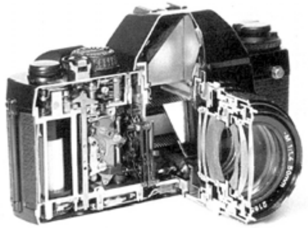
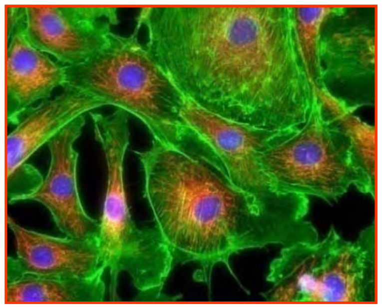
INRIA

Le modèle & l'algorithme
SÉMINAIRES SCIENTIFIQUES



Computational Photography

--- La photographie computationnelle ---



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Ecole Polytechnique

Sony Computer Science Laboratories, Inc

Jeudi 13 Mars 2008

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Introduction

Let's start with *concrete* examples of "<u>Computational Photography</u>" before defining its *scope* and *methodologies*.

Photography

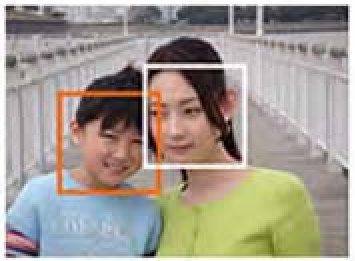
Computational Photography

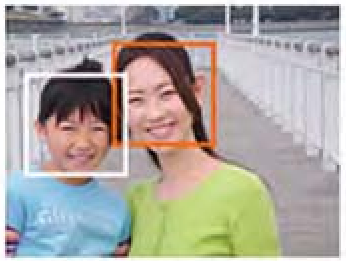
Introduction: Digital Still Cameras (DSCs)

But first, let's review today's
DSC Consumer market (March 2008)

Novelties

Expected





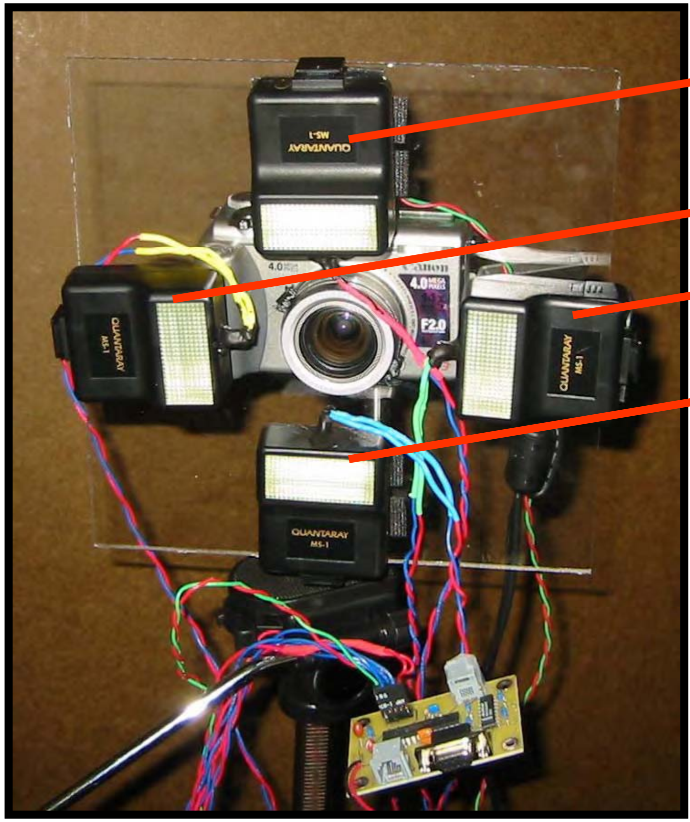
Example 1

Non Photo Realistic Camera

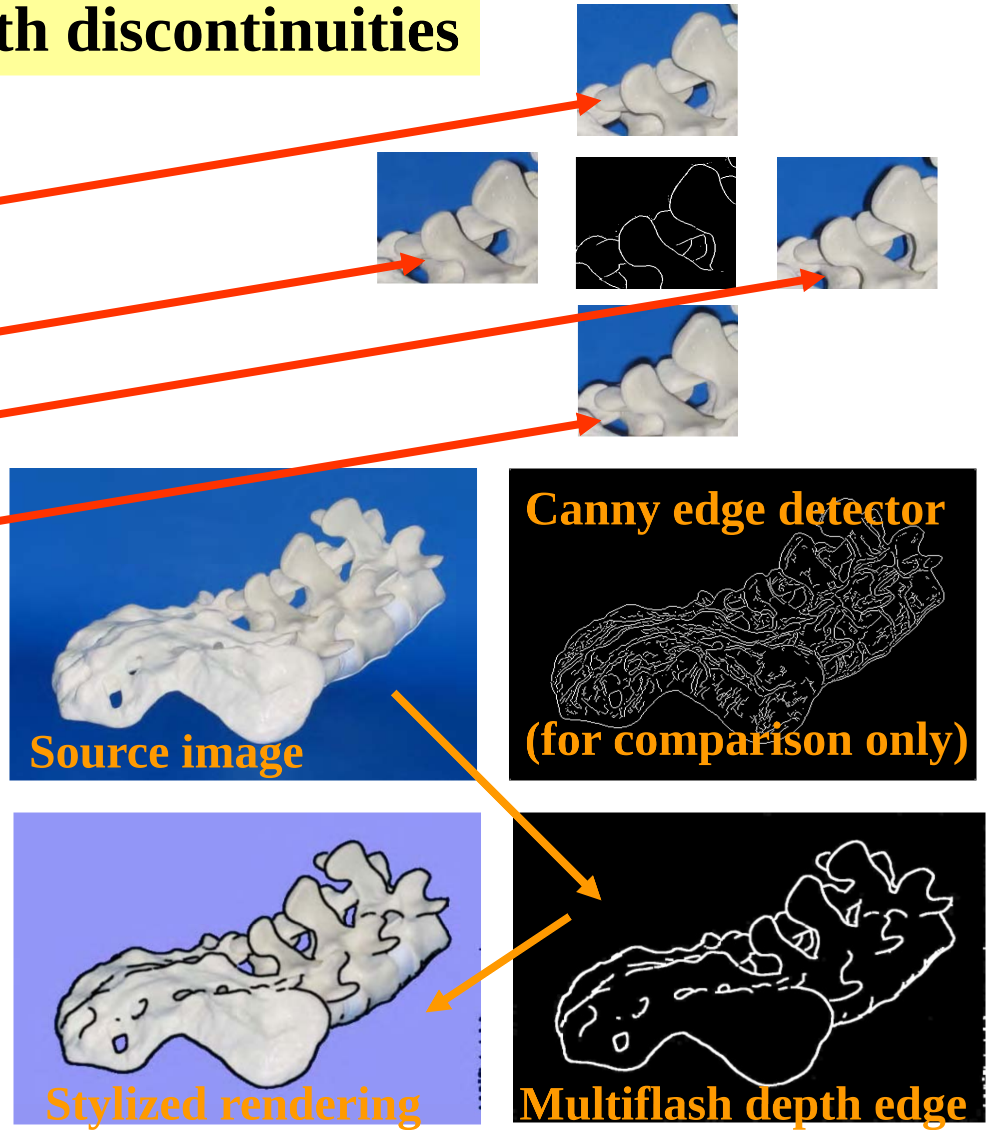
NPR

Warm up: Nonphotorealistic camera (NPR camera)

Multiple flashes to easily get **depth discontinuities**

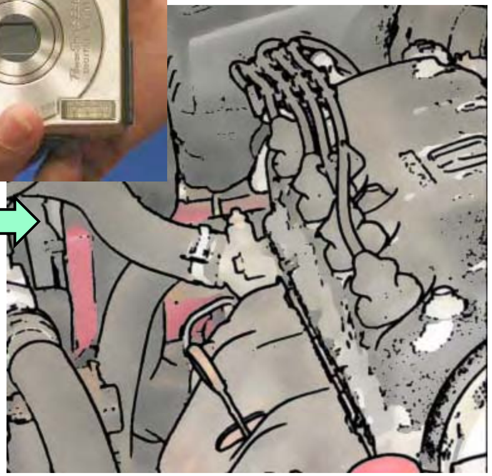


Baseline 50mm (depth 5mm at 2 meters)

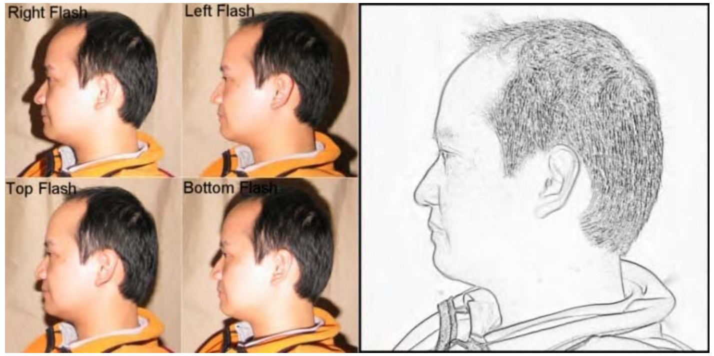


A Non-Photorealistic Camera: Depth Edge Detection and Stylized Rendering with Multi-Flash Imaging.SIGGRAPH 2004
http://www.merl.com/people/raskar/NprCamera/

Warm up: Nonphotorealistic (NPR) camera



Nonphotorealistic filter



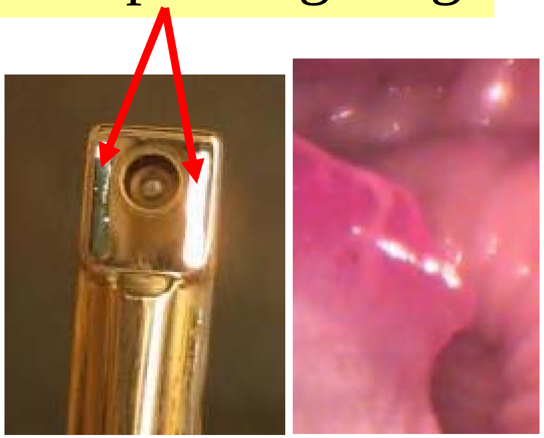
Intensity edge≠depth edge

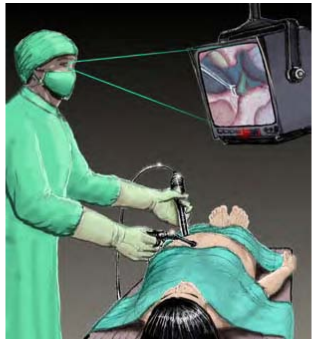
<u>Drawbacks:</u>

- *textured background* required
- does not work for *highly specular objects*
- *baseline*

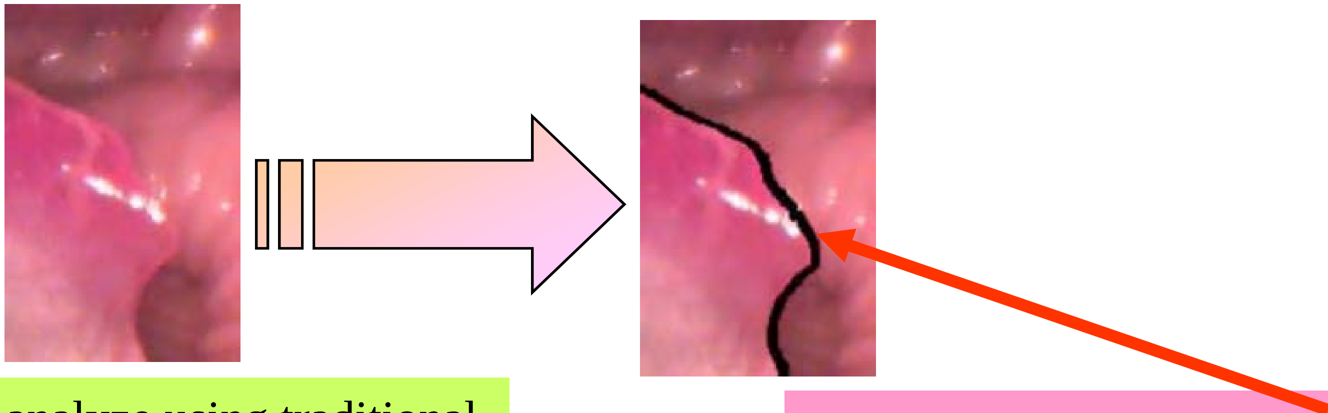
Warm up: Nonphotorealistic (NPR) camera

Laparoscope camera with two fiber optics lighting





Shadow to the right | **Shadow to the left**



Difficult to analyze using traditional image processing techniques

Remove shadows, **show lesion** from depth discontinuity analysis

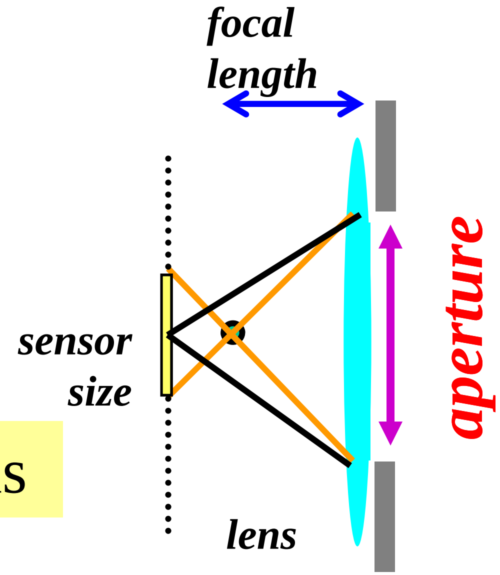
Multi-Flash Camera for Enhanced Laparoscope Images, Unpublished 2004
http://www.merl.com/people/raskar/NprCamera/

Example 2

Synthetic Aperture Focusing Camera

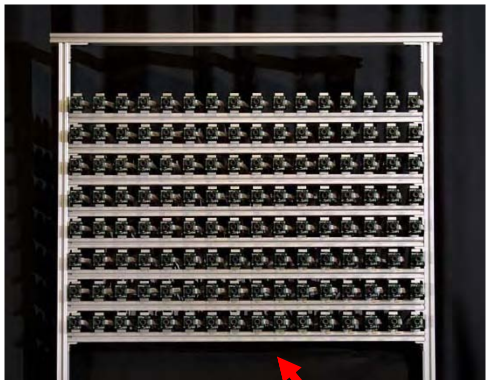
SAF

Warm up: Synthetic aperture focusing camera (SAF)



Aperture means *beyond* pinhole camera algorithms

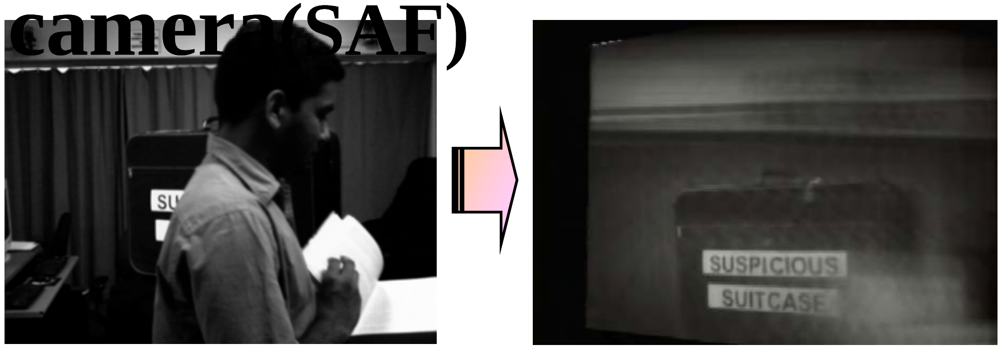
(SAF camera: *1-shot many images*!)



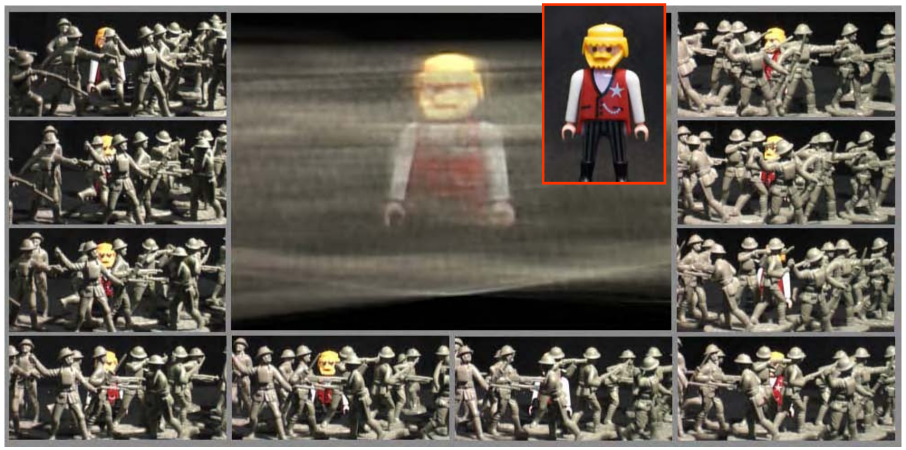
Camera array provides many individual apertures → **synthetic aperture focusing**

High Performance Imaging Using Large Camera Arrays. SIGGRAPH 2005
http://graphics.stanford.edu/projects/array/

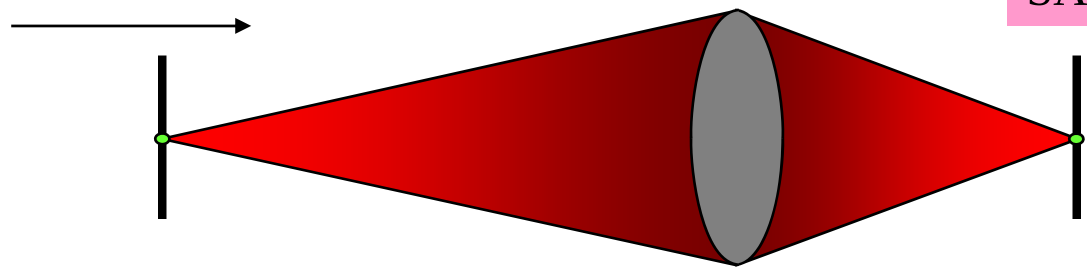
Warm up: Synthetic aperture focusing camera(SAF)



Synthetic aperture focusing



SAF is good enough for image recognition

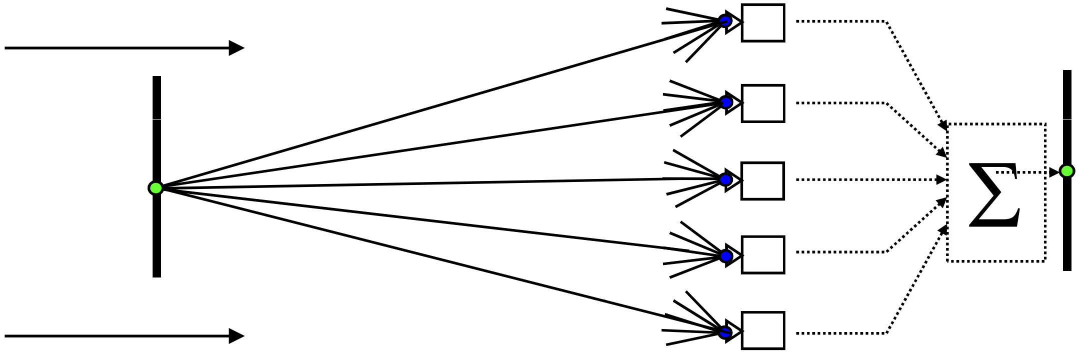


Single camera aperture

3D World

Camera array

Sensor plane



Synthetic aperture
(define a focal plane)

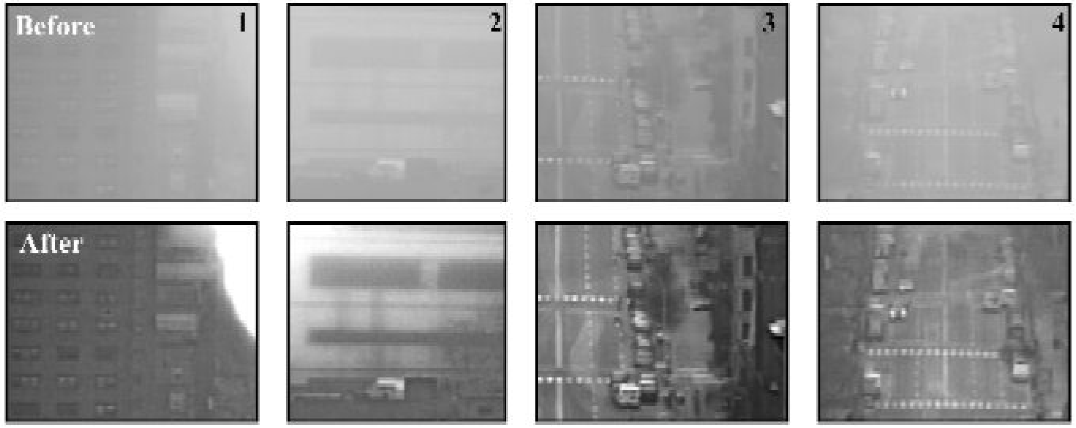
+Bonus: Averaging multiple images **also improve** Signal-to-Noise ratio (SNR)

Example 3

(De)weathering Camera

Warm up: (De)weathering

(a) A scene with rain (b) Reducing rain
(c) A scene with rain (d) Enhancing rain



Removing or adding **weather artifacts** (like fog or rain) in images
→**Image enhancer** with many applications (tele-surveillance, etc)

When does a camera see rain? ICCV05 Polarization-based vision through haze. Applied Optics 2003
http://www1.cs.columbia.edu/CAVE/publications/

Example 4

Sur-realistic Camera
(Gradient camera)

NPR

Warm up: Reilluminating by image fusion

Surrealistic image
→Easier to undertand

Empire of light (Magritte)

Context enhancement by image processing.
Fusion of a scene under different illuminations
(←Gradient image manipulation)

Image Fusion for Context Enhancement. NPAR 2004
http://www.merl.com/people/raskar/

Warm up: Reilluminating by image fusion

Algorithm 1 Basic algorithm

---

for each input image I_i **do**
  Find gradient field $G_i = \nabla I_i$
  Compute importance image W_i from $|G_i|$
end for
for each pixel (x,y) **do**
  Compute mixed gradient field $G(x,y) = \sum_i W_i(x,y) G_i(x,y) / \sum_i W_i(x,y)$
end for
Reconstruct image I' from gradient field G
Normalize pixel intensities in I' to closely match $\sum_i W_i I_i$

Basic idea is to build a <u>*mixed gradient image*</u> from which we <u>*reconstruct*</u> the merged image.

Day

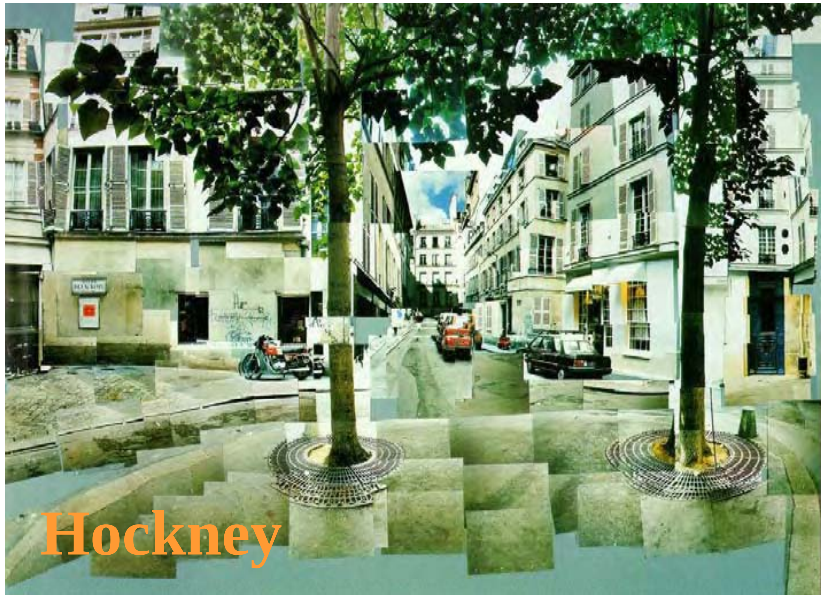
Day+Night

Night

Image Fusion for Context Enhancement. NPAR 2004
http://www.merl.com/people/raskar/

Example 5
Shape-Time Camera
(Depict the world)

Warm up: Depicting the world



Depict world in new ways:
Shape-time photography

(burst-mode on stereo adaptor)

Depiction

Shape-time photography. CVPR 2003
people.csail.mit.edu/billf/

Warm up: Shape-Time photography

(a)

←Based on a probabilistic framework computed via **belief propagations** (BP)

Shape-time photography. CVPR 2003
people.csail.mit.edu/billf/

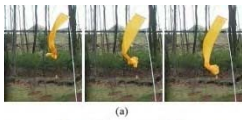
Introduction

So… what's Computational Photography ?

Wrapping-up: Multifacets of Comp. Photography





Recap of our 5 examples:

1. NPR Flash (H/W+S/W)
2. Synthetic Aperture Focusing (H/W+S/W)
3. (De)weathering (S/W)
4. NPR Reillumination (S/W)
5. Shape-time photography (H/W+S/W)

Computational Photography is:

A *rich variety of techniques*:

- **Novel hardware/software camera combinations**.
- **New generation of image processing techniques**

→ **Creativity** is key to success!

Computational Photography: Flash back.

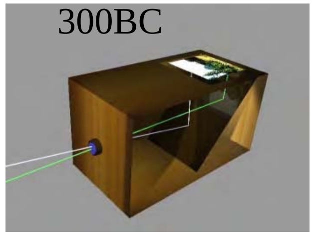
History of photography is *fascinating* but would take too long here…

Joseph Niepce (1825)
8 hours exposure

Louis Ducos du Hauron (1872)

Sony Mavica (1981)
First Electronic still camera

From *camera obscura* to nowadays' digital camera, the process of taking pictures has improved but …remains **essentially the same**…

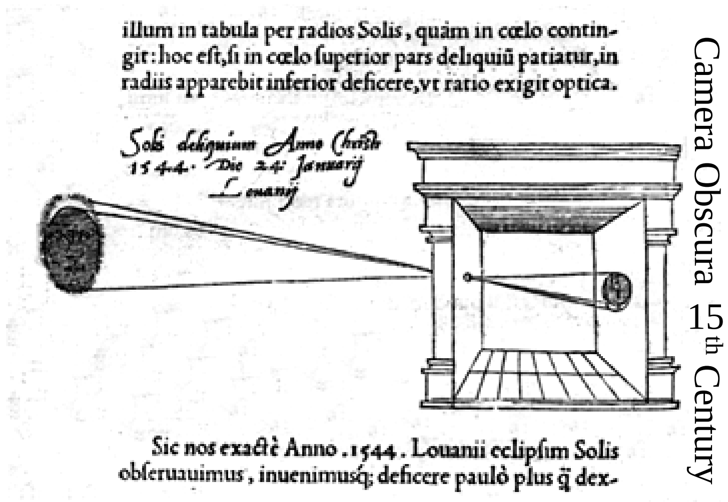


→ Photography HAS BEEN full of trade-offs !!!

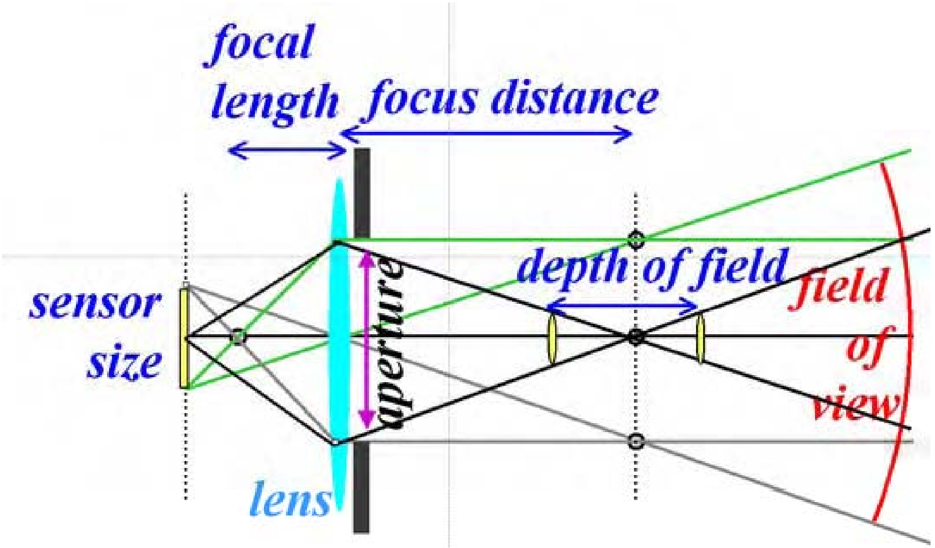
Photography and Realism http://www.wisc.edu/arth/ah407/

Camera Obscura http://www.acmi.net.au/AIC/CAMERA_OBSCURA.html

Computational Photography: Photo parameters



Camera obscura



Nowadays' cameras

- **Focal length** (in mm)
  - Determines the field of view.
    wide angle (<30mm) to
    telephoto(>100mm)
- **Focusing distance**
  - Which distance in the scene is sharp
- **Depth of field**
  - zone around the focus distance that is sharp
- **Aperture** (in f number)
  - Ratio of used diameter and focal lens.
    Number under the divider
  - ➔ small number = large aperture
    (e.g. f/2.8 is a large aperture,
    f/16 is a small aperture)
- **Shutter speed** (in % second)
  - Reciprocity relates shutter speed and aperture
- **Sensitivity** (in ISO)
  - Linear effect on exposure
  - 100 ISO is for bright scenes,
  - 1600 ISO is for dark scenes

Computational Photography

1st goal of computational photography is to ***remove*** camera limitations:

Current DSC

- Focal length
- Focusing distance
- Depth of field
- Aperture
- Shutter speed
- Sensitivity

Ideal DSC

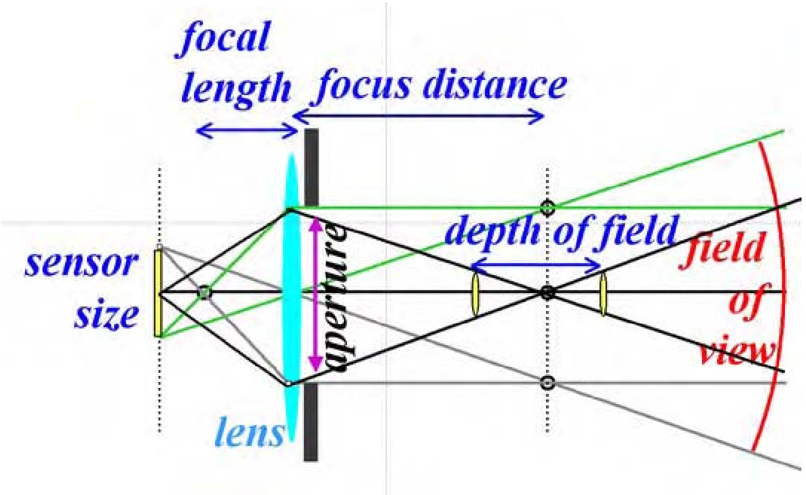
- Complete field of view (fov)
- Sharp image everywhere (dof)
- Noiseless image (iso)
- Bright image never saturated (dr)

➔ Lets see how to override trade-offs!

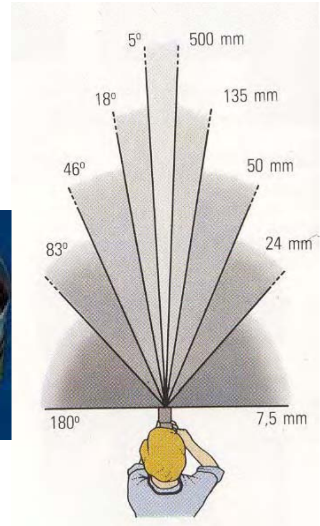
Removing Trade-off

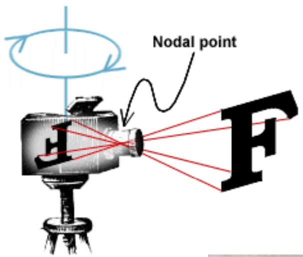
Field of View (fov)

Overriding Trade-offs… field of views



24mm (wide angle) | 50 mm (standard) | 135 mm (telephoto)





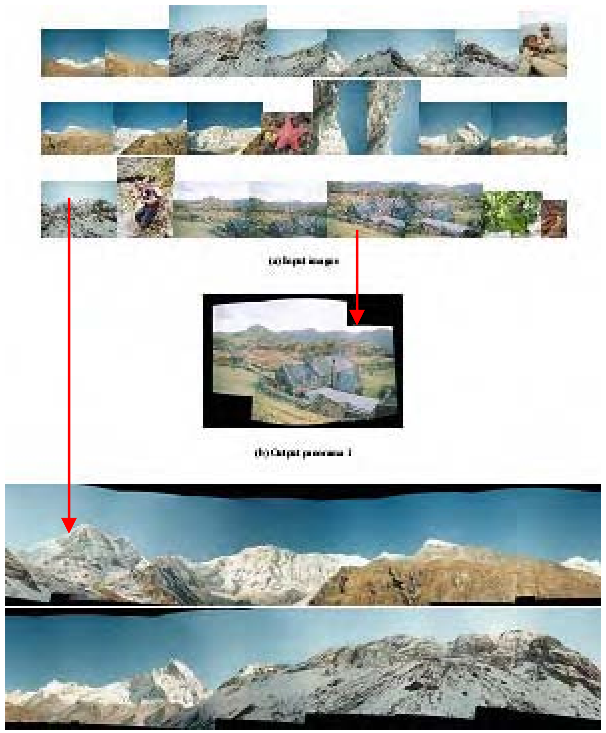
We override field of view limits by **stitching** several pictures

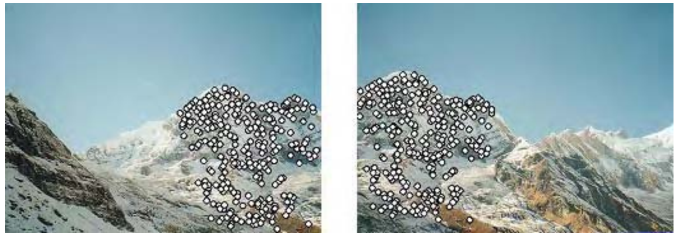
Quicktime VR - an image-based approach to virtual environment navigation. SIGGRAPH 1995
Surround Video: A Multi-Head Camera Approach. Visual Computer Journal 2005

Overriding field of views: Recognizing panoramas

Stitching should be painless→Recognize automatically panoramas!

- •SIFT feature extractor
- •RANSAC
- •Bundle adjustment
- •Multiband blending



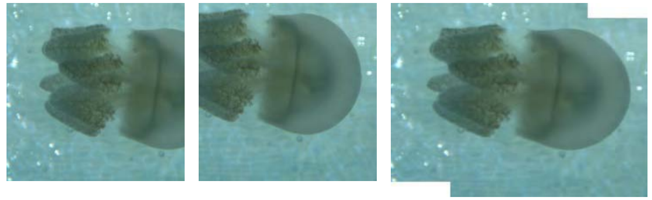


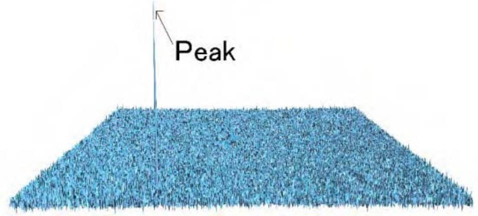
(b) All 80 images registered

Computer methods for creating photomosaics. IEEE Trans. Computer 23 1975.
Recognizing panoramas, ICCV 2003

Overriding field of views: Gigantic panoramas

Stitching should be massive:
→Consumer gigapixel images (Fourier)





$$\underbrace{\frac{F_1(u,v)F_2^*(u,v)}{|F_1(u,v)F_2^*(u,v)|}}_{\text{Cross-power spectrum}} = \exp(2\pi i(ux_t+vy_t))$$

Phase correlation principle:
(Fourier cross-spectrum peak)

The Phase Correlation Image alignment Method. IEEE Int. Conf. on Cybernetics and Society, 1975.
ClairVoyance: A Fast and Robust Precision Mosaicing System for Gigapixel Images, IECON 2006.

Overriding field of views: Surround videos

Surround videos: full view movies:
No intrinsic parameters.

BUT…

- **Parallax**
- **Color correction**
- Compression
- (De)Warping on GPU

Cluster of cameras looking outward

Or catadioptric system (use mirrors to align *virtual* nodal points)

FullView.com / Page on omnidirectional systems http://www.cis.upenn.edu/~kostas/omni.html

Surround video: A multihead camera approach, CVPR 2001, ITCC 2002, Visual Computer Journal 2005.

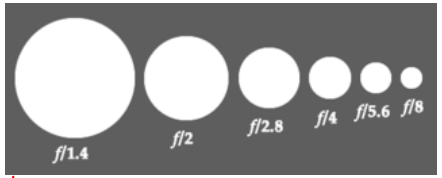
A GPU Panorama Viewer for Generic Camera Models, Shader X5, 2006.

Removing Trade-offs

Dynamic Range

(exposure)

Overriding Trade-offs… Exposure=Qty of light



- **Aperture** (f-stop number)
  - Expressed as ratio between focal length and aperture diameter: diameter = f / <f number>

$$f/\# = N = \frac{f}{D}$$

  - f/2.0, f/2.8, f/4.0, f/5.6, f/8.0, f/11, f/16 (factor of sqrt (2))
  - Small f number means large aperture
  - Main effect: *depth of field*
  - A good standard lens has max aperture f/1.8. A cheap zoom has max aperture f/3.5


F/32 (Pinhole)


F/5

- **Shutter speed**
  - In fraction of a second
  - 1/30, 1/60, 1/125, 1/250, 1/500 (factor of 2)
  - Main effect: *motion blur*


25 sec

- **Sensitivity**
  - Gain applied to CCD/CMOS sensor
  - In ISO, bigger number, more sensitive (100, 200, 400, 800, 1600)
  - Main effect: *sensor noise*

→ degrees of freedom for setting an exposure.

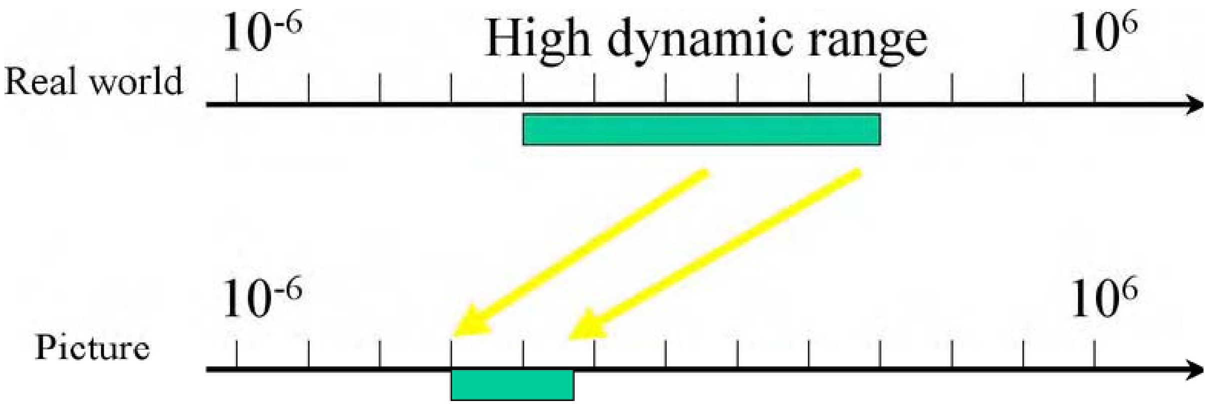
Overriding Trade-offs… Exposure/Dynamic range

Radiant:#photons per joule:

$$\frac{5.034\times 10^{15}}{\text{Photon wavelength}}$$

Radiant flux: energy per sec. (in Watt)

Candela (cd): luminous power per solid angle
Illuminance in candela/m2 (nit) (Irradiance)



Overexposed (white)

Typical scene has dynamic range 1:100.000
(17 bits, 17 f-stops)

Images are quantized and some pixels may be **clamped**:
Underexposed (clamped to 0) or overexposed (clamped to 255)

Overriding Trade-offs… Exposure/Dynamic range

Exposure latitude (film constrast ratio)= range of light intensities.
Digital cameras: pixels in 8-,12- or 16-bit quantized values.
So far we needed to choose the **dynamic range** (DR) properly

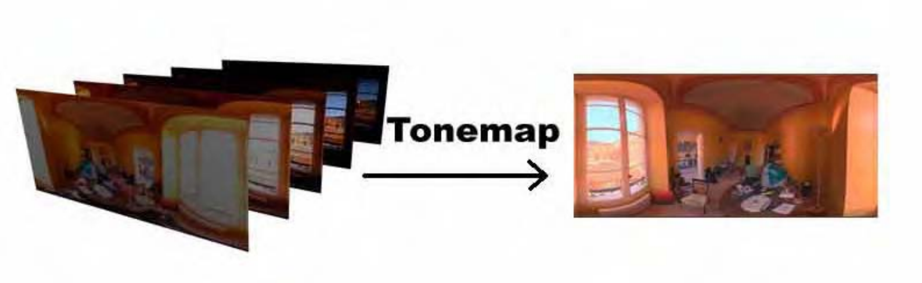
Override exposure limits by `stitching several' dynamic range pictures
From exposed picture (LDR) to **radiance picture** (HDR)

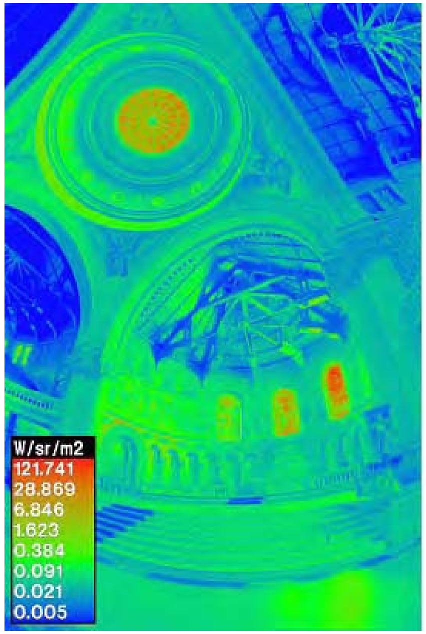
HDRShop http://gl.ict.usc.edu/HDRShop/
Recovering High Dynamic Range Radiance Maps from Photographs, SIGGRAPH 1997

Overriding Dynamic range… Radiance pictures

Tone mapping

Killer application: Image-based ligthing (IBL)





Tone mapped
(for display)

Synthetic rendering using light probes

Photographic tone reproduction, SIGGRAPH 2002. http://www.gregdowning.com/HDRI/tonemap/Reinhard/
Image-Based Lighting (IBL). IEEE Computer Graphics and Applications 22(2): 26-34 (2002)
Backward Compatible High Dynamic Range MPEG Video Compression, SIGGRAPH 2006

Removing Trade-off

Depth of Field (DoF)

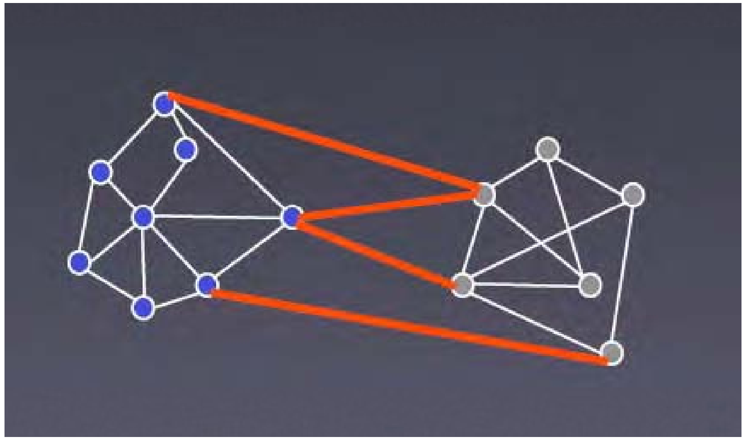
Overriding Depth of field (DoF)

←All-in-focus image from **multiple** focused images using *graph cuts*

Interactive Digital photomontage, SIGGRAPH 2004 http://grail.cs.washington.edu/projects/photomontage/
Graph Cuts for Energy Minimization, ICCV 2003. http://www.cs.cornell.edu/~rdz/graphcuts.html

Overriding Depth of field | Graph cuts

Max flow/min cut graph algorithms applied to images (large graphs)



$$cut(A,B) = \sum_{u \in A, v \in B} w(u,v).$$

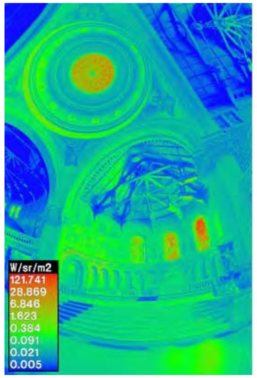
Min cut or max cut

Interactive Digital photomontage, SIGGRAPH 2004 http://grail.cs.washington.edu/projects/photomontage/

Computational Photo.: Overriding Trade-offs…

→Multiple image fusion techniques to remove current photography limits

Field of view → **panorama picture**
(Omnidirectional picture)



Exposure → **radiance picture**
(Omnirange picture)

Depth of field → **all-in-focus picture**
(omnifocus picture)

Picture → Omnipicture
(Multiple Capture Single Image, MCSI)

Human Perception
versus
Digital Image Processing

Qualia

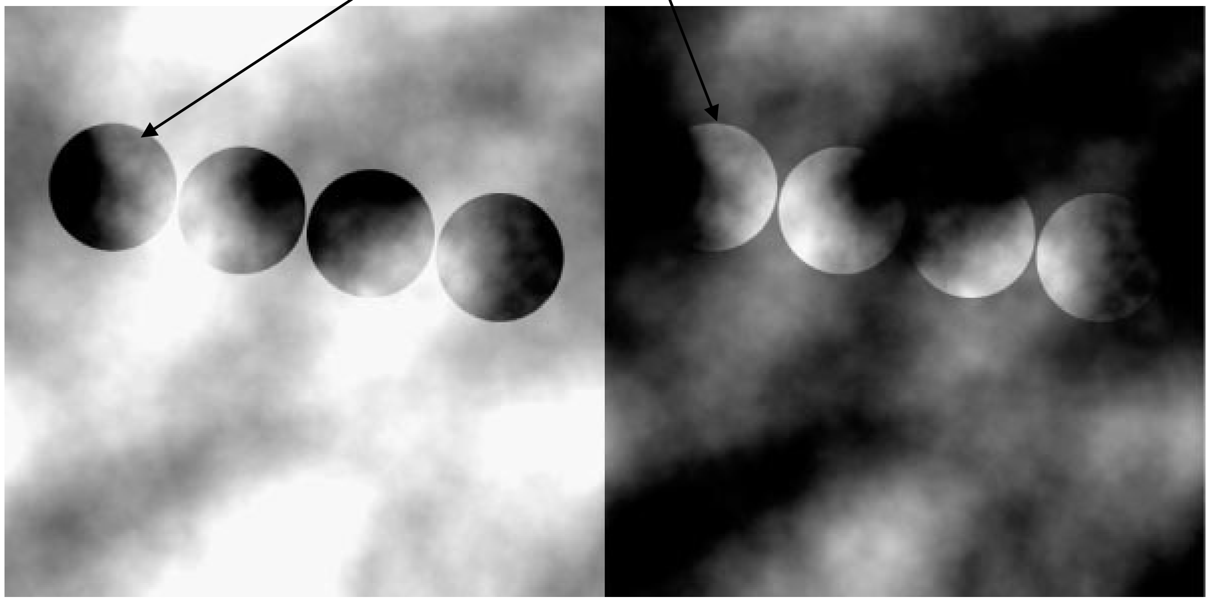
vs

Turing machine computation…

Overriding Dynamic range… Tone mapping

Scientific (measurement) images ≠ Human perceptual images

Disks are exactly identical
but are perceived differently



‘dark disks’ visible *through* light haze

‘light disks’ visible *through* dark haze

Image segmentation and lightness perception, Nature 434, 79-83, 2005

S/W Computational Photo.: Hybrid images

Humans perceive low/high frequency differently according to distances.

Miss Calm and Dr Angry

High frequency (=edges) at small distances

Low frequency at large distances
(= Gaussian filter)

Hybrid images, SIGGRAPH 2006.

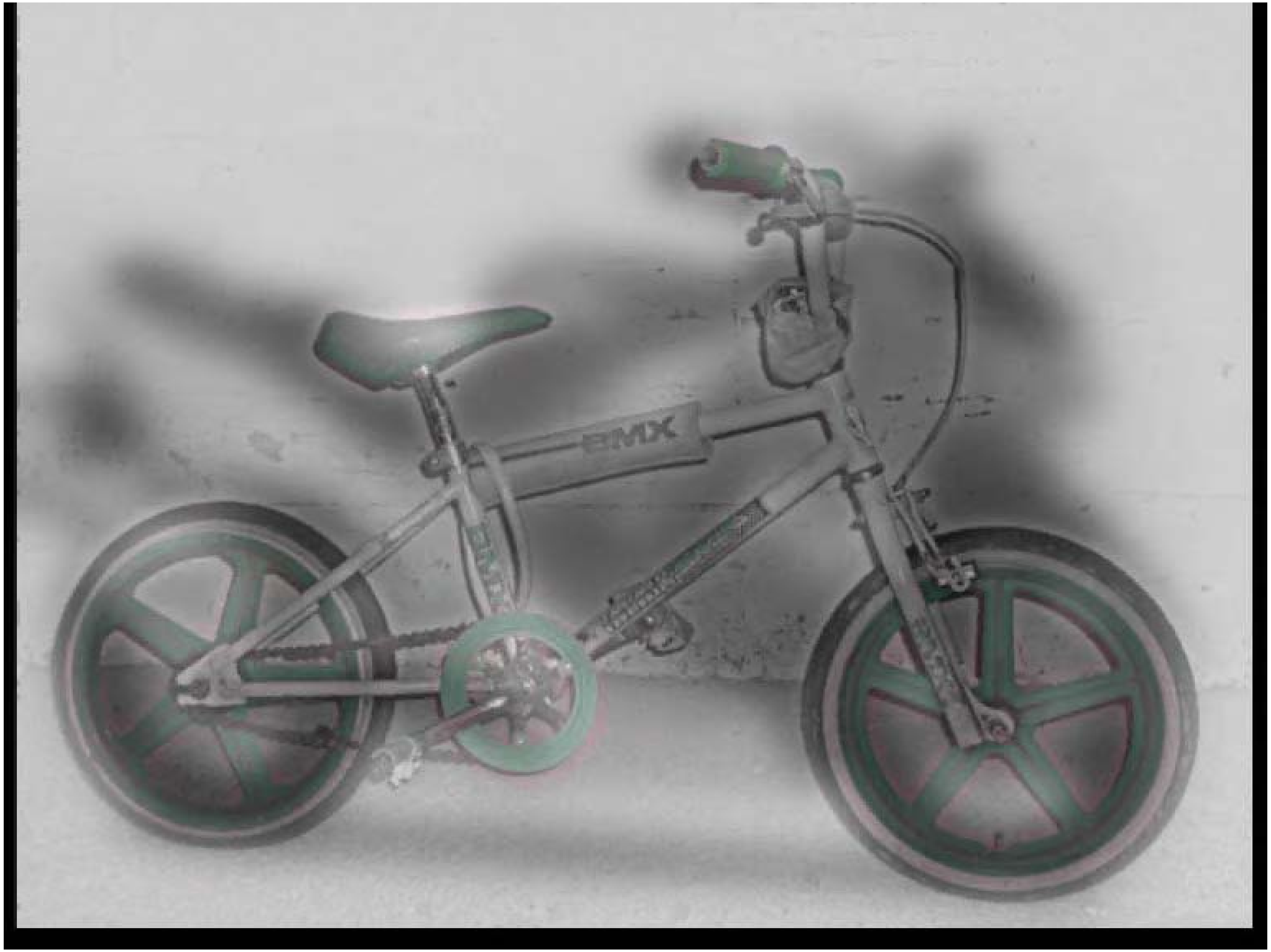
S/W Computational Photo.: Hybrid images

High frequency
at close distance

Low frequency
at far distance

Hybrid images, SIGGRAPH 2006.

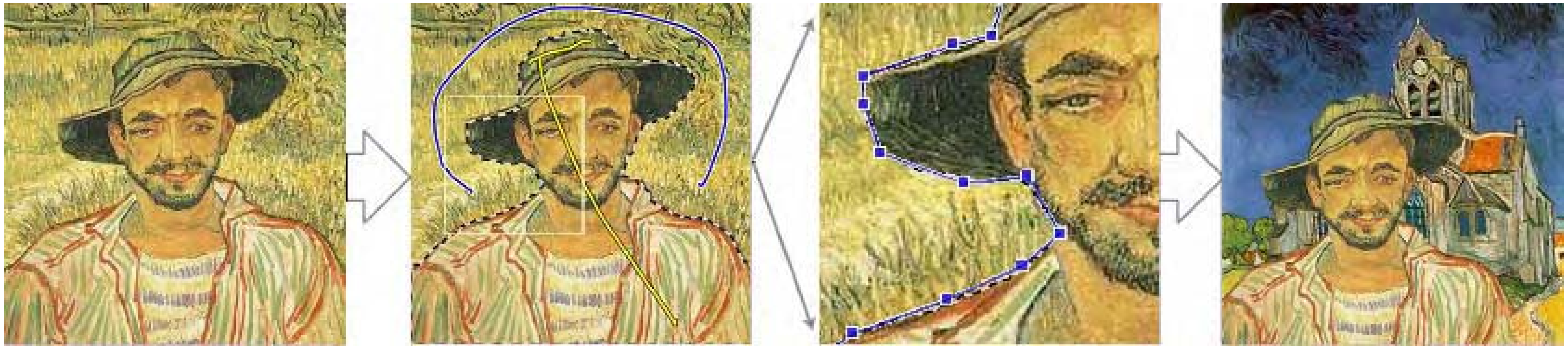
S/W Computational Photo.: Hybrid images

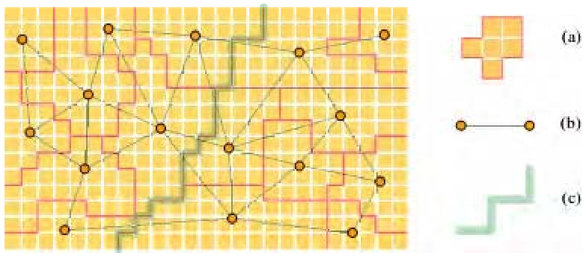


Hybrid images, SIGGRAPH 2006.

Modern
Image Processing
images as graphs

S/W Computational Photo.: Object cutout





Graph cut with **presegmentation**
(mean shift oversegmentation)

(a) Girl (4/2/12) (b) Ballet (4/7/14) (c) Boy (6/2/13)

Lazy snapping, SIGGRAPH 2004 / http://research.microsoft.com/~jiansun/
Implementation http://www.cs.cmu.edu/~mohitg/segmentation.htm

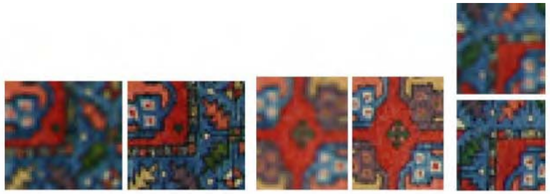
Inpainting...
Texture Synthesis...
Hallucination....

Region filling and object removal by exemplar-based inpainting. IEEE Trans. Image Process. 2004
http://research.microsoft.com/~antcrim/papers.htm

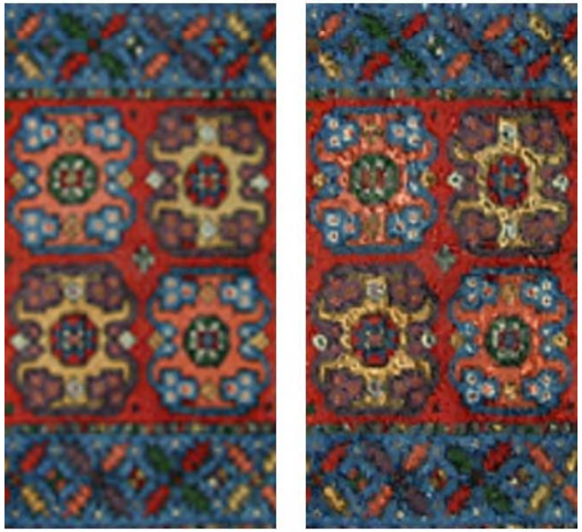
Comp. Photography: Image analogies

Image analogies

A : A' :: B : B'

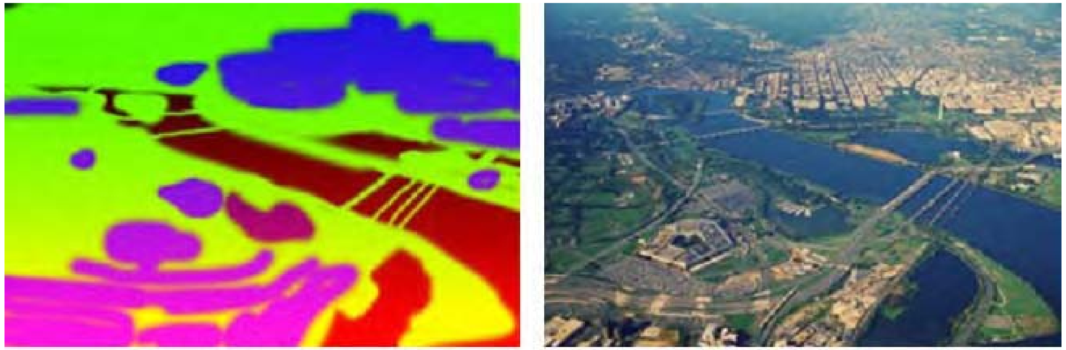


Training pairs (A, A')

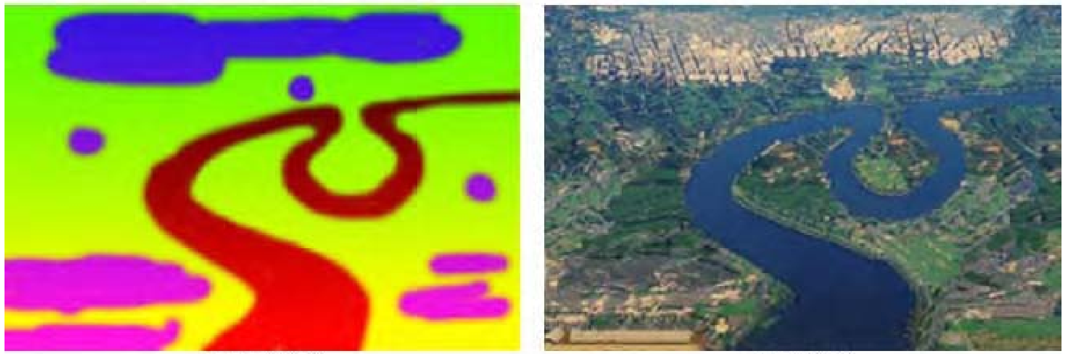


Unfiltered target (B) **Filtered target** (B')

Superresolution



Unfiltered source (A) **Filtered source** (A')

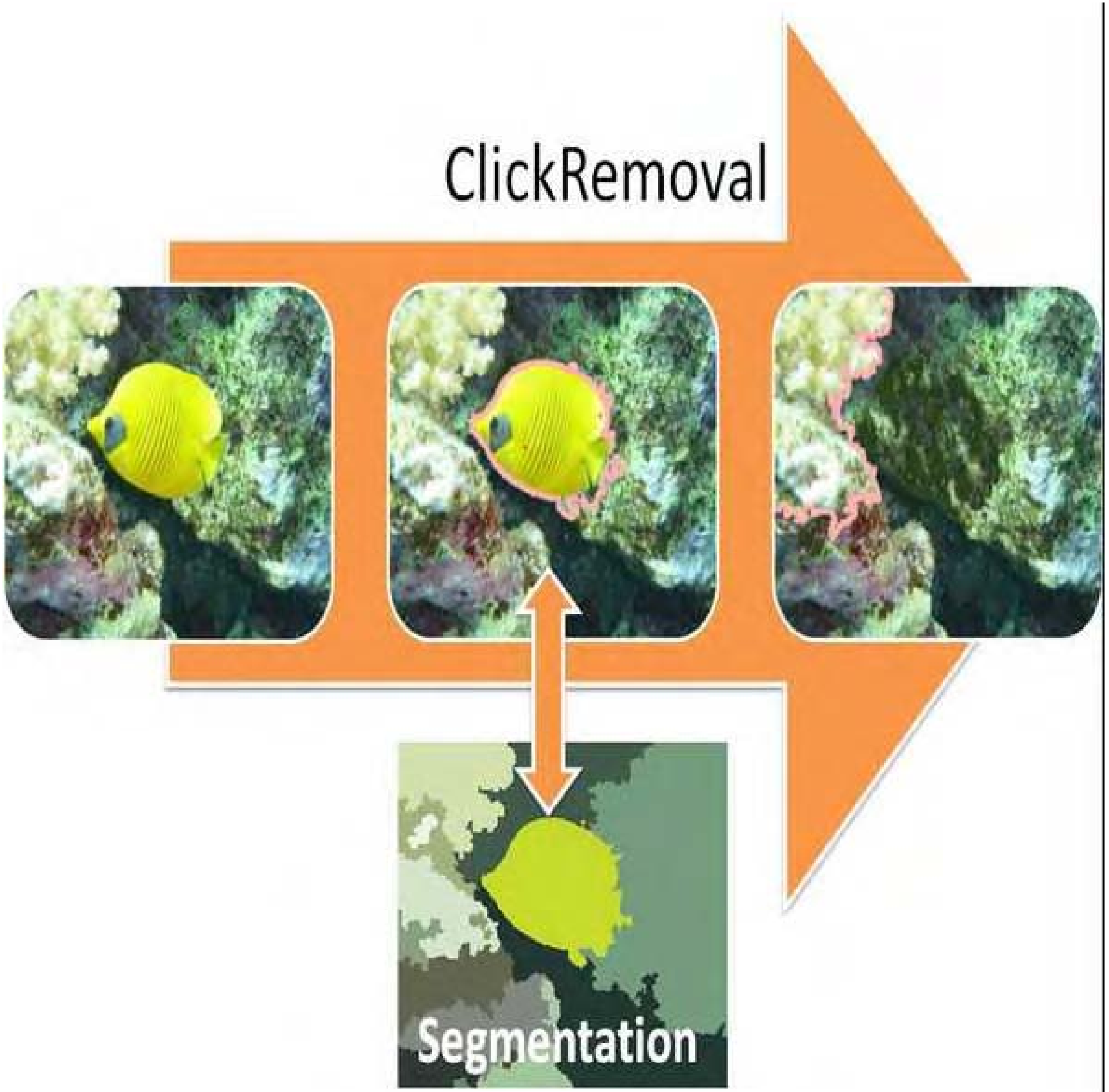


Unfiltered (B) **Filtered** (B')

Pictures by numbers (segmentation)

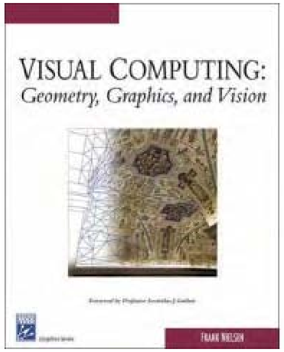
Image analogies, SIGGRAPH 2001

Computational Photography: ClickRemoval applet



Demo

Visual Computing:
Geometry, Graphics, and Vision
2005.

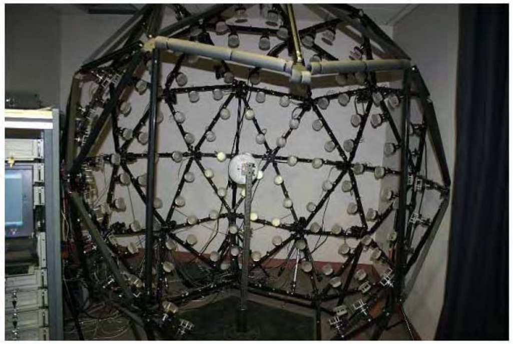


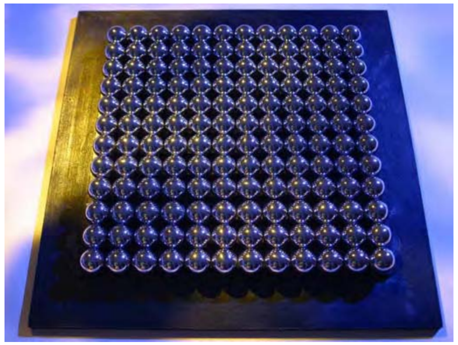
Techniques described
with C++ code

Frank Nielsen, Richard Nock: ClickRemoval: interactive pinpoint image object removal.
ACM Multimedia 2005:

Computational Photography

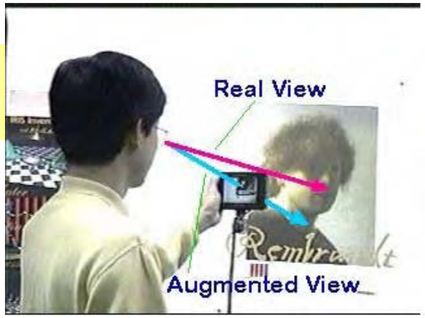
Novel hardware & processing techniques

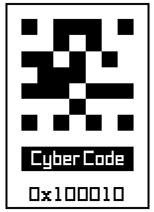




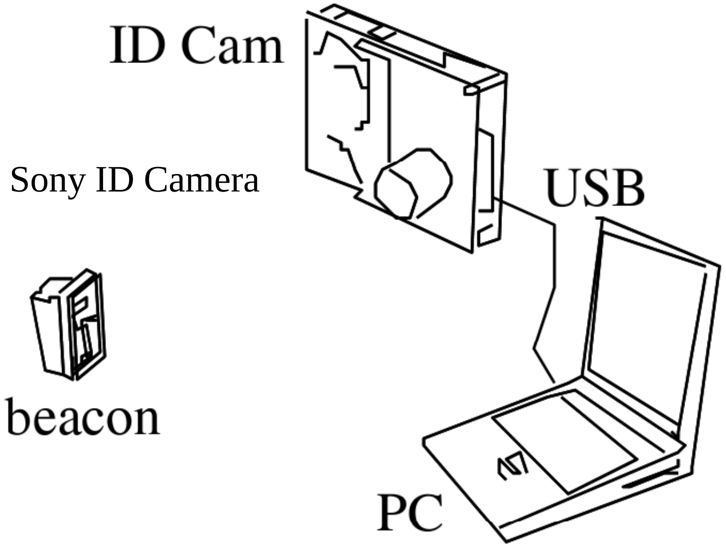
Computational Photo.: ID Camera

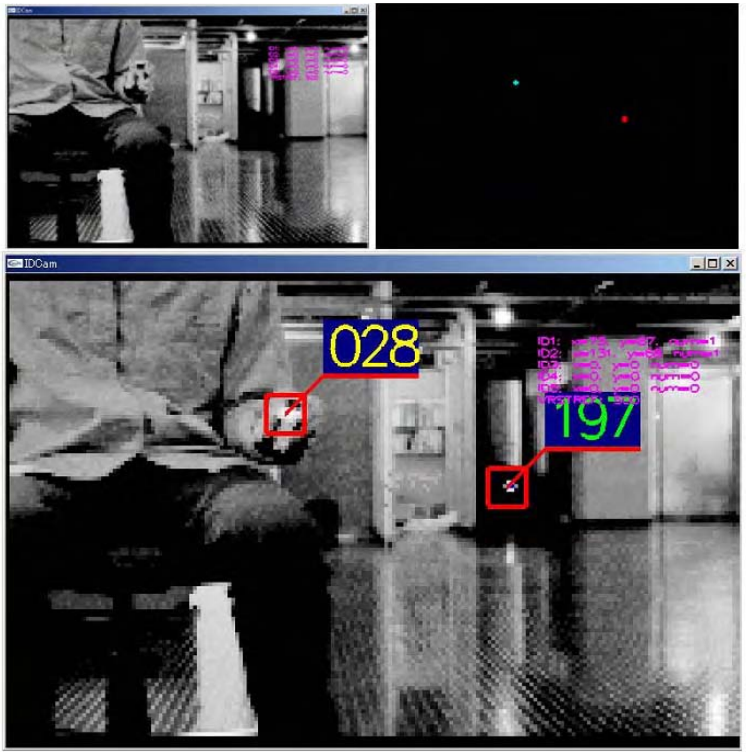
NaviCam Augmented-Reality (AR)





Multiple capture single image (MCSI)
CMOS sensor, image processing on-board





ID CAM: A Smart Camera for Scene Capturing and ID Recognition (ISMAR'03)
The World through the Computer: Computer Augmented Interaction with Real World Environments, UIST 1995

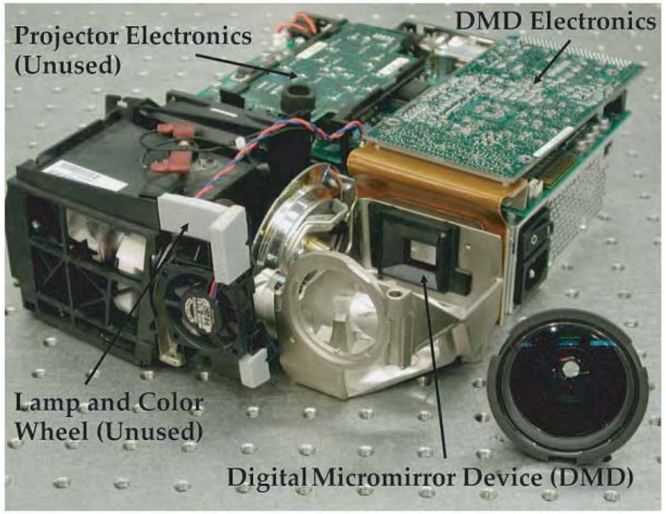
Computational Photography: Vein Viewer

Coaxial Infrared camera + Projector

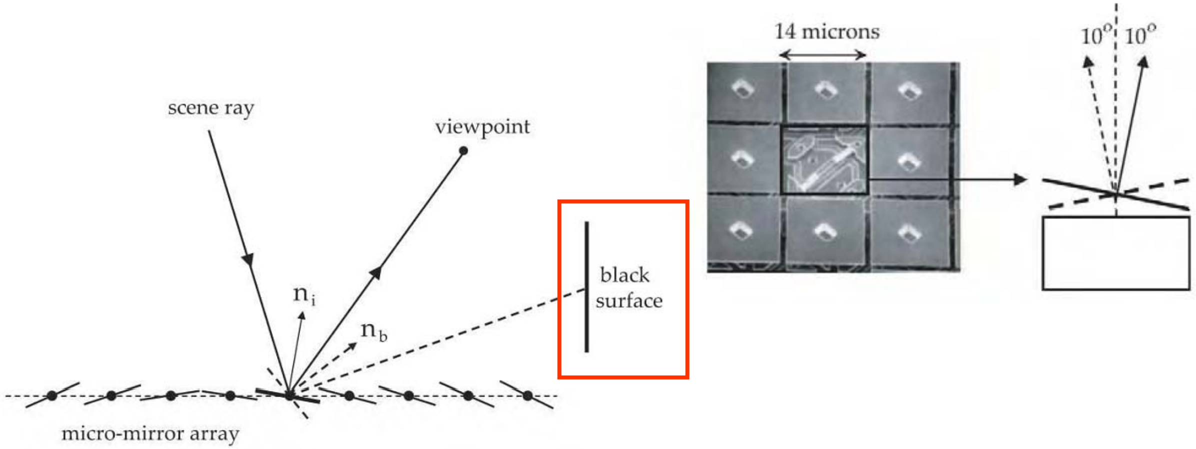
VeinViewer (Luminetx) | http://www.luminetx.com/main/default.aspx

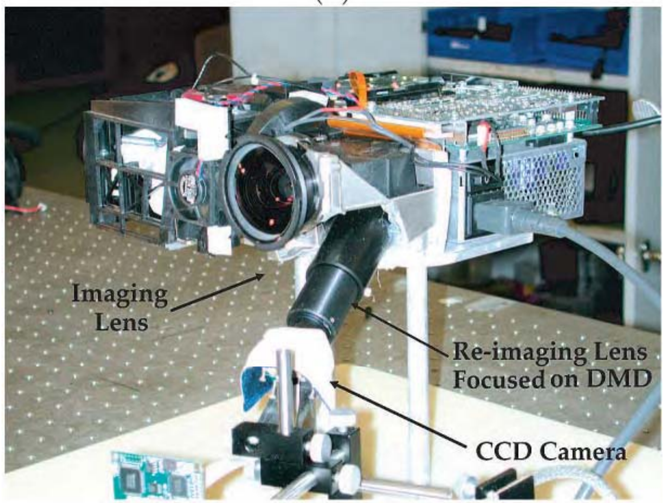
Computing in Optical Domain

H/W Comp. Photo.: Computing in Optical domain



(a)

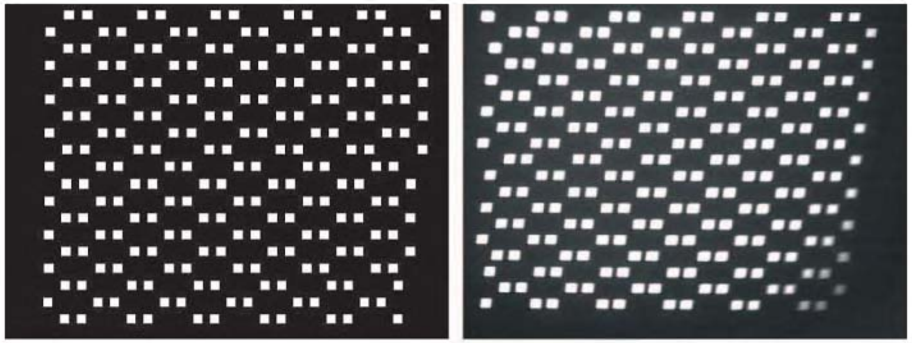




Control the rays in space-time:
Exposure allows **optical** computations
→**Light integration on the sensor**

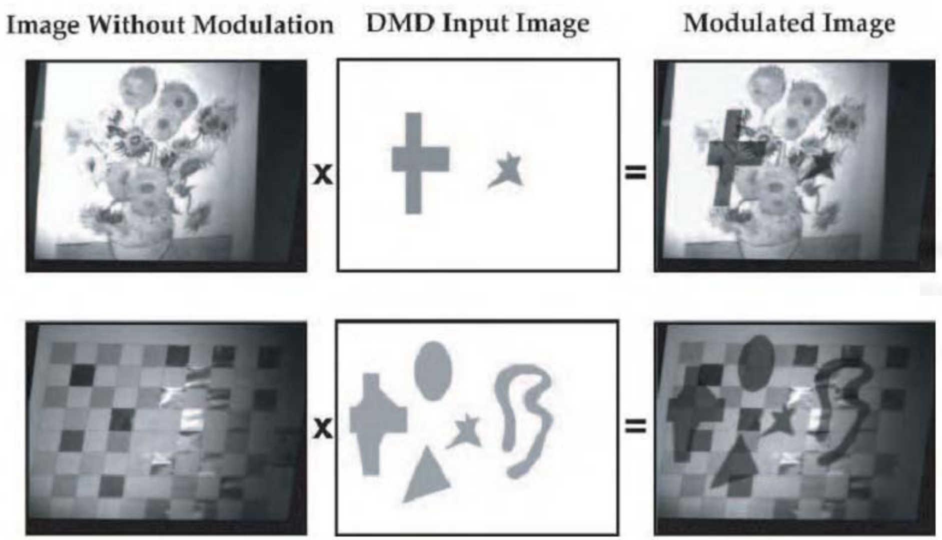
Programmable imaging using a digital micromirror array (CVPR'04)
Programmable Imaging: Towards a Flexible Camera, Int. Journal of Computer Vision. 2006

H/W Comp. Photo.: Computing in Optical domain

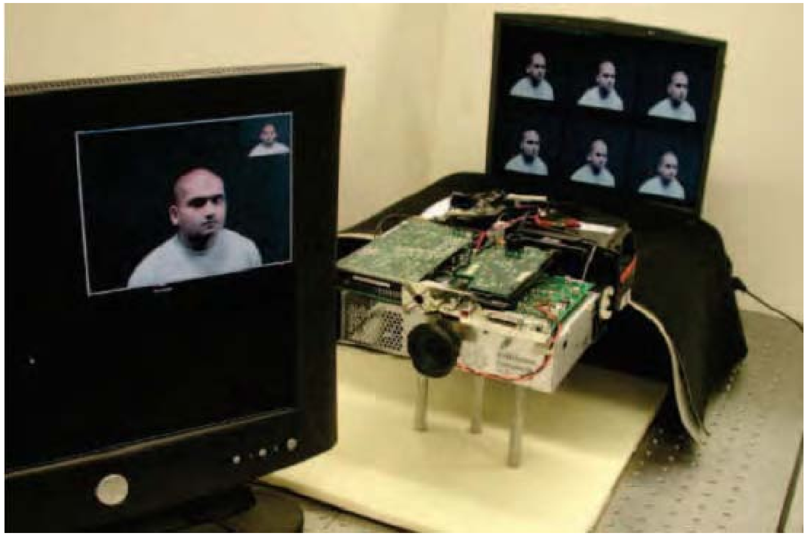


DMD input image   Camera output image

Require to **calibrate** the DMD with the camera coarsely



Convolution in optical domain



Convolution in optical domain for face recognition

Programmable imaging using a digital micromirror array (CVPR'04)
Programmable Imaging: Towards a Flexible Camera, Int. Journal of Computer Vision. 2006

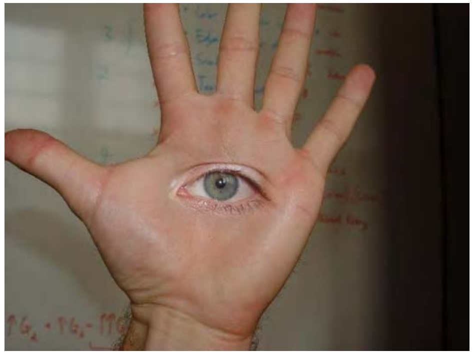
Computing in Gradient Domain

Computational Photography : Loose Copy/Paste

For pasting objects, do not care of precise boundaries/mattes

Former method: Multi-band Laplacian image pyramid blending

New approach based on Poisson image editing using a Poisson equation solver



f* – the known image
Scalar 2D function from (x,y) to grayscale value.
f - the image in the unknown area
Ω – the unknown area (domain of f)

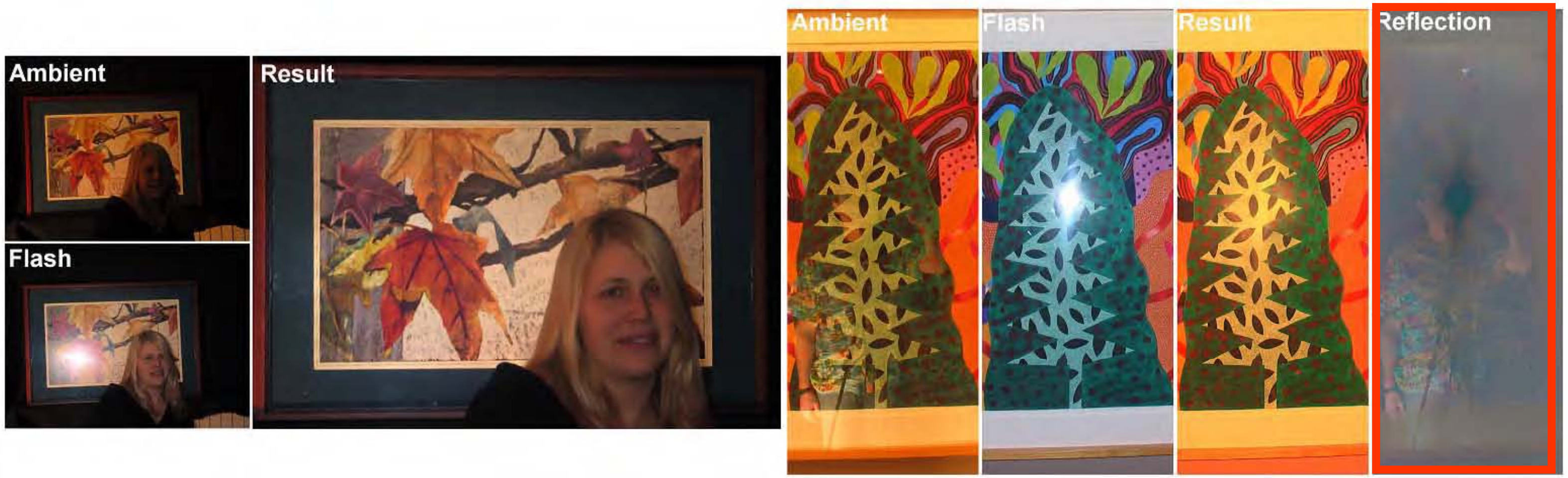
$$\arg\min_{f} \iint_{\Omega} |\nabla f|^2 \quad s.t. \quad f|_{\partial\Omega} = f^*|_{\partial\Omega}$$

Complete the area as smoothly as possible.

Drag-and-drop pasting, SIGGRAPH 2006 [Poisson Image Editing 2003]
The Laplacian Pyramid as a Compact Image Code, IEEE Trans. Communications (1983)

Computing with Flash/no-flash

H/WComp. Photography: Gradient camera



Removing photography artifacts using gradient projection and flash-exposure sampling, SIGGRAPH 2005

S/W Computational Photo.: Matte Extraction

Input Alpha matte Composite

- Seminal blue screen, rotoscoping
- Probability theory of **alpha matting**:
  - ←Bayesian matting, belief propagation

Under constrained problem:

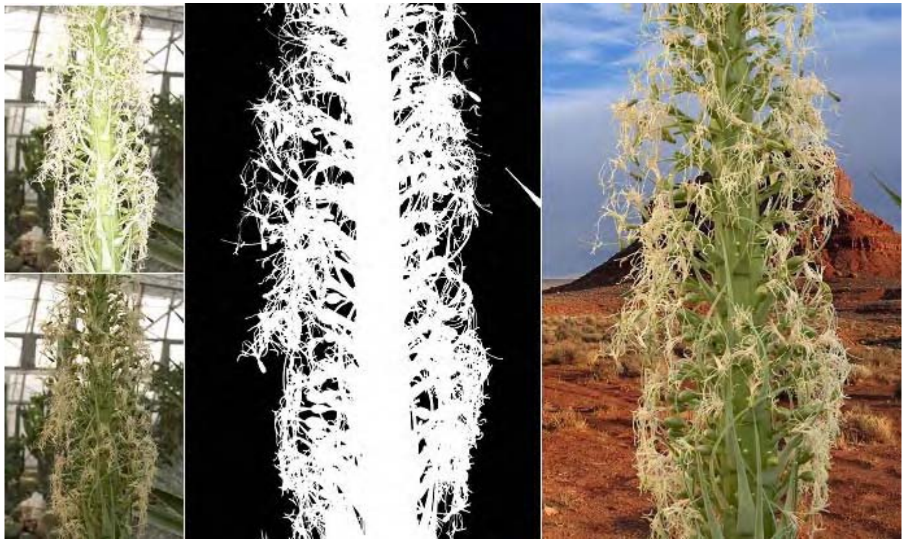
One equation, **three** unknowns

$$I_i = \alpha_i F_i + (1-\alpha_i) B_i$$

➔need to constrain the problem!

➔Many techniques

H/W Computational Photo.: Flash/no flash matting

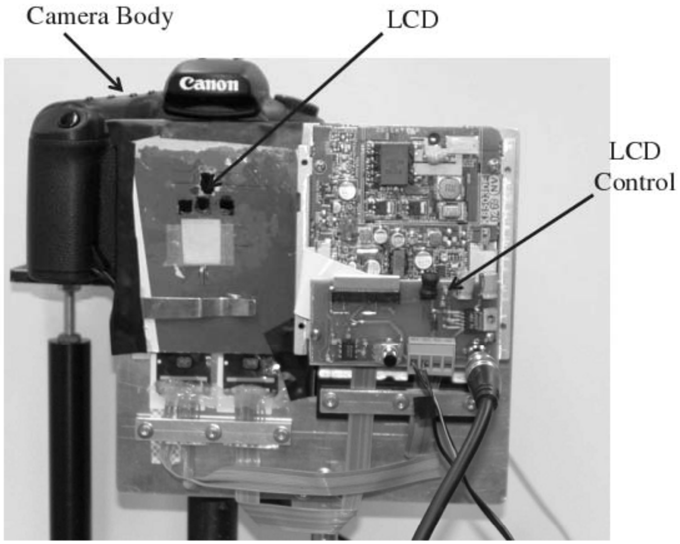


- Need tripod
- Problems with specularity

Flash matting, SIGGRAPH 2006

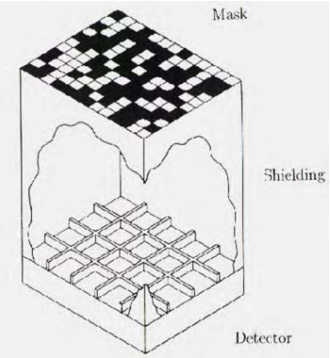
Computing with exotic “lenses”

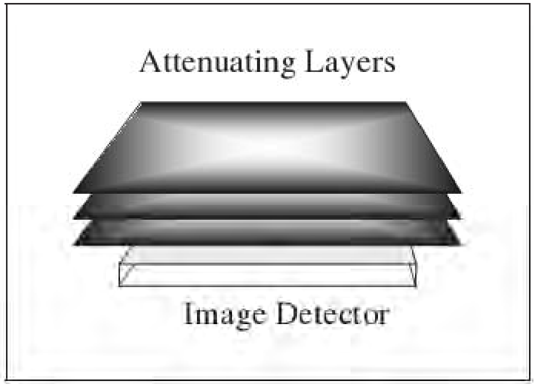
Computational Photo.: Lensless Camera

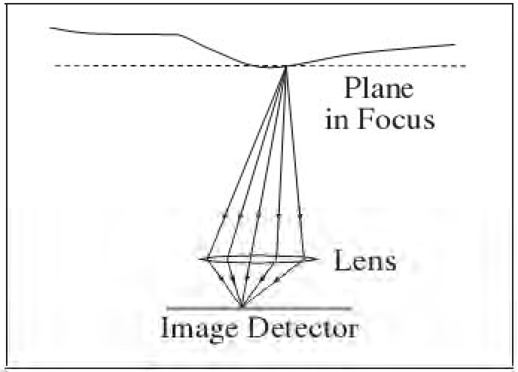


Control the light rays on each layer:

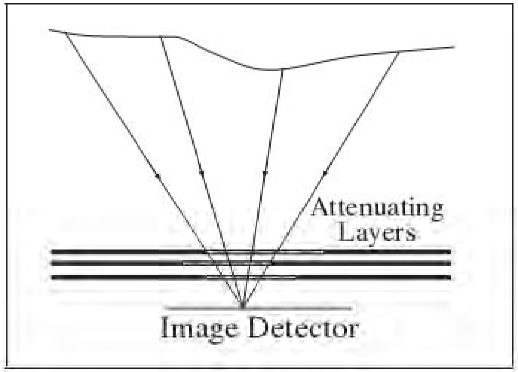
Multiple-layer aperture







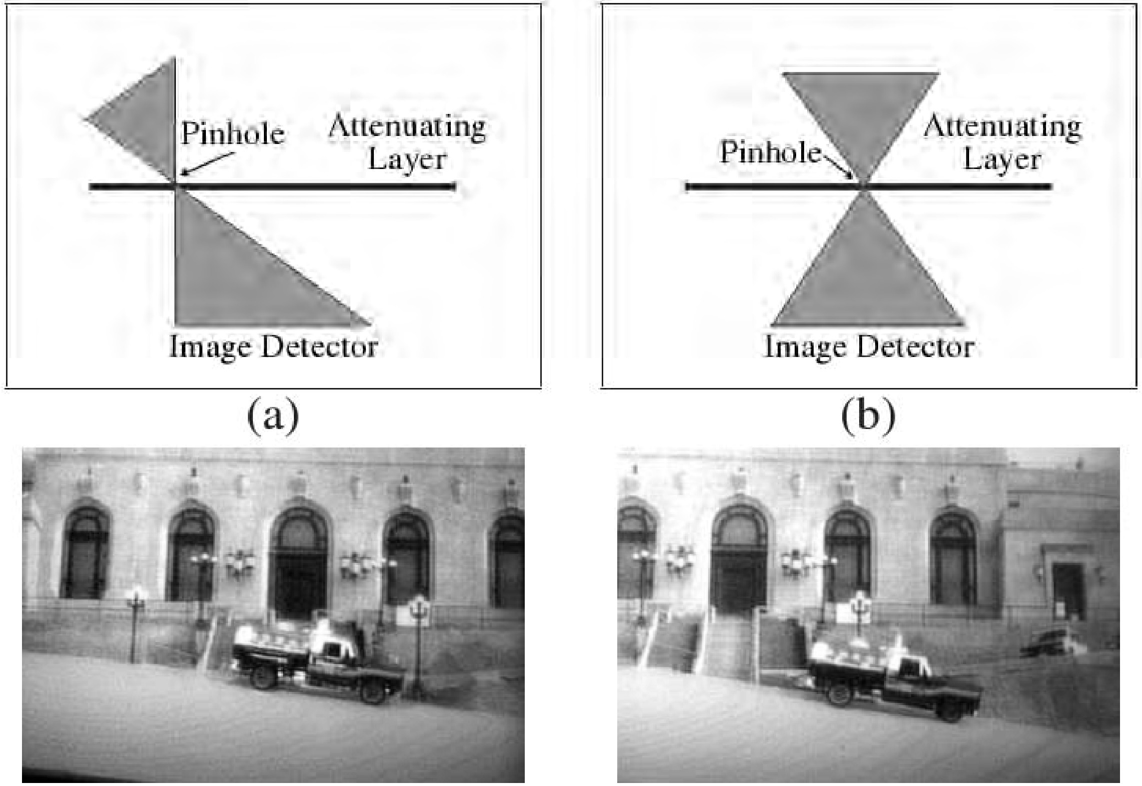
Traditional



New

Lensless Imaging with a Controllable Aperture, CVPR 2006

Computational Photo.: Lensless Camera

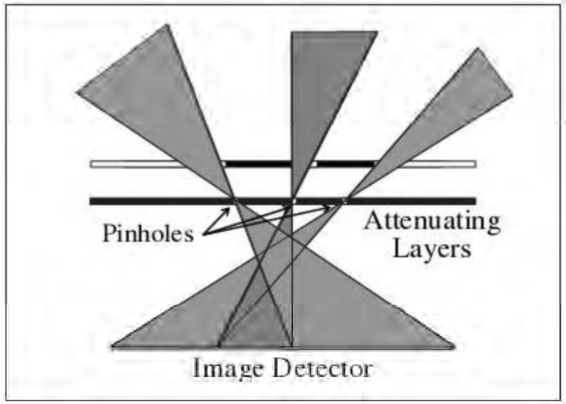


Pan/tilt field of view (fov) without physical moving parts

Computational Photo.: Lensless Camera

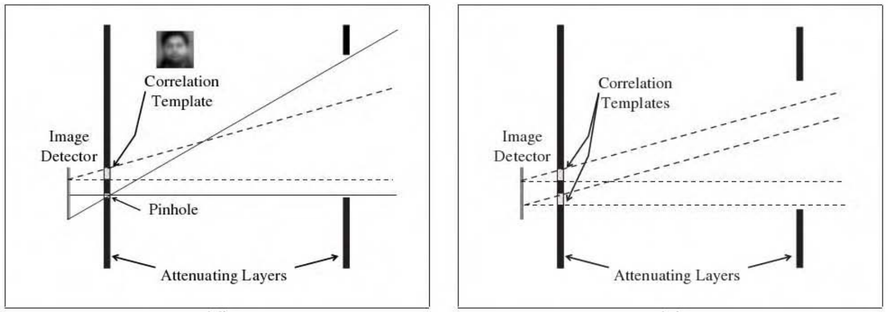
(a)

(b)



Split field of view, spatially varying zoom

(a) (b) (c)



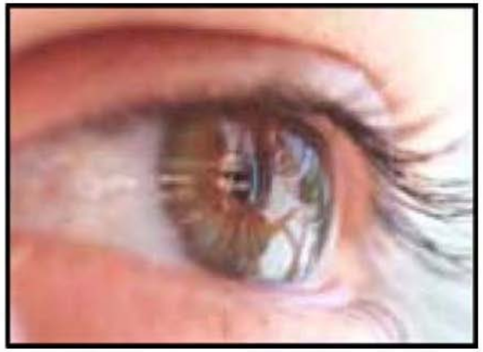
(d) (e)

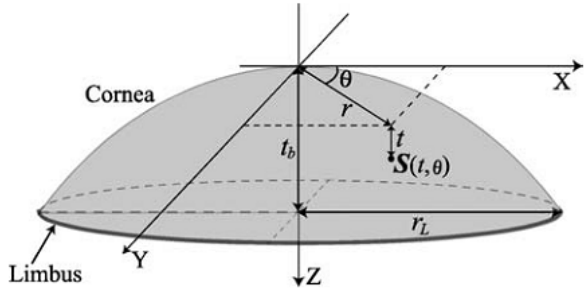
Computations in optical domain

Lensless Imaging with a Controllable Aperture, CVPR 2006

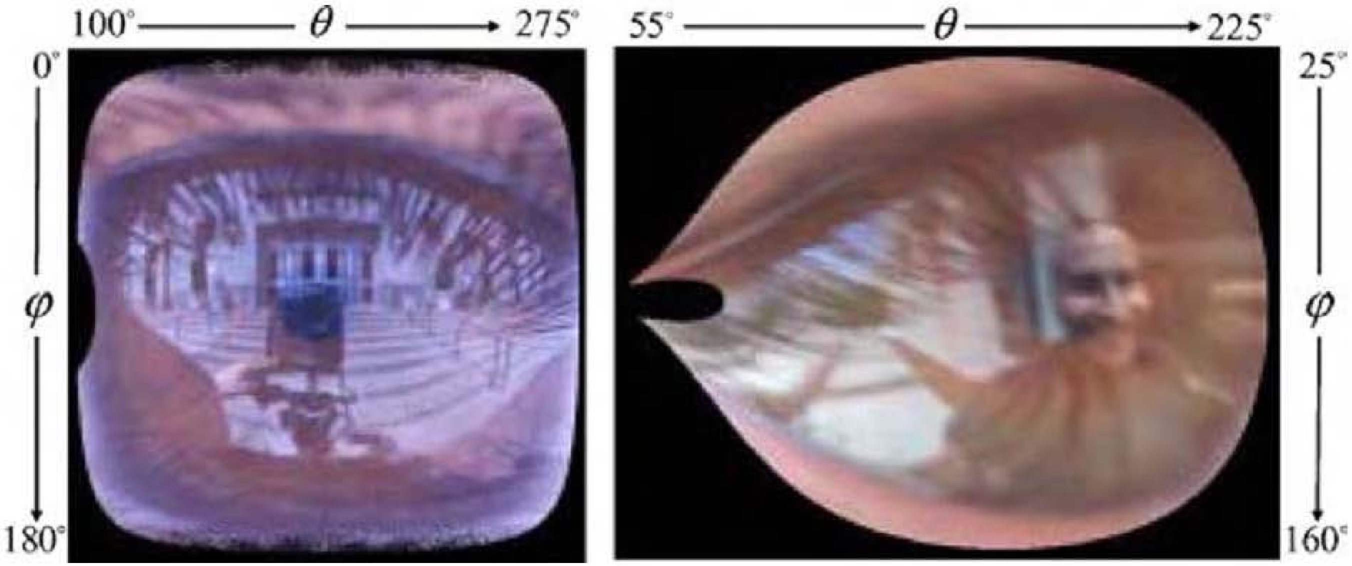
Computational Photography: Eye Optics

Appearances of eyes captures both the environment and gazing direction





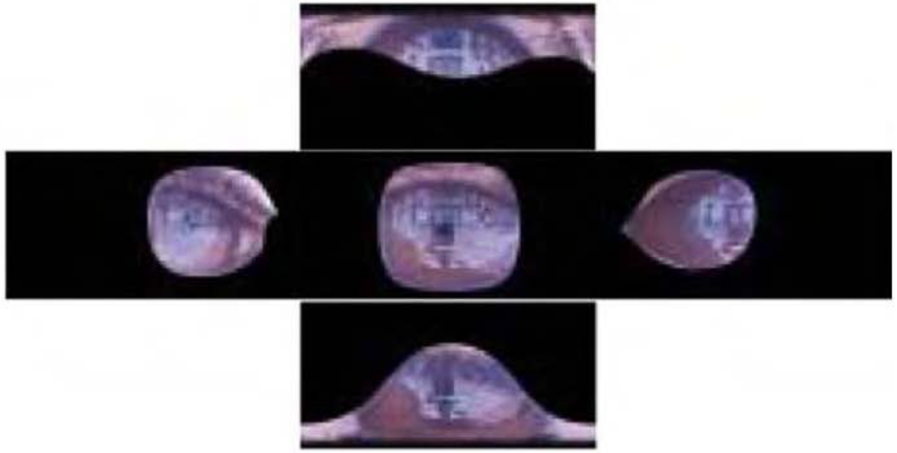
Spherical panorama
(latitude-longitude)



Corneal Imaging System Environment from Eyes, Int. Journal on Computer Vision (IJCV) 2006.
Eyes for relighting, SIGGRAPH 2004.

Computational Photo.: Eye Optics

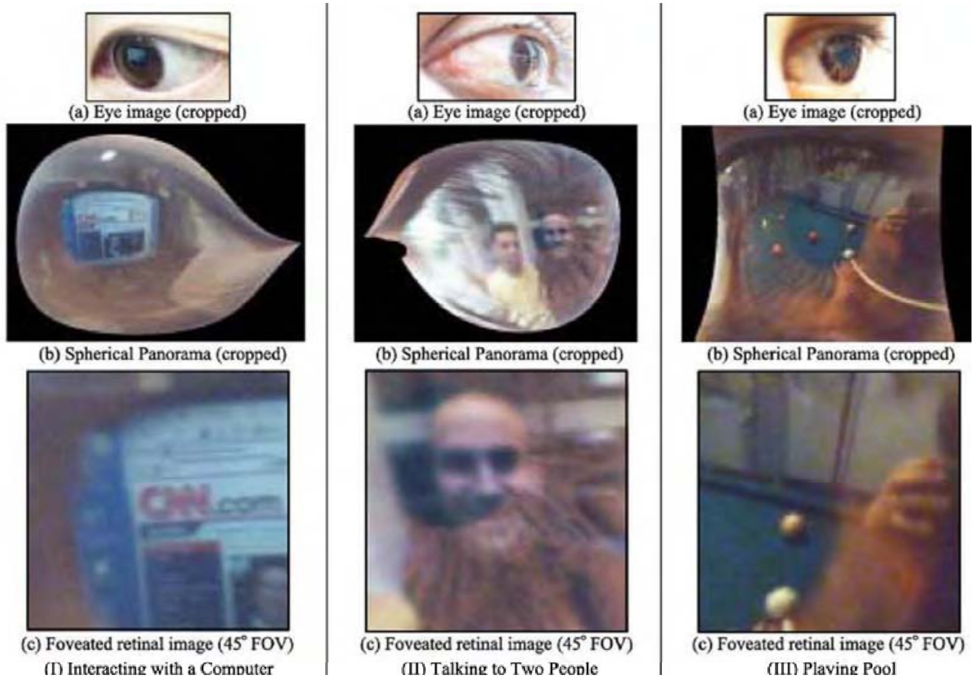
Gazing directions and corneal images

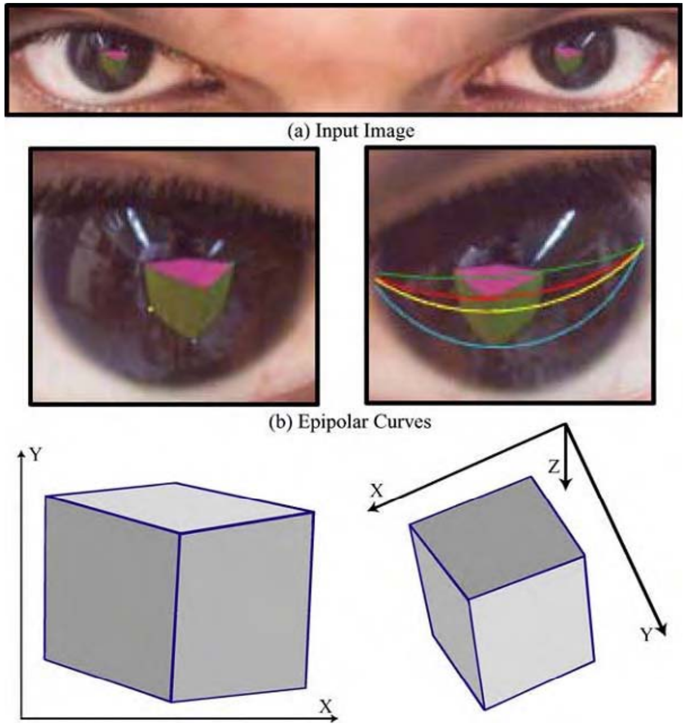


Stitching and blending onto an equirectangular map

Corneal Imaging System Environment from Eyes, Int. Journal on Computer Vision (IJCV) 2006.
Eyes for relighting, SIGGRAPH 2004.

Computational Photo.: Eye Optics



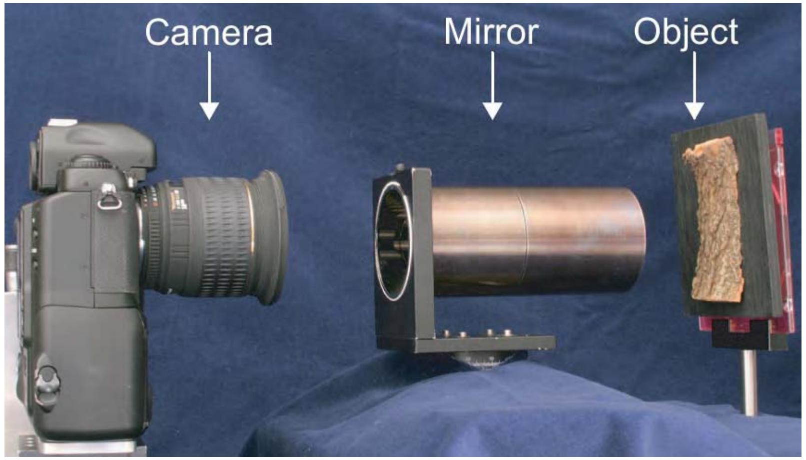


Monitoring activities

Performing 3D reconstruction
Of a 3D cube displayed on a monitor
(Epipolar geometry of corneal imaging system)

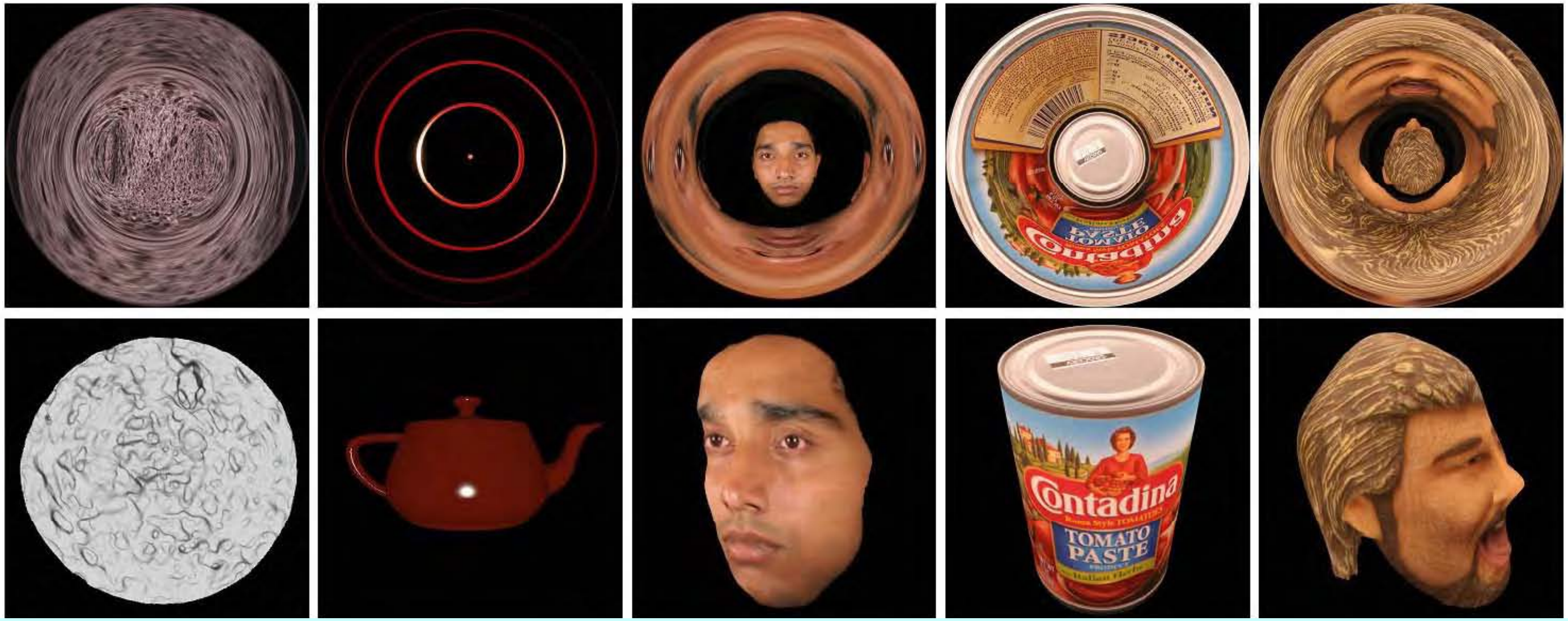
Corneal Imaging System Environment from Eyes, Int. Journal on Computer Vision (IJCV) 2006.
Eyes for relighting, SIGGRAPH 2004.

Comp. Photography: Radial Catadioptric Camera



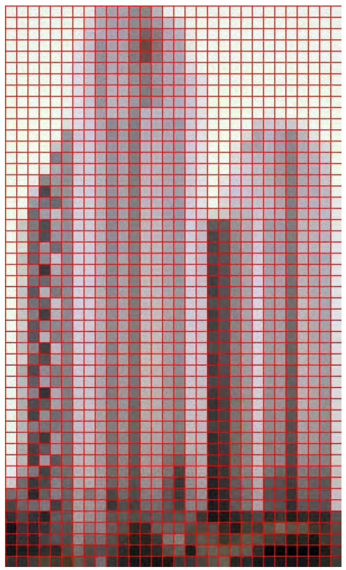
- Capture a *radial* space of rays
- Both mirrored and object parts
- 3D reconstruction with BRDF

(using a single shot!)



Multiview Radial Catadioptric Imaging for Scene Capture SIGGRAPH 2006

Beyond 2D pixels:
4D+ Light fields



Computational Photography: Plenoptic camera

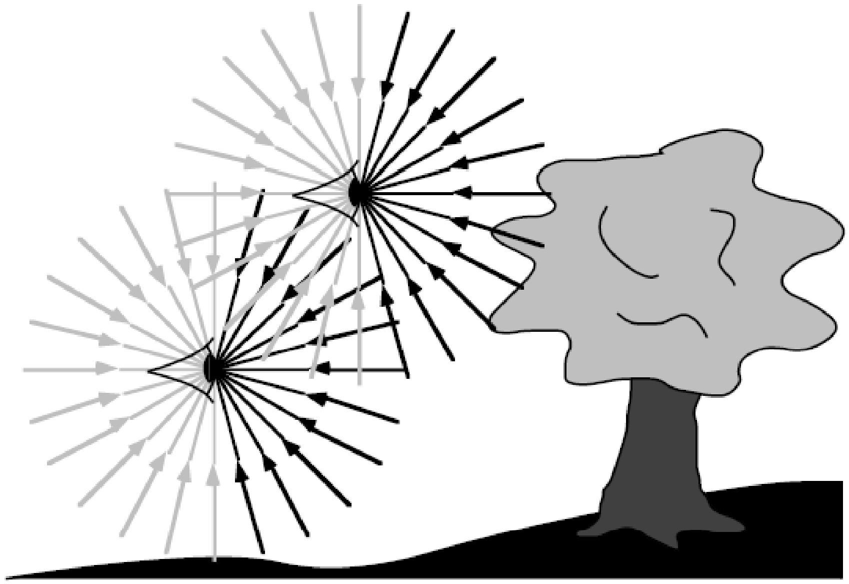


Fig.1.3
The plenoptic function describes the information available to an observer at any point in space and time. Shown here are two schematic eyes-which one should consider to have punctate pupils-gathering pencils of light rays. A real observer cannot see the light rays coming from behind, but the plenoptic function does include these rays.

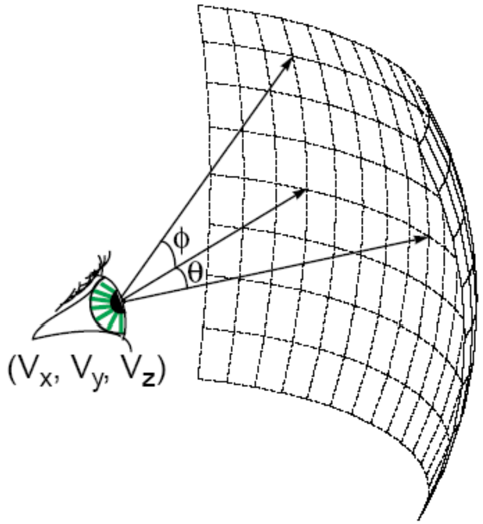


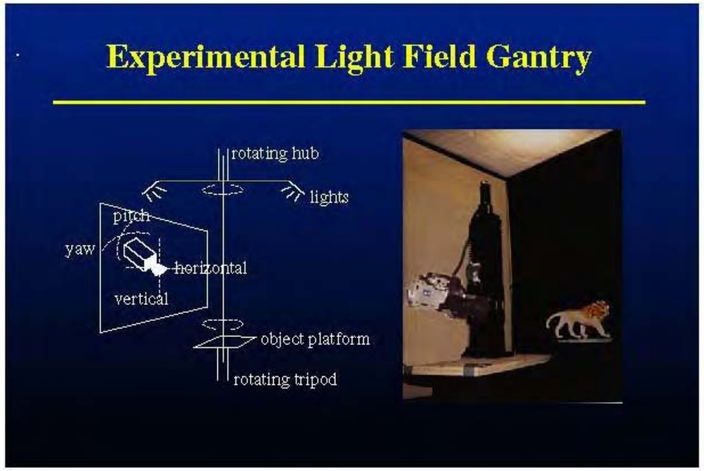
FIGURE 1. The plenoptic function describes all of the image information visible from a particular viewing position.

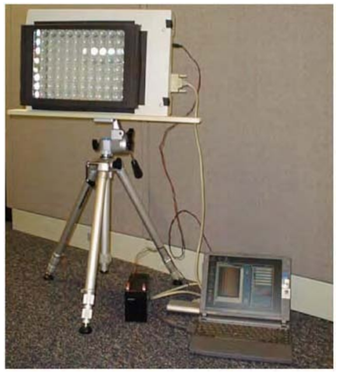
Plenoptic (latin plenus+optics) is a **7D function** $(X,Y,Z,\theta,\phi,\lambda,t)$

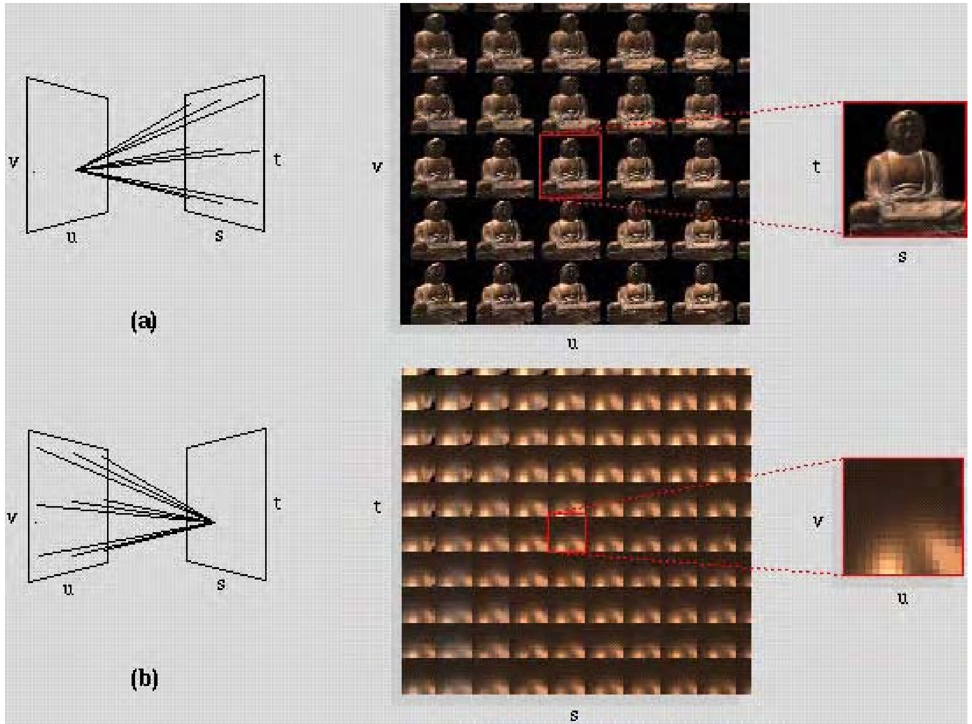
The Plenoptic Function and the Elements of Early Vision 1991
Plenoptic Modeling: An Image-Based Rendering System, SIGGRAPH 1995

Computational Photography: Light field camera

Instead of using a pinhole camera, why not capture a larger set of rays.
→4D light fields



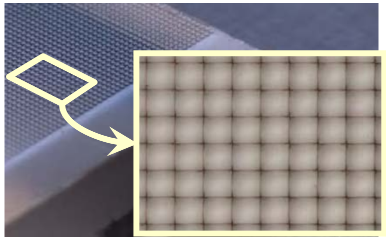


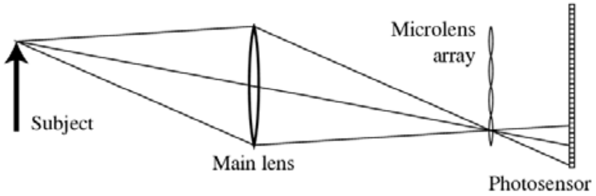


Light field rendering, SIGGRAPH 1996 http://graphics.stanford.edu/papers/light/
The lumigraph, SIGGRAPH 1996

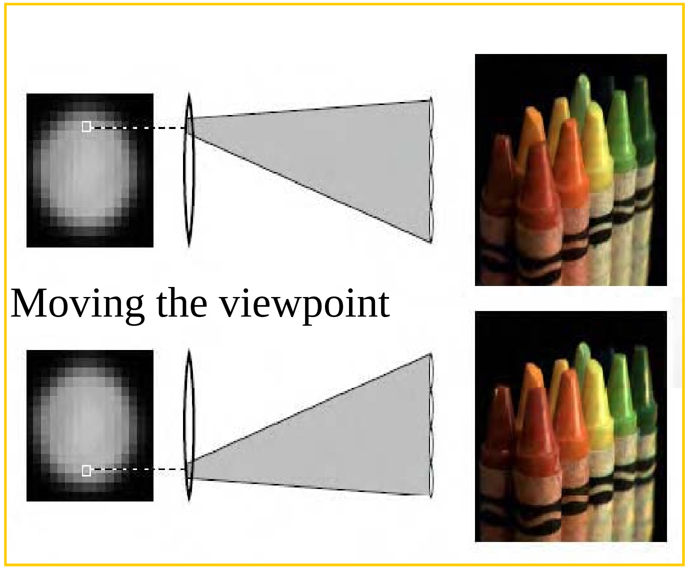
Computational Photography: Light field camera

Acquire first, postprocess later.





Digital refocusing



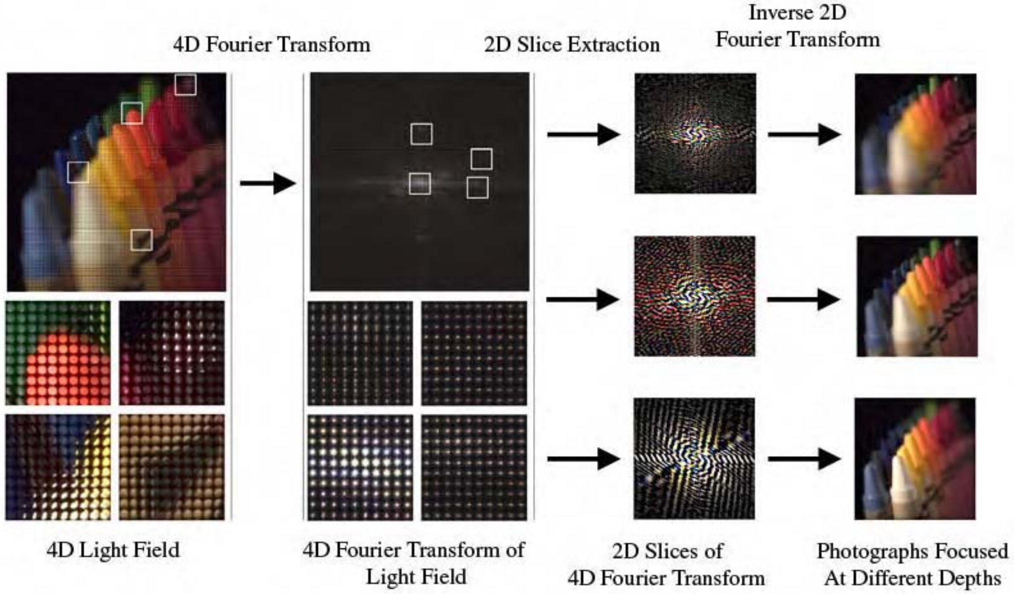
16 MP: 300x300 lens images

Fourier Slice Photography, SIGGRAPH 2006

H/WComp. Photography: Light field camera

(a) (b) (c) (d)

igure 13: A complete light field captured by our prototype. Careful examination (zoom in on electronic version, or use magnifying glass in print) re

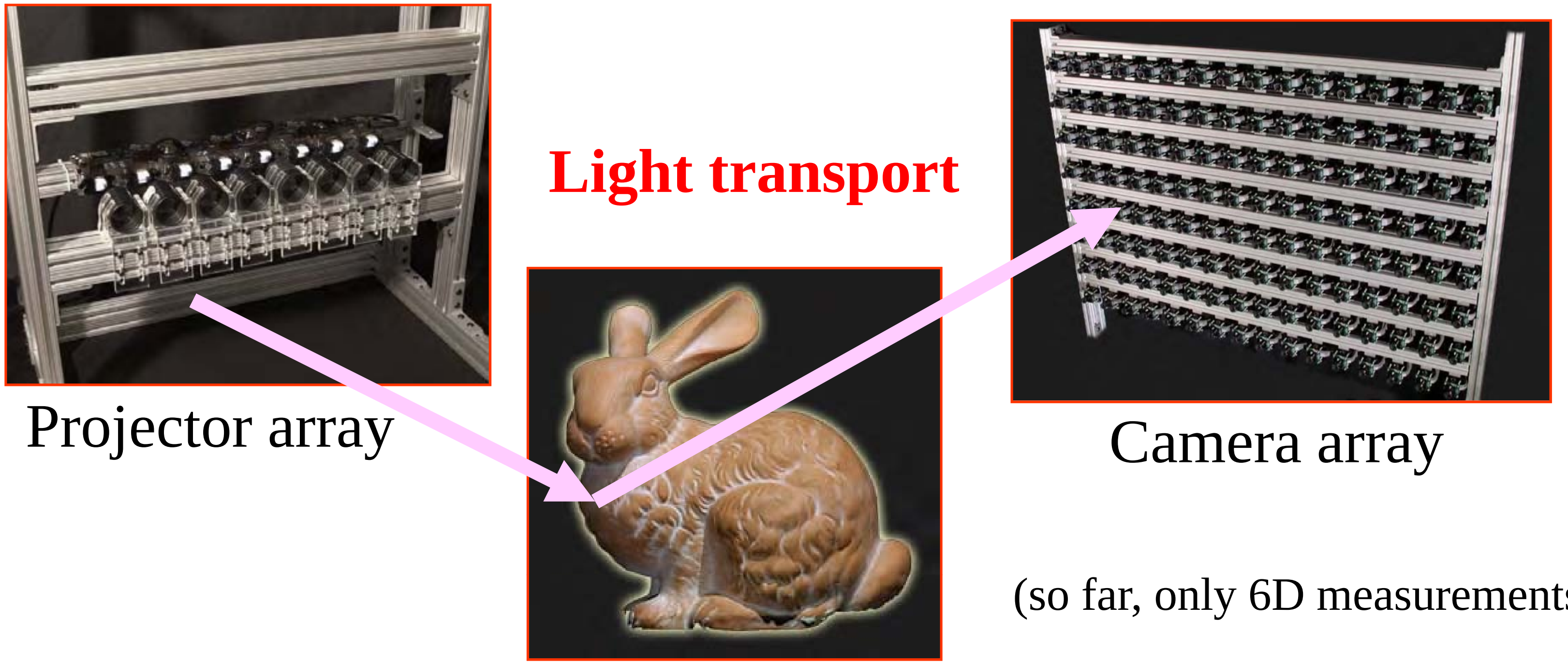


Fourier Slice Photography

Comp. Photography: 8D Reflectance field

<u>4D light field</u> : all rays outgoing at some closure
<u>4D illumination field</u> : all incoming rays some closure
<u>8D reflectance field</u>: ratio of outgoing/incoming rays

8D reflectance field modeled as a transport matrix between the 4D incident light field and the 4D reflected light field.



(so far, only 6D measurements)

Computational Photography

Smart pictures and Smart cameras

Comp. Photography: Novel World Depictions

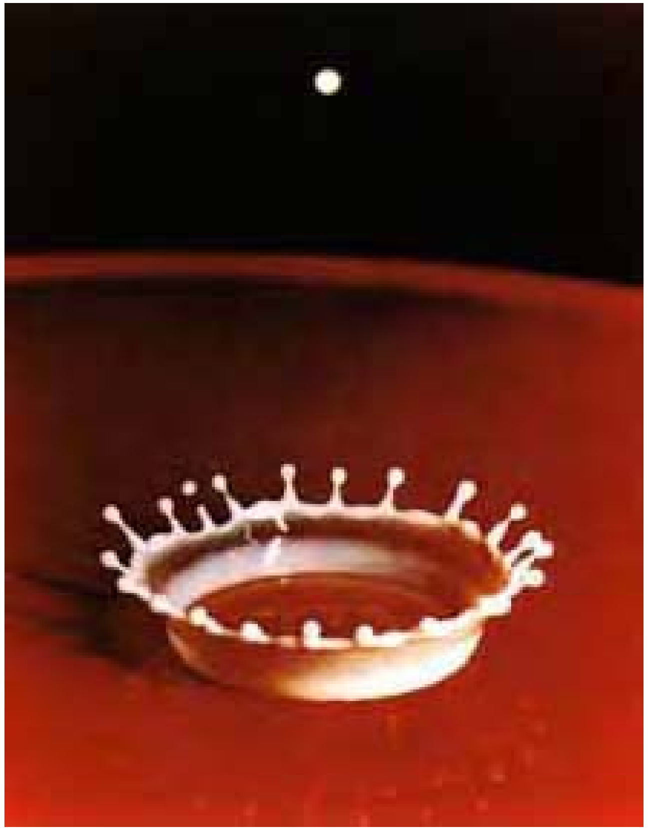
Pablo Picasso

Marc Chagall

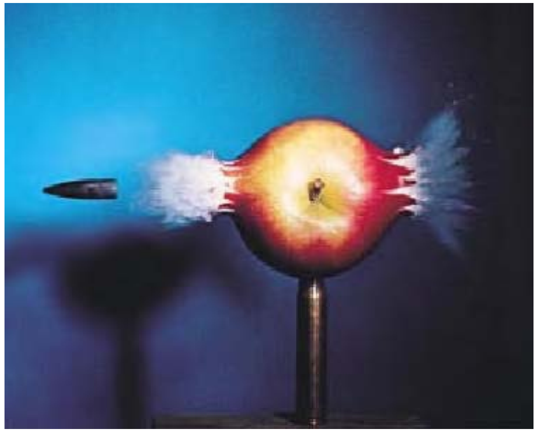
Artists depicting our world

David Hockney, 1985

Comp. Photography: Strobe light photography



Doc Edgerton, 1936



Few microseconds

Hint: Sub-shutter speed if flash lapse is shorter than exposure time

Comp. Photography: Expressive photography

Express artistically or scientifically a scene.
What are the **expressive rays**?

Comp. Photography: Multiperspective panoramas

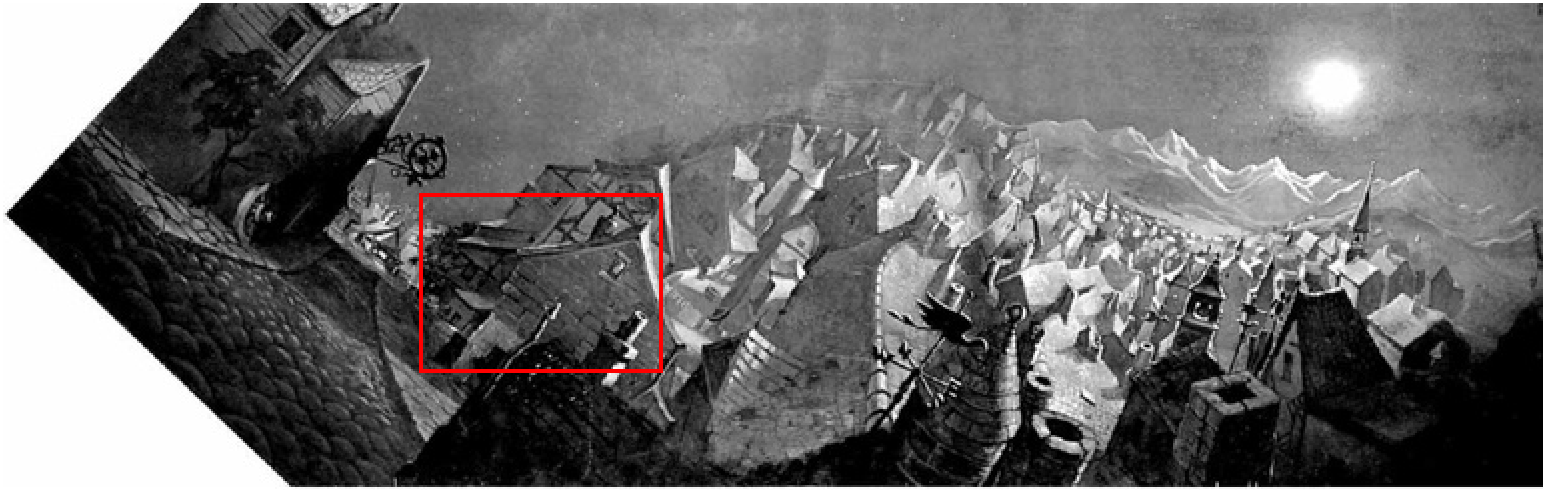
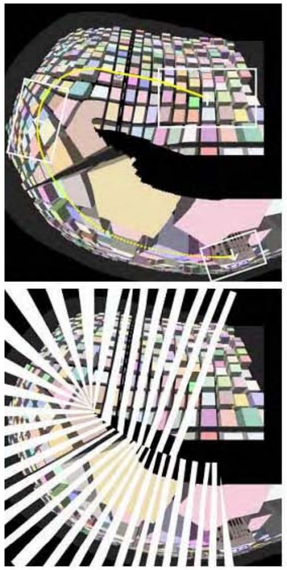
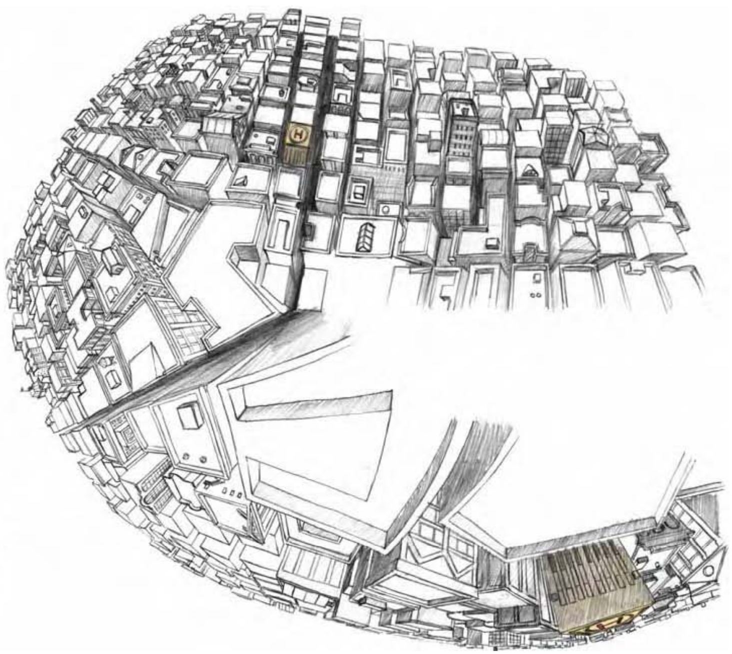


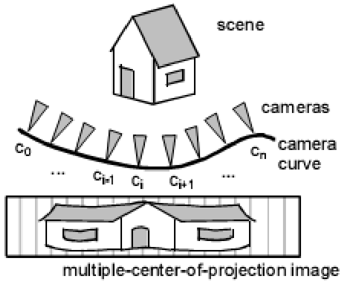
Figure 1 A multiperspective panorama from Disney's 1940 film *Pinocchio*. (Used with permission.)



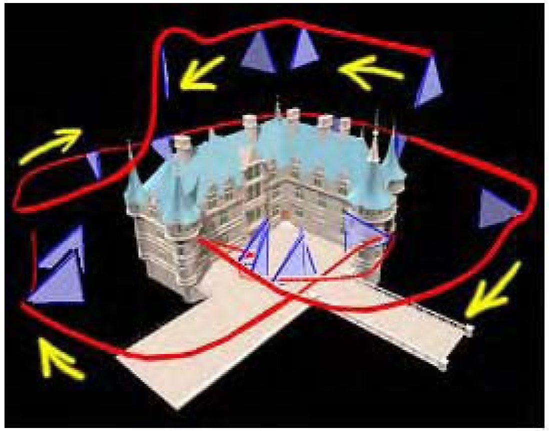


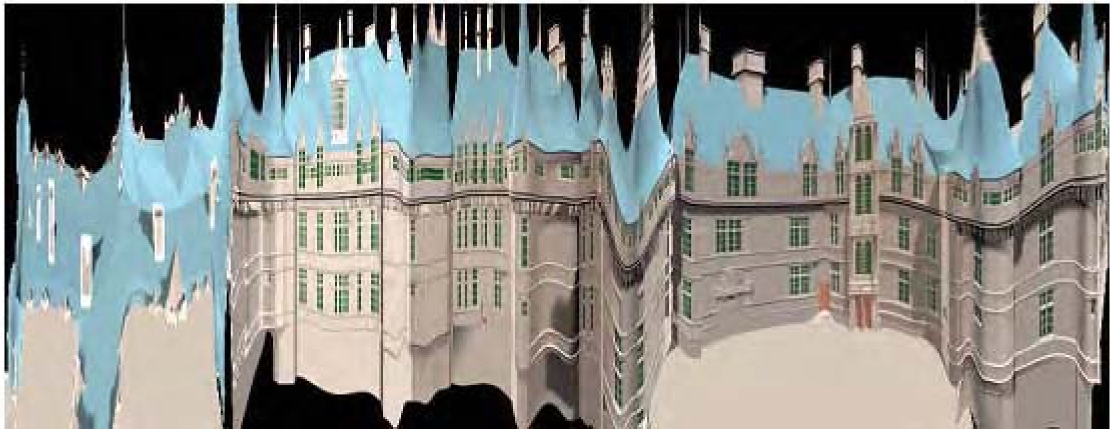
Multiperspective panoramas for cel animation | SIGGRAPH 1997 | http://grail.cs.washington.edu/projects/multirama/

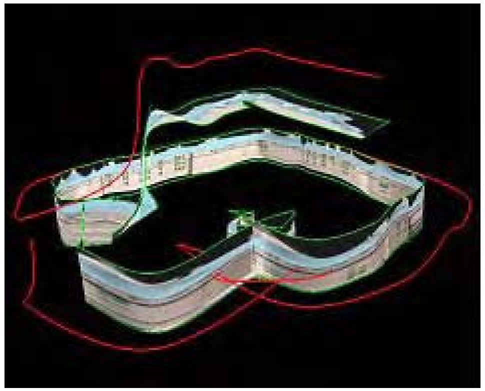
Comp. Photography: Novel World Depictions



Multiperspective images (MCOP)



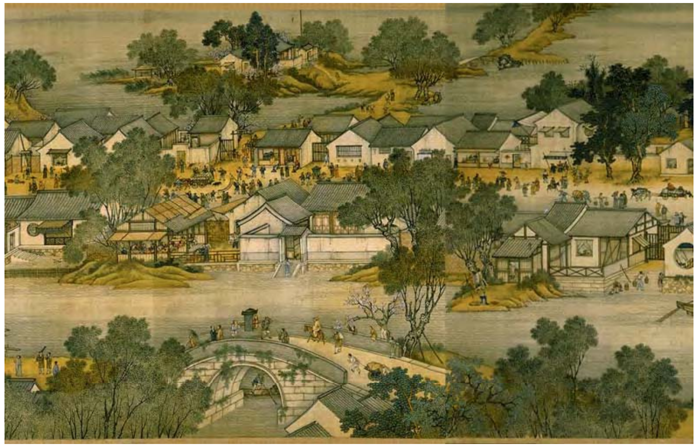




Multiperspective images, SIGGRAPH 1998

Comp. Photography: Novel World Depictions

Route panorama



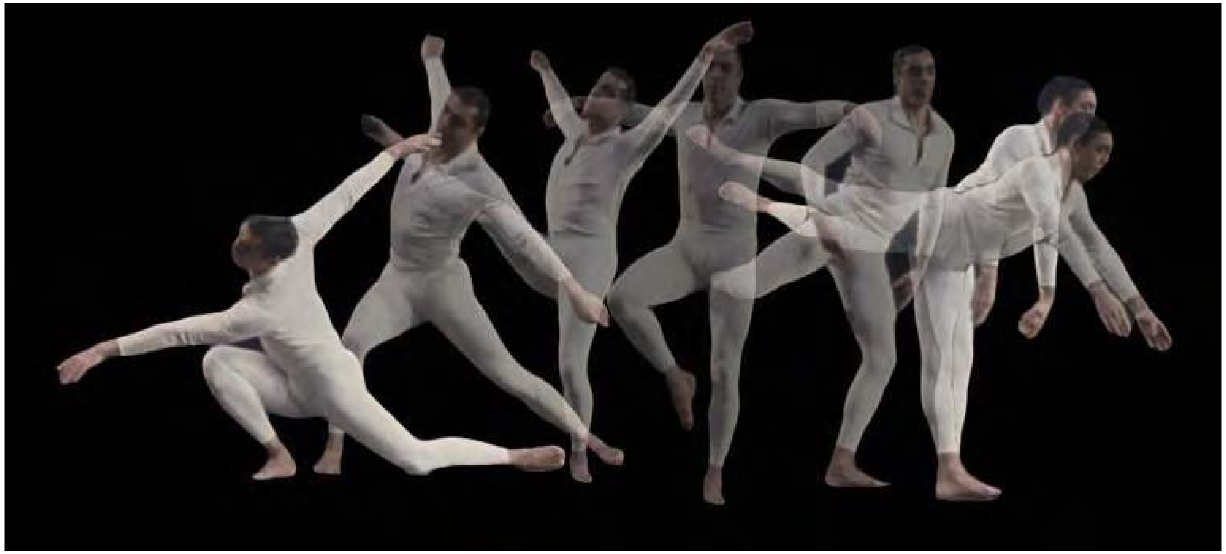
Photographing Long Scenes with Multi-Viewpoint Panoramas, SIGGRAPH 2006

Comp. Photography: Novel World Depictions

Matte extraction: strobing application

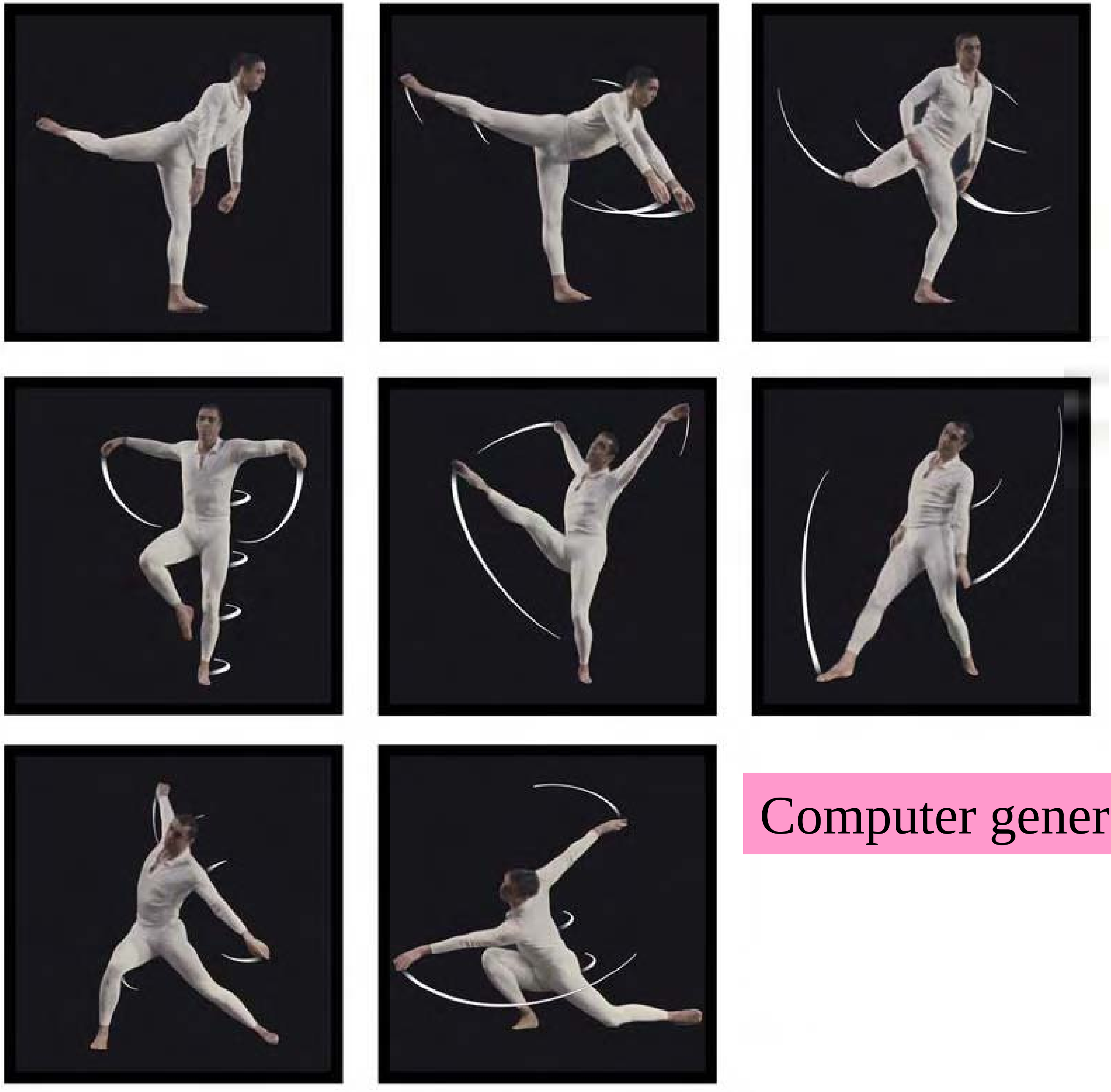
Old film of Etienne-Jules Marey

Mosaicing+matting provides a kinetic experience



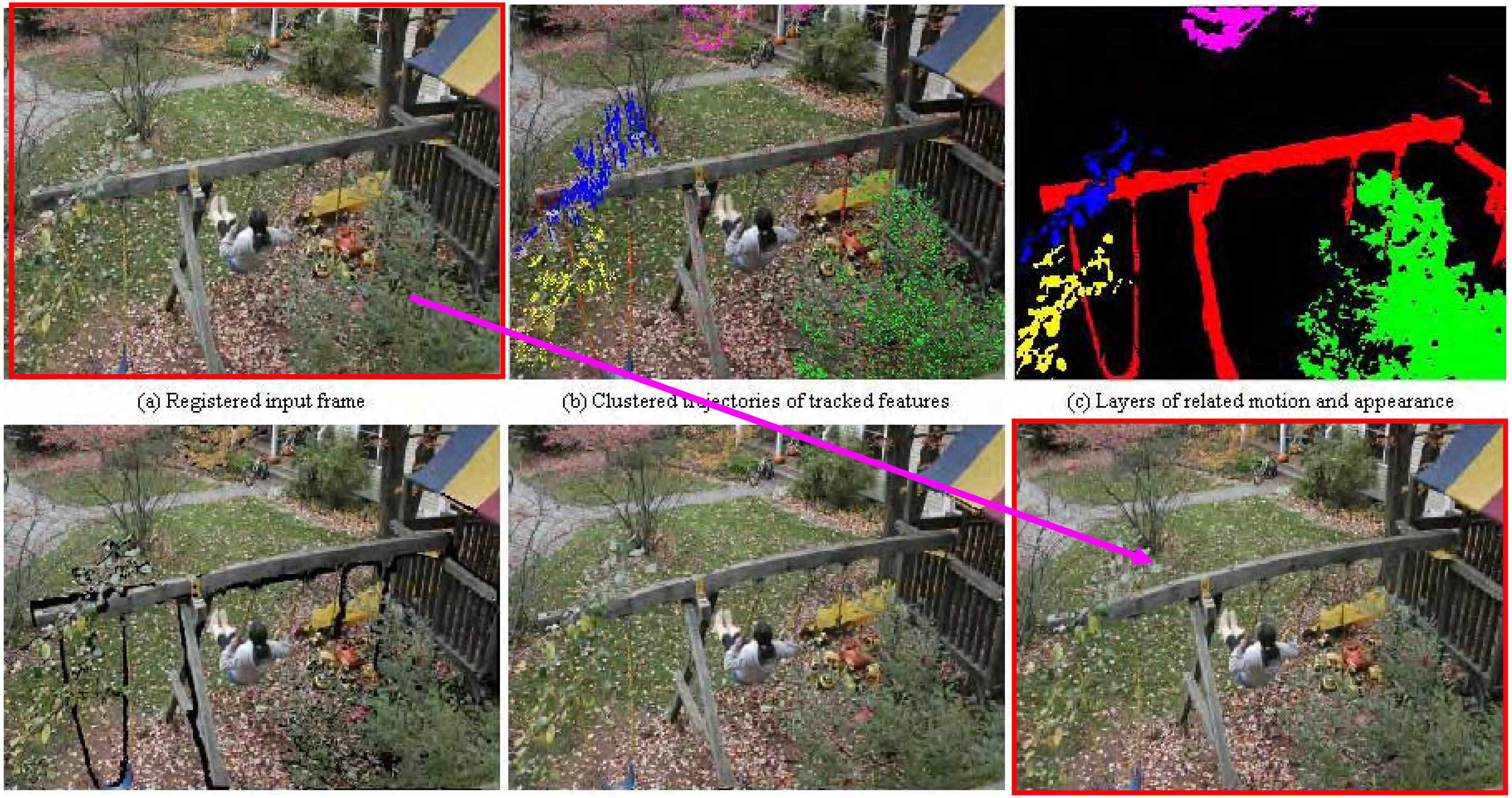
Visualizing motion is important for video-based applications (PVR,etc.)

Comp. Photography: Novel World Depictions



Computer generated motion lines

Computational Photography: Motion amplification



(a) Registered input frame
(b) Clustered trajectories of tracked features
(c) Layers of related motion and appearance
(d) Motion magnified, showing holes
(e) After texture in-painting to fill holes
(f) After user's modification to segmentation map in (c)

A video example best described the result
(Applications to telesurveillance, etc.)

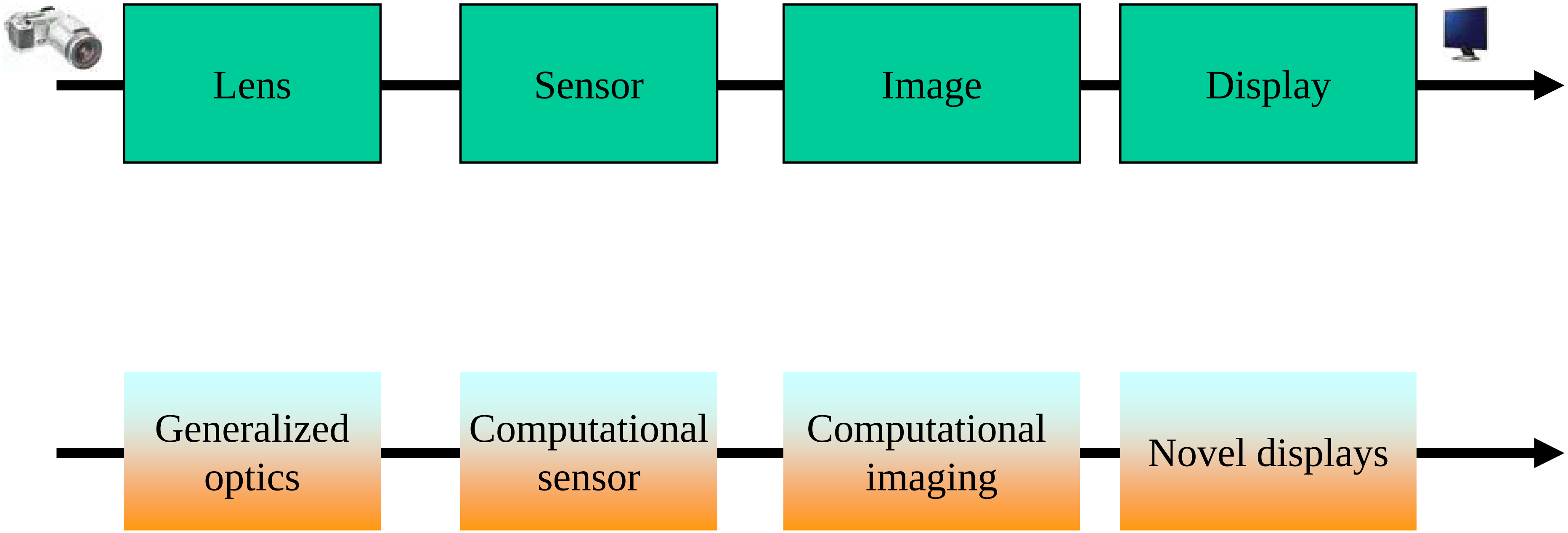
Motion magnification, SIGGRAPH 2005
http://people.csail.mit.edu/celiu/motionmag/motionmag.html

Computational Photography: Motion amplification

Motion magnification, SIGGRAPH 2005
http://people.csail.mit.edu/celiu/motionmag/motionmag.html

Summary

Computational Photography



Computational photography ≠ focal-plane intensities

Computational Photography: Announcement

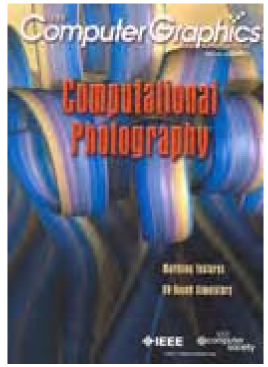
LIX Colloquium at Ecole Polytechnique on

Emerging Trends in Visual Computing

(about 20 guest speakers)

November 18th-20th 2008

Fredo Durand, MIT



Ramesh Raskar, MERL