorded and added to the shared, collective viewing experience. No talent or skills required.

---

Tod Machover: Opera of the Future

Extending expression, learning, and health through innovations in musical composition, performance, and participation

---

Ambisonic Surround-Sound Audio Compression

Charles Holbrow, Tod Machover

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.

---

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.

---

...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!

---

City Symphonies: Massive Musical Collaboration

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

The City Symphony project is a recent Opera of the Future initiative that 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 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/onsite, 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.

170. **Death and the Powers: Global Interactive Simulcast**

Charles Holbrow, Simone Ovsey, Tod Machover, Elena Jessop, Benjamin Bloomberg, Peter A. Torpey

Garrett Parrish, Justin Martinez, Kevin Nattinger

The live global interactive simulcast of the final February 2014 performance of “Death and the Powers” in Dallas made innovative use of satellite broadcast and Internet technologies to expand the boundaries of second-screen experience and interactivity during a live remote performance. In the opera, Simon Powers uploads his mind, memories, and emotions into The System, represented onstage through reactive robotic, visual, and sonic elements. Remote audiences, via simulcast, were treated as part of The System alongside Powers and the operabots. Audiences had an omniscient view of the action of the opera, as presented through the augmented, multi-camera video and surround sound. Multimedia content delivered to mobile devices, through the Powers Live app, privileged remote audiences with perspectives from within The System. Mobile devices also allowed audiences to influence The System by affecting the illumination of the Winspear Opera House’s Moody Foundation Chandelier.

171. **Death and the Powers: Redefining Opera**

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

“Death and the Powers” is a groundbreaking opera that brings a variety of technological, conceptual, and aesthetic innovations to the theatrical world. Created by Tod Machover (composer), 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.

172. **Empathy and the Future of Experience**

David Nunez, Sarah Platte, Akito Oshiro van Troyer, Simone Ovsey, Tod Machover, Benjamin Bloomberg, Peter A. Torpey, Rebecca Kleinberger, Charles Holbrow, Meejin Yoon and the Empathy and Experience class

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.

173. **Fablur**

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

Benjamin Bloomberg, Peter A. Torpey, Tod Machover
Lucerne Festival

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.

Hyperinstruments

Tristan Jehan, Rebecca Kleinberger, Tod Machover

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 of 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.

Hyperproduction: Advanced Production Systems

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.

Hyperscore

Tristan Jehan, Tod Machover

Hyperscore is an application to introduce children and non-musicians to musical composition and creativity in an intuitive and dynamic way. The "narrative" of a composition is expressed as a line-gesture, and the texture and shape of this line are analyzed to derive a pattern of tension-release, simplicity-complexity, and variable harmonization. The child creates or selects individual musical fragments in the form of chords or melodic motives, and layers them onto the narrative-line with expressive brushstrokes. The Hyperscore system automatically realizes a full composition from a graphical representation. Currently, Hyperscore uses a mouse-based interface; the final version will support freehand drawing, and integration with the Music Shapers and Beatbugs to provide a rich array of tactile tools for manipulation of the graphical score.

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.
Remote Theatrical Immersion: Extending “Sleep No More”

Brian Mayton, Jie Qi, Akito Oshiro van Troyer, Tod Machover, Jason Matthew Haas, Benjamin Bloomberg, Peter A. Torpey, Gershon Dublon, Elena Jessop

Punchdrunk

We have collaborated with London-based theater group Punchdrunk to create an online platform connected to their NYC show, Sleep No More. In the live show, masked audience members explore and interact with a rich environment, discovering their own narrative pathways. We have developed an online companion world to this real-life experience, through which online participants partner with live audience members to explore the interactive, immersive show together. Pushing the current capabilities of web standards and wireless communications technologies, the system delivers personalized multimedia content, allowing each online participant to have a unique experience co-created in real time by his own actions and those of his onsite partner. This project explores original ways of fostering meaningful relationships between online and onsite audience members, enhancing the experiences of both through the affordances that exist only at the intersection of the real and the virtual worlds.

SIDR: Deep Learning-Based Real-Time Speaker Identification

Tod Machover, Rebecca Kleinberger

Clement Duhart

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.

Sound Cycles

Charles Holbrow, Rebecca Kleinberger, Tod Machover

Clement Duhart

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.

Using the Voice As a Tool for Self-Reflection

Tod Machover, Rebecca Kleinberger

Our voice is an important part of our individuality. From the voices of others, we understand a wealth of non-linguistic information, such as identity, social-cultural clues, and emotional state. But the relationship we have with our own voice is less obvious. We don’t hear it the way others do, and our brain treats it differently from any other sound. Yet its sonority is deeply connected with how we are perceived by society and how we see ourselves, body and mind. This project is composed of software, devices, installations, and thoughts used to challenge us to gain new insights on our voices. To increase self-awareness, we propose different ways to extend, project, and visualize the voice. We show how our voices sometimes escape our control, and we explore the consequences in terms of self-reflection, cognitive processes, therapy, affective features visualization, and communication improvement.

Vocal Vibrations: Expressive Performance for Body-Mind Wellbeing

Charles Holbrow, Rebecca Kleinberger, Tod Machover, Elena Jessop

Le Laboratoire, The Dalai Lama Center at MIT

Vocal Vibrations explores relationships between human physiology and the vibrations of the voice. The voice is an expressive instrument that nearly everyone possesses and that is intimately linked to the physical form. In collaboration with Le Laboratoire and the MIT Dalai Lama Center, we examine the hypothesis that voices can influence mental and physical health through physico-physiological phenomena. The first Vocal Vibrations installation premiered in Paris, France, in March 2014. The public “Chapel” space of the installation encouraged careful meditative listening. A private “Cocoon” environment guided an individual to explore his/her voice, augmented by tactile and acoustic stimuli. Vocal Vibrations then had a successful showing as the inaugural installation at the new Le Laboratoire Cambridge from November 2014 through March 2015. The installation was incorporated into Le Laboratoire’s Memory/Witness of the Unimaginable exhibit, April 17-August 16, 2015.

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.
Pattie Maes: Fluid Interfaces

Integrating digital interfaces more naturally into our physical lives, enabling insight, inspiration, and interpersonal connections

Sang-won Leigh, Pattie Maes, Harshit Agrawal

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.

Joseph A. Paradiso, Pattie Maes

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.

Scott W. Greenwald, Pattie Maes

Real-time collaborative self-expression in virtual reality.

The Dermal Abyss (d-abyss) is a novel approach to biointerfaces in which the body surface is rendered an interactive display by patterning into the skin biosensors whose colors change in response to variations in the interstitial fluid. This modern interpretation of self-expression blends recent advances in biotechnology with traditional methods in tattoo artistry.

Rony Kubat, Natan Linder, Pattie Maes

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.

191. Express
Tal Achituv, Pattie Maes
Suffers from Cerebral Palsy), Daniel Kish (Expert in Perception and Accessibility for the Blind),
Cristina Powell (Artist
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.

192. EyeRing: A Compact, Intelligent Vision System on a Ring
Suranga Nanayakkara, Pattie Maes
EyeRing is a wearable, intuitive interface that allows a person to point at an object to see or hear more
information about it. We came up with the idea of a micro-camera worn as a ring on the index finger with a
button on the side, which can be pushed with the thumb to take a picture of or a video that is then sent
wirelessly to a mobile phone to be analyzed. The user tells the system what information they are
interested in and receives the answer in either auditory or visual form. The device also provides some
simple haptic feedback. This finger-worn configuration of sensors and actuators opens up a myriad of
possible applications for the visually impaired as well as for sighted people.

193. FingerReader
Pattie Maes
Suranga Nanayakkara, Connie K. Liu
FingerReader is a finger-worn device that helps the visually impaired to effectively and efficiently read
paper-printed text. It works in a local-sequential manner for scanning text that enables reading of single
lines or blocks of text, or skimming the text for important sections while providing auditory and haptic
feedback.

194. Food Attack
Niaja Farve, Pattie Maes
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.

195. GlassProv Improv Comedy System
Scott W. Greenwald, Pattie Maes
Baratunde Thurston, Cultivated Wit
As part of a Google-sponsored Glass developer event, we created a Glass-enabled improv comedy
show together with noted comedians from ImprovBoston and Big Bang Improv. The actors, all wearing
Glass, received cues in real time in the course of their improvisation. In contrast with the traditional model
for improv comedy, punctuated by “freezing” and audience members shouting suggestions, using Glass
allowed actors to seamlessly integrate audience suggestions. Actors and audience members agreed
that this was a fresh take on improv comedy. It was a powerful demonstration that cues on Glass are
suitable for performance: actors could become aware of the cues without having their concentration or
flow interrupted, and then view them at an appropriate time thereafter.

Kevin Wong, Pattie Maes
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.
197. HRQR
Valentin Heun, Pattie Maes
HRQR is a visual Human and Machine Readable Quick Response Code that can replace usual 2D barcode and QR Code applications. The code can be read by humans in the same way it can be read by machines. Instead of relying on a computational error correction, the system allows a human to read the message and therefore is able to reinterpret errors in the visual image. The design is highly inspired by a 2,000 year-old Arabic calligraphy called Kufic.

198. Invisibilia: Revealing Invisible Data as a Tool for Experiential Learning
Judith Amores Fernandez, Pattie Maes
Invisibilia seeks to explore the use of Augmented Reality (AR), head-mounted displays (HMD), and depth cameras to create a system that makes invisible data from our environment visible, combining widely accessible hardware to visualize layers of information on top of the physical world. Using our implemented prototype, the user can visualize, interact with, and modify properties of sound waves in real time by using intuitive hand gestures. Thus, the system supports experiential learning about certain physics phenomena through observation and hands-on experimentation.

199. JaJan!: Remote Language Learning in Shared Virtual Space
Kevin Wong, Pattie Maes
Takako Aikawa
JaJan! is a telepresence system wherein remote users can learn a second language together while sharing the same virtual environment. JaJan! can support five aspects of language learning: learning in context; personalization of learning materials; learning with cultural information; enacting language-learning scenarios; and supporting creativity and collaboration. Although JaJan! is still in an early stage, we are confident that it will bring profound changes to the ways in which we experience language learning and can make a great contribution to the field of second language education.

Chang Long Zhu Jin, Pattie Maes, Joseph A. Paradiso
KickSoul is a wearable device that maps natural foot movements into inputs for digital devices. It consists of an insole with embedded sensors that track movements and trigger actions in devices that surround us. We present a novel approach to use our feet as input devices in mobile situations when our hands are busy. We analyze the foot’s natural movements and their meaning before activating an action.

201. LuminAR
Rony Kubat, Natan Linder, Pattie Maes
LuminAR reinvents the traditional incandescent bulb and desk lamp, evolving them into a new category of robotic, digital information devices. The LuminAR Bulb combines a Pico-projector, camera, and wireless computer in a compact form factor. This self-contained system enables users with just-in-time projected information and a gestural user interface, and it can be screwed into standard light fixtures everywhere. The LuminAR Lamp is an articulated robotic arm, designed to interface with the LuminAR Bulb. Both LuminAR form factors dynamically augment their environments with media and information, while seamlessly connecting with laptops, mobile phones, and other electronic devices. LuminAR transforms surfaces and objects into interactive spaces that blend digital media and information with the physical space. The project radically rethinks the design of traditional lighting objects, and explores how we can endow them with novel augmented-reality interfaces.

202. MARS: Manufacturing Augmented Reality System
Rony Kubat, Pattie Maes, Niaja Farve, Natan Linder
Ben Weissmann, Steelcase
Projected augmented reality in the manufacturing plant can increase worker productivity, reduce errors, gamify the workspace to increase worker satisfaction, and collect detailed metrics. We have built new LuminAR hardware customized for the needs of the manufacturing plant and software for a specific manufacturing use case.

203. Move Your Glass
Niaja Farve, Pattie Maes
Move Your Glass is an activity and behavior tracker that also tries to increase wellness by nudging the wearer to engage in positive behaviors.

204. Oasis
Misha Sra, Pattie Maes
Oasis received the Best Paper Award at VRST 2016.
Oasis is a novel system for automatically generating immersive and interactive virtual reality environments using the real world as a template. The system captures indoor scenes in 3D, detects obstacles like furniture and walls, and maps walkable areas to enable real-walking in the generated virtual environment. Depth data is additionally used for recognizing and tracking objects during the VR experience. The detected objects are paired with virtual counterparts to leverage the physicality of the real world for a tactile experience. Our system allows a casual user to easily create and experience VR in any indoor space of arbitrary size and shape without requiring specialized equipment or training.
Oasis can be used, for example, to create storyspaces where friends and family can remotely participate in a session of storytelling around the campfire. The freedom to move around and interact with the virtual world allows for a new form of storytelling when combined with traditional narration techniques like vocalization, movement, and gestures. We call this human in the loop storytelling distinguishing it from current VR storytelling experiences where the software system is the storyteller.

Valentin Heun, Pattie Maes

Open Hybrid is an open source augmented reality platform for physical computing and Internet of Things. It is based on the web and Arduino.

Daniel Novy, Judith Amores Fernandez, Pattie Maes

PsychicVR integrates a brain-computer interface device and virtual reality headset to improve mindfulness while enjoying a playful immersive experience. The fantasy that any of us could have super hero powers has always inspired us, and by using Virtual Reality and real-time brain activity sensing we are moving one step closer to making this dream real. We non-invasively monitor and record electrical activity of the brain and incorporate this data in the VR experience using an Oculus Rift and the MUSE headband. By sensing brain waves using a series of EEG sensors, the level of activity is fed back to the user via 3D content in the virtual environment. When users are focused, they are able to make changes in the 3D environment and control their powers. Our system increases mindfulness and helps achieve higher levels of concentration while entertaining the user.

Valentin Heun, Pattie Maes

The Reality Editor is a new kind of tool for empowering you to connect and manipulate the functionality of physical objects. Just point the camera of your smartphone at an object and its invisible capabilities will become visible for you to edit. Drag a virtual line from one object to another and create a new relationship between these objects. With this simplicity, you are able to master the entire scope of connected objects.

Judith Amores Fernandez, Pattie Maes

Remot-IO is a system for mobile collaboration and remote assistance around Internet-connected devices. It uses two head-mounted displays, cameras, and depth sensors to enable a remote expert to be immersed in a local user’s point of view, and to control devices in that user’s environment. The remote expert can provide guidance through hand gestures that appear in real time in the local user’s field of view as superimposed 3D hands. In addition, the remote expert can operate devices in the novice’s environment and bring about physical changes by using the same hand gestures the novice would use. We describe a smart radio where the knobs of the radio can be controlled by local and remote users. Moreover, the user can visualize, interact, and modify properties of sound waves in real time by using intuitive hand gestures.

Sang-won Leigh, Pattie Maes

We envision a machine-driven evolution of the human body’s form and function, where the programmable nature of machines plays a crucial role. Robotic joints worn on the wrist turn into extra fingers so that a person acquires skills beyond what five fingers can offer, or performs “tri-manual” tasks with the machine joints. The robot runs on a neural network that learns life-like controls autonomously. Like how a human simulates actions in mind, the robot conducts simulations in a virtual environment to teach itself a variety of handling strategies.

Ethan Zuckerman, Tal Achituv, Pattie Maes

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.

Chang Long Zhu Jin, Tal Achituv, Pattie Maes

Isa Sobrinho

Screen interactions have been shown to contribute to increases in stress, anxiety, and deficiencies in breathing patterns. Since better respiration patterns can have a positive impact on wellbeing, ScreenSpire improves respiration patterns during information work using subliminal biofeedback. By
using subtle graphical variations that are tuned to attempt to influence the user subconsciously. User distraction and cognitive load are minimized. To enable a true seamless interaction, we have adapted an RF based sensor (ResMed S+ sleep sensor) to serve as a screen-mounted contact-free and respiration sensor. Traditionally, respiration sensing is achieved with either invasive or on-skin sensors (such as a chest belt); having a contact-free sensor contributes to increased ease, comfort, and user compliance, since no special actions are required from the user.

Judith Amores Fernandez, Pattie Maes

ShowMe is an immersive mobile collaboration system that allows remote users to communicate with peers using video, audio, and gestures. With this research, we explore the use of head-mounted displays and depth sensor cameras to create a system that (1) enables remote users to be immersed in another person's view, and (2) offers a new way of sending and receiving the guidance of an expert through 3D hand gestures. With our system, both users are surrounded in the same physical environment and can perceive real-time inputs from each other.

Xin Liu, Katia Vega, Pattie Maes, Joseph A. Paradiso

Skrin is an exploration project on digitalized body skin surface using embedded electronics and prosthetics. Human skin is a means for protection, a mediator of our senses and a presentation of ourselves. Through several projects, we expand the expression capacity of body surface and emphasize on the dynamic aesthetics of body texture by technological means.

Niaja Farve, Pattie Maes

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 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.

Rahul Kumar Namdev, Pattie Maes

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.

Judith Amores Fernandez, Pattie Maes

TagMe is an end-user toolkit for easy creation of responsive objects and environments. It consists of a wearable device that recognizes the object or surface the user is touching. The user can make everyday objects come to life through the use of RFID tag stickers, which are read by an RFID bracelet whenever the user touches the object. We present a novel approach to create simple and customizable rules based on emotional attachment to objects and social interactions of people. Using this simple technology, the user can extend their application interfaces to include physical objects and surfaces into their personal environment, allowing people to communicate through everyday objects in very low-effort ways.

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

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.

Xin Liu, Pattie Maes

Is it possible to experience being another lifeform? TreeSense is an visuo-tactile VR system that transforms the user into a tree, starting from the seed till its death. It integrates electronic muscle stimulation into virtual reality, providing tactile stimuli and visual images simultaneously.
WATCH

**Niija Farve, Pattie Maes**
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.

**Christian David Vazquez Machado, Pattie Maes, Takako Aikawa, Alexander Luh, Megan Fu, Afika Nyati**
As more powerful and spatially aware Augmented Reality devices become available, we can leverage the user’s context to embed reality with audio-visual content that enables learning in the wild. Second language learners can explore their environment to acquire new vocabulary relevant to their current location. Items are identified, “labeled” and spoken out loud, allowing users to make meaningful connections between objects and words. As time goes on, word groups and sentences can be presented customized to the user’s current level of competence. When desired, a remote expert can join in real-time for a more interactive “tag-along” learning experience.

**Neri Oxman: Mediated Matter**
*Designing for, with, and by nature*

**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.

**John Klein, Steven Keating**
Our initial experiments in spark electro-sintering 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 electro-sintering: 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.

**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’ 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.

224. **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.

225. **Bots of Babel**

**Laia Mogas-Soldevila, Jared Laucks, Jorge Duro-Royo, Neri Oxman, Markus Kayser**

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))

226. **Building-Scale 3D Printing**

**Neri Oxman, John Klein, Steven Keating**

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.

227. **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.

228. **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.

229. **DCP: Digital Construction Environment**

**Levi Cai, Neri Oxman, Julian Leland, Steven Keating**

The 3D Printed Hemi-Ellipsoidal Dome 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 14.7 m and a height of 3.7 m was manufactured over a print time of 13.5 hours. The geometry of the test print is a hemi-ellipsoidal dome design, where the wall thickness of the formwork cavity decreases with height. This enables optimized structural use of the cast material while providing maximum internal volume. This test print demonstrates many of the benefits of both the Digital Construction Platform and the Print-In-Place process, including the ability to rapidly print large-scale structures, produce complex digitally controlled curvatures, and fabricate on-site.
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.

The DCP v.2 platform consists of a 5-axis Altec AT40GW mobile hydraulic arm with a 6-axis KUKA robotic arm mounted at its endpoint. These two systems implement a micro-macro manipulator robot architecture akin to the biological model of the human shoulder and hand: the large arm is used for gross positioning, while the small arm can perform fine positioning, provide oscillation compensation, and improve force control bandwidth. The arm system has a radial reach of more than 10 meters, and the system’s tracked base provides mobility to the platform.

DCP v.2 was designed using lessons from the v.1 system and has experimentally demonstrated significant improvements. The v.2 platform offers enhanced system control; additional environmental sensors providing real-time feedback to the system; a more rugged, compact, and mobile form factor; a fully electric powertrain with a diesel backup alternative; a photovoltaic-charged lithium battery pack for self-sustaining operation; and a digitally controlled tracked base providing system mobility. The system has successfully demonstrated large-scale digital construction with a range of different media and fabrication processes, including light printing, excavation, welded-chain construction, and additive fabrication with the Print-in-Place process. To explore the potential for on-site fabrication, an architectural test print of a 14.7 m open dome was manufactured with a print time of 13.5 hours. Ongoing research focuses on further improving system control, particularly over nonlinear behaviors like link flexibility and micro-macro manipulator coupling; and developing new interfaces to facilitate interaction with the system.

This project was made possible by the generous support of Altec and Google.
**FitSocket: Measurement for Attaching Objects to People**

Jean-Francois Duval, Neri Oxman, Arthur J Petron, Hugh Herr

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.

---

**Functionally Graded Filament-Wound Carbon-Fiber Prosthetic Sockets**

Neri Oxman

Hugh Herr and the Biomechatronics group

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.

---

**G3P**

Daniel Lizardo, John Klein, Chikara Inamura, Neri Oxman, Markus Kayser

Department of Materials Science and Engineering, MIT Glass Lab

Digital design and construction technologies for product and building scale are generally limited in their capacity to deliver multi-functional building skins. Recent advancements in additive manufacturing and digital fabrication at large are today enabling the fabrication of multiple materials with combinations of mechanical, electrical, and optical properties; however, most of these materials are non-structural and cannot scale to architectural applications. Operating at the intersection of additive manufacturing, biology, and architectural design, the Glass Printing project is an enabling technology for optical glass 3D printing at architectural scale designed to manufacture multi-functional glass structures and facade elements. The platform deposits molten glass in a layer-by-layer (FDM) fashion, implementing numerical control of tool paths, and it allows for controlled optical variation across surface and volume areas.

---

**G3P 2.0**

Daniel Lizardo, Neri Oxman, Chikara Inamura

Pierre-Thomas Brun, Peter Houk, Neri Oxman

The G3P 2.0 platform sets itself apart from traditional 3D printers, industrial glass forming devices, and its own predecessor G3P 1.0 by a fundamental restructuring of architecture and computer-aided machining (CAM) process based on the material properties of silicate glass. Glass is an extreme material. Working temperature range, viscosity, and thermal stress are sufficiently high that we must rethink the glass deposition forming process using new expertise on material behavior. The aim is to produce a platform that is less a printer, in the conventional sense, but rather, a freeform fabrication tool for glass. What results is a truly novel fabrication platform making use of a dynamic thermal and flow control system, digitally integrated with a four-axis motion system. The material fundamentally drives how the machine is used, and in return, the machine can change how glass is formed and used.

---

**Gemini**

Neri Oxman

Gemini is an acoustical "twin chaise" spanning multiple scales of human existence, from the womb to the stretches of the Gemini zodiac. We are exploring interactions between pairs: sonic and solar environments, natural and synthetic materials, hard and soft sensations, and subtractive and additive fabrication. Made of two material elements—a solid wood milled shell housing and an intricate cellular skin made of sound-absorbing material—the chaise forms a semi-enclosed space surrounding the human with a stimulation-free environment, recapitulating the ultimate quiet of the womb. It is the first design to implement Stratasys’ Connex3 technology using 44 materials with different pre-set mechanical combinations varying in rigidity, opacity, and color as a function of geometrical, structural, and acoustical constraints. This calming and still experience of being inside the chaise is an antidote to the stimuli-rich world in which we live.

---

**Lichtenberg 3D Printing**

Neri Oxman, Steven Keating

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.
243. 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.

245. Printing Multi-Material 3D Microfluidics

Neri Oxman, Will Patrick, Steven Keating

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 functionality 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
246. **Rapid Craft**

Neri Oxman

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.

247. **Raycounting**

Neri Oxman

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.

248. **Rottlace**

Christoph Bader, Neri Oxman, Dominik Kolb

Rottlace is a family of masks designed for Icelandic singer-songwriter Bjork. Inspired by Bjork’s most recent album Vulnicura the Mediated Matter group explored themes associated with self-healing and expressing “the face without a skin.” One of the masks from the series was selected for Bjork’s stage performance at the Tokyo Miraikan Museum, and 3D printed by Stratasys using multi-material printing. This process enables the production of elaborate combinations of graded properties distributed over geometrically complex structures within a single object. Graded and tunable material properties are achieved through custom software as well as heterogeneous material modelling workflows. Combined, this computational framework enables micron-scale control of 3D printable material placement over highly complex geometric domains. This enables the design and 3D printing of complex, large-scale objects with continuous variations of modulus and transparency, within a single build.

249. **Silk Pavilion**

Markus Kayser, Jared Laucks, Jorge Duro-Royo, Neri Oxman

James Weaver (Wyss Institute at Harvard University), Fiorenzo Omenetto (Tufts University)

The Silk Pavilion explores the relationship between digital and biological fabrication. The primary structure was created from 26 polygonal panels made of silk threads laid down by a CNC (Computer-Numerically Controlled) machine. Inspired by the silkworm’s ability to generate a 3D cocoon out of a single multi-property silk thread, the pavilion’s overall geometry was created using an algorithm that assigns a single continuous thread across patches, providing various degrees of density. Overall density variation was informed by deploying the silkworm as a biological “printer” in the creation of a secondary structure. Positioned at the bottom rim of the scaffold, 6,500 silkworms spun flat, non-woven silk patches as they locally reinforced the gaps across CNC-deposited silk fibers. Affected by spatial and environmental conditions (geometrical density, variation in natural light and heat), the silkworms were found to migrate to darker and denser areas.

250. **SpiderBot**

Neri Oxman

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.

251. **Synthetic Apiary**

Markus Kayser, Sunanda Sharma, Jorge Duro-Royo, Neri Oxman

Dr. James Weaver (Wyss Institute); Dr. Anne Madden; Dr. Noah Wilson-Rich (Best Bees Company); Dr. Noah, Dr. James Weaver (Wyss Institute); Dr. Anne Madden; Dr. Noah Wilson-Rich (Best B, Dr. James Weaver (Wyss Institute); Dr. Anne Madden; Dr. Noah Wilson-Rich (Best B)

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 that explores the cohabitation of humans and other species through the creation of a controlled atmosphere that can be wrapped, woven, or strung around environmental features or previously printed materials.
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.

253. Vespers

Christoph Bader, Sunanda Sharma, Dominik Kolb, Rachel Smith, Neri Oxman, 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.

Throughout history, technologies express the spirit of their age in design, and are embodied within the archetypes they create. Some archetypes—such as automobiles, airplanes, garments, prosthetic devices, and building skins—have evolved to improve the relationship between object, body, and environment. Others have become relics. The subject of Vespers, the next embodiment of the death mask, is a relic. The objects of Vespers are artifacts, which unite information architectures, manufacturing practices, and—at times—biological augmentation, to grow rather than assemble. Vespers’ death masks, however, are not intended to memorialize the dead. They are designed to reveal cultural heritage and speculate about the perpetuation of life, both culturally and biologically. By pushing the boundaries of cusp technologies—such as high-resolution material modeling, multi-material 3D printing, and synthetic biology—they express the death mask’s deeper meanings and possible future utility, thus bringing it back to life.

The custom of the death mask in the ancient world was believed to strengthen the spirit of the deceased and guard their soul from evil on the way to the afterworld. In this view, death is a conduit to a form of rebirth. The mythical notion that the soul can be guided from a state of death to a new state of life inspired the design of Vespers.

The Vespers collection comprises three series, each with five masks, that are related through time. Here, we unveil the second series. Modeled after Lazarus, this series—the present—explores the transition between life and death, illustrating the progression of the death mask from a symbolic cultural relic—as represented in the first series, past—to a functional biological interface—as revealed in the third series, future. It moves beyond the exterior surface and into the interior volume of the mask, employing a contemporaneous interpretation of the soul’s journey.

Using spatial mapping algorithms, the culturally coded surface colorations and truncated geometries in the first series are transformed into colored, internal strands within transparent, smoothly curved volumes in the second. The second series elucidates embryonic forms through complex internal geometries as it prepares to support the re-engineered life of the third series. In this series, it is the interplay of light that reveals the internal structures. Like spirits (from Latin spiritus, meaning “breath”), these structures reference the distribution of the martyr’s last breath.

The New Ancient collection produced by Stratasys, a 3D printing company, marries ancient crafts and designs of past civilizations with advanced technologies to reimagine design in and of the modern world. Created for this collection Vespers expresses the intertwining of Fear and Love through the continuity of death and life. Vespers’ masks five imaginary martyrs. Each martyr is memorialized three times, through sequential interpretations at three different moments: the past, the present, and the future.

The New Ancient collection was curated by Naomi Kaempfer, Creative Director of Art Fashion Design at Stratasys. Neri Oxman and the Mediated Matter Group would like to thank our collaborators at Stratasys, including Naomi Kaempfer, Arita Mattsoff, Boris Belocon, Gal Begun, Yoav Bressler and Ori Moalem.

254. Water-Based Additive Manufacturing

Neri Oxman, Laia Mogas-Soldevila, Jorge Duro-Royo

Dr. Javier G. Fernandez (Wyss Institute, Harvard University)

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.

Sputniko!: Design Fiction
Sparking discussion about the social, cultural, and ethical implications of emerging technologies through design and storytelling

Mary Tsang
A transgenic chicken commercial for ovulating women
Esgtrogen Farms is a fictional company that raises genetically modified chickens that produce ovulation hormones in their egg whites. The eggs are marketed towards women who are either trying to get pregnant, or work as egg donors for the fertility industry. The slogan reads, “One egg a day is the fertility way.” The project highlights a connection between women and chickens as raw commodities for the biotech industry, performing ways in which women are targeted for bio-consumerism. What is the rhetoric and imagery used in birth management products? Moreover, as avian transgenic technologies become further developed, is it possible to imagine a confluence of the poultry industry with the pharmaceutical health industry?

Mary Tsang
Geeking, workshoplogy, and freak science on the microcolonization of estrogen biomolecules Estrofem! Lab is dedicated to the development of a mobile estrogen lab: a set of tools, protocols, and wetware for low-cost, participatory biohacking necessitated by its genesis project, Open Source Estrogen. Regarded sometimes as hobo science, freak science, and public amateurism, the Estrofem Lab and its workshopologies aim to detect and extract estrogen from bodies and environmental sources, providing the contextual framework for why we hack estrogen, and why we perform science as citizens and hacktivists. This ongoing artistic investigation has led to creation of yeast estrogen sensors (YES-HER yeast) containing human estrogen receptor for detection, vacuum pump solid phase extraction (SPE) using cigarette filters, and DIY column chromatography using broken glass bottles, smashed silica gel, and methanol.

Anne Liu
Forget Me Not: The Botany of Desire & Loss
Nothing triggers memories like smell. Momentary, fleeting, and at times unexpected, one scent can conjure up the warmth of a grandparent, or the heat of a first kiss. Certain botanicals are known for their olfactive properties. Evolved to seduce pollinators and to proliferate the plant’s own genes, the fragrance of flowers have also become entangled in our human dance of seduction.

In the art of perfumery, we have long extracted the scents of flowers to apply to ourselves- what if we did the contrary and engineered a plant to emit the odor profile of a person instead? Could we design new rituals for mourning, new biologies for remembering?

This project is the speculative design of a plant that smells like a person who is emotionally significant to me, but has passed away.

Commercial agendas often drive the progress of certain trajectories of engineering. This project explores the alternative design of plants that is not driven nor thoroughly integrated in capitalist production. Exploring emotions such as loneliness, isolation, and feelings of guilt and anxiety towards human impacts on the environment, the function of these inquiries is to reflect on past, current and future trajectories of human influences on plant life.
257. **Hormone Microperformance**  
**Mary Tsang**

I am a traveling saleswoman, a nomadic cuntress performing with sex hormones. 
Exhibited at Raumschiff Gallery during Ars Electronica in Linz, Hormone Microperformance is an installation of hormonal shrines situated next to the “freak-science” experimentation process from which it originates. Hormones, when isolated from the body, act as pheromones that can influence the mind and behavior through chemical signaling. Using urine samples given by the other artists of the show, sex hormones were extracted and connected to oxygen masks for the audience to inhale and experience. What they experience is a microcolonization of the mind that is both ancient and evolutionary, but imperceptible to the naked eye.

258. **Human Perfume**

I am currently creating perfumes that capture the smell of individuals who have emotional significance to me. An exploration in the use of science for emotional ends, I have successfully bottled the scent profiles of three people. In the obsessively hygienic and reason driven laboratory where I distill these smells, I often reflect on the constant negotiation between the animal with the cultured human within ourselves. This projecting is currently conducted in tandem with research in neuroscience correlating olfactory stimuli with behavioral responses.

259. **(Im)possible Baby**  
**Ai Hasegawa, Sputniko!**

(Im)possible Baby is a speculative design project that aims to stimulate discussions about the social, cultural, and ethical implications of emerging biotechnologies that could enable same-sex couples to have their own, genetically related children. Delivering a baby from same-sex parents is not a sci-fi dream anymore, due to recent developments in genetics and stem cell research. In this project, the DNA data of a lesbian couple was analyzed using 23andme to simulate and visualize their potential children, and then we created a set of fictional, “what if” future family photos using this information to produce a hardcover album which was presented to the couple as a gift. To achieve more public outreach, we worked with the Japanese national television service, NHK, to create a 30-minute documentary film following the whole process, which aired in October 2015.

260. **I want to become a cephalopod**  
**Miriam Simun**

A transhumanist project towards co-evolution.

261. **Open Source Estrogen**  
**Mary Tsang, Sputniko!**

Biomolecules to biopolitics: hormones with institutional biopower! Open Source Estrogen combines do-it-yourself science, body and gender politics, and ethics of hormonal manipulation. The goal of the project is to create an open source protocol for estrogen biosynthesis. The kitchen is a politically charged space, prescribed to women as their proper dwelling, making it the appropriate place to prepare an estrogen synthesis recipe. With recent developments in the field of synthetic biology, the customized kitchen laboratory may be a ubiquitous possibility in the near future. Open-access estrogen would allow women and transgender females to exercise greater control over their bodies by circumventing governments and institutions. We want to ask: What are the biopolitics governing our bodies? More importantly, is it ethical to self-administer self-synthesized hormones?

262. **Pop Roach**  
**Ai Hasegawa, Sputniko!**

Facing issues of food crisis by overpopulation, this project explores a possible future where a small community of activists arises to design an edible cockroach that can survive in harsh environments. These genetically modified roaches are designed to pass their genes to the next generations; thus the awful black and brown roaches will be pushed to extinction by the newly designed, cute, colorful, tasty, and highly nutritional “pop roach.” The color of these “pop roaches” corresponds to a different flavor, nutrition, and function, while the original ones remain black or brown, and not recommended to be eaten. How will genetic engineering shift our perception of food and eating habits? Pop Roach explores how we can expand our perception of cuisine to solve some of the world’s most pressing problems.

263. **Red Silk of Fate-Tamaki’s Crush**  
**Sputniko! Fukutake Foundation**

Red String of Fate is an East Asian mythology in which gods tie an invisible red string between those that are destined to be together. Sputniko! has collaborated with scientists from NIAS to genetically engineer silkworms to spin this mythical “Red String of Fate” by inserting genes that produce oxytocin, a social-bonding “love” hormone, and the genes of a red-glowing coral into silkworm eggs. Science has long challenged and demystified the world of mythologies: from Galileo’s belief that the earth revolved around the sun, to Darwin’s theory of evolution and beyond—but in the near future, could science be recreating our mythologies? The film unravels a story around the protagonist Tamaki, an aspiring genetic engineer,
who engineers her own “Red Silk of Fate” in the hopes of winning the heart of her crush, Sachihiko. However, strange, mythical powers start to inhabit her creation...

264. **Teshima 8 Million Lab**

*Sputniko! Naruse Inokuma Architects*

Teshima 8 Million Lab is the first Shinto shrine worshipping a genetically engineered life - a silkworm created in Sputniko’s new work Red Silk of Fate–Tamaki’s Crush. In the Shinto religion, “Yaoyorozu” (which literally means “8 Million”) is a word used to describe the myriad of gods believed to reside in almost anything - such as the wind, the ocean, trees and animals. Conceived by artist Sputniko!, Teshima 8 Million Lab sets out to create new members of Yaoyorozu, forming a mythology from emerging science and art. Far from the big city and located on a site blessed with an abundance of nature, the facility invites the exploration of alternative perspectives on our future of nature and beliefs, as science continues to move forward.

265. **Tranceflora - Amy’s Glowing Silk**

*Sputniko! National Institute of Agrobiological Sciences, Gucci*

We collaborated with NIAS (National Institute of Agricultural Science) to genetically engineer silkworms to develop new kinds of silk for future fashion. For an exhibition at Tokyo’s Gucci Gallery, we designed a Nishijin-Kimono dress, working with NIAS’s glowing silk (created by injecting the genes of a glowing coral and jellyfish into silkworm eggs).

---

**Joseph A. Paradiso: Responsive Environments**

*Augmenting and mediating human experience, interaction, and perception with sensor networks*

266. **Chain API**

*Brian Mayton, Spencer Russell, Joseph A. Paradiso, Gershon Dublon*

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.

267. **ChainFORM**

*Ken Nakagaki, Joseph A. Paradiso, Artem Dementyev, Hiroshi Ishii*

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.

268. **ChromoSkin**

*Chris Schmandt, Manisha Mohan, Katie Vega, Joseph A. Paradiso, Cindy Hsin-Liu Kao*

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.

269. Circuit Stickers
Leah Buechley, Nan-wei Gong, Joseph A. Paradiso, Jie Qi
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.

270. Circuit Stickers Activity Book
Leah Buechley, Joseph A. Paradiso, Jie Qi
The Circuit Sticker 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.

271. Circuit Storybook
Kevin Slavin, Joseph A. Paradiso, Jie Qi
Sonja de Boer

272. DoppelLab: Experiencing Multimodal Sensor Data
Brian Mayton, Joseph A. Paradiso, Gershon Dublon
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.

273. Doppelmarsh: Cross-Reality Environmental Sensor Data Browser
Brian Mayton, Spencer Russell, Joseph A. Paradiso, Gershon Dublon, Donald Derek Haddad, Evan Lynch
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 QuatraSense, 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.

274. Experiential Lighting: New User Interfaces for Lighting Control
Nan Zhao, Matthew Aldrich, Joseph A. Paradiso
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).
275. **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 a 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.

276. **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.

277. **Halo Flex**  
Joseph A. Paradiso, Nan Zhao  
Halo Flex is the latest version of a series of wearable lighting devices that illuminates the face. It explores how light manipulates our facial qualities and visual perception. It brings together flexible circuits with wearable sensing to define a new form of dynamically controlled E-makeup.

A wire bend circlelet functions as the base. A flexible circuit board curves around the frame. Translucent solder mask, copper, and translucent dielectric material assemble a decorative pattern. Ten RGB LEDs are positioned on the bottom layer to achieve a variety of lighting effects. Lighting compositions can be set manually using a Bluetooth enabled device, such as a smart phone, or automatically using the onboard motion sensor. Halo explores opportunities for wearable lighting.

278. **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.

279. **HearThere: Ubiquitous Sonic Overlay**  
Spencer Russell, Joseph A. Paradiso, Gershon Dublon  
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.

280. **KickSoul: A Wearable System for Foot Interactions with Digital Devices**  
Chang Long Zhu Jin, Pattie Maes, Joseph A. Paradiso  
KickSoul is a wearable device that maps natural foot movements into inputs for digital devices. It consists of an insole with embedded sensors that track movements and trigger actions in devices that surround us. We present a novel approach to use our feet as input devices in mobile situations when our hands are busy. We analyze the foot’s natural movements and their meaning before activating an action.

281. **ListenTree: Audio-Haptic Display in the Natural Environment**  
Joseph A. Paradiso, Edwina Portocarrero, Gershon Dublon, V. Michael Bove  
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.

282. Living Observatory: Sensor Networks for Documenting and Experiencing Ecology

Brian Mayton, Spencer Russell, Joseph A. Paradiso, Gershon Dublon, Donald Derek Haddad, Glorianna Davenport

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 others 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.

283. Low-Power Gesture Input with Wrist-Worn Pressure Sensors

Joseph A. Paradiso, Artem Dementyev

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 light-weight 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 ink-jet 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.

284. Low-Power Wireless Environmental Sensor Node

Joseph A. Paradiso, Brian Mayton

Tidmarsh is a 600-acre former cranberry farm near Plymouth, MA that is being restored to natural wetland. As the restoration proceeds, we have deployed hundreds of wireless sensors to track the environment as it is transformed. Data from the sensors is made available in real time, feeding a multitude of projects within Responsive Environments. We are currently developing the next version of our sensing platform, hundreds of which will be installed in the coming months. The sensor node measures and wirelessly transmits temperature, humidity, atmospheric pressure, sound, motion, and several wavelengths of light. External probes, such as soil moisture, temperature, and redox potential can be connected as well.

285. Mediated Atmospheres

Asaph Azaria, Nan Zhao, Joseph A. Paradiso

Cues from the physical environment are constantly perceived and interpreted—unconsciously finding their way into our cognition and influencing our experiences. Manipulating them has been shown to be powerful at affecting mood and cognitive performances. Utilizing this, we present a modular workspace capable of digitally transforming its ambiance, via video projection spatial sound and controllable lighting. In parallel, our workspace obtains information about the occupant's state, monitoring their movements, facial expressions, and biosignals. Leveraging this, we investigate the interplay between ambiance and the occupant. We research the effect of such workspace on perception, physiology, and cognitive performance, and compare it to real-life spaces in use around MIT.

286. MedRec

Asaph Azaria, Andrew Lippman, Ariel Ekblaw, Joseph A. Paradiso

Thiago Vieira

We face a well-known need for innovation in electronic medical records (EMRs), but the technology is cumbersome and innovation is impeded by inefficiency and regulation. We demonstrate MedRec as a solution tuned to the needs of patients, the treatment community, and medical researchers. It is a novel, decentralized record management system for EMRs that uses blockchain technology to manage authentication, confidentiality, accountability, and data sharing. A modular design integrates with providers’ existing, local data-storage solutions, enabling interoperability and making our system convenient and adaptable. As a key feature of our work, we engage the medical research community with an integral role in the protocol. Medical researchers provide the “mining” necessary to secure and sustain the blockchain authentication log, in return for access to anonymized, medical metadata in the form of “transaction fees.”
287. **Mindful Photons: Context-Aware Lighting**

**Matthew Aldrich, Nan Zhao, Joseph A. Paradiso**

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.

288. **NailO**

**Cindy Hsin-Liu Kao, Chris Schmandt, Joseph A. Paradiso, Artem Dementyev**

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; but in its more neutral, natural-looking example it can be worn and used only for its functionality. As a nail art sticker, NailO is small, discreet, and removable. Interactions through NailO can be private and subtle, 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.

289. **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 neuroplasticity 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.

290. **Quantizer: Sonification Platform for High-Energy Physics Data**

**Joseph A. Paradiso, Juliana Cherston**

Inspired by previous work in the field of sonification, we are building a data-driven composition platform that will enable users to map collision event information from experiments in high-energy physics to audio properties. In its initial stages, the tool will be used for outreach purposes, allowing physicists and composers to interact with collision data through novel interfaces. Our longer-term goal is to develop strategic mappings that facilitate the auditory perception of hidden regularities in high-dimensional datasets, and thus evolve into a useful analysis tool for physicists as well, possibly for the purpose of monitoring slow control data in experiment control rooms. The project includes a website with real-time audio streams and basic event data, which is not yet public.

291. **SensorChimes: Musical Mapping for Sensor Networks**

**Joseph A. Paradiso, Evan Lynch**

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.

292. **SensorTape: Modular and Programmable 3D-Aware Dense Sensor Network on a Tape**

**Cindy Hsin-Liu Kao, Joseph A. Paradiso, Artem Dementyev**

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.

293. **Skrin**

Xin Liu, Katia Vega, Pattie Maes, Joseph A. Paradiso

Skrin is an exploration project on digitalized body skin surface using embedded electronics and prosthetics. Human skin is a means for protection, a mediator of our senses and a presentation of ourselves. Through several projects, we expand the expression capacity of body surface and emphasize on the dynamic aesthetics of body texture by technological means.

294. **StretchyKeyboard: Multi-sensory Fabric as Deformable Musical Interface**

Irmandy Wicaksono, Joseph A. Paradiso

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 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 also developed additional textile-based inputs such as ribbon controller, trackpad, and fur for a more expressive control. This soft sensate surface contributes towards seamless, interactive, and washable media.

295. **Tid'Zam**

Donald Derek Haddad, Joseph A. Paradiso, Clement Duhart

The Tidmarsh project is interested in the documentation of ecological processes to understand their spatial and temporal evolution. Its cross-reality component provides user experiences for numerical reconstructions of outdoor environments thanks to data collected from real-time sensor networks. Tid'Zam analyses multi-source audio streams in real-time to identify events happening on Tidmarsh, such as bird calls, frogs, or car noise. Its Deep Learning stack offers an interface to create and improve the different classifier units from a Web interface. In addition, its interactive HCI has been designed to provide a training feedback mechanism between users/experts and the neural networks in order to improve knowledge for both the system and the users.

---

**Alex 'Sandy' Pentland: Human Dynamics**

Exploring how social networks can influence our lives in business, health, governance, and technology adoption and diffusion

296. **bandicoot: A Python Toolbox for Mobile Phone Metadata**

Yves-Alexandre de Montjoye, Alex 'Sandy' Pentland

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.

297. **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.

298. DeepShop: Understanding Purchase Patterns via Deep Learning

Alex ‘Sandy’ Pentland, Yoshihiko Suhara, Xiaowen Dong
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.

299. Enigma

Guy Zyskind, Alex ‘Sandy’ Pentland
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 hash table 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.

300. Incentivizing Cooperation Using Social Pressure

Dhaval Adjodah, Alex ‘Sandy’ Pentland, 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.

301. Leveraging Leadership Expertise More Effectively in Organizations

Dhaval Adjodah, Alex ‘Sandy’ Pentland
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.

302. 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 fit an inference model using machine learning techniques from phone records. We then formulate an optimization method to improve system efficiency. Coupling mobile phone data with traffic counts and road network infrastructure data 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.
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.

On the Reidentifiability of Credit Card Metadata

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.

Open Badges

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.

openPDS/ SaferAnswers: Protecting the Privacy of Metadata

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.

Prediction Markets: Leveraging Internal Knowledge to Beat Industry Prediction Experts

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.

Recurrent Neural Network in Context-Free Next-Location Prediction

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

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 & visualization tools to craft interventions that affect social behavior.

rhythm.mit.edu
Social Bridges in Community Purchase Behavior

Vivek K. Singh, Alex ‘Sandy’ Pentland, Yoshihiko Suhara, Xiaowen Dong

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 Physics of Unemployment

Abdullah M. Almaatouq, Alex ‘Sandy’ Pentland

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.

The Ripple Effect: You Are More Influential Than You Think

Alex ‘Sandy’ Pentland, Esteban Moro Egido, Yan Leng, Xiaowen Dong

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.
### Affective Response to Haptic Signals

**Grace Leslie, Rosalind W. Picard**  
**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.

### An EEG and Motion-Capture Based Expressive Music Interface for Affective Neurofeedback

**Grace Leslie, Rosalind W. Picard**  
**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.

### Automated Tongue Analysis

**Craig Ferguson, Weixuan ‘Vincent’ Chen, Akane Sano, Rosalind W. Picard, Javier Hernandez**

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.

### Automatic Stress Recognition in Real-Life Settings

**Javier Hernandez, Robert R. Morris, Rosalind W. Picard**

Technologies to automatically recognize stress are extremely important to prevent chronic psychological stress and pathophysiological risks associated with it. The introduction of comfortable and wearable biosensors has created new opportunities to measure stress in real-life environments, but there is often great variability in how people experience stress and how they express it physiologically. In this project, we modify the loss function of Support Vector Machines to encode a person’s tendency to feel more or less stressed, and give more importance to the training samples of the most similar subjects. These changes are validated in a case study where skin conductance was monitored in nine call center employees during one week of their regular work. Employees working in this type of setting usually handle high volumes of calls every day, and they frequently interact with angry and frustrated customers that lead to high stress levels.

### Autonomic Nervous System Activity in Epilepsy

**Ming-Zher Poh, Rosalind W. Picard**

We are performing long-term measurements of autonomic nervous system (ANS) activity on patients with epilepsy. In certain cases, autonomic symptoms are known to precede seizures. Usually in our data, the autonomic changes start when the seizure shows in the EEG, and can be measured with a wristband (much easier to wear every day than wearing an EEG). We found that the larger the signal we measure on the wrist, the longer the duration of cortical brain-wave suppression following the seizure. The duration of the latter is a strong candidate for a biomarker for SUDEP (Sudden Unexpected Death in Epilepsy), and we are working with scientists and doctors to better understand this. In addition, bilateral changes in ANS activity may provide valuable information regarding seizure focus localization and semiology.
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>318</td>
<td><strong>BrightBeat: Effortlessly Influencing Breathing for Cultivating Calmness and Focus</strong></td>
<td>Rosalind W. Picard, Asma Ghandeharioun</td>
<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 to not require constant focus or attention in order to be effective.</td>
</tr>
<tr>
<td>319</td>
<td><strong>Building the Just-Right-Challenge in Games and Toys</strong></td>
<td>Elliott Hedman, Rosalind W. Picard</td>
<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>
</tr>
<tr>
<td>320</td>
<td><strong>EDA Explorer</strong></td>
<td>Weixuan 'Vincent' Chen, Szymon Fedor, Akane Sano, Natasha Jaques, Rosalind W. Picard, Sara Taylor Victoria Xia</td>
<td>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.</td>
</tr>
<tr>
<td>321</td>
<td><strong>EngageME</strong></td>
<td>Ognjen (Oggi) Rudovic, Rosalind W. Picard</td>
<td>EngageME is a project aimed at building a new technology that can better engage children with ASC (Autism Spectrum Conditions) in communication centered activities. In this context, EngageME investigates the use of humanoid robots such as NAO. To facilitate the children’s engagement during their interaction with NAO, EngageME explores multi-modal behavioural cues (facial expressions, head pose, audio and physiology) to realize fully automated context-sensitive estimation of engagement. This technology builds upon the state-of-the-art machine learning, bringing novel personalized and culture-tailored models for the engagement measurement.</td>
</tr>
<tr>
<td>322</td>
<td><strong>Fathom: Probabilistic Graphical Models to Help Mental Health Counselors</strong></td>
<td>Karthik Dinakar, Henry A. Lieberman, Rosalind W. Picard</td>
<td>MIT EECS, Jackie Chen</td>
</tr>
<tr>
<td>323</td>
<td><strong>FEEL: A Cloud System for Frequent Event and Biophysiological Signal Labeling</strong></td>
<td>Rosalind W. Picard, Yadid Ayzenberg</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. 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>
</tr>
</tbody>
</table>
325. "Kind and Grateful": Promoting Kindness and Gratitude with Pervasive Technology

Sara Taylor, Asaph Azaria, Rosalind W. Picard, Asma Ghandeharion

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.

326. Lensing: Cardiolinguistics for Atypical Angina

Rosalind W. Picard, Karthik Dinakar

Matthew Nock (Harvard), David Blei (Columbia), Catherine Kreatsoulas (Harvard)

Conversations between two individuals—whether between doctor and patient, mental health therapist and client, or between two people romantically involved with each other—are complex. Each participant contributes to the conversation using her or his own "lens." This project involves advanced probabilistic graphical models to statistically extract and model these dual lenses across large datasets of real-world conversations, with applications that can improve crisis and psychotherapy counseling and patient-cardiologist consultations. We’re working with top psychologists, cardiologists, and crisis counseling centers in the United States.

327. Mapping the Stress of Medical Visits

Elliott Hedman, Rosalind W. Picard

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.

328. Measuring Arousal During Therapy for Children with Autism and ADHD

Elliott Hedman, Rosalind W. Picard

Physiological arousal is an important part of occupational therapy for children with autism and ADHD, but therapists do not have a way to objectively measure how therapy affects arousal. We hypothesize that when children participate in guided activities within an occupational therapy setting, informative changes in electrodermal activity (EDA) can be detected using iCalm. iCalm is a small, wireless sensor that measures EDA and motion, worn on the wrist or above the ankle. Statistical analysis describing how equipment affects EDA was inconclusive, suggesting that many factors play a role in how a child’s EDA changes. Case studies provided examples of how occupational therapy affected children’s EDA. This is the first study of the effects of occupational therapy’s in situ activities using continuous physiologic measures. The results suggest that careful case study analyses of the relation between therapeutic activities and physiological arousal may inform clinical practice.

329. 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.

330. Modulating Peripheral and Cortical Arousal Using a Musical Motor Response Task

Grace Leslie, Rosalind W. Picard

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.
332. **Panoply**

Robert R. Morris, Rosalind W. Picard

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.

333. **Predicting Bonding in Conversations**

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.

334. **Predicting Perceived Emotions in Animated GIFs with 3D Convolutional Neural Networks**

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 propose to use 3D convolutional neural networks (CNNs) to extract spatiotemporal features from GIFs. We evaluate our methodology on a crowd-sourcing platform called GIFGIF with more than 6,000 animated GIFs, and achieve a better accuracy than any previous approach in predicting crowd-sourced 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.

335. **Predicting Students' Wellbeing from Physiology, Phone, Mobility, and Behavioral Data**

Ehi Nosakhare, Rosalind W. Picard, Asma Ghandeharioun, Asaph Azaria, Sara Taylor, Natasha Jaques, Akane Sano

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 conversations, 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.

Craig Ferguson, Fengjiao Peng, Akane Sano, Rosalind W. Picard, Akshay Mohan, 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.

Szymon Fedor, Rosalind W. Picard
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.

Sara Taylor, Akane Sano, Rosalind W. Picard
Miriam Zisook
We are applying learnings from the SNAPSHOTT study to the problem of changing behavior, exploring
the design of user-centered tools which can harness the experience of collecting and reflecting on
personal data to promote healthy behaviors—including stress management and sleep regularity. We
draw on commonly used theories of behavior change as the inspiration for distinct conceptual designs
for a behavior-change application based on the SNAPSHOTT study. This approach will enable us to
compare the types of visualization strategies that are most meaningful and useful for acting on each
theory.

Sara Taylor, Akane Sano, Rosalind W. Picard, Cesar A. Hidalgo
Harvard Medical School, Brigham and Women’s Hospital
The SNAPSHOTT 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 Macro Connections 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 MIT
undergraduate students who are socially connected. We have collected data from about 170
participants, totaling over 5,000 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.

Kristina Johnson, Rosalind W. Picard
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.
Rosalind W. Picard, Micah Eckhardt

Stories, language, and art are at the heart of 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.

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

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.

Kristina Johnson, Rosalind W. Picard

Northeastern University

Individuals with autism are known to have difficulties connecting with other people, reciprocating social interactions, and being emotionally regulated by others. Yet, until recently, very little attention has been given to the way people interact together, in a system, rather than by themselves. 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.

Weixuan ‘Vincent’ Chen, Akane Sano, Rosalind W. Picard, Javier Hernandez

This study aims to bring objective measurement to the multiple “pulse” and “pulse-like” 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.

Rosalind W. Picard, Yadid Ayzenberg

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.

Thariq Shihipar, Sara Taylor, Rosalind W. Picard

Despite a vast body of knowledge about the importance of sleep, exercise, and healthy eating, our daily schedules are often planned around work and social events, not healthy behaviors. We’re prompted to plan throughout the day by devices and people, and we think about our schedules in terms of things to do; but sleep is rarely considered until we’re tired and it’s late. This project proposes a way that our everyday use of technology can help improve sleep habits and estimate mood.

A smartphone’s unlock screen is an unobtrusive way of prompting user reflection throughout the day by posing “microquestions” as users unlock their phone. The questions are easily answered with a single-swipe. Since we unlock our phones 50 to 200 times per day, microquestions can collect information with minimal intrusiveness to the user’s daily life.

Can these swipe-questions help users mentally plan their day around wellbeing, and trigger healthier behaviors?

Rosalind W. Picard, Karthik Dinakar
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valinor: Mathematical Models to Understand and Predict Self-Harm</td>
<td>Matthew Nock (Harvard), Eric Horvitz (Microsoft Research)</td>
</tr>
<tr>
<td></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>
</tr>
<tr>
<td>Wavelet-Based Motion Artifact Removal for Electrodermal Activity</td>
<td>Weixuan 'Vincent' Chen, Natasha Jaques, Szymon Fedor, Akane Sano, Rosalind W. Picard, Sara Taylor</td>
</tr>
<tr>
<td></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>
</tr>
<tr>
<td>Iyad Rahwan: Scalable Cooperation</td>
<td>Iyad Rahwan, Lorenzo Coviello</td>
</tr>
<tr>
<td></td>
<td>Reimagining the way society organizes, cooperates, and governs itself</td>
</tr>
<tr>
<td>Cognitive Limits of Social Networks</td>
<td>Iyad Rahwan, Lorenzo Coviello</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>Crowdsourcing Under Attack</td>
<td>Iyad Rahwan, Manuel Cebrian</td>
</tr>
<tr>
<td></td>
<td>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.</td>
</tr>
<tr>
<td>Ethics of Autonomous Vehicles</td>
<td>Sohan Dsouza, Edmond Awad, Iyad Rahwan, Azim Shariff, Jean-François Bonnefon</td>
</tr>
<tr>
<td></td>
<td>Adoption of self-driving, Autonomous Vehicles (AVs) promises to dramatically reduce the number of traffic accidents, but some inevitable accidents will require AVs to choose the lesser of two evils, such as running over a pedestrian on the road or the sidewalk. Defining the algorithms to guide AVs confronted with such moral dilemmas is a challenge, and manufacturers and regulators will need psychologists to apply methods of experimental ethics to these situations.</td>
</tr>
<tr>
<td>Honest Crowds</td>
<td>Morgan Ryan Frank, Lorenzo Coviello, Lijun Sun, Iyad Rahwan, Manuel Cebrian</td>
</tr>
</tbody>
</table>
|                                                                      | 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.

**Human-Machine Cooperation**

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.

**Moral Machine**

Sohan Dsouza, Edmond Awad, Iyad Rahwan

Azim Shariff, Jean-François 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.

**Nightmare Machine**

Nick Obradovich, Pinar Yanardag, Manuel Cebrian, Iyad Rahwan

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!

**Promoting Cooperation through Peer Pressure**

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.

---

**Ramesh Raskar: Camera Culture**

Making the invisible visible—inside our bodies, around us, and beyond—for health, work, and connection

**6D Display**

Nikhil Naik, Ramesh Raskar

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.

**AnEye: Extending the Reach of Anterior Segment Ophthalmic Imaging**

Shantanu Sinha, Ramesh Raskar

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.

**Beyond the Self-Driving Car**

Barmak Heshmat Dehkordi, Ramesh Raskar

Gurmukh Bhasin

This concept gallery shows the chain of startups and ideas that will follow after the emergence of self-driving cars.

**Blind and Reference-Free Fluorescence Lifetime Estimation via Consumer Time-of-Flight Sensors**

Ayush Bhandari, Ramesh Raskar

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.

**Bokode: Imperceptible Visual Tags for Camera-Based Interaction from a Distance**

Nikhil Naik, Ramesh Raskar

With over a billion people carrying camera-phones worldwide, we have a new opportunity to upgrade the classic bar code to encourage a flexible interface between the machine world and the human world. Current bar codes must be read within a short range, and the codes occupy valuable space on products. We present a new, low-cost, passive optical design so that bar codes can be shrunk to fewer than 3mm and can be read by unmodified ordinary cameras several meters away.

**Coded Computational Photography**

Nikhil Naik, Ramesh Raskar

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.

**Computation Ear Imaging**

**Food sensing on smartphones**

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 × 37 mm × 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.

**Health-Tech Innovations with Tata Trusts, Mumbai**

Anshuman Das, Ramesh Raskar

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
Anshuman Das, Ramesh Raskar

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.

Guy Satat, Ramesh Raskar, Nikhil Naik

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.

Barmak Heshmat Dehkordi, Ramesh Raskar

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/fl/

Nikhil Naik, Ramesh Raskar

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.

Barmak Heshmat Dehkordi, Guy Satat, Ramesh Raskar

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 bio-medical imaging, as well as imaging through fog and clouds.

Achuta Kadambi, Ramesh Raskar, Ayush Bhandari

We are exploring mathematical modeling of time-of-flight imaging problems and solutions.
<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LensChat: Sharing Photos with Strangers</strong></td>
<td>Nikhil Naik, Ramesh Raskar, Wei-Chao Chen</td>
<td>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.</td>
</tr>
<tr>
<td><strong>Looking Around Corners</strong></td>
<td>Otkrist Gupta, Ayush Bhandari, Nikhil Naik, Micha Feigin-Almon, Ramesh Raskar, Achuta Kadambi</td>
<td>Using a femtosecond laser and a camera with a time resolution of about one trillion frames per second, we recover objects hidden out of sight. We measure speed-of-light timing information of light scattered by the hidden objects via diffuse surfaces in the scene. The object data are mixed up and are difficult to decode using traditional cameras. We combine this “time-resolved” information with novel reconstruction algorithms to untangle image information and demonstrate the ability to look around corners.</td>
</tr>
<tr>
<td><strong>Nashik Smart Citizen Collaboration with TCS</strong></td>
<td>Anshuman Das, Ramesh Raskar</td>
<td>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.</td>
</tr>
<tr>
<td><strong>NETRA: Smartphone Add-On for Eye Tests</strong></td>
<td>Nikhil Naik, Ramesh Raskar</td>
<td>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.</td>
</tr>
<tr>
<td><strong>New Methods in Time-of-Flight Imaging</strong></td>
<td>Ayush Bhandari, Anshuman Das, Micha Feigin-Almon, Ramesh Raskar, Achuta Kadambi</td>
<td>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.</td>
</tr>
<tr>
<td><strong>Optical Brush: Enabling Deformable Imaging Interfaces</strong></td>
<td>Barmak Heshmat Dehkordi, Ramesh Raskar</td>
<td>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.</td>
</tr>
<tr>
<td><strong>PhotoCloud: Personal to Shared Moments with Angled Graphs of Pictures</strong></td>
<td>Ramesh Raskar, Otkrist Gupta, Nikhil Naik</td>
<td>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.</td>
</tr>
</tbody>
</table>
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.

Terahertz time-gated spectral imaging for content extraction through layered structures.

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.

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).

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.

Within the last few years, cellphone subscriptions have spread widely and now cover even the remotest parts of the planet. Adequate access to healthcare, however, is not widely available, especially in developing countries. We propose a new approach to converting cellphones into low-cost scientific devices for microscopy. Cellphone microscopes have the potential to revolutionize health-related screening and analysis for a variety of applications, including blood and water tests. Our optical system is more flexible than previously proposed mobile microscopes, and allows for wide field-of-view panoramic imaging, the acquisition of parallax, and coded background illumination, which optically enhances the contrast of transparent and refractive specimens.

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.

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.

How can we show our 16-megapixel photos from our latest trip on a digital display? How can we create screens that are visible in direct sunlight as well as complete darkness? How can we create large displays that consume less than 2W of power? How can we create design tools for digital decal
application and intuitive-computer aided modeling? We introduce a display that is high-resolution but updates at a low frame rate: a slow display. We use lasers and monostable light-reactive materials to provide programmable space-time resolution. This refreshable, high-resolution display exploits the time decay of monostable materials, making it attractive in terms of cost and power requirements. Our effort to repurpose these materials involves solving underlying problems in color reproduction, day-night visibility, and optimal time sequences for updating content.

**Smartphone dermatoscope**

Alex Olwal, Ramesh Raskar, Nikhil Naik

Jan Zizka

Motion sensing is of fundamental importance for user interfaces and input devices. In applications where optical sensing is preferred, traditional camera-based approaches can be prohibitive due to limited resolution, low frame rates, and the required computational power for image processing. We introduce a novel set of motion-sensing configurations based on laser speckle sensing that are particularly suitable for human-computer interaction. The underlying principles allow these configurations to be fast, precise, extremely compact, and low cost.

**SpecTrans: Classification of Transparent Materials and Interactions**

Boxin Shi, Shigeo Yoshida, Nikhil Naik, Alex Olwal, Ramesh Raskar

Michitaka Hirose, Atsushi Hiyama, Tomohiro Tanikawa

Surface and object recognition is of significant importance in ubiquitous and wearable computing. While various techniques exist to infer context from material properties and appearance, they are typically neither designed for real-time applications nor for optically complex surfaces that may be specular, textureless, and even transparent. These materials are, however, becoming increasingly relevant in HCI for transparent displays, interactive surfaces, and ubiquitous computing. We present SpecTrans, a new sensing technology for surface classification of exotic materials, such as glass, transparent plastic, and metal. The proposed technique extracts optical features by employing laser and multi-directional, multi-spectral LED illumination that leverages the material’s optical properties. The sensor hardware is small in size, and the proposed classification method requires significantly lower computational cost than conventional image-based methods, which use texture features or reflectance analysis, thereby providing real-time performance for ubiquitous computing.

**StreetScore**

Cesar A. Hidalgo, Ramesh Raskar, Nikhil Naik

Jade Philipoom

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.

**The Next 30 Years of VR**

Barmak Heshmat Dehkordi, Ramesh Raskar

In this visual brainstorming, we present the next 30 years of VR in a set of concept designs.

**Theory Unifying Ray and Wavefront Lightfield Propagation**

Nikhil Naik, Ramesh Raskar

Tom Cuypers, George Barbastathis, Se Baek Oh

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.

**Time-of-Flight Microwave Camera**

Micha Feigin-Almon, Ramesh Raskar, Nikhil Naik

Andrew Temme, Gregory Charvat

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.

**Towards In-Vivo Biopsy**

Barmak Heshmat Dehkordi, Guy Satat, Ramesh Raskar

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.

**Trillion Frames Per Second Camera**

Ramesh Raskar

MIT Department of Chemistry, Moungi Bawendi

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.

**Ultrasound Tomography**

Micha Feigin-Almon, Ramesh Raskar, Nikhil Naik

Brian Anthony

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**

Boxin Shi, Nikhil Naik, Hang Zhao, Ramesh Raskar

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**

Nikhil Naik, Ramesh Raskar

bendale, jbobgess

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.
Andrew Lippman: Viral Communications
Creating scalable technologies that evolve with user inventiveness

400. 8K Time into Space
Andrew Lippman, Hisayuki Ohmata
8K Time into Space is a user interface for a video exploration system with an 8K display. 8K is an ultra high-definition video system and it can present a huge amount of visual content on one display. In our system, video thumbnails with shifted playback time in chronological order are spaced out like tiles. The time range of a scene that a viewer wants to check can be adjusted with a touch interface, and resolution of the thumbnails is changed depending on the range. 8K Time into Space aims to provide responsive and intuitive experiences for video consumption.

401. As You Need It
Yasmine (Jasmin) Rubinovitz, Andrew Lippman
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.

402. Captions++
Tomer Weller, Andrew Lippman
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 timeline. 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.

403. 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.

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

405. IoT Recorder
Thariq Shihipar, Andrew Lippman
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.

406. MedRec
Asaph Azaria, Andrew Lippman, Ariel Ekblaw, Joseph A. Paradiso
Thiago Vieira
We face a well-known need for innovation in electronic medical records (EMRs), but the technology is cumbersome and innovation is impeded by inefficiency and regulation. We demonstrate MedRec as a solution tuned to the needs of patients, the treatment community, and medical researchers. It is a novel, decentralized record management system for EMRs that uses blockchain technology to manage authentication, confidentiality, accountability, and data sharing. A modular design integrates with
providers’ existing, local data-storage solutions, enabling interoperability and making our system convenient and adaptable. As a key feature of our work, we engage the medical research community with an integral role in the protocol. Medical researchers provide the “mining” necessary to secure and sustain the blockchain authentication log, in return for access to anonymized, medical metadata in the form of “transaction fees.”

407. NewsClouds

Thariq Shihipar, Andrew Lippman

NewsClouds presents a visual exploration of how the news reporting of an event evolves over time. Each “cloud” represents a publication and each competing news organization usually emphasizes different aspects of that same story. Using the time sliders, that evolution becomes evident. In addition, each word or phrase can be expanded to show its links and context. We are building an archive of events associated with ongoing US election developments.

408. News Graph

Yasmine (Jasmin) Rubinovitz, Andrew Lippman

This project aims to show a different picture of the data behind the news, looking at how we analyze, represent, and interact with it.

Video content is constantly created and added to the public archives, but there is never time to watch it all. News Graph explores a new method for interacting with news media.

By analyzing the words that are said, extracting entities that appear, and finding the connections between them, we are able to map connections between video segments. Each connection represents two entities that were mentioned in the same video segment, and a video segment can be mapped to a number of connections.

409. Perspectives

Yasmine (Jasmin) Rubinovitz, Andrew Lippman

The news is probably one of the first things people check in the morning, but how much does what you know and understand about the world depend on your news source? Will you view the world differently if you head over to CNN instead of BBC?

“Perspectives” is presenting top news stories from many points of view. The viewer can easily see the different perspectives and get the whole story.

410. PubPub

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

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.

411. Solar Micro-Mining

Andrew Lippman, Ariel Ekblaw

Tal Achituv, Jonathan Harvey-Buschel

Bitcoin generates net-new value from “mining” in a distributed network. In this work, we explore solar micro-mining rigs that transform excess energy capacity from renewable energy (hard to trade) into money (fungible). Each rig runs a small Bitcoin miner and produces Bitcoin dust for micropayments. We envision these micro-miners populating a highly distributed network, across rooftops, billboards, and other outdoor spaces. Where systematic or environmental restrictions limit the ability to freely trade the underlying commodity, micro-mining produces new economic viability. Renewable energy-based, micropayment mining systems can broaden financial inclusion in the Bitcoin network, particularly among populations that need a currency for temporary store of value and must rely on flexible electricity off the grid (e.g., unbanked populations in the developing world). This exploration seeds a longer-term goal to enable open access to digital currency via account-free infrastructure for the public good.

412. Super Cut Notes

Tomer Weller, Andrew Lippman

A large portion of popular media is remixed: existing media content is spliced and re-ordered in a manner that serves a specific narrative. Super Cut Notes is a semi-comical content remix tool that allows a user to splice and combine the smallest bits of media: words. By tapping into the dataset of our group’s SuperGlue platform, it has access to a huge dictionary of words created by SuperGlue’s transcription module. Users are able to input a text of any length, choose video-bits of individual words that match their text, and create a video of their combination—in the style of cut-and-pasted ransom notes.

413. SuperGlue

Tomer Weller, Andrew Lippman

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.

**414. This Is How**

**Tomer Weller, Andrew Lippman**

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.

**415. Viralcasting**

**Andrew Lippman**

Ditch the truck. Live, collaborative broadcasting through mixed-reality

**416. VR Codes**

**Andrew Lippman**

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.

**417. Wall of Now**

**Tomer Weller, Andrew Lippman**

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.

**418. Watch People Watch**

**Tomer Weller, Suzanne Wang, Andrew Lippman**

Recording your reaction to a short video is becoming the new gossip; famous watchers get as many as 750,000 views. We attempt to transform this utterly useless and talentless event into a socially constructive alternative to simultaneous, synchronized, group viewing. Any user can opt in to be recorded and added to the shared, collective viewing experience. No talent or skills required.

---

**Mitchel Resnick: Lifelong Kindergarten**

Engaging people in creative learning experiences

**419. Active Drawing**

**Jennifer Jacobs**

Sumit Gogia, Joel Brandt, and Radomir Mech.
Stefania Druga

The main purpose of this project is to develop a hands-on learning activity around tinkering with microbiological bricks to be play-tested with kids and educators.

I am exploring how microorganisms can create generative art and music and how we could transform any affordable webcam into a microscope that can connect directly to the computer. I am also looking at how this live stream from microcosmos world could be visualized in many different ways by applying multiple filters and image transformations such that it provides us with many new perspectives about the world around us. This live connection to living organisms enables us also to imagine new ways of interacting and tinkering with them. Some initial explorations lead to the creation of a bio-kaleidoscope that is alive (literally).

I hope this project will explore new ways in which kids could play with the micro-cosmos around us, explore the magic at the intersection of digital, physical and bio tinkering and discover how using familiar things, such as webcams, to do unfamiliar actions can boost our creative confidence.

Carmelo Presicce, Mitchel Resnick, 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, 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.

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.

---

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.

O Desafio Aprendizagem Criativa Brasil é uma iniciativa da Fundação Lemann e do MIT Media Lab que visa fomentar a implementação de soluções inovadoras – novas tecnologias, produtos e serviços – que ajudem a tornar a educação brasileira mais mão na massa, significativa, colaborativa e divertida.

O Desafio também tem como objetivo identificar, conectar e apoiar indivíduos brasileiros – artistas, pesquisadores, educadores, desenvolvedores de tecnologia, empreendedores e tomadores de decisão – que possam ter um papel-chave no avanço de práticas de Aprendizagem Criativa, especialmente no que se refere a projetos mão na massa envolvendo programação e construção no mundo físico, em escolas públicas (de Educação Infantil ao Ensino Médio) e ambientes de aprendizagem não formais de todo o Brasil.

Os representantes dos projetos selecionados ganharão uma Creative Learning Fellowship para ajudar a implementar seu trabalho. Entre outros benefícios, os fellows irão:

- Receber apoio técnico, educacional e empresarial para implementar seus projetos durante o período do programa;
- Familiarizar-se com a Aprendizagem Criativa e o trabalho do Lifelong Kindergarten Group (LLK) do MIT Media Lab;
Ajuda pesquisadores do LLK (e a comunidade do MIT Media Lab) a aprender mais sobre desafios e oportunidades inerentes à educação brasileira;

Ingressar em uma comunidade ativa de outros fellows e adeptos da Aprendizagem Criativa.

Ao entrarem para essa rede de profissionais, tomadores de decisão e pesquisadores que compartilhem dos mesmos ideais, esperamos que os fellows possam aprender com as experiências do grupo e, juntos, ajudar a catalisar uma transformação grande e sustentável na educação brasileira e contribuir para o desenvolvimento de uma sociedade mais participativa e criativa para todos.

Alisha Panjwani, Leo Burd
Rachel Garber

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.

Shruti Dhariwal, Natalie Rusk

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.

Srishti Sethi, Katherine McConachie, Andrew Sliwinski, J. Philipp Schmidt, Yumiko Murai, Natalie Rusk, Mitchel Resnick, Grif Peterson

Learning Creative Learning is an online course that introduces ideas and strategies for supporting creative learning. The course engages educators, designers, and technologists from around the world in applying creative learning tools and approaches from the MIT Media Lab. We view the course as an experimental alternative to traditional Massive Open Online Courses (MOOCs), putting greater emphasis on peer-to-peer learning, hands-on projects, and sustainable communities.

Grif Peterson

Learning Creative Learning is an online course that introduces ideas and strategies for supporting creative learning. The course engages educators, designers, and technologists from around the world in applying creative learning tools and approaches from the MIT Media Lab. We view the course as an experimental alternative to traditional Massive Open Online Courses (MOOCs), putting greater emphasis on peer-to-peer learning, hands-on projects, and sustainable communities.

Grif Peterson

The Lemann-MIT Creative Learning Challenge aims to support the design and implementation of innovative technologies, products, services and initiatives that help make Brazilian education more meaningful, hands-on, collaborative and playful.

The Challenge also aims to identify, support, and connect Brazilian individuals -- artists, researchers, educators, technology developers, entrepreneurs and decision makers -- who might play a key role in fostering creative learning practices, especially coding and making, in Brazilian public K12 schools and non-formal educational environments.

Representatives from the selected projects will receive a Creative Learning Fellowship to support the implementation of their work. Among other things, the Fellows will:

Receive technical, educational and entrepreneurial support for the implementation of their projects during the Fellowship period;

Get more familiarized with Creative Learning and the work of the MIT Media Lab’s Lifelong Kindergarten Group (LLK);
Help LLK researchers (and the broader Media Lab community) learn more about challenges and opportunities inherent to Brazilian education;

Join an active community of other Creative Learning fellows and supporters.

By joining a network of practitioners, decision makers and researchers who share the same ideals, we hope the Fellows will learn from each others’ experiences and, together, help catalyze a large and sustainable transformation of Brazilian education and contribute to the development of a more participatory and creative society for all.

Sarah Otts, Mitchel Resnick, Natalie Rusk, Moran Tsur

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.

Jie Qi

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 Telefonica Vivo) e o Lifelong Kindergarten Group do MIT Media Lab. Atualmente, contamos com centenas de participantes de todo o Brasil.


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 17 million projects on the Scratch website, with thousands of new projects every day. (For information on who has contributed to Scratch, see the Scratch Credits page.)

Eric Rosenbaum, Carl Bowman, Christopher Willis-Ford, Andrew Sliwinski, Kasja Chmielinski, Timothy Mickel, Ray Schamp

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.

**Scratch Community Blocks**  
Sayamindu Dasgupta, Natalie Rusk, Mitchel Resnick, Andrew Sliwinski  
Benjamin Mako Hill  
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**  
Kasia Chmielinski, Abisola Okuk, Saskia Leggett  
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.

**Scratch Extensions**  
Eric Rosenbaum, Andrew Sliwinski, Christopher Willis-Ford, Stefania Druga, Sayamindu Dasgupta, Kreg Hanning  
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.

**ScratchJr**  
Chris Garrity, Mitchel Resnick, Andrew Sliwinski, Sayamindu Dasgupta, Timothy Mickel  
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 Online Community**  
Mitchel Resnick, Natalie Rusk, Christian Balch, Sarah Otts, Eric Schilling

**Scratch Pad**  
Eric Rosenbaum, Jie Qi, Andrew Sliwinski, Stefania Druga, Kreg Hanning, Mitchel Resnick, Natalie Rusk  
Scratch Pad 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 Scratch Pad 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 MakeyMakey which was designed to make these connections electronically, the Scratch Pad is designed to create these connections through motion and mechanism.

**Slap Snap Tap**  
Joy Buolamwini, Ethan Zuckerman, Mitchel Resnick  
Slap Snap Tap combines wearable sensors with physical block programming to enable enhanced expression through movement. By slapping on a set of sensor straps, snapping in code that links movement triggers to sound actions, and tapping the sensors to activate a play experience, users can combine motion and sound in creative ways. A dancer can create music through movement; an athlete can add emphasis to her performance; demonstrators can synchronize and amplify a chant; and anyone can create sound effects for life moments. Slap Snap Tap is a method of the Slay Play endeavor which aims to broaden participation in computational creation by using movement as a pathway into computational thinking.
## Deb Roy: Social Machines
**Understanding and empowering human networks**

<table>
<thead>
<tr>
<th>Project</th>
<th>Authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AINA: Aerial Imaging and Network Analysis</td>
<td>Deb Roy, Neo (Mostafa) Mohsenvand</td>
<td>This project is aimed at building a machine learning pipeline that will discover and predict links between the visible structure of villages and cities (using satellite and aerial imaging) and their inhabiting social networks. The goal is to estimate digitally invisible villages in India and Sub-Saharan Africa. By estimating the social structure of these communities, our goal is to enable targeted intervention and optimized distribution of information, education technologies, goods, and medical aid. Currently, this pipeline is implemented using a GPU-powered Deep Learning system. It is able to detect buildings and roads and provide detailed information about the organization of the villages. The output will be used to construct probabilistic models of the underlying social network of the village. Moreover, it will provide information on the population, distribution of wealth, rate and direction of development (when longitudinal imaging data is available), and disaster profile of the village.</td>
</tr>
<tr>
<td>ChatterBox</td>
<td>Eric Chu</td>
<td>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.</td>
</tr>
<tr>
<td>Human Atlas</td>
<td>Eric Chu, Martin Saveski, Soroush Vosoughi, Deb Roy</td>
<td>This project aims to map and analyze the publicly knowable social connections of various communities, allowing us to gain unprecedented insights about the social dynamics in such communities. Most analyses of this sort map online social networks, such as Twitter, Facebook, or LinkedIn. While these networks encode important aspects of our lives (e.g., our professional connections) they fail to capture many real-world relationships. Most of these relationships are, in fact, public and known to the community members. By mapping this publicly knowable graph, we get a unique view of the community that allows us to gain deeper understanding of its social dynamics. To this end, we built a web-based tool that is simple, easy to use, and allows the community to map itself. Our goal is to deploy this tool in communities of different sizes, including the Media Lab community and the Spanish town of Jun.</td>
</tr>
<tr>
<td>Play Analytics</td>
<td>Mina Soltangheis, Anneli Hershman, Ivan Sysoev, Juliana Nazare, Eric Chu</td>
<td>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.</td>
</tr>
<tr>
<td>Playful Words</td>
<td>Mina Soltangheis, Ivan Sysoev, Sneha Priscilla Makini, Juliana Nazare, Preeta Bansal, Deb Roy, Nazmus Saquib, Eric Chu, Anneli Hershman</td>
<td>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 are planning to pilot and deploy our system initially in the Boston area with a focus on low-income families, where the need for literacy support is particularly acute. 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.</td>
</tr>
<tr>
<td>ShapeBlocks</td>
<td>Nazmus Saquib, Deb Roy</td>
<td>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.</td>
</tr>
</tbody>
</table>
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.

**SpeechBlocks**
Anne Hershman, Ivan Sysoev, Juliana Nazare, Sneha Priscilla Makini
SpeechBlocks is a self-expressive literacy app that helps young children explore alphabetic principles through manipulating letter blocks. Phonemes and words are heard when letter blocks are tapped, put together (blended into words), or pulled apart (segmented into sounds). There is no correct combination of letters, so children can create real and nonsense words. SpeechBlocks encourages children’s intrinsic motivation by avoiding extrinsic rewards such as points or prizes. Words from a “word shelf” and letters from a “letter shelf” serve as scaffolds that children can use and remix.

**StoryBlocks**
Juliana Nazare, Anneli Hershman
Molly Scott
Supporting self-expression through storytelling and story remixing.

StoryBlocks is a mobile application where children can create stories using a combination of oral narrative and written text as well as build off each other’s narratives to create collaborative stories.

In collaboration with Molly Scott, Graduate Student in the Infant & Child Laboratory, Temple University
We tested a physical version of StoryBlocks with kids to see what sorts of stories they would create.

**The Electome: Measuring Responsiveness in the 2016 Election**
Soroush Vosoughi, Raphael Schaad, Perng-Hwa Kung, Prashanth Vijayaraghavan, William Powers, Deb Roy, Andrew Heyward, Russell Stevens, Sophie Chou, Neo (Mostafa) Mohsenvand Lisa Conn, Uzra Khan, John West, Shawn Musgrave, Kevin Aiken
The Electome: Where AI Meets Political Journalism

The Electome project 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-occurrent 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.

Soroush Vosoughi, Guolong Wang, Neo (Mostafa) Mohsenvand, Prashanth Vijayaraghavan, Deb Roy, Russell Stevens

The Foodome addresses how to create deeper understanding and predictive intelligence about the relationships between how we talk and learn about food, and what we actually eat. Our aim is to build a food learning machine that comprehensively maps, for any given food, its form, function, production, distribution, marketing, science, policy, history, and culture (as well as the connections among all of these aspects). We are gathering and organizing a wide variety of data, including news/social content, recipes and menus, and sourcing and purchase information. We then use human-machine learning to uncover patterns within and among the heterogeneous food-related data. Long term, the Foodome is meant to help improve our understanding of, access to, and trust in food that is good for us; find new connections between food and health; and even predict impacts of local and global events on food.

Soroush Vosoughi, Guolong Wang, Neo (Mostafa) Mohsenvand, Prashanth Vijayaraghavan, Deb Roy, Russell Stevens

Visible Communities

Michael Koehrsen, Raphael Schaad, Deb Roy
 Partners in Health, MIT Tata Center, Google

Zach Both, Eugene Yi, Preeta Basal, James Kondo

Enabling rural communities to put themselves on the map

Vast regions of the world are unmapped by commercial services, and communities living there are digitally invisible. Visible Communities is a system that combines what local people using smartphones see on the ground with what computers can detect from satellite images, to create an interactive map at a fine resolution that continuously improves. The map captures both spatial and social data: houses and the paths connecting them, and the households living there and their relationships.

Enabling communities to put themselves on the map is a powerful way to increase their own visibility, and in turn serves institutional needs to improve infrastructure planning and humanitarian aid delivery. Existing approaches to do community-driven mapping either require outside experts to facilitate, or the results are lower-tech and not easy to keep up to date. In collaboration with Partners in Health (PH), and supported by the MIT Tata Center, we are piloting this social machine in a sparsely populated, hilly region with a Community Health Worker (CHW) network in Burera, Rwanda.

The smartphone app enables CHWs to self-map their communities. We are intentionally designing an intuitive pre-literacy touch interface enabling a wide range of users to participate without much training. By removing barriers for people at the base of the socio-economic pyramid and designing with natural social dynamics in mind, we hope to unlock existing, self-motivated human potential.
experience these wonders, as diving is expensive, mentally and physically challenging, needs a large
time investment, and requires access to large bodies of water. Most existing SCUBA diving simulations in
VR are limited to visual and aural displays. We propose a virtual reality system, Amphibian, that provides
an immersive SCUBA diving experience through a convenient terrestrial simulator. Users lie on their
torso on a motion platform with their outstretched arms and legs placed in a suspended harness. Users
receive visual and aural feedback through the Oculus Rift head-mounted display and a pair of
headphones. Additionally, we simulate buoyancy, drag, and temperature changes through various
sensors.

### Support Information

**CAPS: Curbing Assault to Protect Society**
Chris Schmandt, Manisha Mohan
Smart clothing which responds to initial signs of assault like disrobing and produces repulsive odors to
repel the violator.

**ChromoSkin**
Chris Schmandt, Manisha Mohan, Katia Vega, Joseph A. Paradiso, Cindy Hsin-Liu Kao
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.

**DuoSkin**
Cindy Hsin-Liu Kao, Chris Schmandt, Andres Calvo
Asta Roseway, Christian Holz, Paul Johns from Microsoft Research
DuoSkin is a fabrication process that enables anyone to create customized functional devices that can
be attached directly to the skin. Using gold metal leaf, a material that is cheap, skin-friendly, and robust for
everyday wear, we demonstrate three types of on-skin interfaces: sensing touch input, displaying output,
and wireless communication. DuoSkin draws from the aesthetics found in metallic jewelry-like
temporary tattoos to create on-skin devices which resemble jewelry. DuoSkin devices enable users to
travel and to interact with their mobile devices, display information, and store information on their skin while serving as a
statement of personal style. We believe that in the future, on-skin electronics will no longer be black-boxed and mystified; instead, they will converge towards the user friendliness, extensibility, and
aesthetics of body decorations, forming a DuoSkin integrated to the extent that it has seemingly
disappeared.

**Living Jewelry**
Chris Schmandt, Joseph A. Paradiso, Artem Dementyev, Deborah Ajilo, Cindy Hsin-Liu Kao
Inrak Choi (Stanford), Sean Follmer
This work explores a dynamic future where jewelry pieces are no longer static, but they become moving
objects on the body. Engineered with the functionality of miniaturized robotics, this ‘living’ jewelry roams
on unmodified clothing, changing location and reconfiguring appearance according to social context.
They also interact with surroundings and generate shape-changing clothing and dynamic pattern
designs.

**NailO**
Cindy Hsin-Liu Kao, Chris Schmandt, Joseph A. Paradiso, Artem Dementyev
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;
but in its more neutral, natural-looking example it can be worn and used only for its functionality. As a nail
art sticker, NailO is small, discreet, and removable. Interactions through NailO can be private and subtle,
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.

**SensorTape: Modular and Programmable 3D-Aware Dense Sensor Network on a Tape**
Cindy Hsin-Liu Kao, Joseph A. Paradiso, Artem Dementyev
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 Sensor Tape 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.

Variable Reality is an augmented reality system designed for reading digital and physical books more intuitively and efficiently. Through a head-worn display device such as Oculus Rift, the user is able to instantly access and display any desired book contents onto either a real book or a hand, depending on the need and affordability. Quick hand gestures integrated with the system further facilitate natural user interactions.

Kevin Slavin: Playful Systems
Designing systems that become experiences to transcend utility and usability

20 Day Stranger
Kevin Slavin, Taylor Levy, Che-Wei Wang
Tinsley Galyean, Dalai Lama Center for Ethics and Transformative Values
20 Day Stranger is a mobile app that creates an intimate and anonymous connection between you and another person. For 20 days, you get continuous updates about where they are, what they are doing, and eventually even how they are feeling, and them likewise about you. But you will never know who this person is. Does this change the way you think about other people you see throughout your day, any one of which could be your stranger?

AutomaTiles
Kevin Slavin, Jonathan Bobrow
A tabletop set of cellular automata ready to exhibit complex systems through simple behaviors, AutomaTiles explores emergent behavior through tangible objects. Individually they live as simple organisms, imbued with a simple personality; together they exhibit something “other” than the sum of their parts. Through communication with their neighbors, complex interactions arise. What will you discover with AutomaTiles?

Case and Molly
Kevin Slavin, Gregory Borenstein
Case and Molly is a prototype for a game inspired by (and in homage to) William Gibson’s novel Neuromancer. It’s about the coordination between virtual and physical, “cyberspace” and “meat.” We navigate the tension between our physical surroundings and our digital networks in a state of continuous partial attention; Case and Molly uses the mechanics and aesthetics of Neuromancer to explore this quintessential contemporary dynamic. The game is played by two people mediated by smartphones and an Oculus Rift VR headset. Together, and under time pressure, they must navigate Molly through physical space using information that is only available to Case. In the game, Case sees Molly’s point of view in immersive 3D, but he can only communicate a single bit of information to her. Meanwhile, Molly traverses physical obstacles hoping Case can solve abstract puzzles in order to gain access to the information she needs.

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?

Kevin Slavin

Cordon Sanitaire

Named for, and inspired by, the medieval practice of erecting barriers to prevent the spread of disease, Cordon Sanitaire is a collaborative, location-based mobile game in which players seek to isolate an infectious "patient zero" from the larger population. Every day, the game starts abruptly, synchronizing all players at once, and lasts for two minutes. In 60 seconds, players must choose either to help form the front line of a quarantine, or remain passive. Under pressure, the "uninfected" attempt to collaborate without communication, seeking to find the best solution for the group. When those 60 seconds end, a certain number of players are trapped inside with patient zero, and the score reflects the group's ability to cooperate under duress.

Kevin Slavin

Designing Immersive Multi-Sensory Eating Experiences

Food offers a rich multi-modal experience that can deeply affect emotion and memory. We're interested in exploring the artistic and expressive potential of food beyond mere nourishment, as a means of creating memorable experiences that involve multiple senses. For instance, music can change our eating experience by altering our emotions during the meal, or by evoking a specific time and place. Similarly, sight, smell, and temperature can all be manipulated to combine with food for expressive effect. In addition, by drawing upon people's physiology and upbringing, we seek to create individual, meaningful sensory experiences. Specifically, we are exploring the connection between music and flavor perception.

Kevin Slavin, Jonathan Bobrow

Dice++

Today, algorithms drive our cars, our economy, what we read, and how we play. Modern-day computer games utilize weighted probabilities to make games more competitive, fun, and addictive. In casinos, slot machines—once a product of simple probability—employ similar algorithms to keep players playing. Dice++ takes the seemingly straight probability of rolling a die and determines an outcome with algorithms of its own.

Kevin Slavin, Michael Lazer Walker

For Once In Your Life...

"For Once In Your Life..." is a site-specific interactive radio play that uses the various sensors in a smartphone to determine specific details, such as where the user walks within a space, to dynamically affect the story. It's a blend of experiential theatre, modern choice-based interactive fiction, and audio walks such as the work of Janet Cardiff.

Shoshannah Tekofsky, Kevin Slavin

University of Tilburg

GAMR

Does how you play reflect who you really are? The Media Lab and Tilburg University are bringing science into the game to figure out the connections between our play style and our cognitive traits. To do that, we are gathering data from League of Legends, World of Warcraft, and Battlefield 4, and Battlefield: Hardline players to gain insights across all the major online game genres (MOBA, MMORPG, and FPS). In return, every participant will get an in-depth GAMR profile that shows their personality, brain type, and gamer type.

Kevin Slavin, Michael Lazer Walker

Hello, Operator!

Hello, Operator! is a vintage telephone switchboard from 1927, refurbished and wired up to a modern computer. It currently runs a time-management game; other games being prototyped are exploring the narrative potential of the system. Overall, the project exists to explore what we gain when we are able to physically engage with the antiquated technology that made the past tick.

Miguel Perez, Kevin Slavin

Holobiont Urbanism: Revealing the Microbiological World of Cities

This project investigates urban metagenomics to reveal the invisible microbiological worlds within our cities. Using honeybees to gather samples and hives modified to capture "bee debris," the project employs genetic sequencing to discern and visualize urban microbiological neighborhoods and render microbiological landscapes of the city. The Holobiont project was first displayed at the Palazzo Mora in the 2016 Venice Architecture Biennale, with an installation that includes a "metagenomic beehive." Creative, scientific, development and production collaboration with: Ben Berman, Dr. Elizabeth Henaff, Regina Flores Mir, Dr. Chris Mason, Devora Najjar, Tri-Lox, and Chris Woebken, with contributions from Timo Arnall and Jack Schulze and local beekeepers in Brooklyn, Sydney, and Venice.
<table>
<thead>
<tr>
<th>Page</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>470</td>
<td>Homeostasis</td>
<td>Kevin Slavin, Denis Bozic</td>
</tr>
<tr>
<td></td>
<td>A large-scale art installation that investigates the biological systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>that represent and embody human life, and their relationship to the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>built environment. This synthetic organism, built from interconnected</td>
<td></td>
</tr>
<tr>
<td></td>
<td>microbiological systems, will be sustained in part through its own</td>
<td></td>
</tr>
<tr>
<td></td>
<td>feedback and feedforward loops, but also through interactions with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the architectural systems (like HVAC). As the different systems react</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and exchange material inputs and outputs, they move towards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>homeostasis. In the process, Homeostasis creates a new landscape of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the human body, in which we can experience the wonder and vulnerability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>of its interconnected systems.</td>
<td></td>
</tr>
<tr>
<td>471</td>
<td>MicroPsi: An Architecture for Motivated Cognition</td>
<td>Kevin Slavin, Joscha Bach</td>
</tr>
<tr>
<td></td>
<td>The MicroPsi project explores broad models of cognition, built on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a motivational system that gives rise to autonomous social and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cognitive behaviors. MicroPsi agents are grounded AI agents, with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>neuro-symbolic representations, affect, top-down/bottom-up</td>
<td></td>
</tr>
<tr>
<td></td>
<td>perception, and autonomous decision making. We are interested in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>finding out how motivation informs social interaction (cooperation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and competition, communication and deception), learning, and playing,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>shapes personality; and influences perception and creative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>problem-solving.</td>
<td></td>
</tr>
<tr>
<td>472</td>
<td>radiO_o</td>
<td>Kevin Slavin, Mark Feldmeier, Che-Wei Wang, Taylor Levy, Daniel Novy</td>
</tr>
<tr>
<td></td>
<td>radiO_o is a battery-powered speaker worn by hundreds of party guests,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>turning each person into a local mobile sound system. The radiO_o</td>
<td></td>
</tr>
<tr>
<td></td>
<td>broadcast system allows the DJ to transmit sounds over several</td>
<td></td>
</tr>
<tr>
<td></td>
<td>pirate radio channels to mix sounds between hundreds of speakers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>roaming around the space and the venue's existing sound system.</td>
<td></td>
</tr>
<tr>
<td>473</td>
<td>Sneak: A Hybrid Digital-Physical Tabletop Game</td>
<td>Kevin Slavin, Gregory Borenstein</td>
</tr>
<tr>
<td></td>
<td>Sneak is a hybrid digital tabletop game for two-to-four players about</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deception, stealth, and social intuition. Each player secretly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>controls one agent in a procedurally generated supervillain Lair.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Their mission is to find the secret plans and escape without</td>
<td></td>
</tr>
<tr>
<td></td>
<td>getting discovered, shot, or poisoned by another player. To</td>
<td></td>
</tr>
<tr>
<td></td>
<td>accomplish this, players must interact and blend in with a series of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>computer-controlled henchmen while keeping a close eye on their</td>
<td></td>
</tr>
<tr>
<td></td>
<td>human opponents for any social cues that might reveal their</td>
<td></td>
</tr>
<tr>
<td></td>
<td>identity. Sneak introduces a number of systems that are common in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>video games, but were impractical in tabletop games that did not</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deeply integrate a smartphone app. These include procedural map</td>
<td></td>
</tr>
<tr>
<td></td>
<td>generation, NPC pathfinding, dynamic game balancing, and the use of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sound.</td>
<td></td>
</tr>
<tr>
<td>474</td>
<td>Soft Exchange: Interaction Design with Biological Interfaces</td>
<td>Kevin Slavin</td>
</tr>
<tr>
<td></td>
<td>The boundaries and fabric of human experience are continuously</td>
<td>interacting at an imperceptible scale. Though hidden, these systems</td>
</tr>
<tr>
<td></td>
<td>redefined by microorganisms, interacting at an imperceptible scale.</td>
<td>condition our bodies, environment, and even sensibilities and desires.</td>
</tr>
<tr>
<td></td>
<td>Though hidden, these systems condition our bodies, environment, and</td>
<td>The proposed works introduce a model of interaction in which the</td>
</tr>
<tr>
<td></td>
<td>even sensibilities and desires. The proposed works introduce a</td>
<td>microbiome is an extension of the human sensory system, accessed</td>
</tr>
<tr>
<td></td>
<td>model of interaction in which the microbiome is an extension of the</td>
<td>through a series of biological interfaces that enable exchange.</td>
</tr>
<tr>
<td></td>
<td>human sensory system, accessed through a series of biological</td>
<td>Biological Interfaces transfer discrete behaviors of microbes into</td>
</tr>
<tr>
<td></td>
<td>interfaces that enable exchange. Biological Interfaces transfer</td>
<td>information across scales, where it may be manipulated, even if</td>
</tr>
<tr>
<td></td>
<td>discrete behaviors of microbes into information across scales, where</td>
<td>unseen. In the same way the field of HCI has articulated our</td>
</tr>
<tr>
<td></td>
<td>it may be manipulated, even if unseen. In the same way the field of</td>
<td>exchanges with electronic signals. Soft Exchange opens up the question</td>
</tr>
<tr>
<td></td>
<td>HCI has articulated our exchanges with electronic signals.</td>
<td>of how to design for this other invisible, though present, and</td>
</tr>
<tr>
<td></td>
<td>Soft Exchange opens up the question of how to</td>
<td>vibrant material.</td>
</tr>
<tr>
<td>475</td>
<td>Storyboards</td>
<td>Nazmus Saquib, Shantell Martin, Jonathan Bobrow</td>
</tr>
<tr>
<td></td>
<td>Giving opaque technology a glass house, Storyboards present the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tinkers or owners of electronic devices with stories of how their</td>
<td></td>
</tr>
<tr>
<td></td>
<td>devices work. Just as the circuit board is a story of star-crossed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>lovers--Anode and Cathode--with its cast of characters (resistor,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>capacitor, transistor), Storyboards have their own characters driving</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a parallel visual narrative.</td>
<td></td>
</tr>
<tr>
<td>476</td>
<td>Troxes</td>
<td>Jonathan Bobrow</td>
</tr>
<tr>
<td></td>
<td>The building blocks we grow up with and the coordinate systems we</td>
<td></td>
</tr>
<tr>
<td></td>
<td>are introduced to at an early age shape the design space with which</td>
<td></td>
</tr>
<tr>
<td></td>
<td>we think. Complex systems are difficult to understand because they</td>
<td></td>
</tr>
<tr>
<td></td>
<td>often require transition from one coordinate system to another. We</td>
<td></td>
</tr>
<tr>
<td></td>
<td>could even begin to say that empathy is precisely this ability to map</td>
<td></td>
</tr>
<tr>
<td></td>
<td>easily to many different coordinates. Troxes is a building blocks kit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>based on the triangle, where kids get to build their building blocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>and then assemble Platonic and Archimedean solids.</td>
<td></td>
</tr>
</tbody>
</table>
Action Path

Emilie Reiser, Ethan Zuckerman, Erhardt Graeff, Rahul Bhargava

Action Path is a mobile app to help people learn about and engage with issues in their community. The app uses push notifications tied to geography that invite people to provide meaningful feedback on nearby issues as they traverse the city. Most platforms for civic engagement, whether online or offline, are inconvenient and disconnected from the source of the issues they are meant to address. Action Path addresses barriers to effective civic engagement by inviting people’s input, converting individual actions into collective action, and providing context and a sense of efficacy.

Algorithmic Justice League

Joy Buolamwini, Ethan Zuckerman

WWW.CODEDGAZE.COM

An unseen force is rising—helping to determine who is hired, granted a loan, or even how long someone spends in prison. This force is called the coded gaze.

However, many people are unaware of the growing impact of the coded gaze and the rising need for fairness, accountability, and transparency in coded systems. Without knowing discriminatory practices are at play, citizens are unable to affirm their rights or identify violations.

The Algorithmic Justice League aims to:

1) highlight algorithmic bias through provocative media and interactive exhibitions
2) provide space for people to voice concerns and experiences with coded discrimination
3) develop practices for accountability during the design, development, and deployment phases of coded systems.

CivilServant: User-Led Randomized Trials Online

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.

Code4Rights

Joy Buolamwini, Ethan Zuckerman

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

Ethan Zuckerman, Catherine D’Ignazio, Rahul Bhargava

DataBasic is a suite of web-based tools that give people fun and relevant ways to 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!

Data Therapy

Rahul Bhargava, Ethan Zuckerman

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

483. DeepStream

Gordon Mangum, Ethan Zuckerman
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.

484. 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.

485. FOLD

Ethan Zuckerman, Kevin Zeng Hu, Alexis Hope, Matthew Carroll, Cesar A. Hidalgo
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.

486. Going Dark: Collective Action in the reddit Blackout

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.

487. "Make the Breast Pump Not Suck!“ Hackathon

Ethan Zuckerman, Tal Achituv, Alexis Hope, Che-Wei Wang, Taylor Levy, Catherine D’Ignazio
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.

488. Media Cloud

Ethan Zuckerman, Alexis Hope, Sands Fish, Rahul Bhargava, Anushka Shah, Natalie Gyenes
David LaRochelle, Hal Roberts

Media Cloud is a platform for studying media ecosystems—the relationships between professional and citizen media, between online and offline sources. 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. 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.
Mission Wildlife

Poseidon Ho, Ethan Zuckerman, Gabriel Miller
Mission Wildlife is a collaboration between MIT Center for Civic Media and San Diego Zoo Global with the vision of leading the fight against extinction. It leverages the zoo’s 3 million annual visitors, and try to focus the attention of them towards the threats to the endangered species in the zoo by integrating Augmented Reality Gamification. It was released on the 100th anniversary of San Diego Zoo and a week after Pokemon Go, when visitors already had solid foundations for Augmented Reality games. They competed against each other by triggering 3D animations from animal signs, taking selfies, and sharing photos on their social media with specific hashtags with the goal of spreading awareness about certain issues. This experience has not only made us realize the impact of creating social change with technology and gamification, but also exhibited a real-life example of how small actions can collectively make a large difference.

MoboWater

Poseidon Ho, Emilie Reiser, Ethan Zuckerman, Nickolaos Savidis
MoboWater is a crowd-sensing platform that combines three components allowing anyone to conduct instantaneous water sensing anytime, anywhere. The hardware kit, attachable to mobile devices, includes a 200x micro lens to make water turbidity and bacteria visible. We are also developing modules for conductivity, pH, and heavy metals. The mobile application embeds custom training models to perform image processing for analyzing water purity and recognizing specific objects. The web application visualizes water properties into location-based open datasets, and is designed for citizens and communities to create data-driven campaigns. MoboWater is expanding water-sensing technologies beyond research laboratories and transforming the way citizens evaluate and interact with their water supplies.

NetStories

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.

NewsPix

Ethan Zuckerman, Catherine D'Ignazio, Matthew Carroll
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.

Open Water Project

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 make it possible for anyone to build, modify, and deploy water quality sensors in their own neighborhood.

PageOneX

Ethan Zuckerman, Edward Platt, Rahul Bhargava
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.
Peer Appreciation in the Workplace

Andrés Monroy Hernández, 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

Emilie Reiser, Ethan Zuckerman, Alexis Hope, Jude Mwenda Ntabathia, Rahul Bhargava, Joy Buolamwini

Promise Tracker is a mobile phone-based data collection system that enables communities to monitor the performance of their local governments.

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. Promise Tracker is designed to increase civic engagement and efficacy of community members who use it, giving them a path towards data-driven advocacy on local issues.

We are currently working with community-based organizations in Brazil who are piloting the platform to monitor infrastructure and services in their cities.

Scanner Grabber

Ethan Zuckerman, Tal Achituv, Pattie Maes

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.

Slap Snap Tap

Joy Buolamwini, Ethan Zuckerman, Mitchel Resnick

Luke Berndt (OpenMhz)

Slap Snap Tap combines wearable sensors with physical block programming to enable enhanced expression through movement. By slapping on a set of sensor straps, snapping in code that links movement triggers to sound actions, and tapping the sensors to activate a play experience, users can combine motion and sound in creative ways. A dancer can create music through movement; an athlete can add emphasis to her performance; demonstrators can synchronize and amplify a chant; and anyone can create sound effects for life moments. Slap Snap Tap is a method of the Slay Play endeavor which aims to broaden participation in computational creation by using movement as a pathway into computational thinking.

The Babbling Brook

Ethan Zuckerman, Catherine D'Ignazio

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.