

Computational Photography

Sommersemester 2007

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Organization

- lectures
- discussion of research papers
- student projects
 - (1-2 student(s) per group)
 - list of possible ideas
 - presentation of ideas
 - project proposal (2 pages)
 - implementation
 - presentation of results
 - report (like a conference paper 6-8 pages)

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Film-like Photography with bits	Computational Photography			
	Computational Processing	Computational Imaging/Optics	Computational Sensor	Smart Light Computational Illumination
Image processing applied to captured images to produce "better" images. Examples: Interpolation, Filtering, Enhancement, Dynamic Range Compression, Color Management, Morphing, Hole Filling, Artistic Image Effects, Image Compression, Watermarking.	Processing of a set of captured images to create "new" images. Examples: Mosaicing, Matting, Super-Resolution, Multi-Exposure HDR, Light Field from Multiple View, Structure from Motion, Shape from X.	Capture of optically coded images and computational decoding to produce "new?" images. Examples: Coded Aperture, Optical Tomography, Diaphanography, SA Microscopy, Integral Imaging, Assorted Pixels, Catadioptric Imaging, Holographic Imaging.	Detectors that combine sensing and processing to create "smart" pixels. Examples: Artificial Retina, Retinex Sensors, Adaptive Dynamic Range Sensors, Edge Detect Chips, Focus of Expansion Chips, Motion Sensors.	Adapting and Controlling Illumination to Create "revealing" image Examples: Flash/no flash, Lighting domes, Multi-flash for depth edges, Dual Photos, Polynomial texture Maps, 4D light source

[Tumblin 2005]

Outline

- digital camera technology
- computational sensing
- multi-dimensional imaging
- computational imaging in other fields

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Conventional Cameras and Advanced Processing

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Cameras



- sensor
- optics
- processing

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Cameras



[Georgiev 06]

- sensor
- optics
- processing
- weird stuff



Removing Camera Shake

[Fergus 06]



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Removing Camera Shake

[Fergus 06]



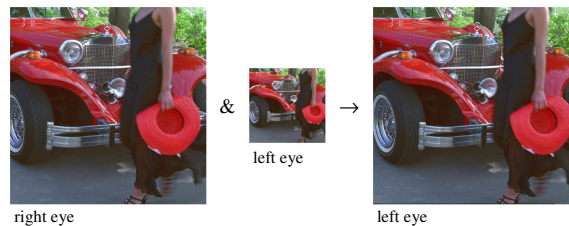
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Hallucinating Resolution

applications

- high-resolution pre-image + normal-resolution snapshot = high-resolution snapshot

[Sawhney01]

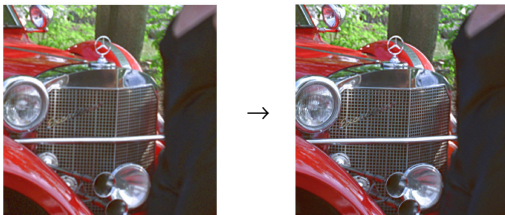


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Hallucinating Resolution

applications

- high-resolution pre-image + normal-resolution snapshot = high-resolution snapshot



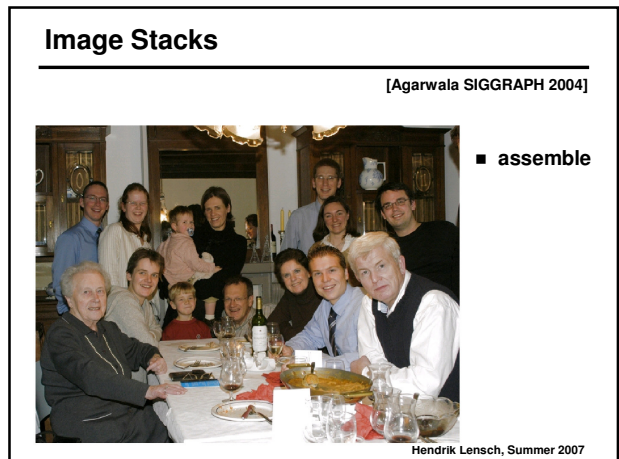
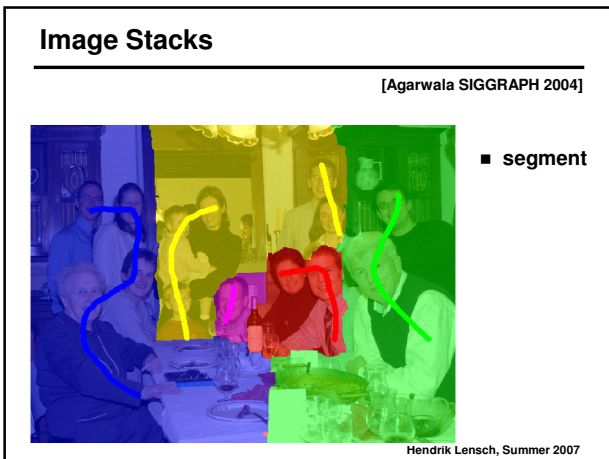
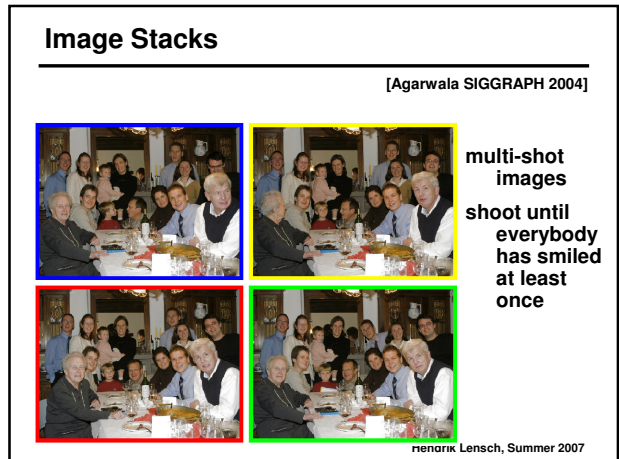
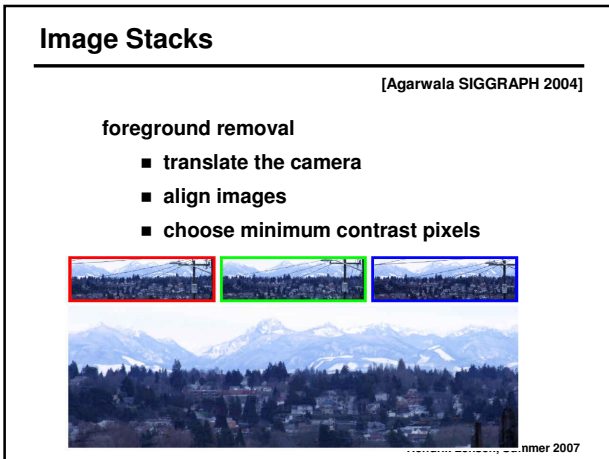
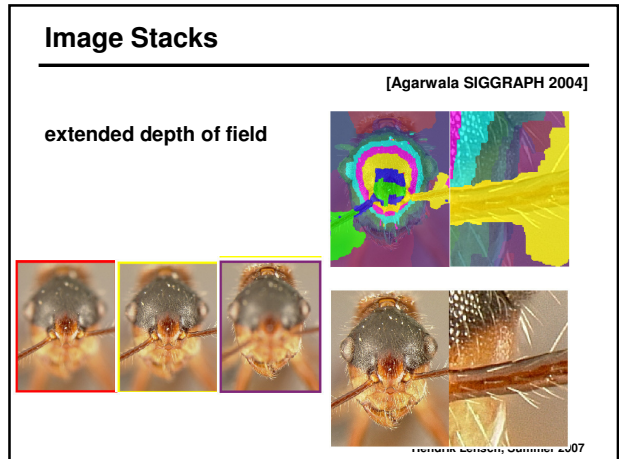
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Hallucinating Resolution

applications

- high-resolution pre-image + normal-resolution snapshot = high-resolution snapshot
- normal-resolution full-frame snapshot + high-resolution partial-frame patches = high-resolution snapshot
- normal-resolution normal-frame-rate video + high-resolution low-frame-rate video = high-resolution HDTV

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Fun with Multiple Cameras and Videos

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Circles of Cameras



Manex's bullet time array

[Rademacher 1998]

[Seitz 2001]



multi-perspective panorama

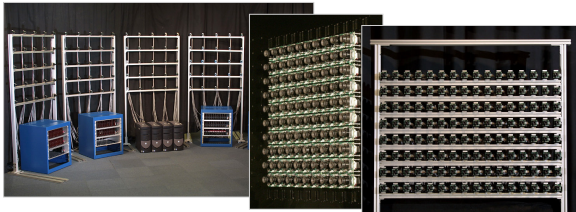


peripheral photograph

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Stanford Multi-Camera Array

- widely spaced → light field capture
- tightly packed → high-performance imaging
- intermediate spacing → synthetic aperture photography



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Light Fields

[Levoy & Hanrahan, 1996]



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View Interpolation with Image-based Priors



[Fitzgibbon et al. 2003]

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View Interpolation with Image-based Priors



[Fitzgibbon et al. 2003]

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Synthetic Aperture

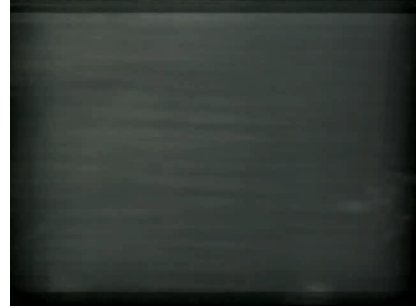
[Wilburn 05]



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Synthetic Aperture

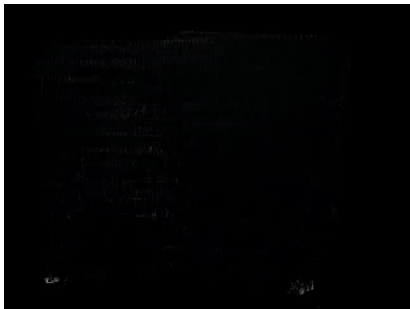
[Wilburn 05]



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Synthetic Aperture

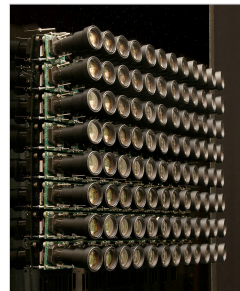
[Wilburn 05]



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Tiled Camera Array

Can we match the image quality of a cinema camera?



world's largest video camera
no parallax for distant objects
poor lenses limit image quality
seamless mosaicing isn't hard

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Tiled panoramic image (before geometric or color calibration)



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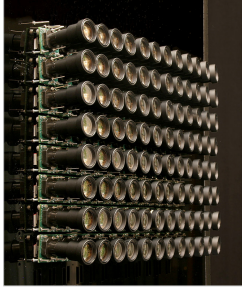
Tiled panoramic image (after calibration and blending)



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Tiled Camera Array

Can we match the image quality of a cinema camera?

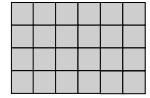


world's largest video camera
no parallax for distant objects
poor lenses limit image quality
seamless mosaicing isn't hard
per-camera exposure metering
HDR within and between tiles

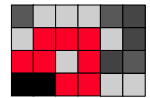
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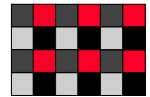
same exposure
in all cameras



individually
metered



checkerboard
of exposures



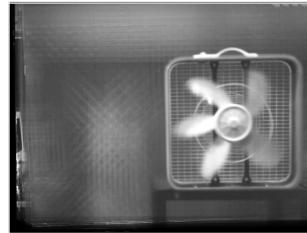
High-performance photography as multi-dimensional sampling

spatial resolution
field of view
frame rate
dynamic range
bits of precision
depth of field
focus setting
color sensitivity

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Spacetime Aperture Shaping

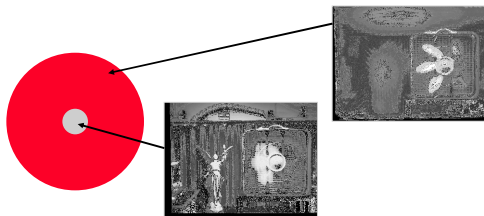
[Wilburn 05]



shorten exposure time to freeze
motion → dark
stretch contrast to restore level
→ noisy
increase (synthetic) aperture to
capture more light →
decreases depth of field

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Spacetime Aperture Shaping



center of aperture: few cameras, long exposure →
high depth of field, low noise,
but action is blurred
periphery of aperture: many cameras, short exposure →
freezes action, low noise,
but low depth of field

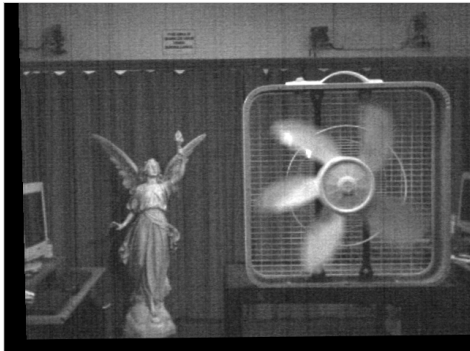
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Spacetime Aperture Shaping



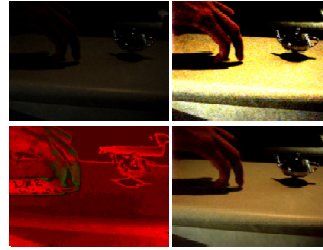
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Spacetime Aperture Shaping

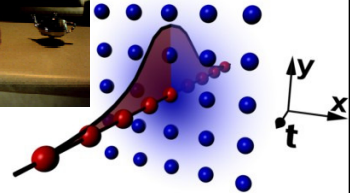


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Low Dynamic Range Video Enhancement



[Bennett & McMillan 2005]



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Stanford CityBlock Project

capture video while driving
extract middle column from each frame
stack them to create a panorama



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Stanford CityBlock Project



Stanford CityBlock Project

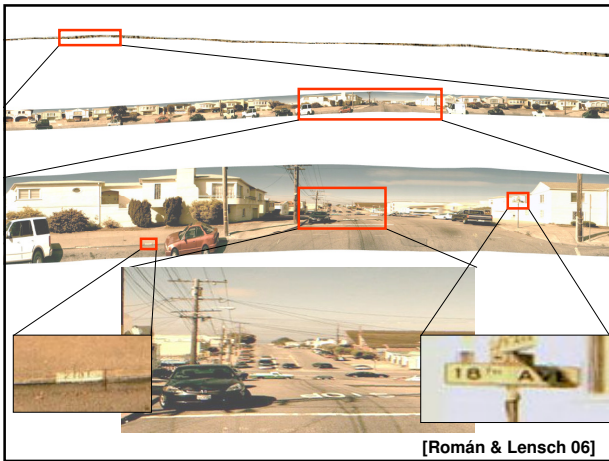


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Stanford CityBlock Project



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Abnormal Illumination

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Light Sources

- point light sources
- monitors
- projectors
- natural lighting

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Flash/No-Flash Photography

- enhance image quality

flash

no-flash

combined

[Petschnigg et al. 2004]
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More Flash-noflash Algorithms

[Agrawal SIGGRAPH 2005]

Ambient

Flash

Result

remove features that don't appear in both
(as determined from image gradients)

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Multi-Flash Images

- extract edge information

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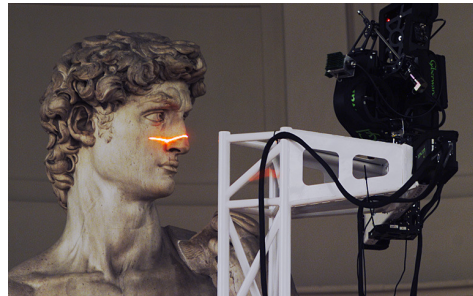
Multi-Flash Images

- extract edge information



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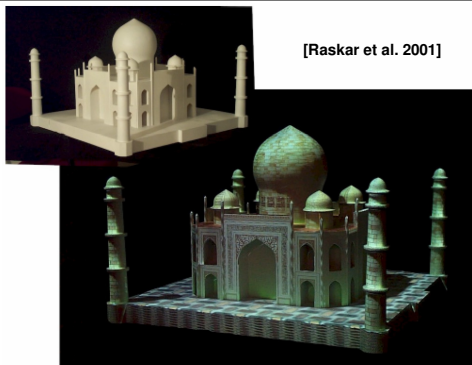
3D Range Scanning



[Levoy et al. 2000]

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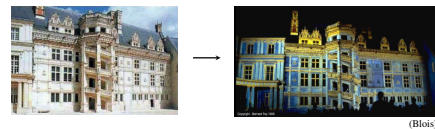
Shader Lamps



[Raskar et al. 2001]

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Non-photorealistic Illumination (NPI)

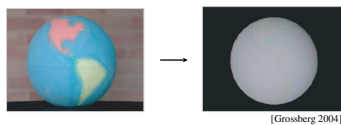


what are interesting "light field bulbs",
and what are they good for?

- recoloring

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Non-photorealistic illumination (NPI)



what are interesting "light field bulbs",
and what are they good for?

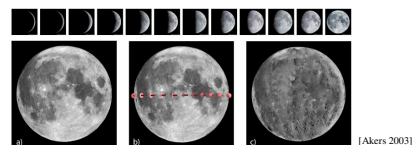
- recoloring
- cloaking



?

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Non-photorealistic illumination (NPI)



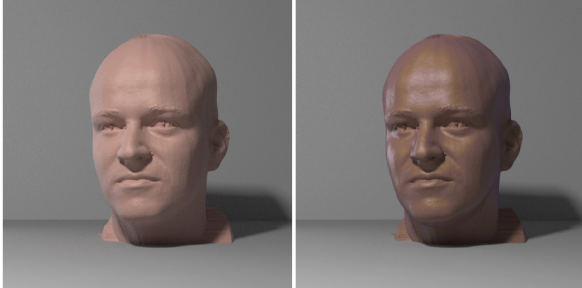
what are interesting "light field bulbs",
and what are they good for?

- recoloring
- cloaking
- everywhere-grazing light

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Measuring the BRDF

- opaque surfaces



[Steve Marschner 1999]

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Digitizing Actors



The Matrix Reloaded [ESC Entertainment 2003]

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Light Stage I

- capturing a reflectance field

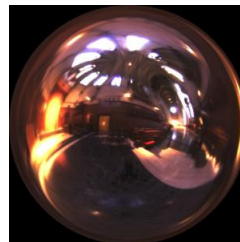


[Debevec et al. 2000]

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Light Stage III

- relighting real objects with virtual light sources

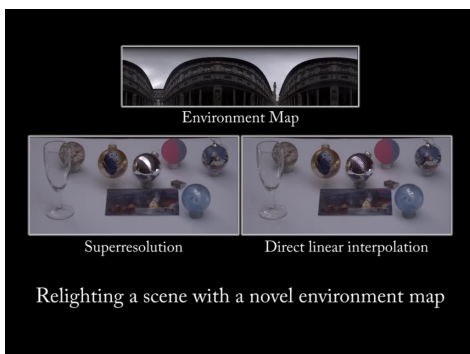


[Debevec et al. 2002]

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Reflectance Fields

[Fuchs 07]



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Environment Matting

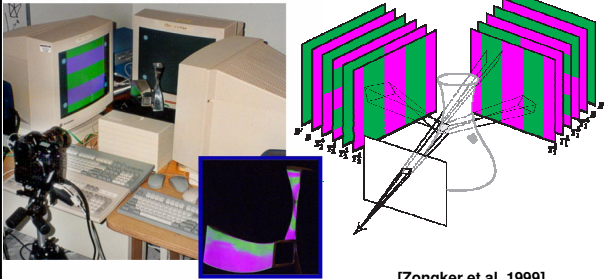
- capture refracting objects



[Zongker et al. 1999]

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Environment Matte Acquisition

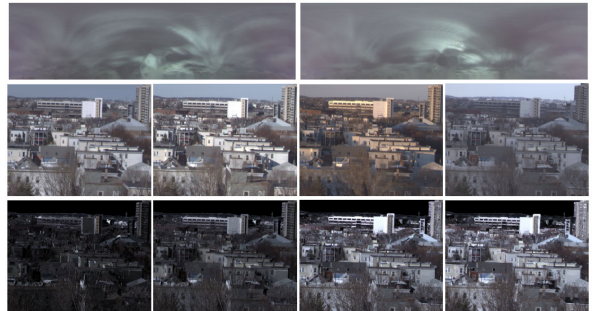


[Zongker et al. 1999]

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Natural Lighting

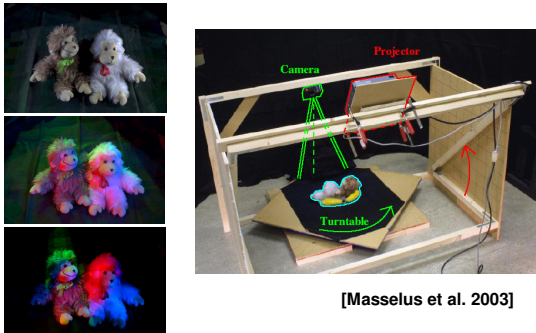
■ outdoor environment mattes



[Matusik 2004]

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Relighting with 4D incident light fields



[Masselus et al. 2003]

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Dual Photography

photograph

dual image



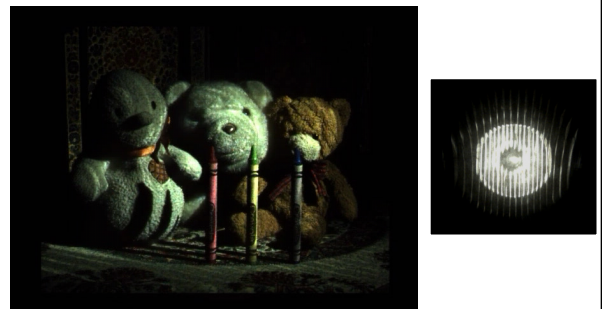
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6D Reflectance Field



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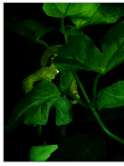
6D Reflectance Field



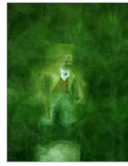
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Synthetic Aperture Confocal Imaging

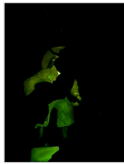
[Levoy 04]



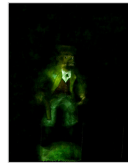
single viewpoint



synthetic aperture image

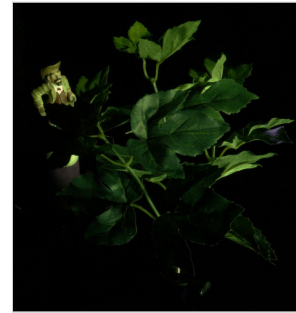


confocal image



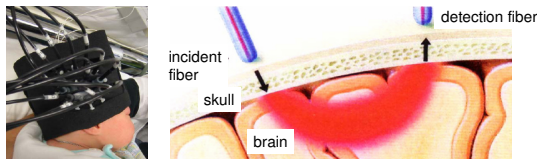
combined

Selective illumination using object-aligned mattes

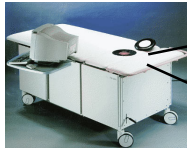


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Optical Tomography



[Helsinki University, Meriläinen 2005]



[University of Leiden, Hooft 2004]

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Computational Imaging in Other Fields

medical imaging

- rebinning
- transmission tomography
- reflection tomography

airborne sensing

- multi-perspective panoramas
- synthetic aperture radar

astronomy

- coded-aperture imaging
- interferometric imaging

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Computational Imaging in Other Fields

geophysics

- seismic reflection surveying
- borehole tomography

biology

- confocal microscopy
- deconvolution microscopy

physics

- diffraction tomography
- diffuse optical tomography
- inverse scattering

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