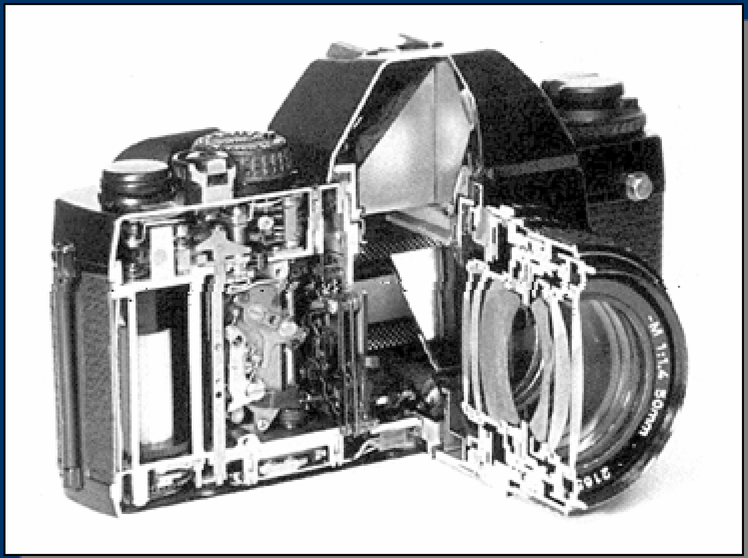
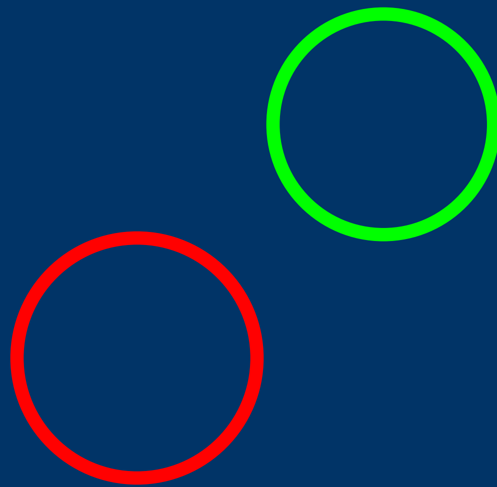
Camera Culture

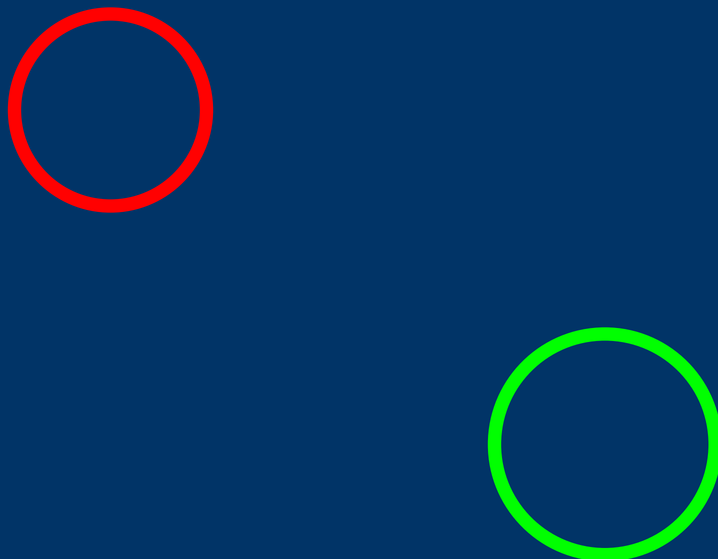


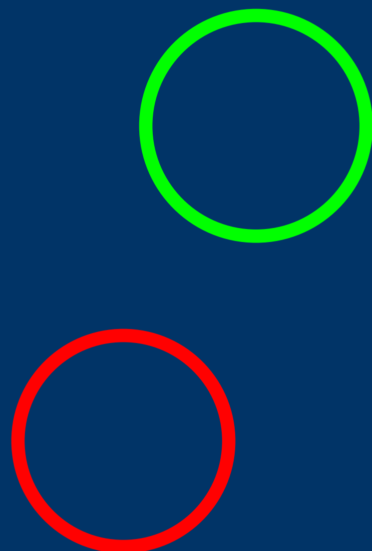
Ramesh Raskar
Associate Prof, Media Lab, MIT

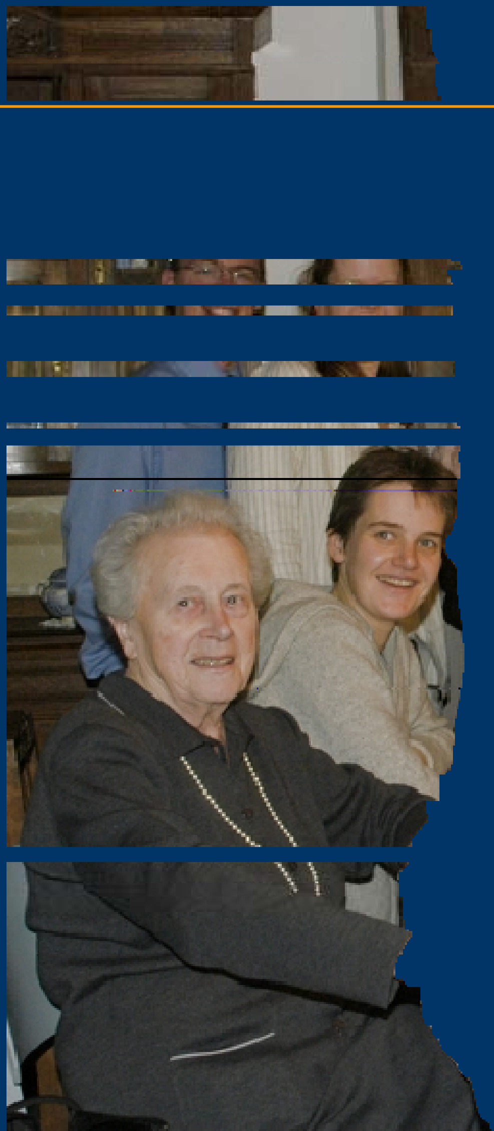
Course WebPage :
http://raskar.info/course.html

Agrawala et al, Digital Photomontage, Siggraph 2004









Agrawala et al, Digital Photomontage, Siggraph 2004

actual

set of originals

→

perceived

photomontage

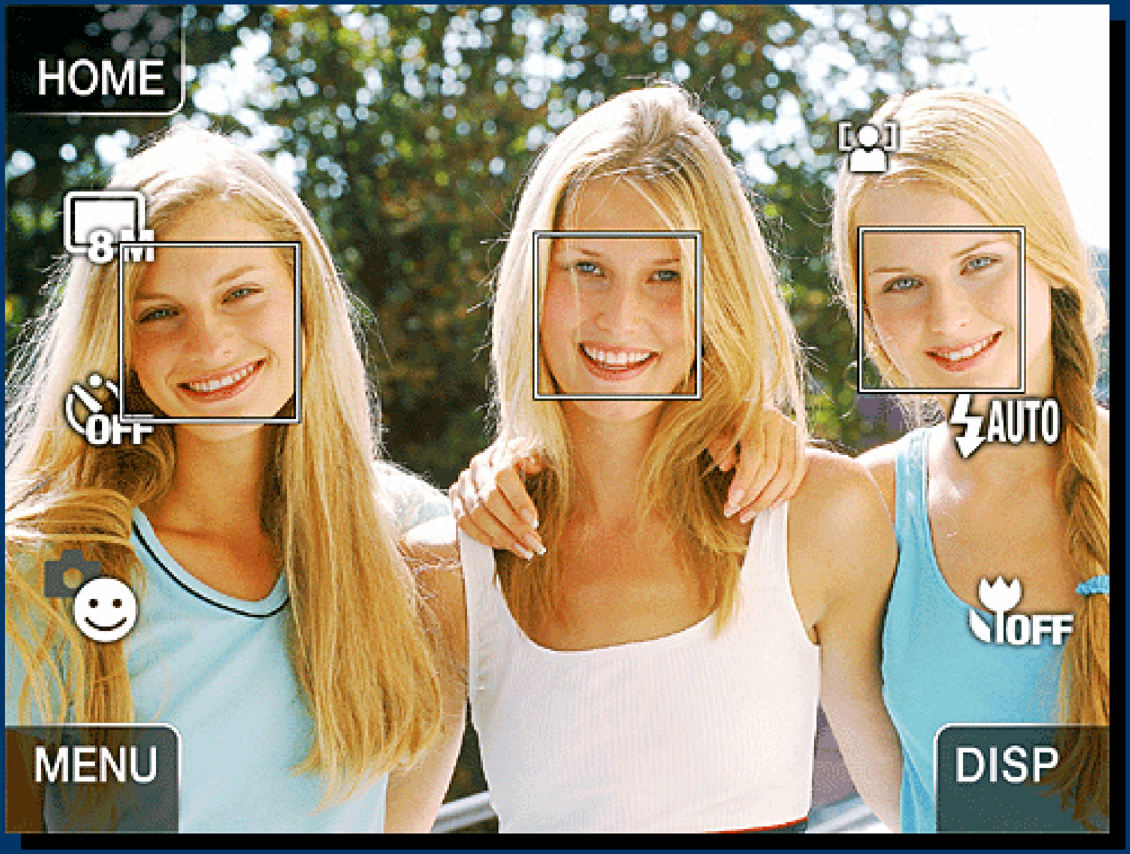
Source images

Brush strokes

Computed labeling

Composite

Sony 'Smile' Shutter



The Sony Cyber-shot DSC-T200 can recognize faces and snaps when it senses a smile.

Motivation

- Why Study Cameras Now ?
  - So what .. everyone has in their pocket..
  - Applied Optics has studied every aspect of the lens
  - Sensor electronics has its own field

Digital cameras are boring: Film-like Photography

- Roughly the same features and controls as film cameras
  - zoom and focus
  - aperture and exposure
  - shutter release and advance
  - one shutter press = one snapshot

- but things are changing…

Digital camera technology

- Plentiful Computing and Memory
  - fast auto-focus systems
  - optical image stabilization
  - automatic face detection
- Photoshop/Imaging Software
  - replacing traditional darkroom techniques
  - warping images, stitching panoramas
  - will eventually replace the view and panoramic camera

Emerging Field

- Digital Images:
    - Democratization: Flickr, YouTube, ‘I F*n Shot That’ Beastie Boys
    - Image and Video Blogs
    - Future new reporting from You, I-reporter
- Many fields
  - Surveillance
  - Entertainment
  - Mobile phone camera based games
  - HCI
  - Factory Automation and Robotics
  - Tele-presence and Tele-conference
  - Authentication and verification
- But they all use an ordinary camera!
  - Build a super-camera, exceed human eye abilities
  - Change the camera to adapt for the application
  - Redefine camera with a new design
  - Understand pre-capture issues and post-capture techniques
  - Support superior meta-tagging

Courses in the last year

* Computational Photography
<http://graphics.cs.cmu.edu/courses/15-463/2005_fall/www/463.html> (Efros, CMU)
* Computational Photography
<http://www.cc.gatech.edu/classes/AY2005/cs4803cp_summer/> (Essa, Georgia Tech)
* Computational Photography
<http://graphics.stanford.edu/courses/cs448-04-spring/announcement.html>
(Levoy & Wilburn, Stanford)
* Computational Photography
<http://people.csail.mit.edu/fredo/PhotoSeminar05/index.htm>
(Durand, MIT)
* Computational Photography
<http://www.eecis.udel.edu/%7Eyu/Teaching/CISC849.html> (Yu, Delaware)
* Instroduction to Visual Computing
<http://www.cs.toronto.edu/%7Ekyros/courses/320/> and Visual Modeling
<http://www.cs.toronto.edu/%7Ekyros/courses/2530/> (Kutulakos, UToronto)
* Topics in Image-based Modeling and Rendering
<http://www.cs.ucsd.edu/classes/wi03/cse291-j/>(Kriegman, UCSD)
* *Symposium on Computational Photography and Video
<http://photo.csail.mit.edu/> *(May 2005, MIT)
*

* *Siggraph 2005 Course on Computational Photography
<http://www.merl.com/people/raskar/photo/> *(July 2005)

Motivation

- Why Computational Cameras Now ?
- What will be the dominant platform for imaging ?
- What are the opportunities ?
- What is different from image processing ?
- How will it impact social computing ?
    - Supporting computations that are carried out by/for groups of people, blogs, collab-filtering, participatory sensing, soc-nets

Cameras Everywhere

- 500 Million Camera phones -> 1 Billion
  - Dwarfs most electronic platforms
- Rapid increase in automated surveillance
- Next media:
    - Google Earth, YouTube, Flickr ..
    - Text, Speech, Music, Images, Video, 3D, ..
    - Technology and Art will exploit which media next ?
- Key element for art, research, products, social-computing ..
- Image processing vs Computational Photo
  - Beyond Post-capture computation
    - What will Photoshop2025 look like ?
    - Do we need to understand the camera ?
      - Aperture, Autofocus, Motion Blur, Bokeh, Sensor parameters, Infrared light

Goals

- Change the rules of the game
  - Emerging optics, illumination, novel sensors
  - Exploit priors and online collections
- Applications
  - Better scene understanding/analysis
  - Capture visual essence
  - Superior Metadata tagging for effective sharing
  - Fuse non-visual data
    - Sensors for disabled, new art forms, crowdsourcing, bridging cultures

Vein Viewer (Luminetx)

Locate subcutaneous veins

Vein Viewer (Luminetx)

Near-IR camera locates subcutaneous veins and project their location onto the surface of the skin.

Coaxial IR camera + Projector

Topics

- Imaging Devices, Modern Optics and Lenses
- Emerging Sensor Technologies
- Mobile Photography
- Visual Social Computing and Citizen Journalism
- Imaging Beyond Visible Spectrum
- Computational Imaging in Sciences
  Trust in Visual Media
- Solutions for Visually Challenged
- Cameras in Developing Countries
- Future Products and Business Models

Topics not covered

- Only a bit of topics below
- Art and Aesthetics
    - 4.343 Photography and Related Media
- Software Image Manipulation
  - Traditional computer vision,
  - Camera fundamentals, Image processing, Learning,
    - 6.815/6.865 Digital and Computational Photography
- Optics
    - 2.71/2.710 Optics
- Photoshop
  - Tricks, tools
- Camera Operation
  - Whatever is in the instruction manual

- Format
  - Lectures and guest talks
    - Google Streetview,
    - Canon consumer imaging,
    - Nokia Mobile Comp Photography+Augmented Reality,
    - RedShift (thermal imaging),
    - Microsoft (Gigapixel imaging, moment camera),
    - Intel (Distributed imaging+storage)
  - In-class discussion, surveys

- Grading
    - (Tentative)
    - Read/Analyze/Present one or two papers
    - Final Survey paper/Project and present
    - Class discussion
      - In class, submit online, dig new recent work/suggest ideas/provoke questions
    - Class notes
    - To receive credit, you must attend regularly, present material on chosen topics and participate in discussions

- Credit
    - Survey paper/Project: 60%
    - Paper presentation: 20%
    - Class participation: 20%

	Topic	Topic	Guest Speaker
1	Feb 06	Introductions	
2	Wed 13 Feb	Imaging Devices, Modern Optics and Lenses	
3	Wed 20 Feb	Mobile Photography	HP Research Labs (Tom Malzbender on CameraPhone Usage, GPS-based tools)
4	Wed 27 Feb	Visual Social Computing and Citizen Journalism	Google Maps Streetview (Luc Vincent, TBA)
5	Wed 05 Mar	Emerging Sensor Technologies	Nokia Research, Mobile Computational Photography (TBA)
6	Wed 12 Mar	Beyond Visible Spectrum	RedShift Technologies(Matthias Wagner, Thermal Imaging)
7	Wed 19 Mar		Intel Research (Rahul Sukthankar)
SPRING BREAK			
8	Wed 02 Apr	Trust in Imaging	Microsoft ?
9	Wed 09 Apr	Computational Imaging in Sciences	Canon USA (Consumer Imaging Group) (TBA)
10	Wed 16 Apr	Solutions for Visually Challenged	
11	Wed 23 Apr	NO class	
12	Wed 30 Apr	Cameras in Developing Countries Future Products and Business Models	
13	Wed 07 May	Student Presentations	
14	Wed 14 May	Student Presentations	

Homework

- What will a camera look like in 10 years, 20 years?
- What will be the dominant platform and why?

- Send by email [raskar(at)media.mit.]

Survey

- Are you a **photographer** ?
- Are you a **digiphoto-artist** ?
- Do you use camera for vision/image processing? Real-time processing?
- Brief Introductions

Instructor: Ramesh Raskar

Associate Professor at Media Lab, Camera Culture group
Senior Research Scientist at MERL 2000-2008

Active Research Areas:
Projector-based Computational Illumination and Displays
Computational photography
Non-photorealistic rendering

http://raskar.info

Cameras and Photography

Art,   Magic, Miracle

Are <u>BOTH</u> a 'photograph'?

http://research.famsi.org/kerrmaya.html

Slide idea: Steve Seitz

New Ways of Seeing the World

"Multiple-Center-of-Projection Images" Rademacher, P, Bishop, G., SIGGRAPH '98

What rays are most expressive?

Andrew Davidhazy, RIT: http://www.rit.edu/~andpph/

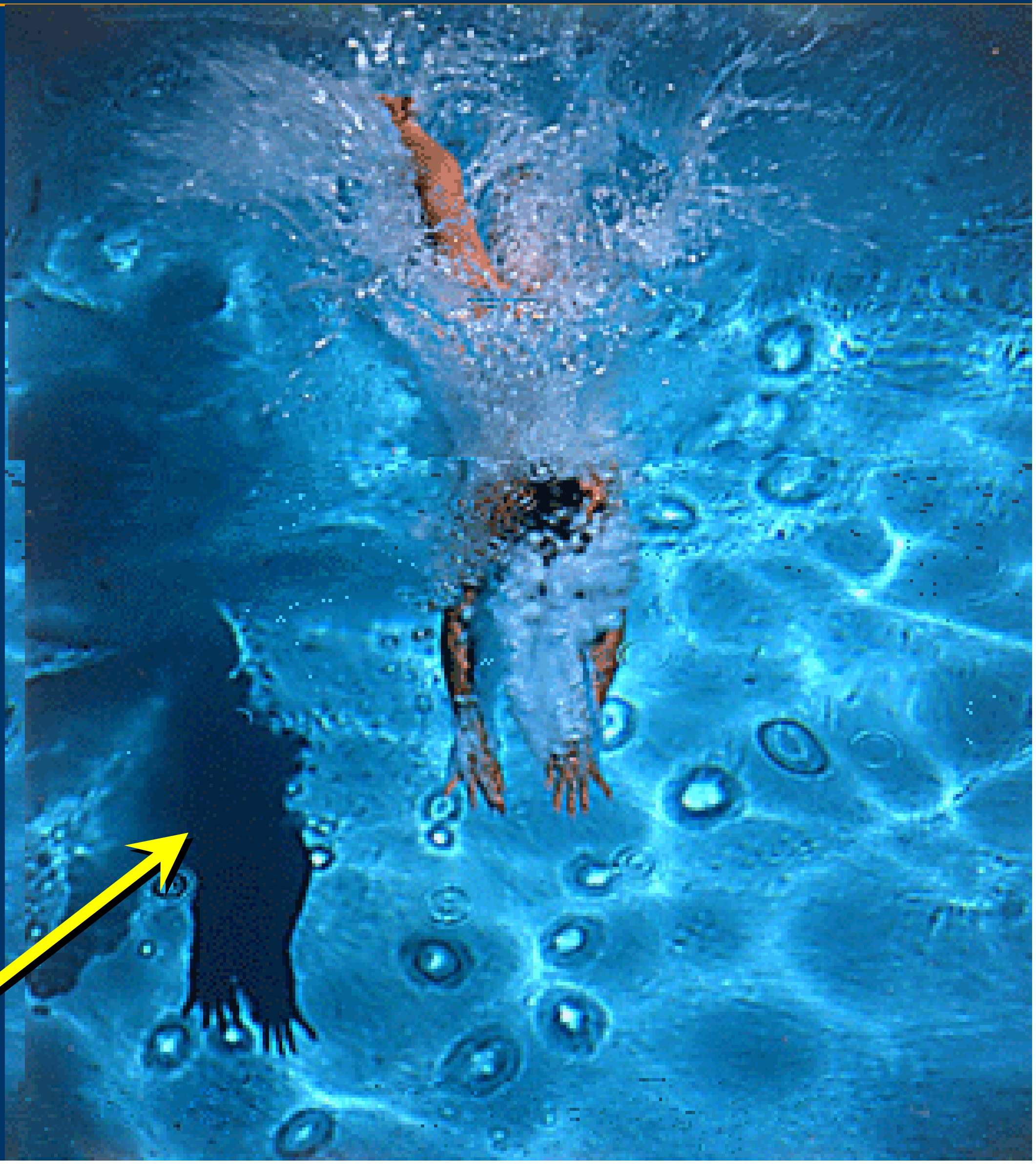
Thick photography: interaction

What other ways better reveal shape to human viewers?

(Without direct shape measurement?)

Time for space wiggle.
Gasparini, 1998.

Can you understand this shape better?



What is Computational Camera ?

- Generate photos that cannot be creates by a single camera at a single instant

- Create the <u>ultimate camera</u> that mimics the eye

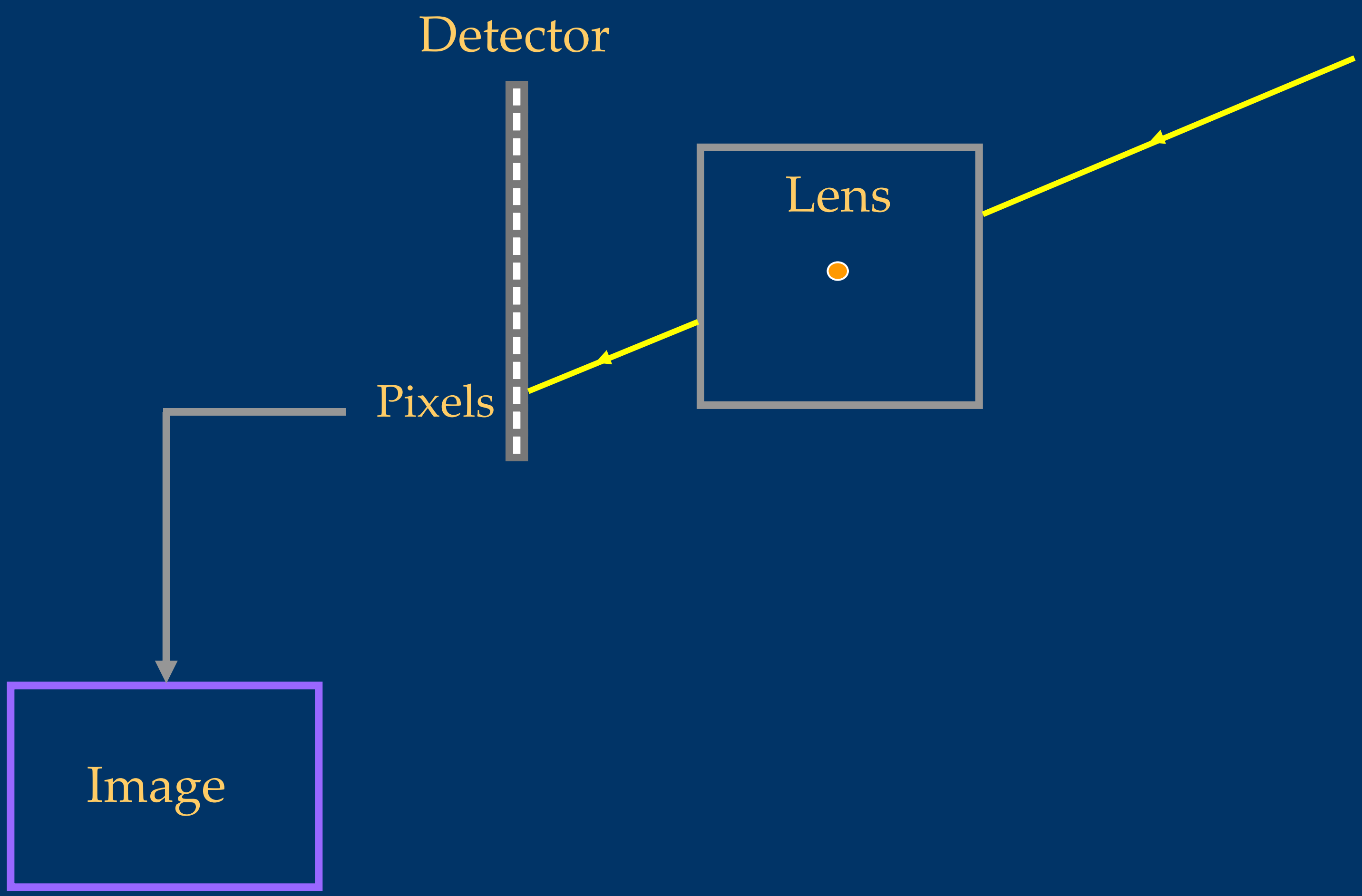
- Create <u>impossible photos</u> that don't mimic the eye
- Learn from scientific imaging (tomography, coded aperture, coherence, phase-contrast)

Improving FILM-LIKE Camera Performance

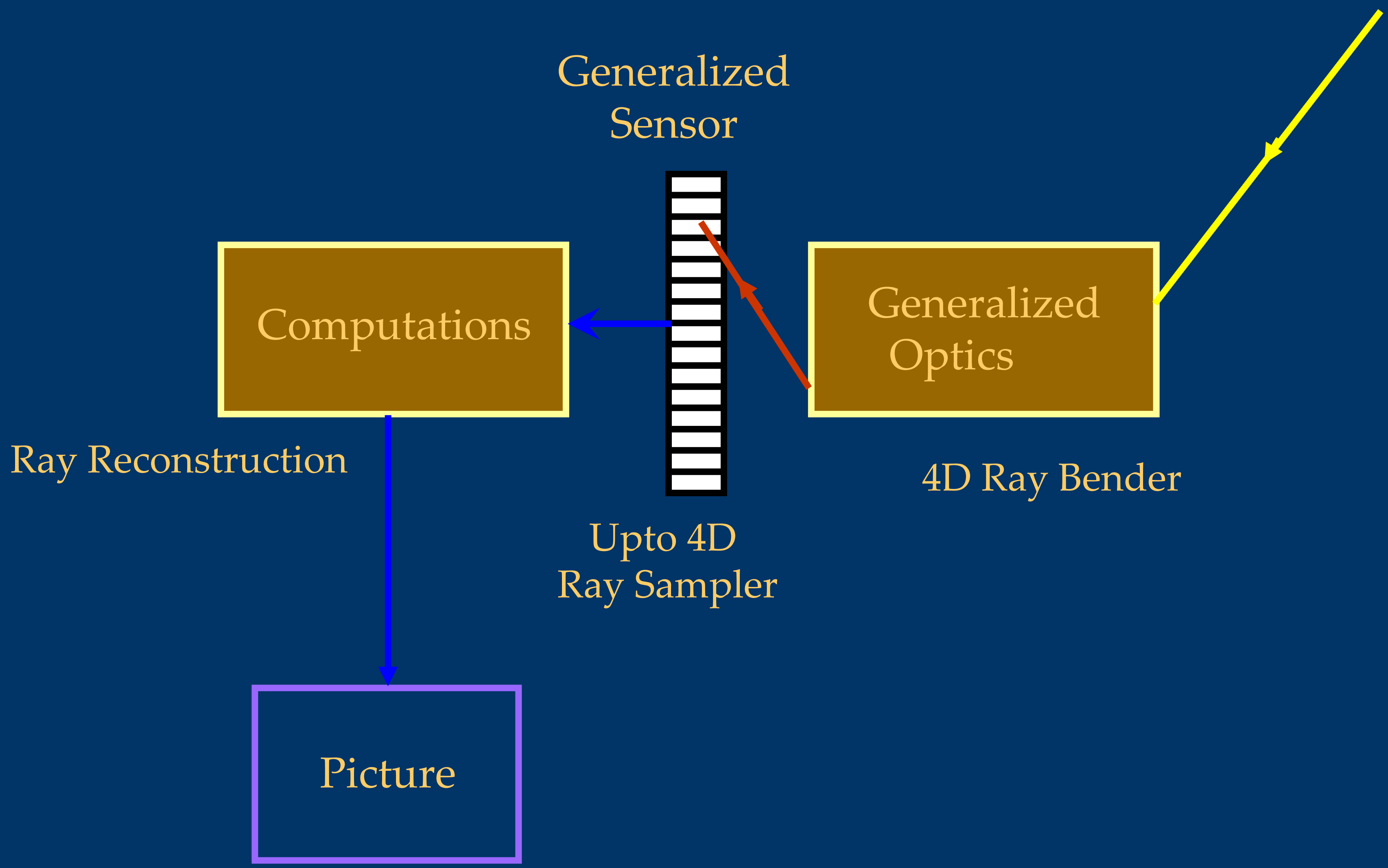
What would make it 'perfect' ?

- Dynamic Range
- Vary Focus Point-by-Point
- Field of view vs. Resolution
- Exposure time and Frame rate

Traditional 'film-like' Photography



Computational Camera:
Optics, Sensors and Computations



Novel Cameras

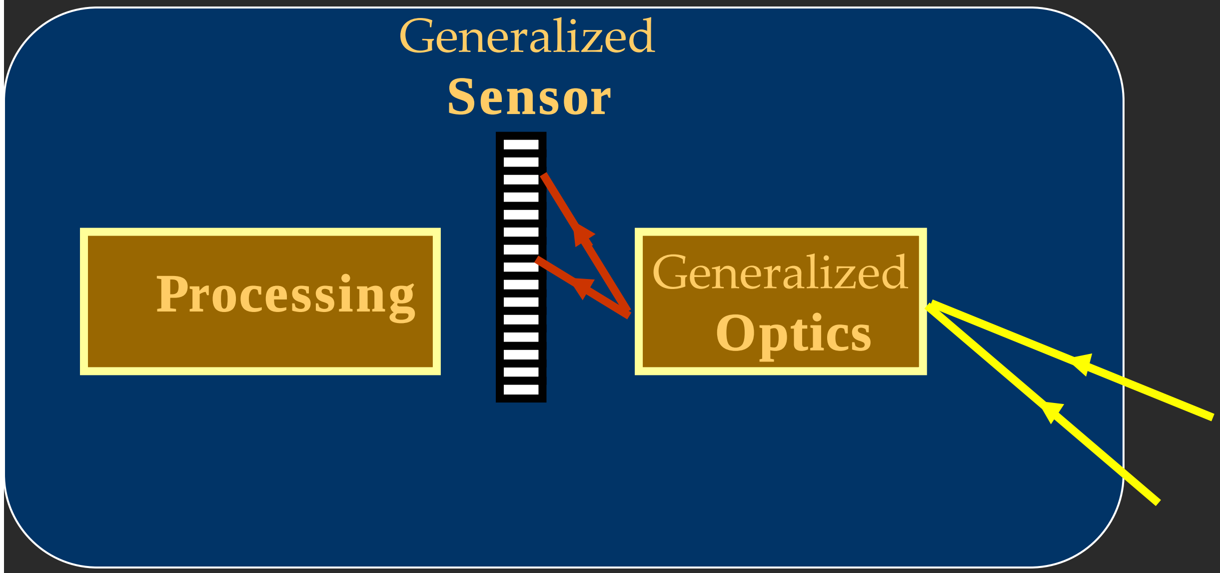
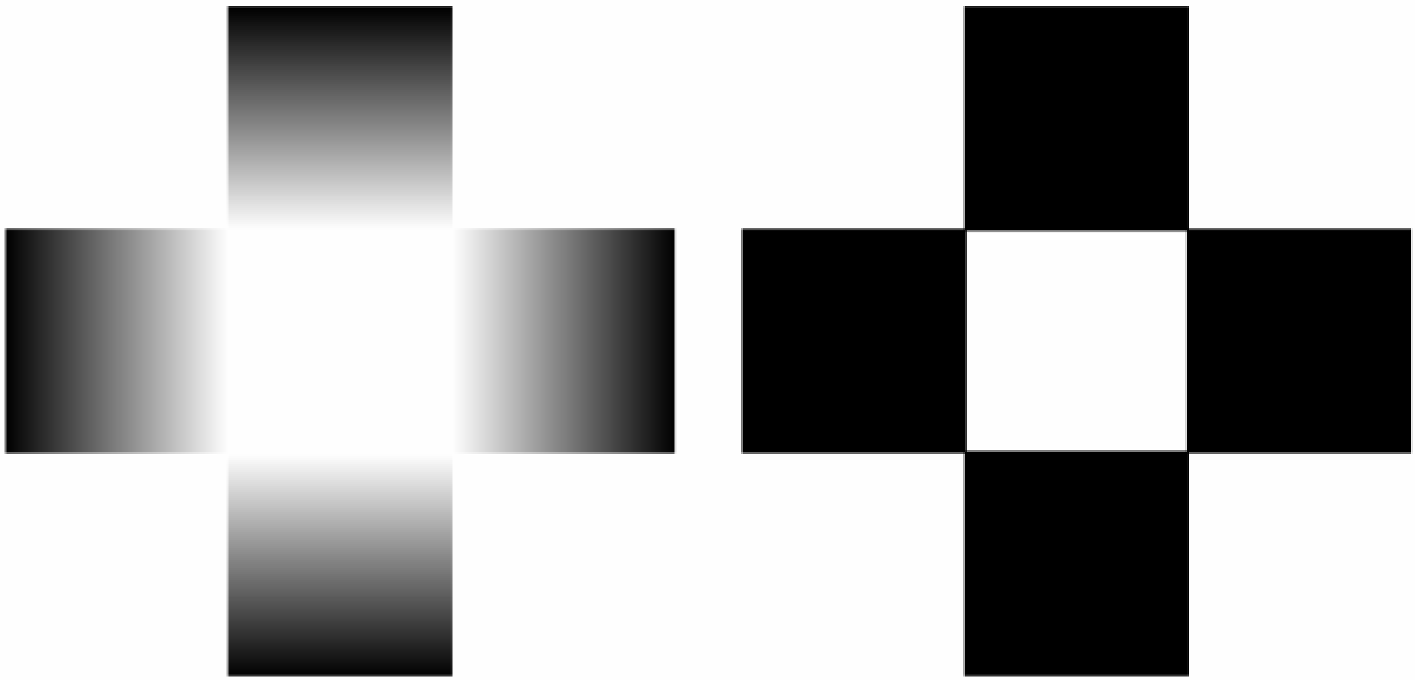


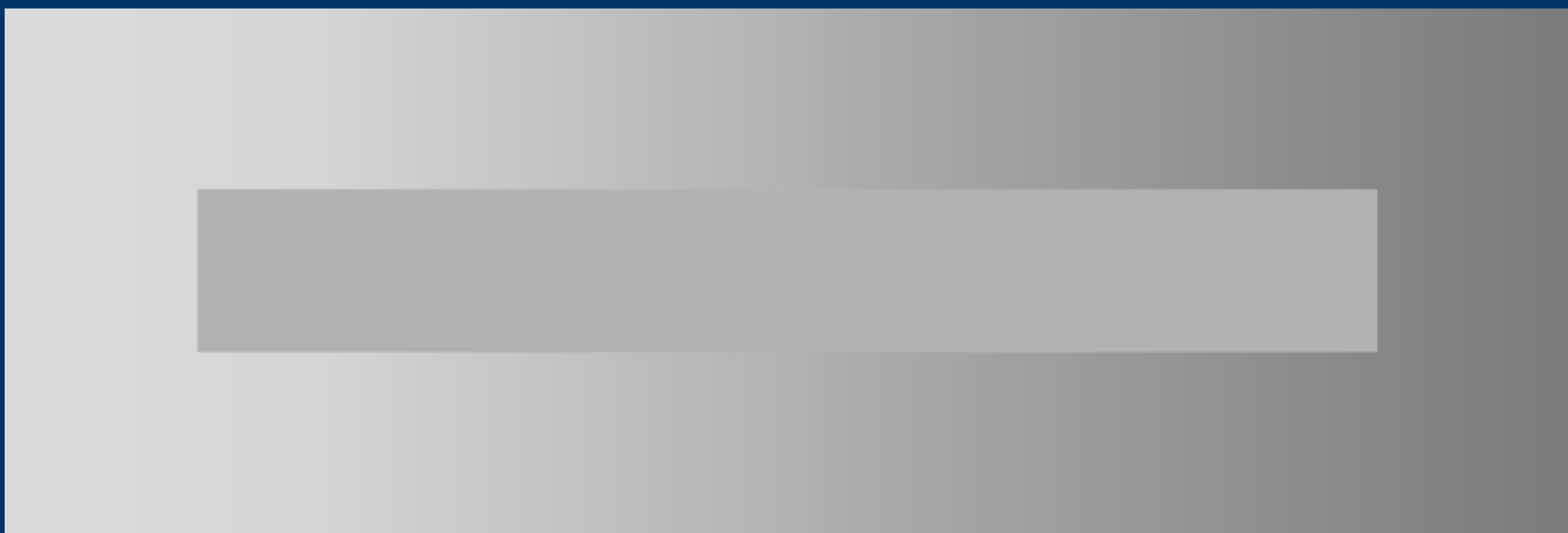
Photo = Illusion

The image is just a record of pixel values.

We do not see pixel values directly: Adaptation.

What we see is an illusion generated from the above record through internal adaptation of the visual system.





Dynamic Range

Short Exposure

Goal: High Dynamic Range

Long Exposure

High depth-of-field

- adjacent views use different focus settings
- for each pixel, select sharpest view

[Haeberli90]

close focus distant focus composite

Long-range
synthetic aperture photography

Levoy et al., SIGG2005

Synthetic aperture videography

Focus Adjustment: Sum of Bundles

- Epsilon Photography
  - Vary focus, exposure polarization, illumination
  - Vary time, view
  - Better than any one photo
- Achieve effects via multi-photo fusion
- Create a Super-camera
  - Mimic human eye

Varying Focus: Extended depth-of-field

Agrawala et al, Digital Photomontage, Siggraph 2004

Source images

Computed labeling

Composite

Two Different Foggy Conditions

Varying Polarization

Yoav Y. Schechner, Nir Karpel 2005

Best polarization state

Worst polarization state

Best polarization state

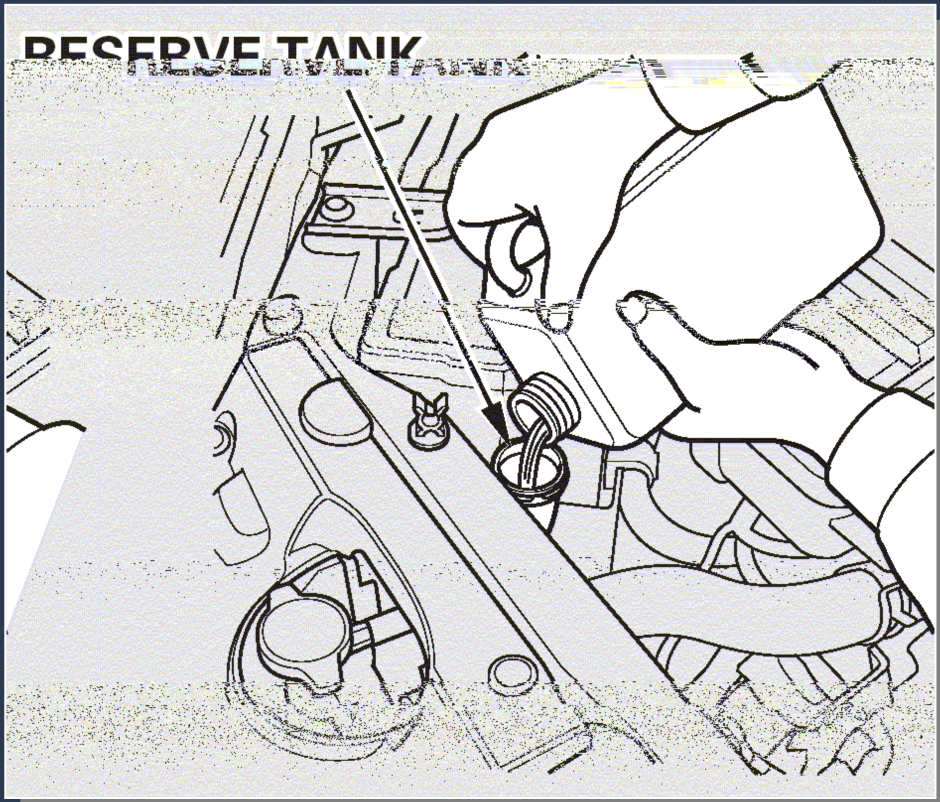
Recovered image

[Left] The raw images taken through a polarizer. [Right] White-balanced results:
The recovered image is much clearer, especially at distant objects, than the raw image

Varying Polarization

- Schechner, Narasimhan, Nayar
- Instant dehazing of images using polarization

- Epsilon Photography
  - Create a Super-camera
  - Mimic human retina
  - Low-level visual processing
- Coded Photography
  - Mid-level visual processing



Car Manuals

What are the problems with ‘real’ photo in conveying information ?

Why do we hire artists to draw what can be photographed ?

- Shadows
- Clutter
- Many Colors

- Highlight Shape Edges
- Mark moving parts
- Basic colors

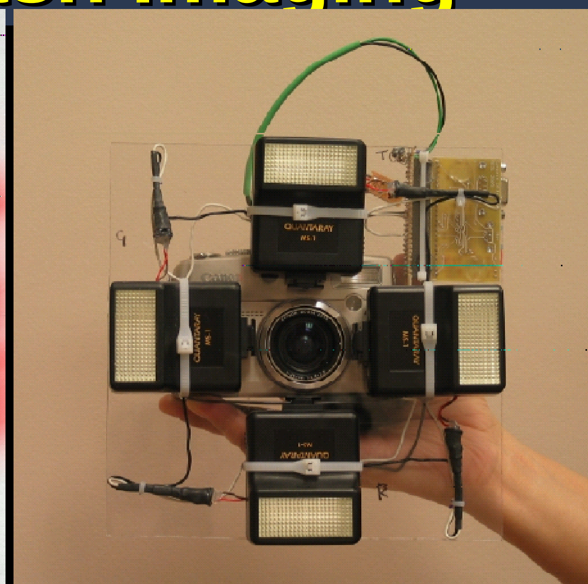
A New Problem

Shadows	Highlight Edges
Clutter	Mark moving parts
Many Colors	Basic colors

Non-photorealistic Camera: Depth Edge Detection and Stylized Rendering

using

Multi-Flash Imaging

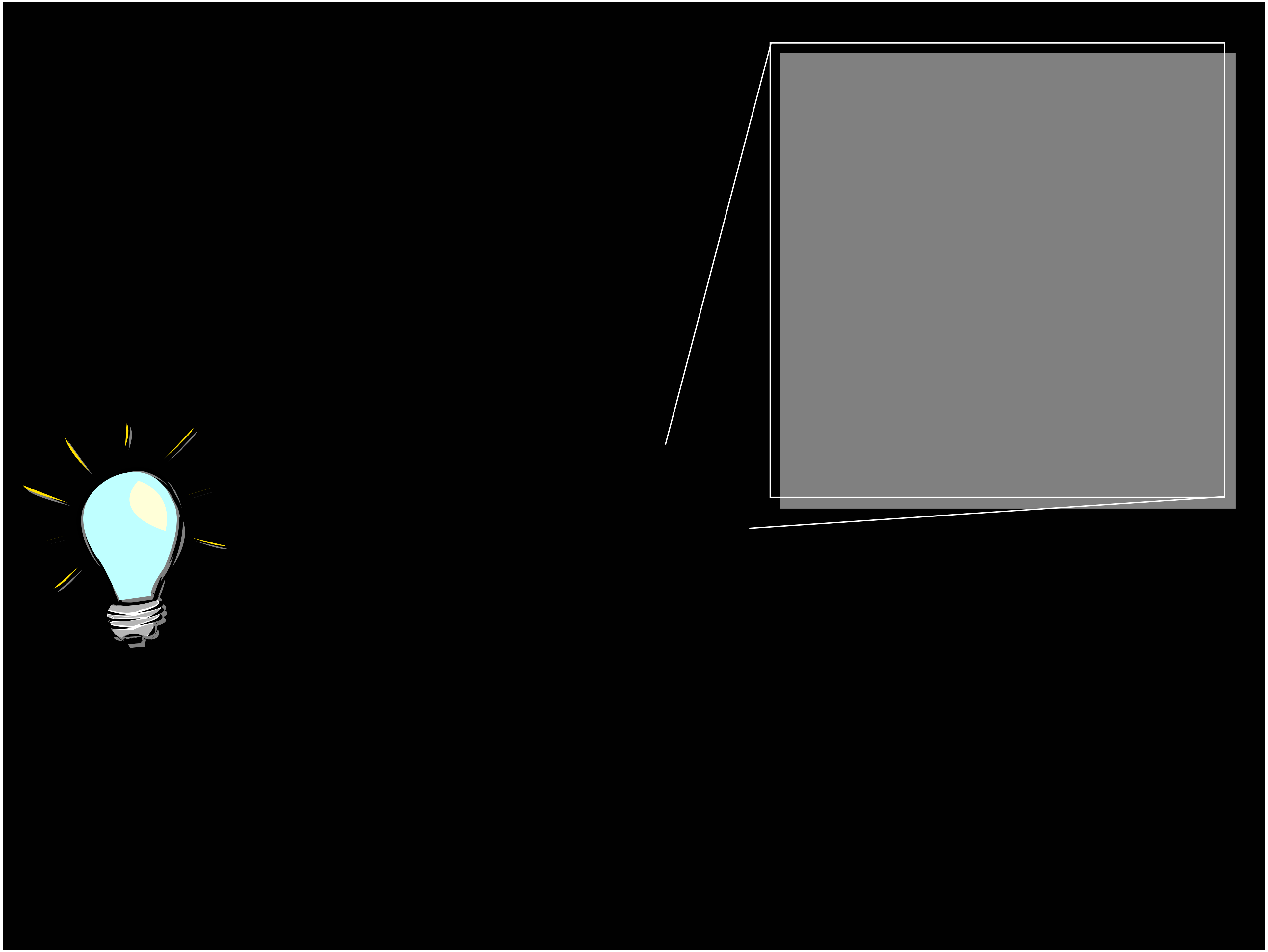


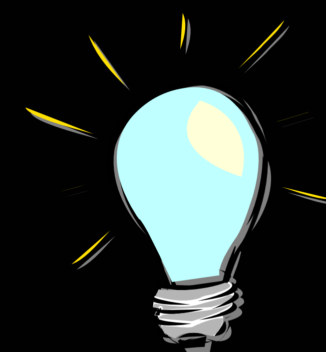
Ramesh Raskar, Karhan Tan, Rogerio Feris, Jingyi Yu, Matthew Turk

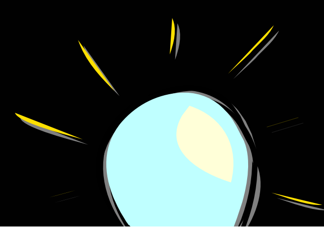
Mitsubishi Electric Research Labs (MERL), Cambridge, MA

U of California at Santa Barbara

U of North Carolina at Chapel Hill



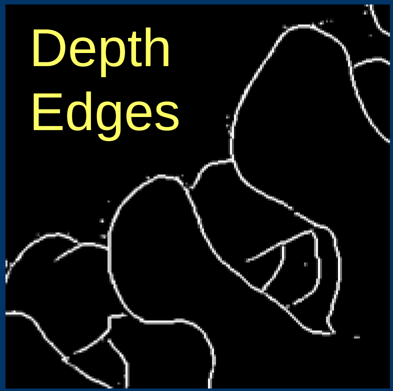




Depth Discontinuities

Internal and external

Shape boundaries, Occluding contour, Silhouettes



Depth
Edges

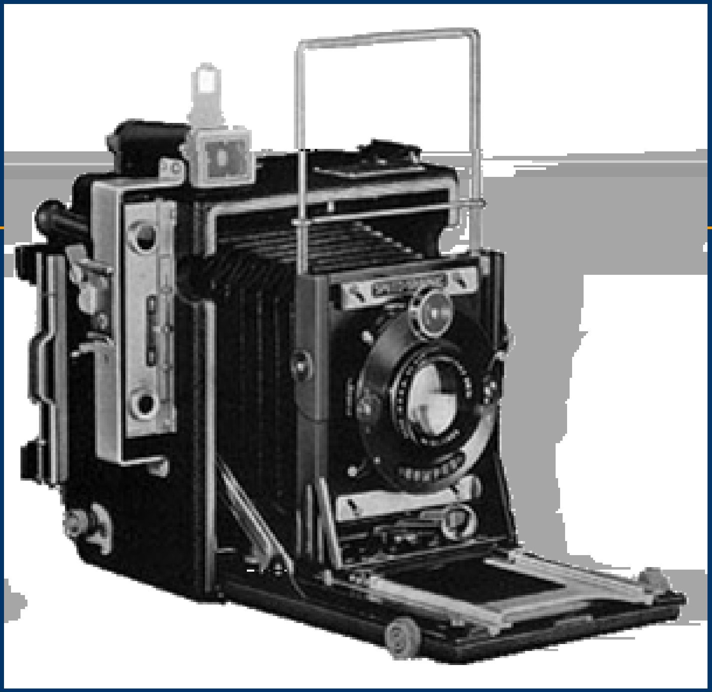
Our Method

Photo

Result

Our Method

Canny Intensity
Edge Detection



Computational Illumination

A Night Time Scene:

Objects are Difficult to Understand due to Lack of Context Dark Bldgs

Enhanced Context :
All features from night scene are preserved, but background in clear

‘Well-lit’ Bldgs

Reflections in
bldgs windows

Tree, Street
shapes

Night Image

Background is captured from day-time scene using the same fixed camera

Result: Enhanced Image

Day Image

Denoising Challenging Images

Available light:

+ nice lighting

- noise/blurriness
- color

No-flash

Flash:

+ details

+ color

- flat/artificial

Flash

Elmar Eisemann and Frédo Durand , Flash Photography Enhancement via Intrinsic Relighting

Georg Petschnigg, Maneesh Agrawala, Hugues Hoppe, Richard Szeliski, Michael Cohen, Kentaro Toyama. Digital Photography with Flash and No-Flash Image Pairs

Use no-flash image relight flash image

No-flash

Flash

Result

Flash and Ambient Images

[Agrawal, Raskar, Nayar, Li   Siggraph05]

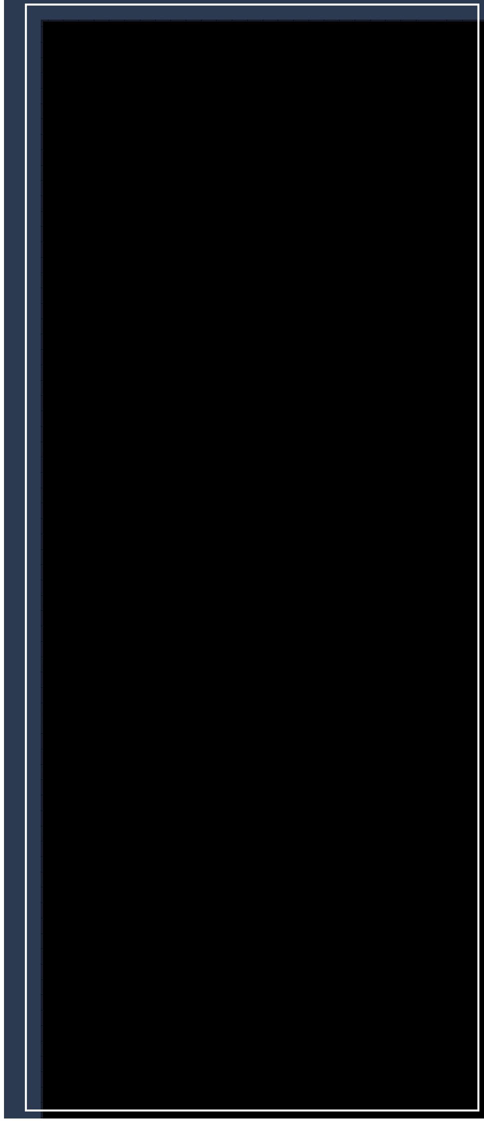
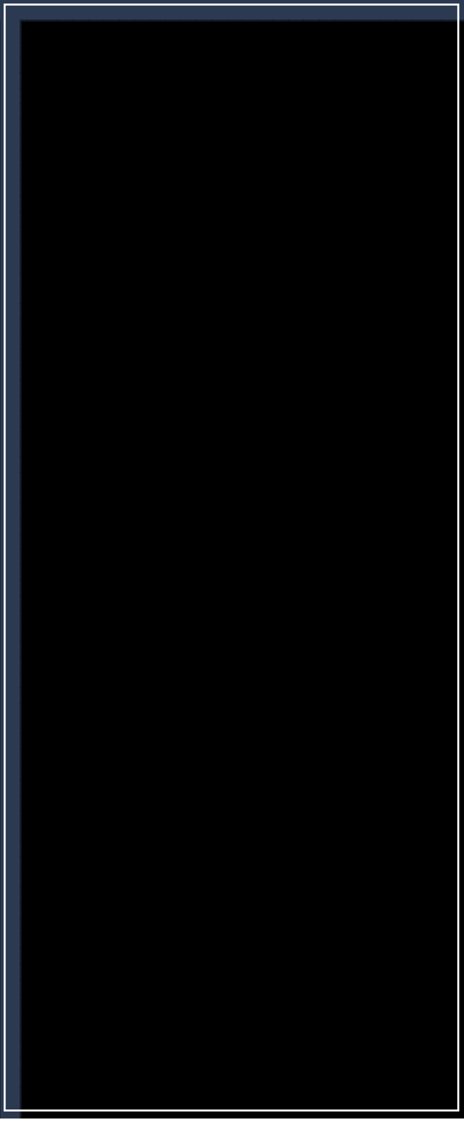
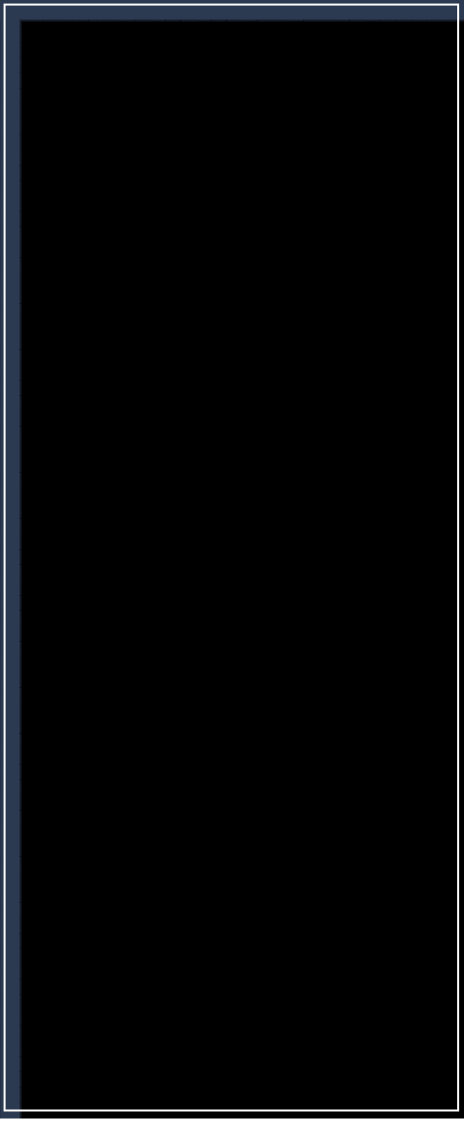
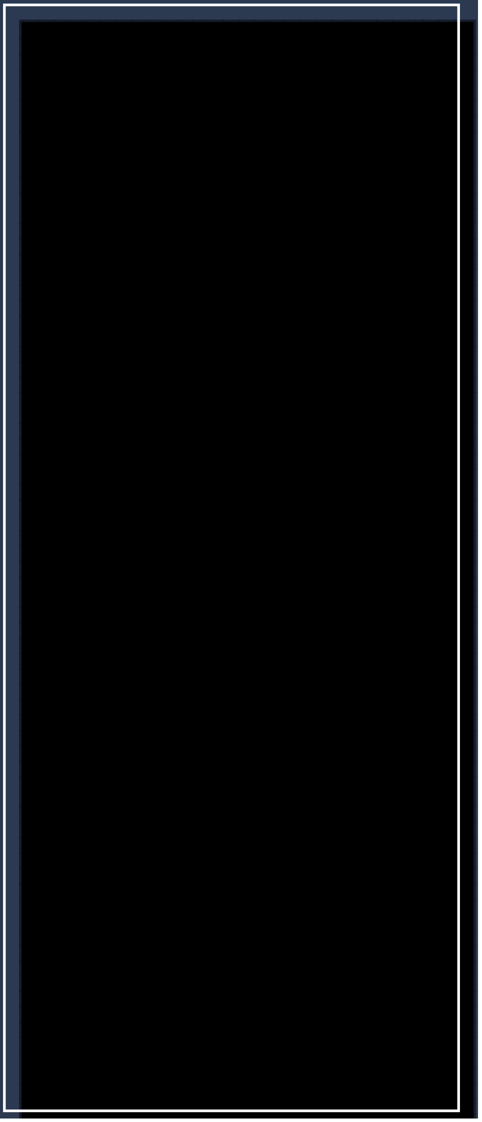
Ambient	Flash	Result	Reflection Layer
			

Image Fusion and Reconstruction

- Epsilon Photography
  - Vary focus, exposure polarization, illumination
  - Vary time, view
  - Better than any one photo
- Achieve effects via multi-image fusion
- Exploit lighting

Topics

- Smart Lighting
  - Light stages, Domes, Light waving, Towards 8D
- Computational Imaging outside Photography
  - Tomography, Coded Aperture Imaging
- Smart Optics
  - Handheld Light field camera, Programmable imaging/aperture
- Smart Sensors
  - HDR Cameras, Gradient Sensing, Line-scan Cameras, Demodulators
- Speculations

Debevec et al. 2002: ‘Light Stage 3’

Image-Based Actual Re-lighting

Debevec et al., SIGG2001

Light the actress in Los Angeles

Film the background in Milan,
Measure incoming light,

Matched LA and Milan lighting.

Matte the background

Light field photography using a handheld plenoptic camera

Ren Ng, Marc Levoy, Mathieu Brédif,
Gene Duval, Mark Horowitz and Pat Hanrahan

Prototype camera

Contax medium format camera

Kodak 16-megapixel sensor

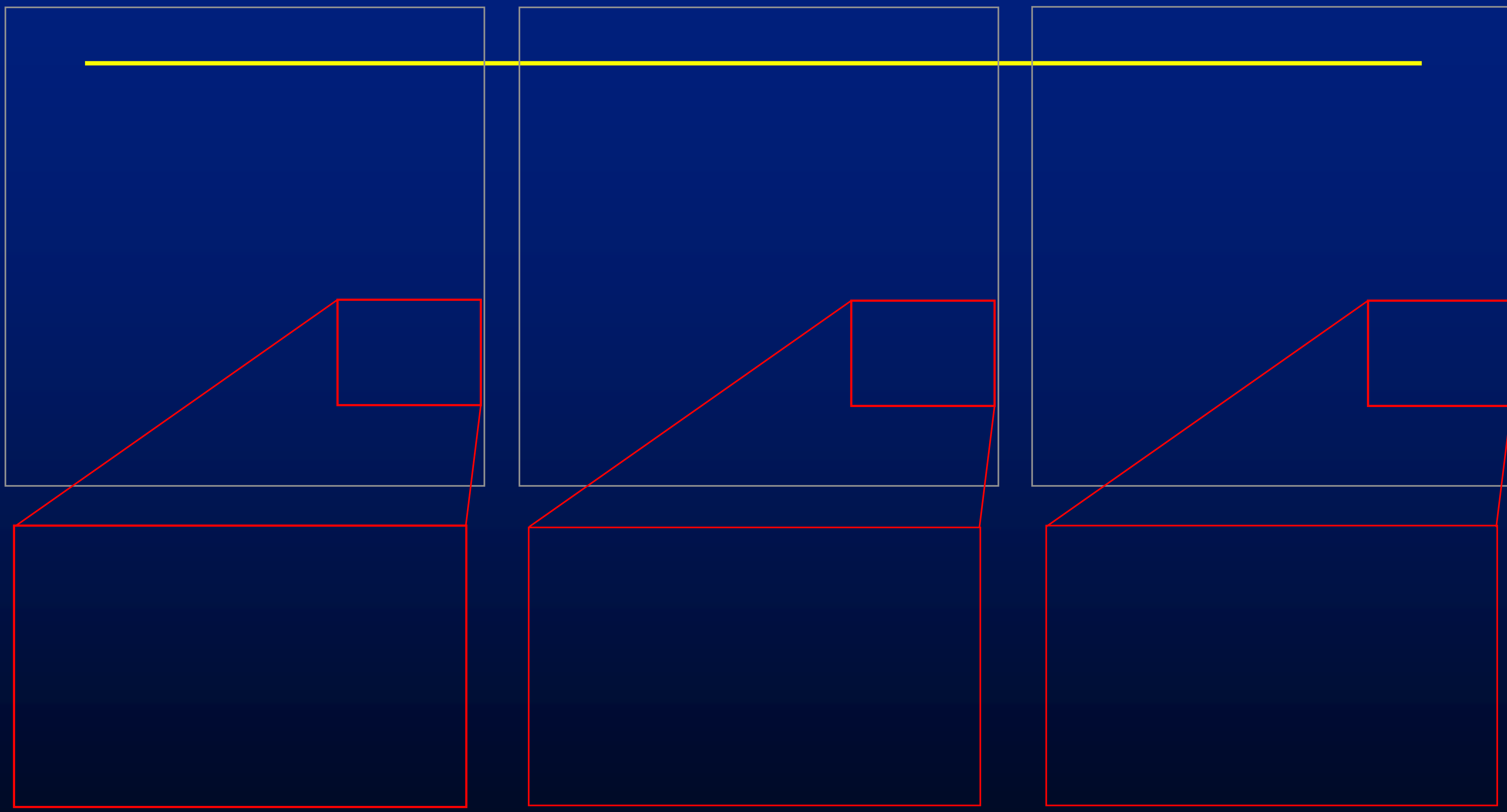
Adaptive Optics microlens array

125μ square-sided microlenses

4000 × 4000 pixels ÷ 292 × 292 lenses = 14 × 14 pixels

Example of digital refocusing

Extending the depth of field



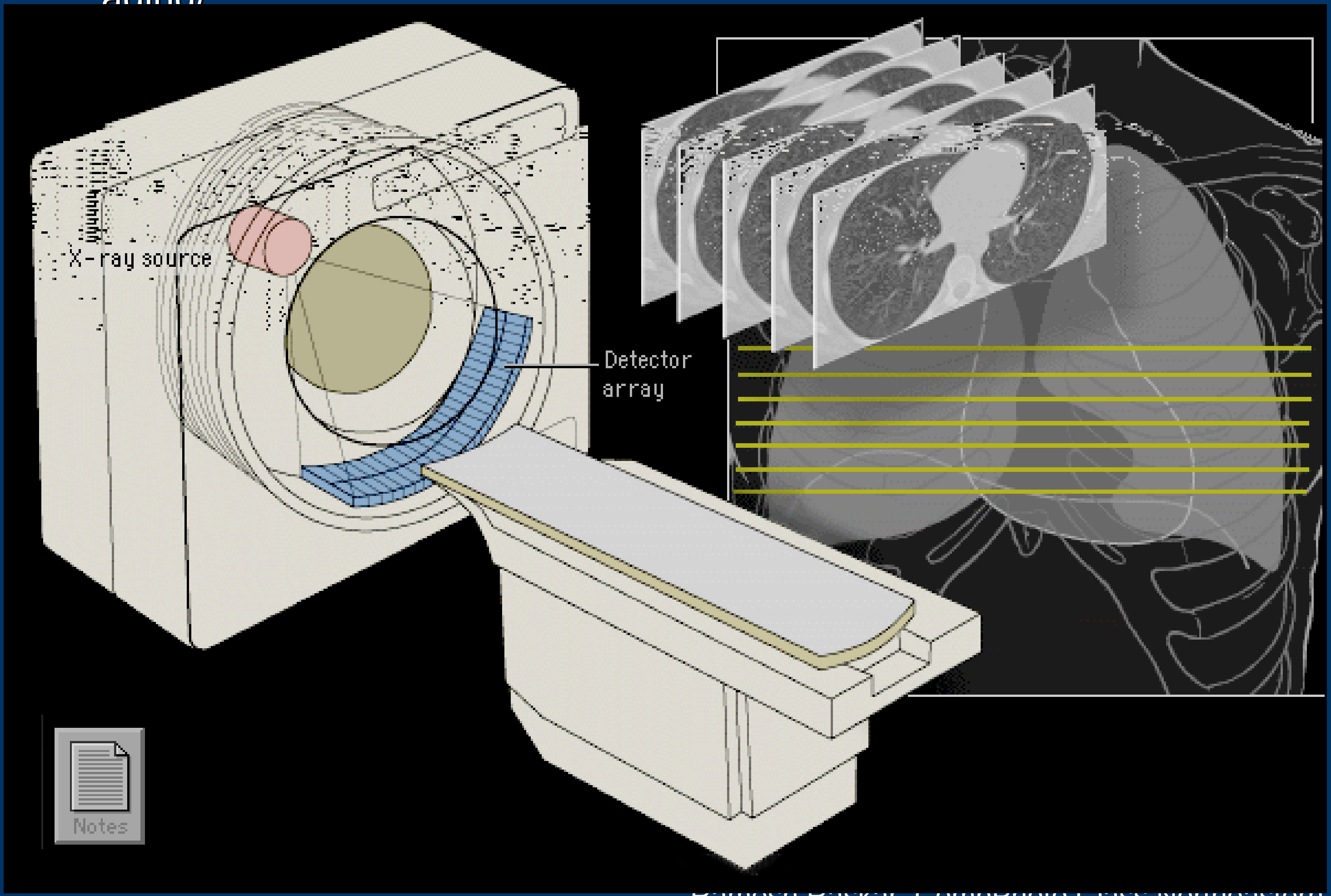
conventional photograph,
main lens at *f* / 4

conventional photograph,
main lens at *f* / 22

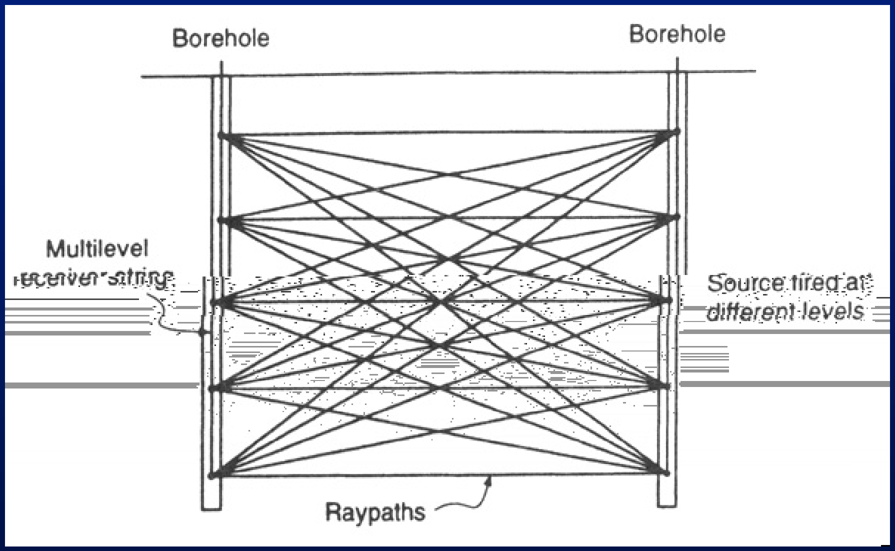
light field, main lens at *f* / 4,
after all-focus algorithm
[Agarwala 2004]

Imaging in Sciences: Computer Tomography

- http://info.med.yale.edu/intmed/cardio/imaging/techniques/ct_imaging/



Borehole tomography



(from Reynolds)

- receivers measure end-to-end travel time
- reconstruct to find velocities in intervening cells
- must use limited-angle reconstruction method (like ART)

Deconvolution microscopy

ordinary microscope image

deconvolved from focus stack

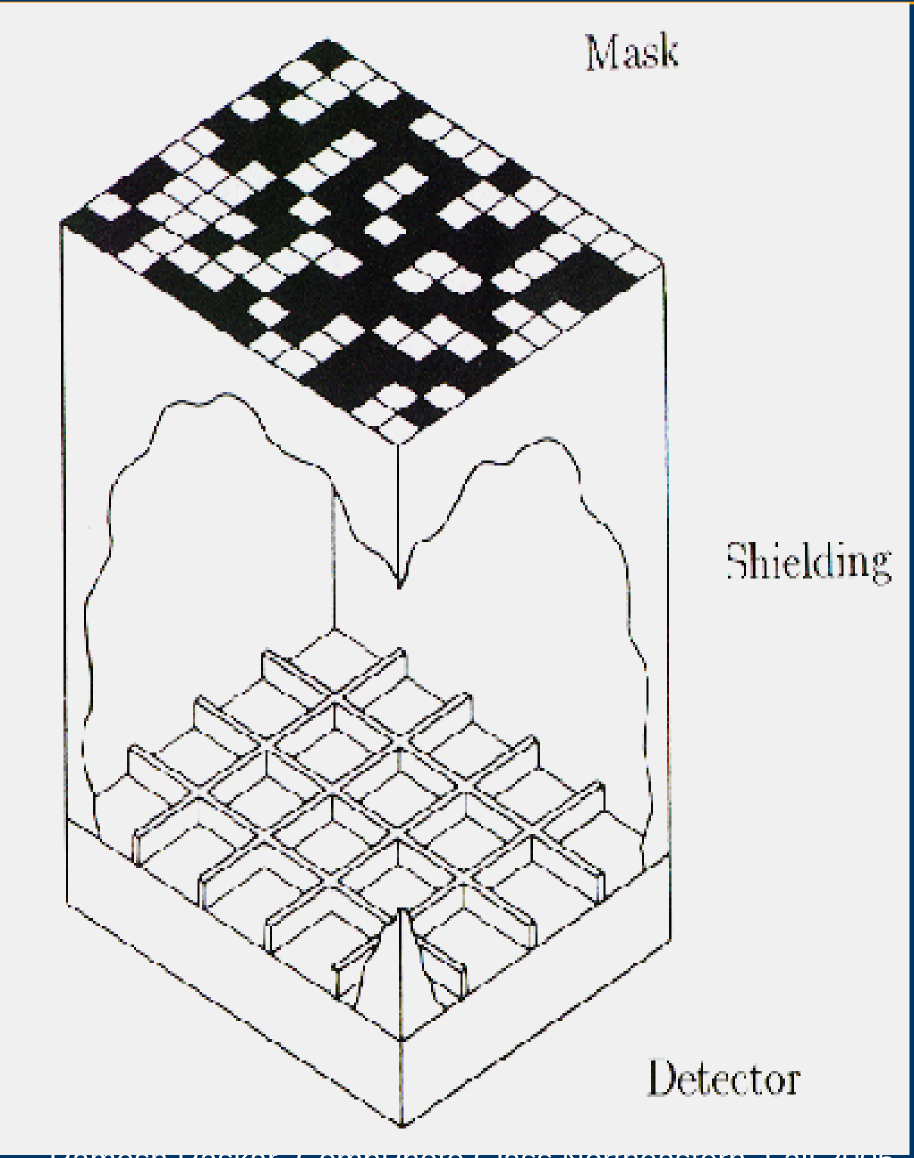
- competitive with confocal imaging, and much faster
- assumes emission or attenuation, but not scattering
- therefore cannot be applied to opaque objects
- begins with less information than a light field (3D vrs 4D)

Coded-Aperture Imaging

- Lens-free imaging!
- Pinhole-camera sharpness, without massive light loss.
- No ray bending (OK for X-ray, gamma ray, etc.)

- Two elements
  - Code Mask: binary (opaque/transparent)
  - Sensor grid

- Mask autocorrelation is delta function (impulse)
- Similar to MotionSensor ?



Mask in a Camera

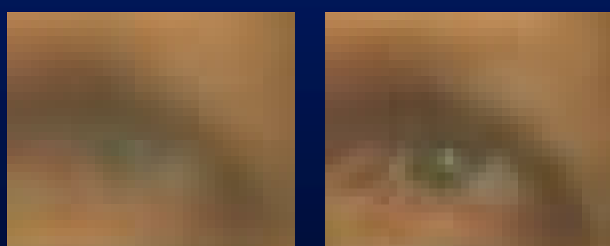
Mask

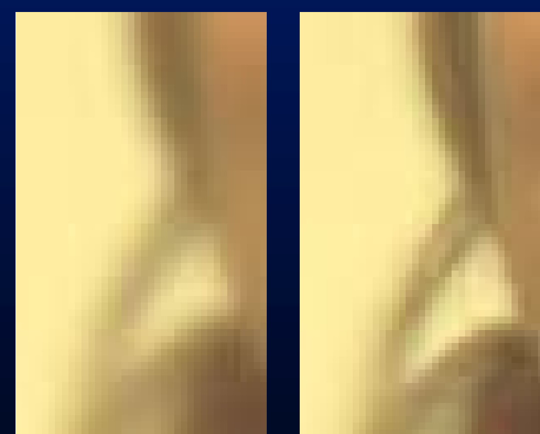
Aperture

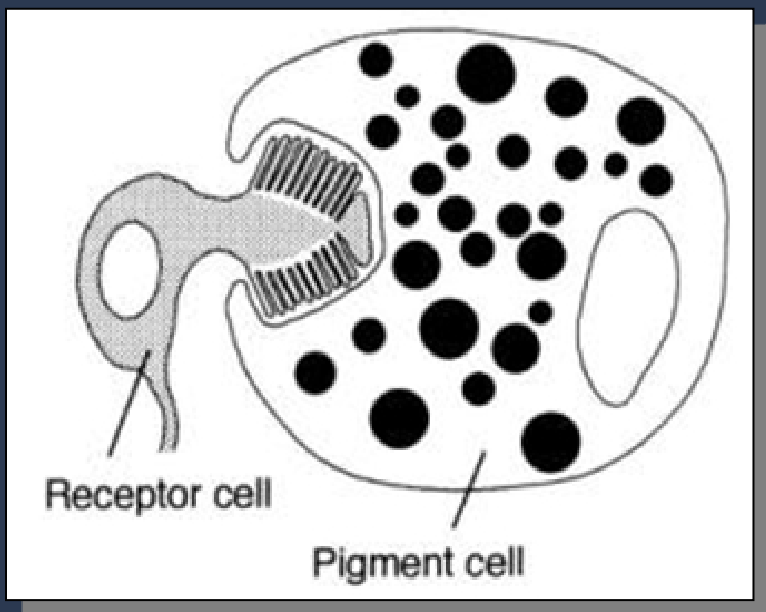
Canon EF 100 mm 1:1.28 Lens,
Canon SLR Rebel XT camera

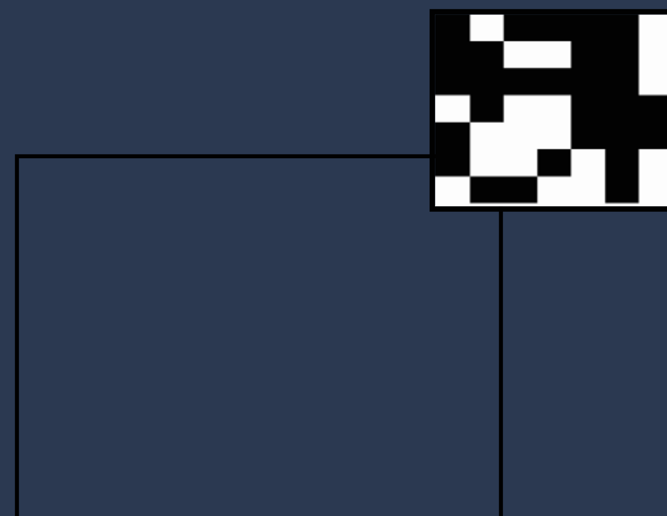
Captured Blurred Image

Refocused Image on Person

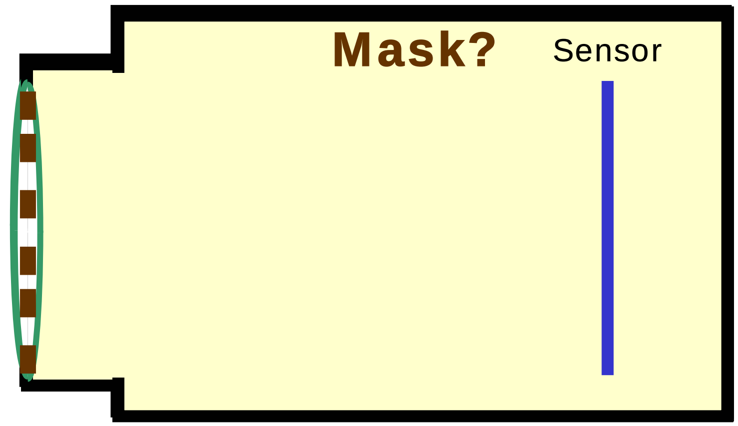


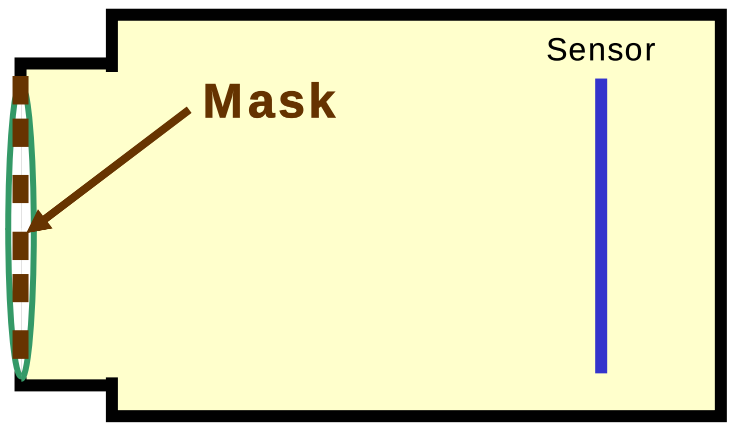






Larval Trematode Worm





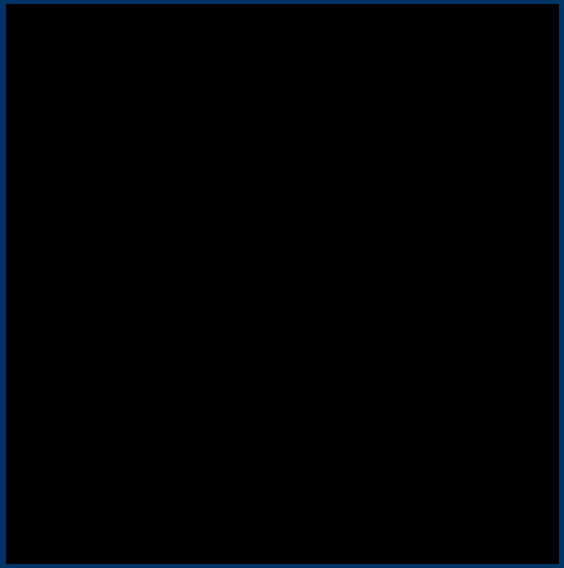
Full Resolution Digital Refocusing:

Coded Aperture Camera

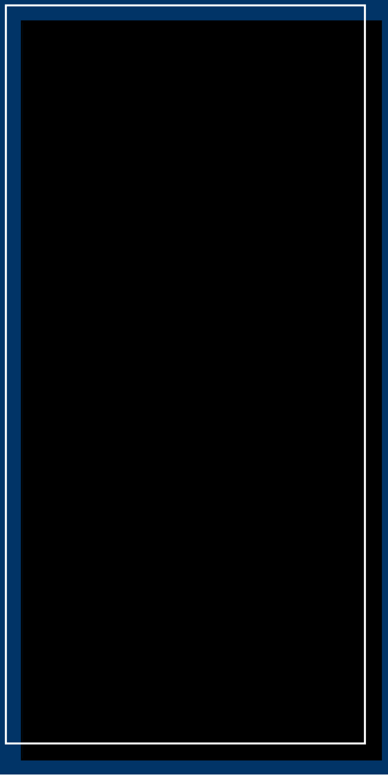
4D Light Field from 2D Photo:

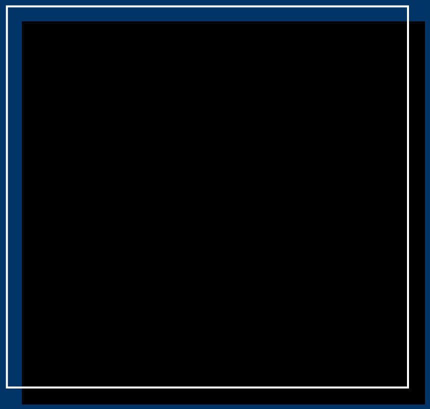
Heterodyne Light Field Camera

Novel Sensors



- Gradient sensing
- HDR Camera, Log sensing
- Line-scan Camera
- Demodulating
- Motion Capture
- 3D





Line Scan Camera: PhotoFinish 2000 Hz

The CityBlock Project

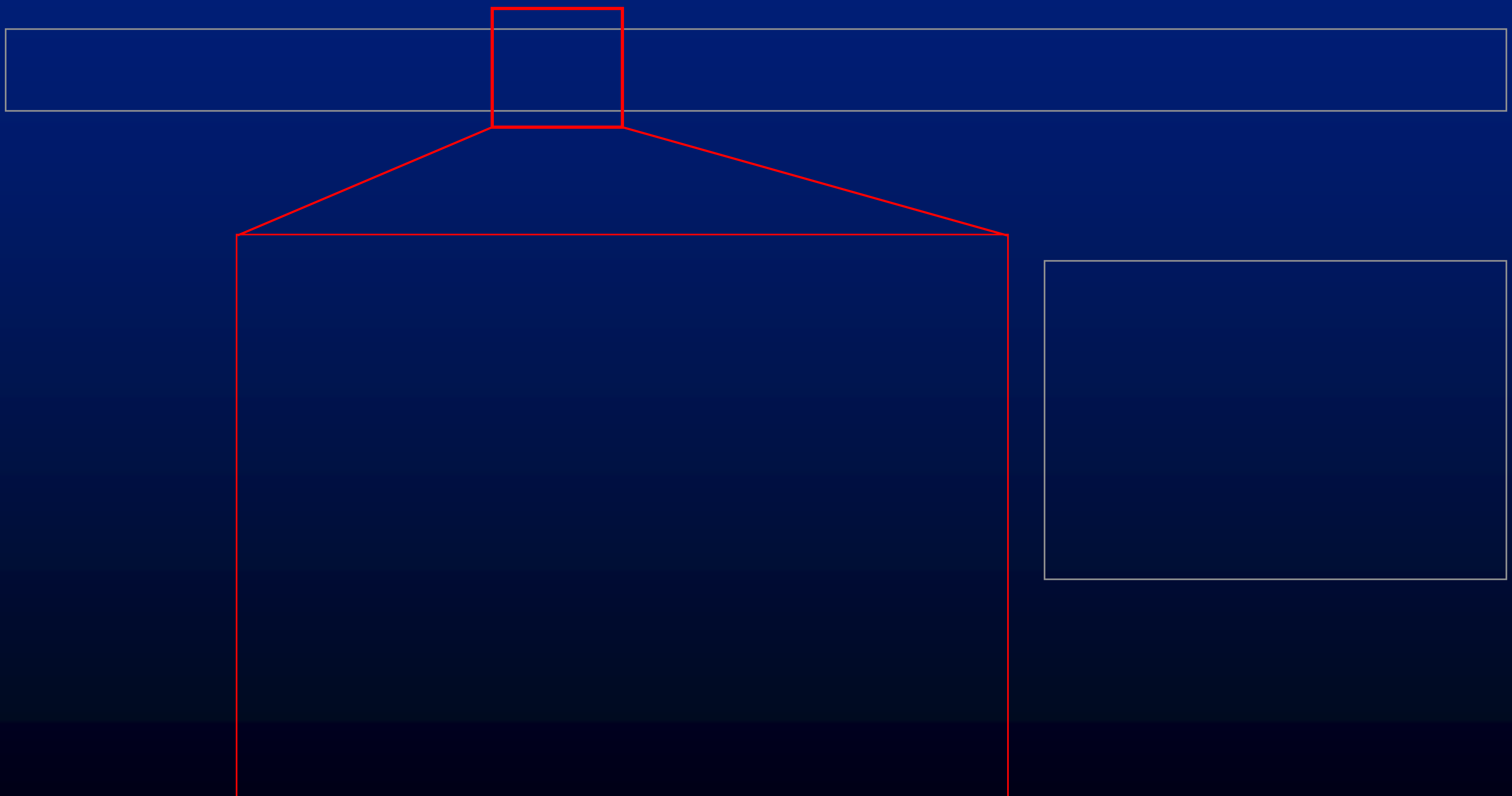


Figure 2 results

Blurred Taxi

Image Deblurred by solving a linear system. No post-processing

Fluttered Shutter Camera

Raskar, Agrawal, Tumblin Siggraph2006

Ferroelectric shutter in front of the lens is turned opaque or transparent in a rapid binary sequence

Participatory Urban Sensing

Deborah Estrin talk yesterday

Static/semi-dynamic/dynamic data

A. City Maintenance

-Side Walks

B. Pollution

-Sensor network

C. Diet, Offenders

-Graffiti

-Bicycle on sidewalk

(Erin Brockovich)^n

Future ..

Citizen Surveillance
Health Monitoring

http://research.cens.ucla.edu/areas/2007/Urban_Sensing/

Crowdsourcing

Object Recognition
Fakes
Template matching

Amazon Mechanical Turk:
Steve Fossett search

ReCAPTCHA=OCR

http://www.wired.com/wired/archive/14.06/crowds.html

Community Photo Collections

U of Washington/Microsoft: Photosynth

GigaPixel Images

Microsoft HDView

http://www.xrez.com/owens_giga.html

http://www.gigapxl.org/

Beyond Visible Spectrum

RedShift

Cedip

Trust in Images

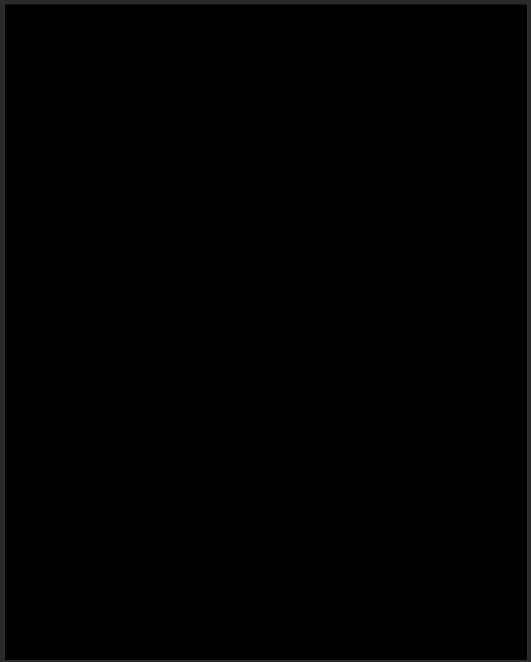
From Hany Farid

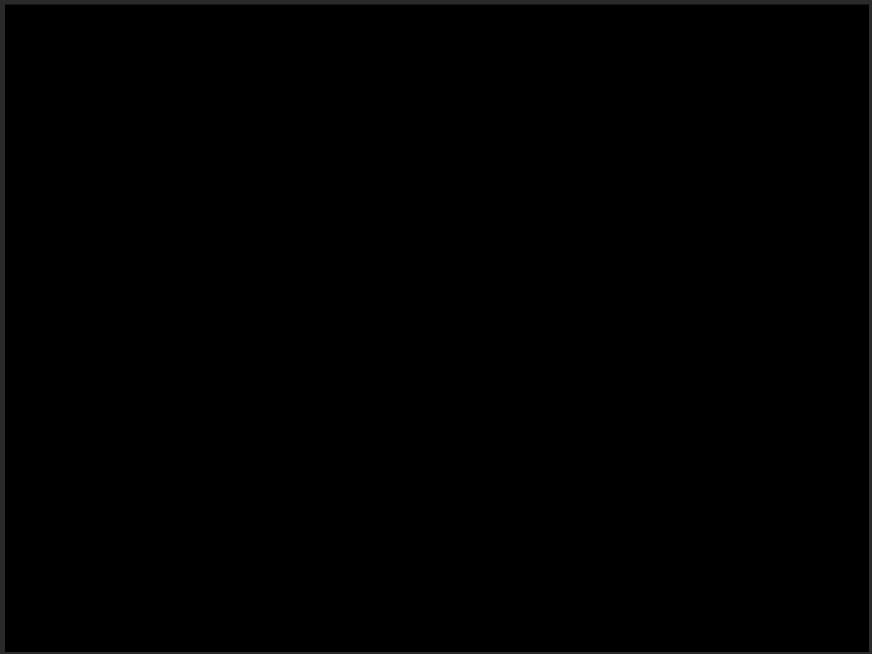
Trust in Images

LA Times March'03

From Hany Farid

Cameras in Developing Countries





Community news program run by village women

http://news.bbc.co.uk/2/hi/south_asia/7147796.stm

Future Products and Business Models

Solutions for the Visually Challenged

http://www.seeingwithsound.com/

Vision thru tongue

http://www.pbs.org/kcet/wiredscience/story/97-mixed_feelings.html

Fantasy Configurations

- ‘Cloth-cam’: ‘Wallpaper-cam’ elements 4D light emission and 4D capture in the surface of a cloth…
- Floating Cam: ad-hoc wireless networks form camera arrays in environment…
- Flat-cams

Next Class

- Homework
  - What will a camera look like in 10 years, 20 years?
  - What will be the dominant platform and why?
  - Send by email [raskar(at)media.mit.]
- Volunteer
  - Class notes
  - Select/read/present/paper
  - (Extra Credit)

- Format
  - Lectures and guest talks
    - Google Streetview,
    - Canon consumer imaging,
    - Nokia Mobile Comp Photography+Augmented Reality,
    - RedShift (thermal imaging),
    - Microsoft (Gigapixel imaging, moment camera),
    - Intel (Distributed imaging+storage)
  - In-class discussion, surveys

- Grading
    - (Tentative)
    - Read/Analyze/Present one or two papers
    - Final Survey paper/Project and present
    - Class discussion
      - In class, submit online, dig new recent work/suggest ideas/provoke questions
    - Class notes
    - To receive credit, you must attend regularly, present material on chosen topics and participate in discussions

- Credit
    - Survey paper/Project: 60%
    - Paper presentation: 20%
    - Class participation: 20%

	Topic	Topic	Guest Speaker
1	Feb 06	Introductions	
2	Wed 13 Feb	Imaging Devices, Modern Optics and Lenses	
3	Wed 20 Feb	Mobile Photography	HP Research Labs (Tom Malzbender on CameraPhone Usage, GPS-based tools)
4	Wed 27 Feb	Visual Social Computing and Citizen Journalism	Google Maps Streetview (Luc Vincent, TBA)
5	Wed 05 Mar	Emerging Sensor Technologies	Nokia Research, Mobile Computational Photography (TBA)
6	Wed 12 Mar	Beyond Visible Spectrum	RedShift Technologies(Matthias Wagner, Thermal Imaging)
7	Wed 19 Mar		Intel Research (Rahul Sukthankar)
SPRING BREAK			
8	Wed 02 Apr	Trust in Imaging	Microsoft ?
9	Wed 09 Apr	Computational Imaging in Sciences	Canon USA (Consumer Imaging Group) (TBA)
10	Wed 16 Apr	Solutions for Visually Challenged	
11	Wed 23 Apr	NO class	
12	Wed 30 Apr	Cameras in Developing Countries Future Products and Business Models	
13	Wed 07 May	Student Presentations	
14	Wed 14 May	Student Presentations	