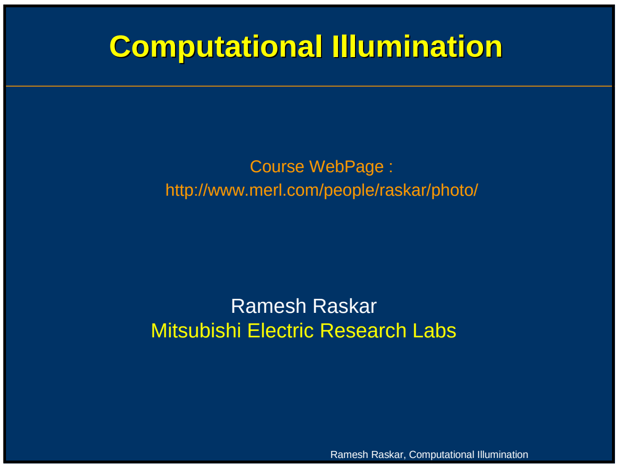
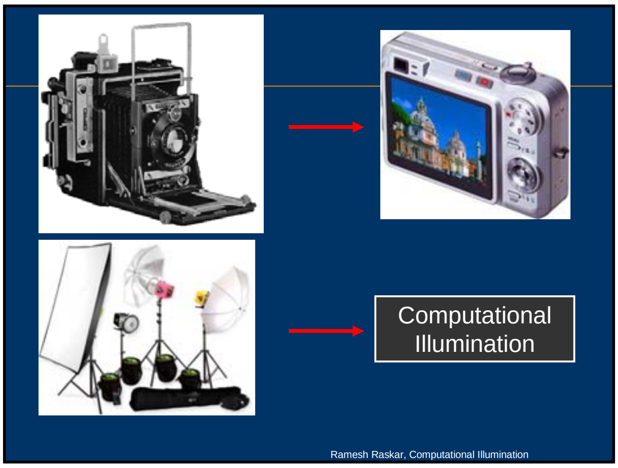
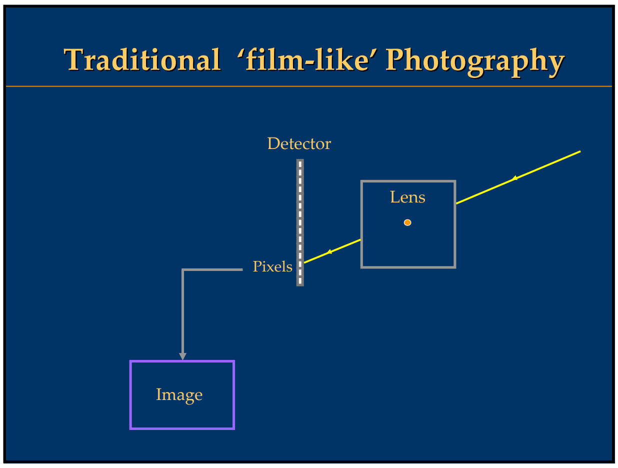
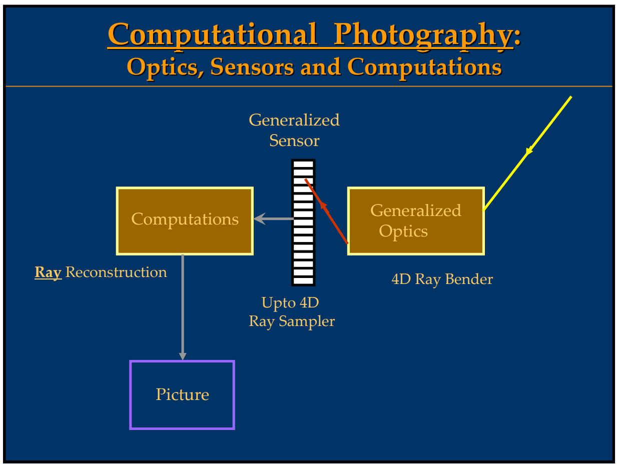
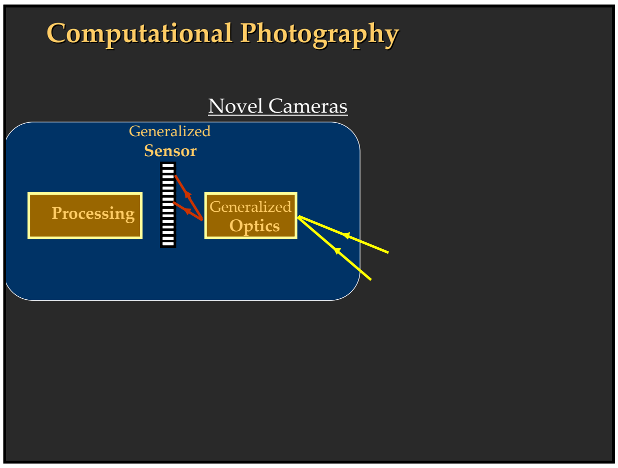
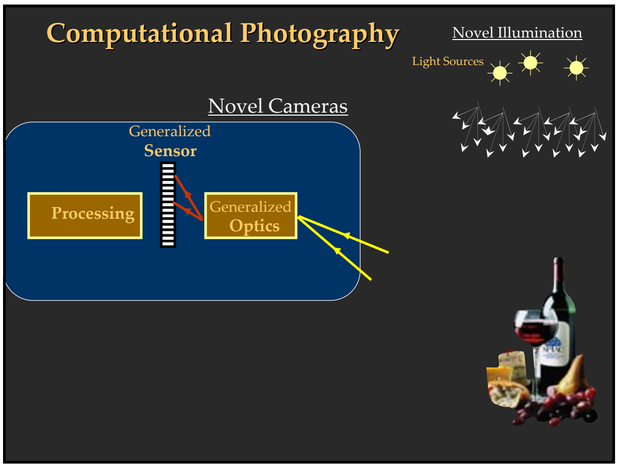

Computational Illumination
Course WebPage :
http://www.merl.com/people/raskar/photo/
Ramesh Raskar
Mitsubishi Electric Research Labs
Ramesh Raskar, Computational Illumination

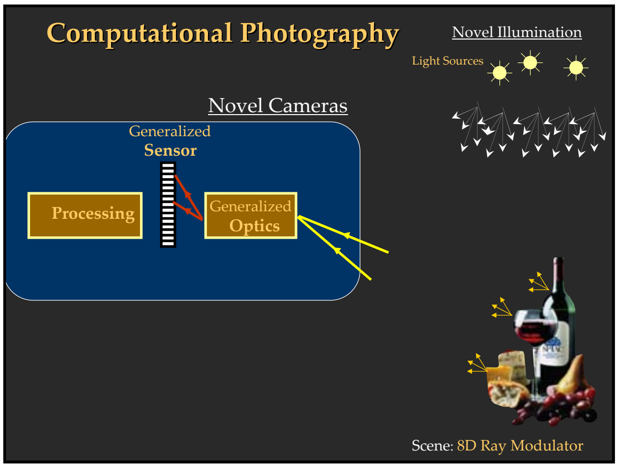

Computational Illumination
Ramesh Raskar, Computational Illumination

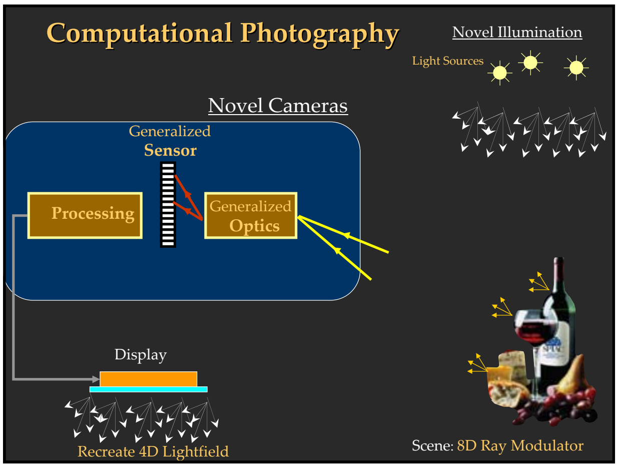

Traditional 'film-like' Photography
Detector
Lens
Pixels
Image

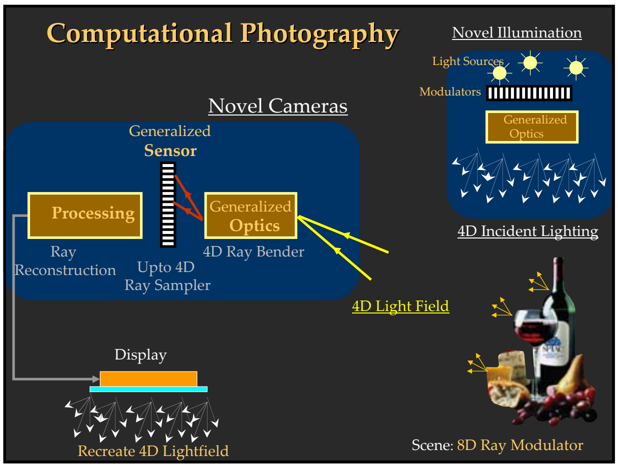

Computational Photography:
Optics, Sensors and Computations
Generalized Sensor
Computations
Generalized Optics
Ray Reconstruction
4D Ray Bender
Upto 4D Ray Sampler
Picture

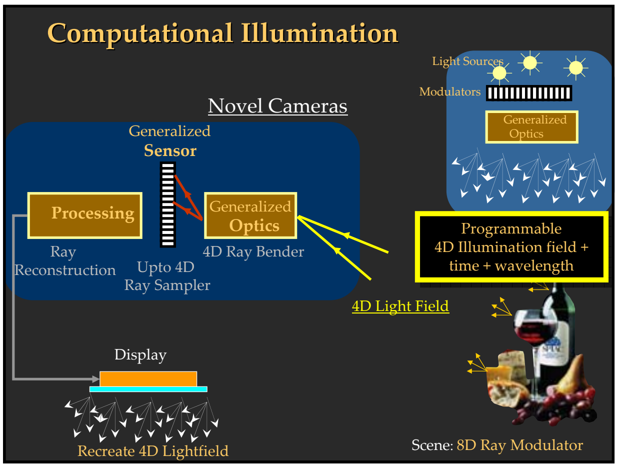

Computational Photography
Novel Cameras
Generalized Sensor
Processing
Generalized Optics

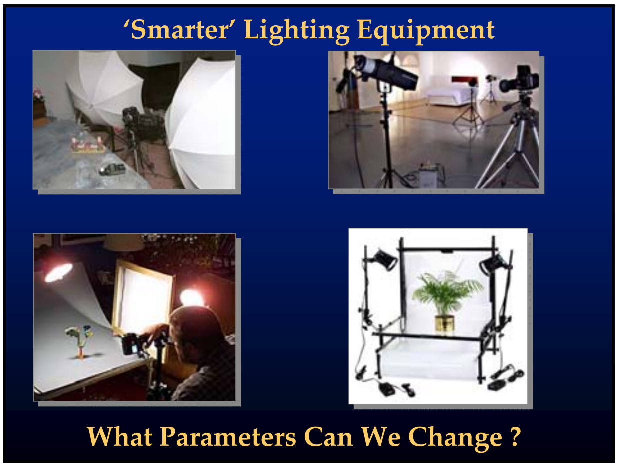

Computational Photography
Novel Illumination
Light Sources
Novel Cameras
Generalized Sensor
Processing
Generalized Optics

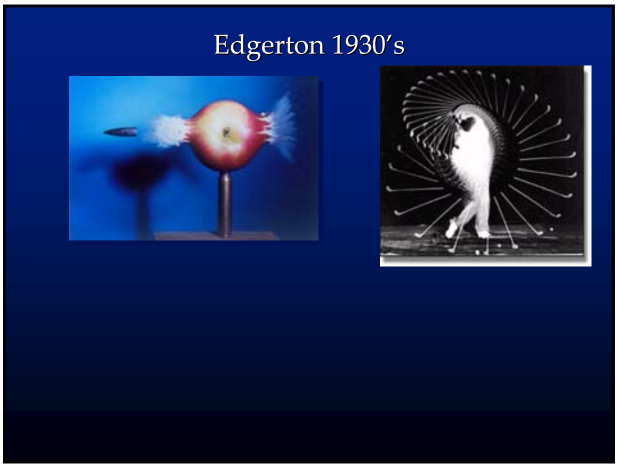

Computational Photography
Novel Illumination
Light Sources
Novel Cameras
Generalized
Sensor
Processing
Generalized
Optics
Scene: 8D Ray Modulator


Computational Photography
Novel Illumination
Light Sources
Novel Cameras
Generalized
Sensor
Processing
Generalized
Optics
Display
Recreate 4D Lightfield
Scene: 8D Ray Modulator

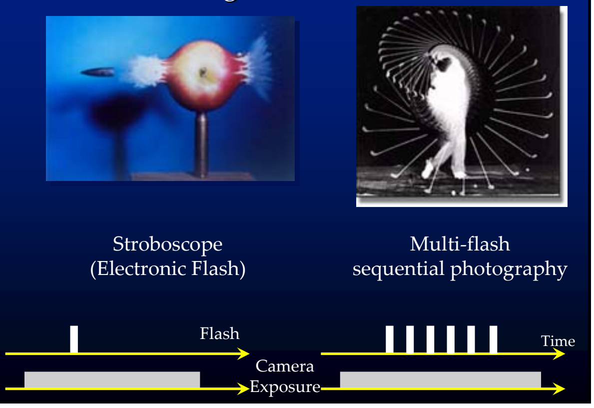

Computational Photography
Novel Illumination
Light Sources
Modulators
Generalized
Optics
4D Incident Lighting
Novel Cameras
Generalized
Sensor
Processing
Generalized
Optics
Ray
Reconstruction
Upto 4D
Ray Sampler
4D Ray Bender
4D Light Field
Display
Recreate 4D Lightfield
Scene: 8D Ray Modulator


Computational Illumination
Light Sources
Modulators
Generalized
Optics
Novel Cameras
Generalized
Sensor
Processing
Generalized
Optics
Ray
Reconstruction
Upto 4D
Ray Sampler
4D Ray Bender
Programmable
4D Illumination field +
time + wavelength
4D Light Field
Display
Recreate 4D Lightfield
Scene: 8D Ray Modulator


'Smarter' Lighting Equipment
What Parameters Can We Change ?


Edgerton 1930's

Edgerton 1930's



Computational Illumination:

Programmable 4D Illumination Field + Time + Wavelength

- Presence or Absence, Duration, Brightness
  - Flash/No-flash
- Light position
  - Multi-flash for depth edges
  - Programmable dome (image re-lighting and matting)
- Light color/wavelength
- Spatial Modulation
  - Synthetic Aperture Illumination
- Temporal Modulation
  - TV remote, Motion Tracking, Sony ID-cam, RFIG
- Exploiting (uncontrolled) natural lighting condition
  - Day/Night Fusion

Computational Illumination

- Presence or Absence, Duration, Brightness
  - Flash/No-flash
- Light position
  - Multi-flash for depth edges
  - Programmable dome (image re-lighting and matting)
- Light color/wavelength
- Spatial Modulation
  - Synthetic Aperture Illumination
- Temporal Modulation
  - TV remote, Motion Tracking, Sony ID-cam, RFIG
- General lighting condition
  - Day/Night

Denoising Challenging Images

Available light:

+ nice lighting

- noise/blurriness
- color

Flash:

+ details
+ color

- flat/artificial

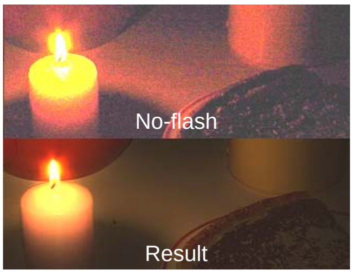
Elmar Eisemann and Frédo Durand , Flash Photography Enhancement via Intrinsic Relighting

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

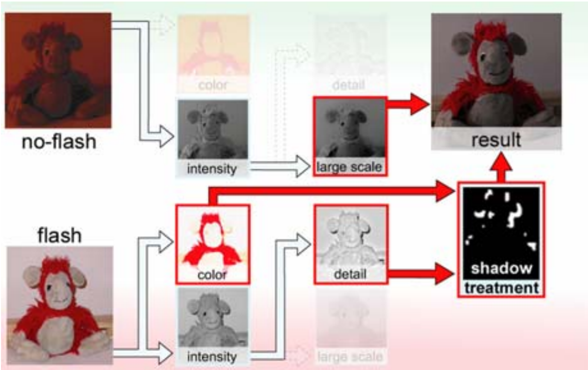
Denoise no-flash image using flash image

Transfer detail from flash image to no-flash image

+ original lighting
+ details/sharpness
+ color



Cross-Bilateral Filter based Approach



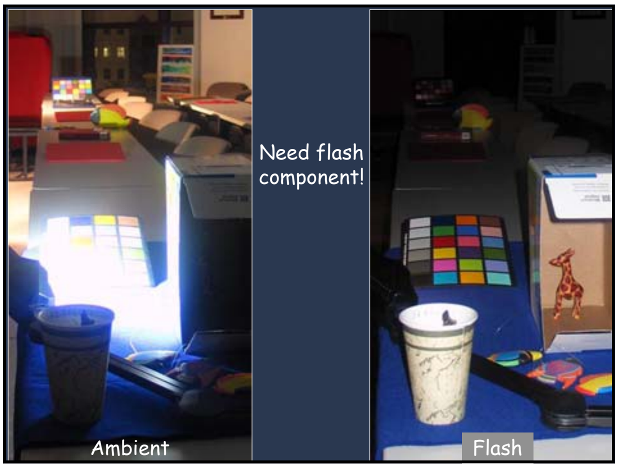
Cross Bilateral Filter

- When no-flash image is too noisy
- Borrow similarity from flash image
  - ➢ edge stopping from flash image

Detail Layer

Intensity / Large-scale = Detail

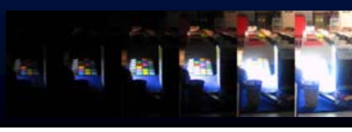
Recombination: Large scale * Detail = Intensity

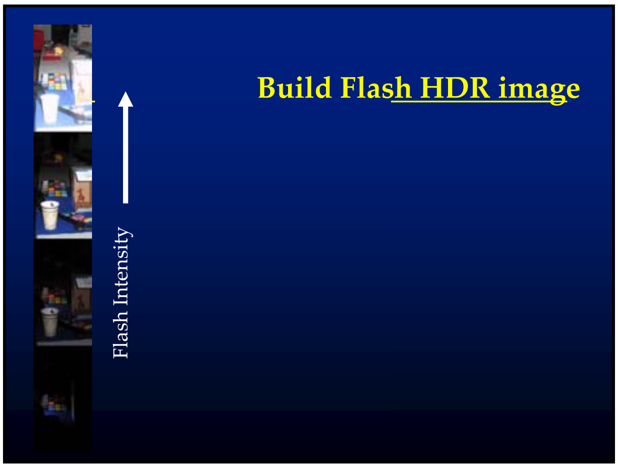


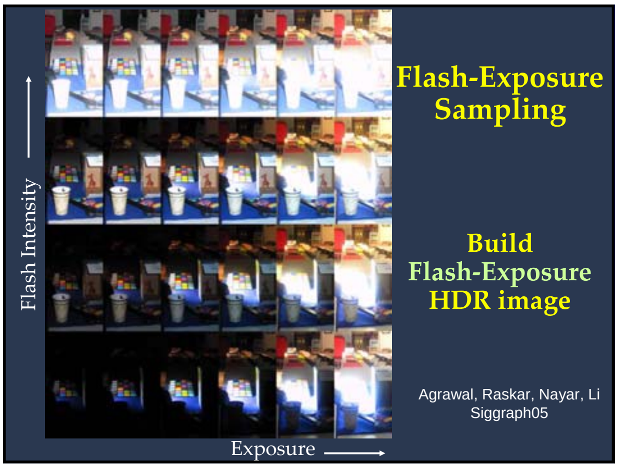
Build Exposure HDR image

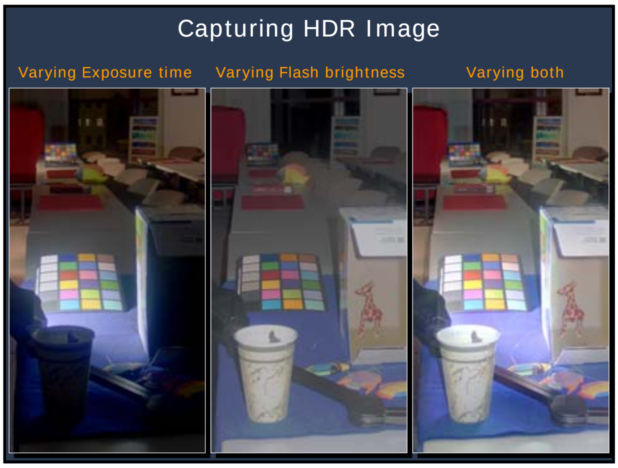
- Multiple images with different exposure
  - Debevec & Malik, Siggraph 97
  - Nayar & Mitsunaga, CVPR 00

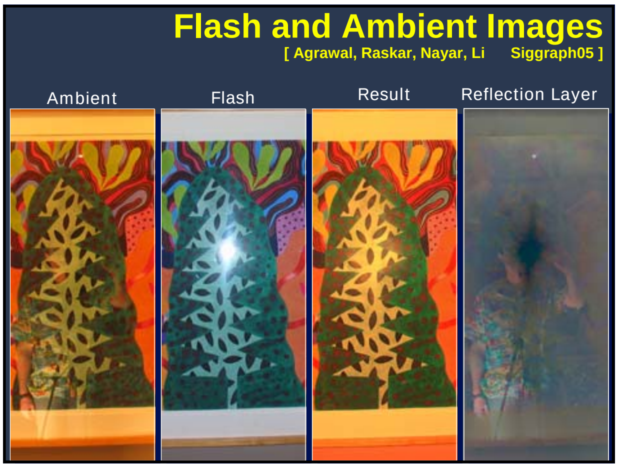
Increasing Exposure ⟶

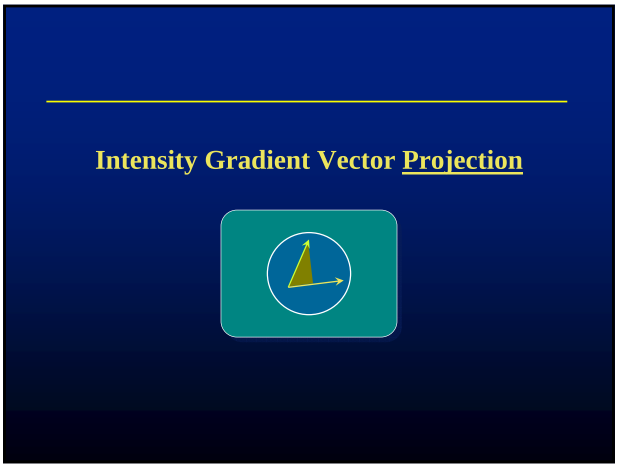


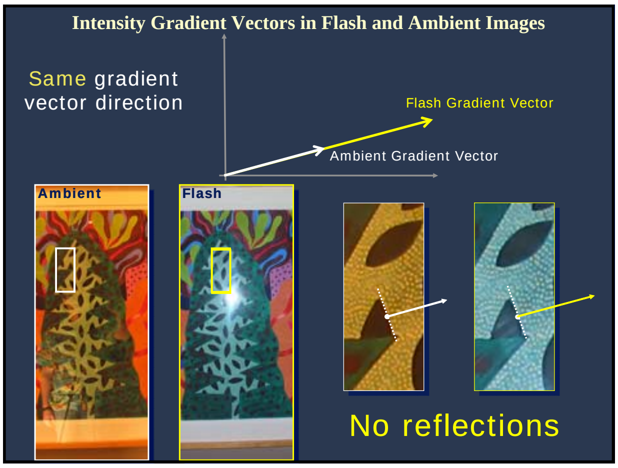

Build Flash HDR image
Flash Intensity

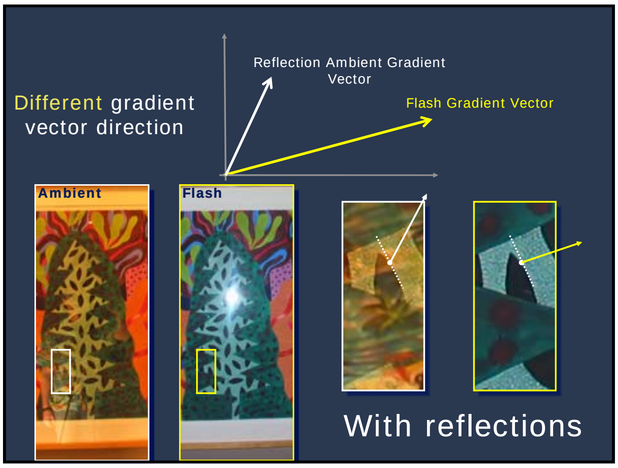

Flash-Exposure Sampling
Build Flash-Exposure HDR image
Agrawal, Raskar, Nayar, Li
Siggraph05
Flash Intensity
Exposure

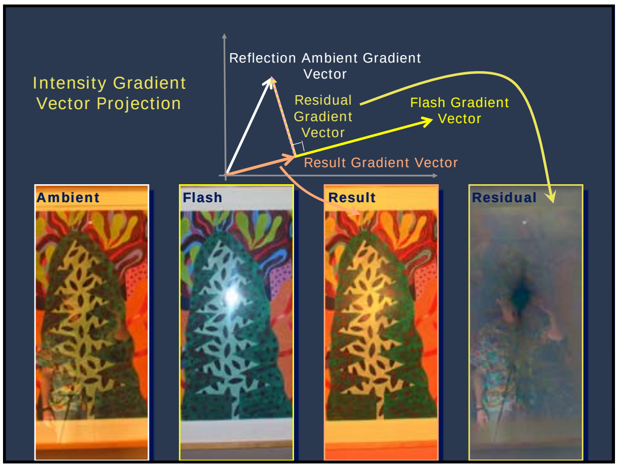

Capturing HDR Image
Varying Exposure time
Varying Flash brightness
Varying both

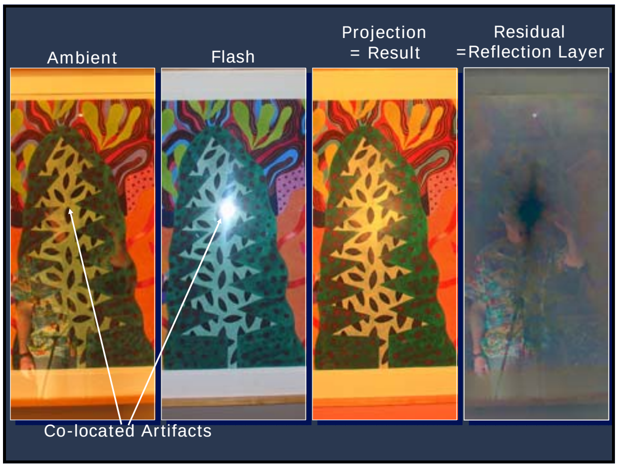

Flash and Ambient Images
[Agrawal, Raskar, Nayar, Li Siggraph05]
Ambient
Flash
Result
Reflection Layer


Intensity Gradient Vector Projection


Intensity Gradient Vectors in Flash and Ambient Images
Same gradient vector direction
Flash Gradient Vector
Ambient Gradient Vector
Ambient
Flash
No reflections







Computational Illumination

- Presence or Absence, Duration, Brightness
  - Flash/No-flash
- Light position
  - Programmable dome (image re-lighting and matting)
  - Multi-flash for depth edges
- Light color/wavelength
- Spatial Modulation
  - Synthetic Aperture Illumination
- Temporal Modulation
  - TV remote, Motion Tracking, Sony ID-cam, RFIG
- General lighting condition
  - Day/Night

Ramesh Raskar, Computational Illumination

Synthetic Lighting

Paul Haeberli, Jan 1992

Ramesh Raskar, Computational Illumination

Debevec et al. 2002: ‘Light Stage 3’

Ramesh Raskar, Computational Illumination

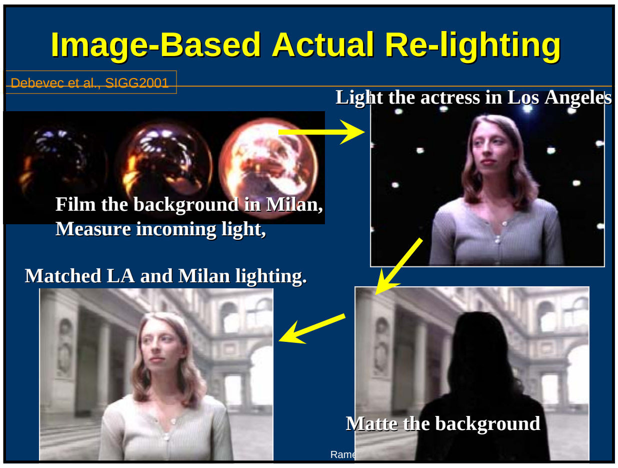
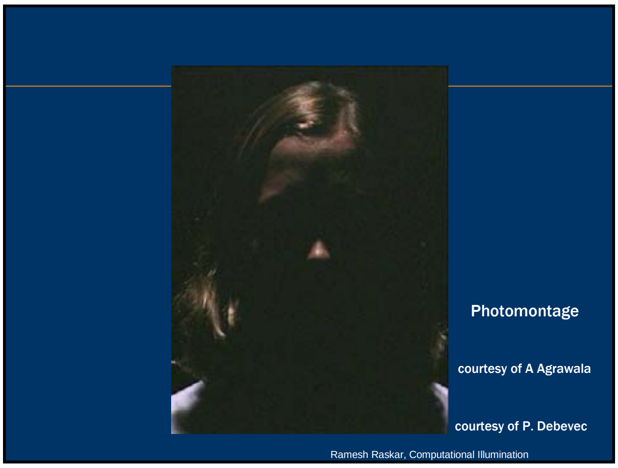


Image-Based Actual Re-lighting
Debevec et al., SIGG2001
Light the actress in Los Angeles
Film the background in Milan,
Measure incoming light,
Matched LA and Milan lighting.
Matte the background


Photomontage
courtesy of A Agrawala
courtesy of P. Debevec
Ramesh Raskar, Computational Illumination

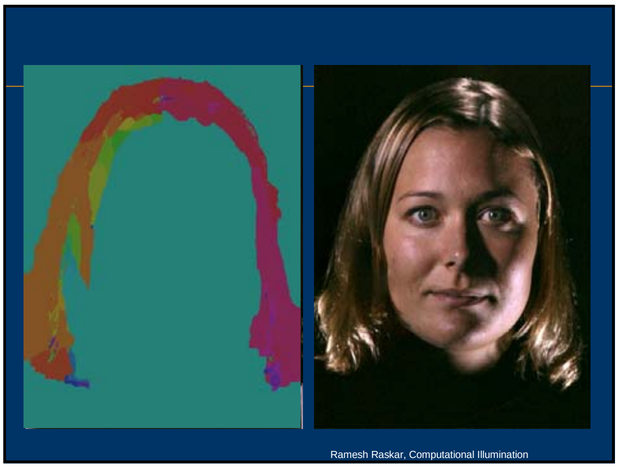
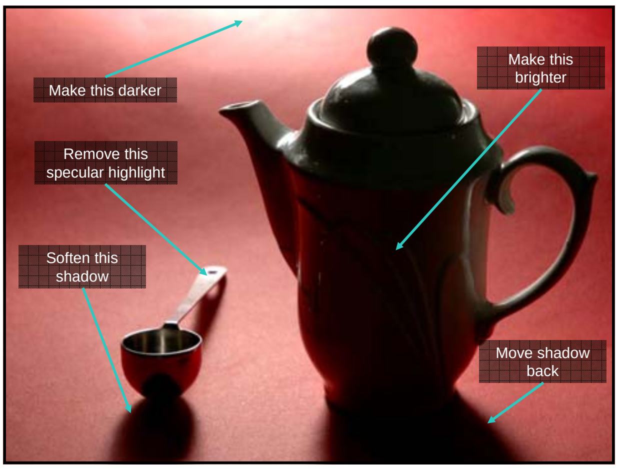
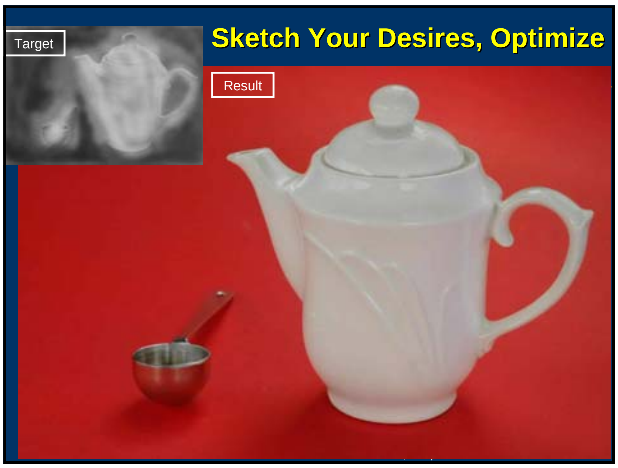

Ramesh Raskar, Computational Illumination

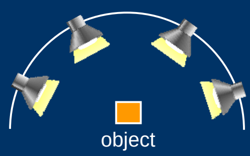

Table-top Computed Lighting for
Practical Digital Photography
Ankit Mohan, Jack Tumblin
Northwestern University
Bobby Bodenheimer
Vanderbilt University
Cindy Grimm, Reynold Bailey
Washington University in St. Louis
eurographics symposium on rendering 2005
Ramesh Raskar, Computational Illumination


Make this darker
Make this brighter
Remove this specular highlight
Soften this shadow
Move shadow back

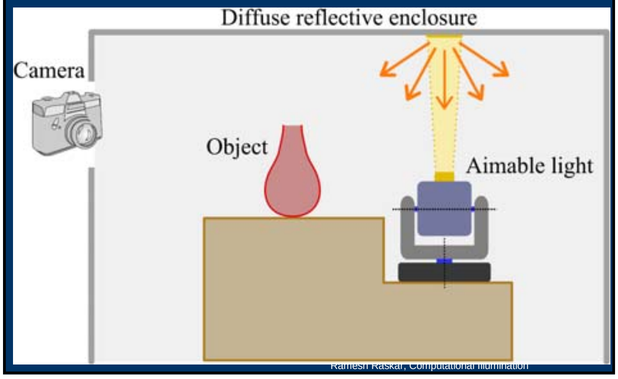

Sketch Your Desires, Optimize
Target
Result

Acquisition for Relighting

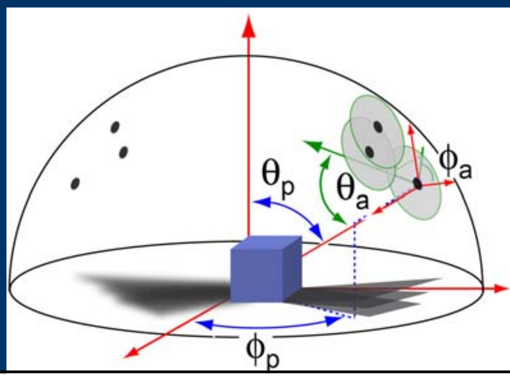
- Uniquely lit basis images
- Known light-positions



'Aimed Spot': low-risk movement

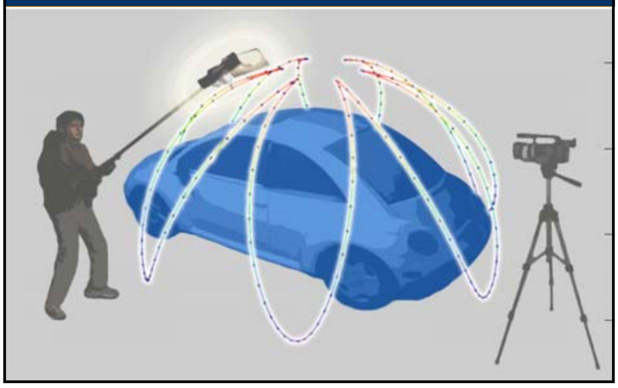


Overlapped Spots avoid aliasing

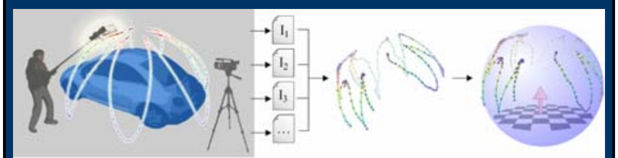


"Light Waving"

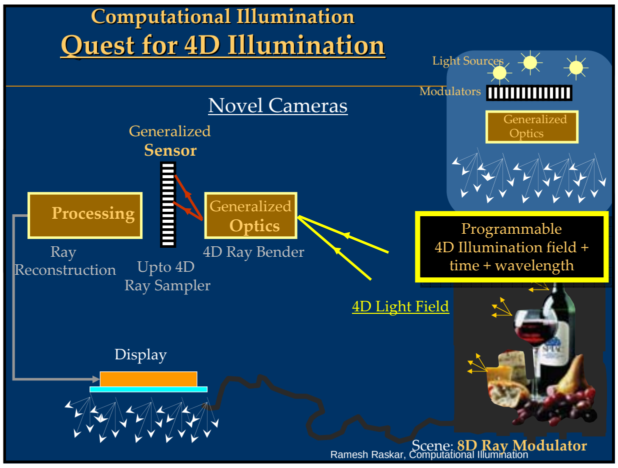
Tech Sketch (Winnemoller, Mohan, Tumblin, Gooch)

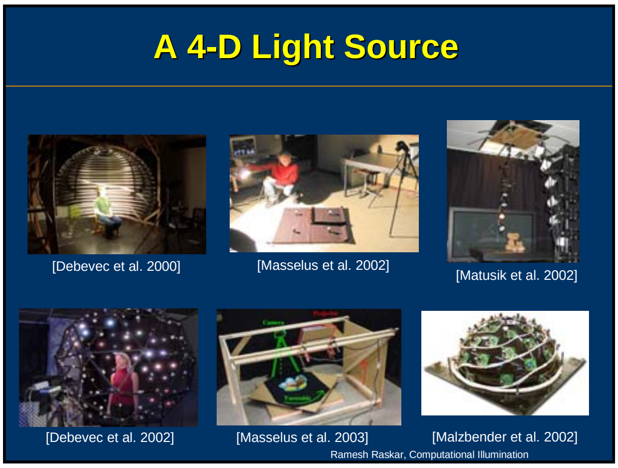


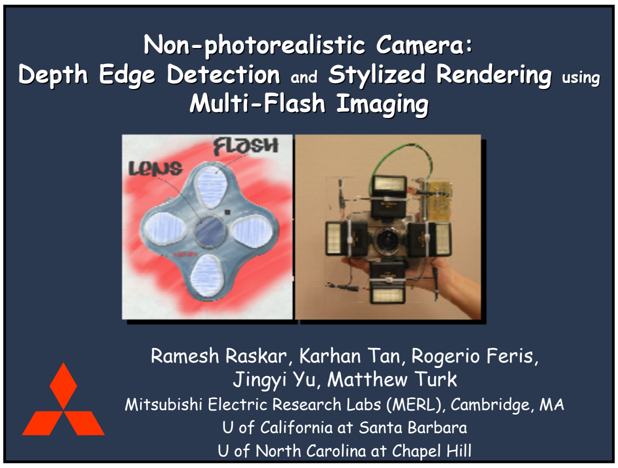
Light Waving: Estimating Light Positions From Photographs Alone

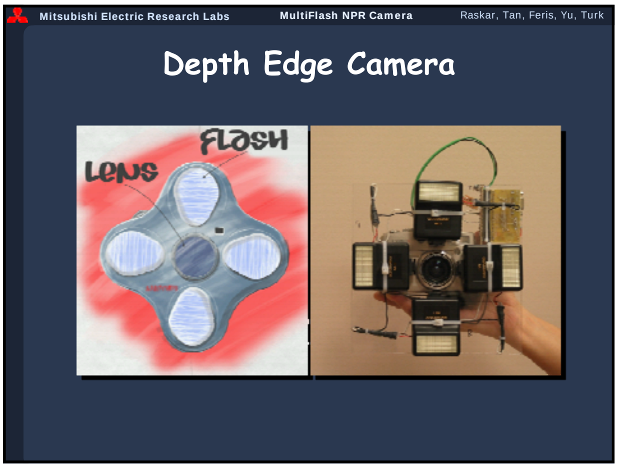


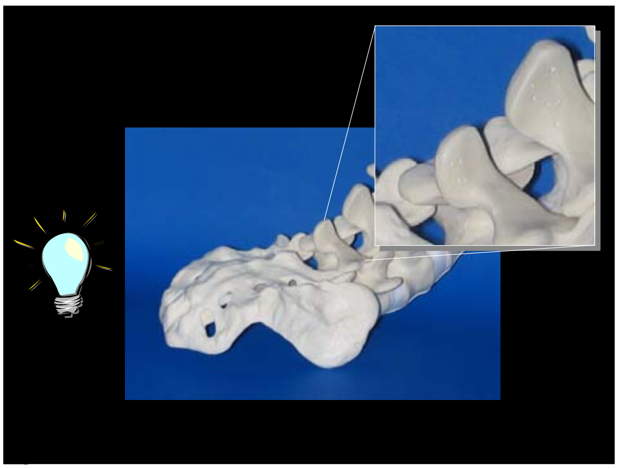
Holger Winnemöller, Ankit Mohan, Jack Tumblin, Bruce Gooch
Northwestern University

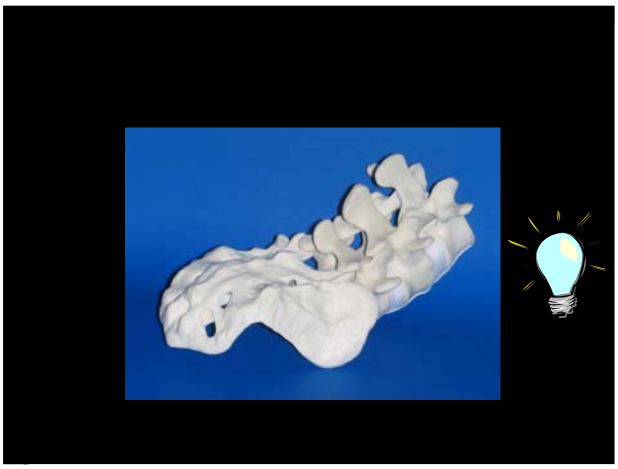

Computational Illumination
Quest for 4D Illumination
Light Sources
Modulators
Generalized Optics
Novel Cameras
Generalized Sensor
Processing
Generalized Optics
Ray Reconstruction
Upto 4D Ray Sampler
4D Ray Bender
Programmable 4D Illumination field + time + wavelength
4D Light Field
Display
Scene: 8D Ray Modulator
Ramesh Raskar, Computational Illumination


A 4-D Light Source
[Debevec et al. 2000]
[Masselus et al. 2002]
[Matusik et al. 2002]
[Debevec et al. 2002]
[Masselus et al. 2003]
[Malzbender et al. 2002]
Ramesh Raskar, Computational Illumination

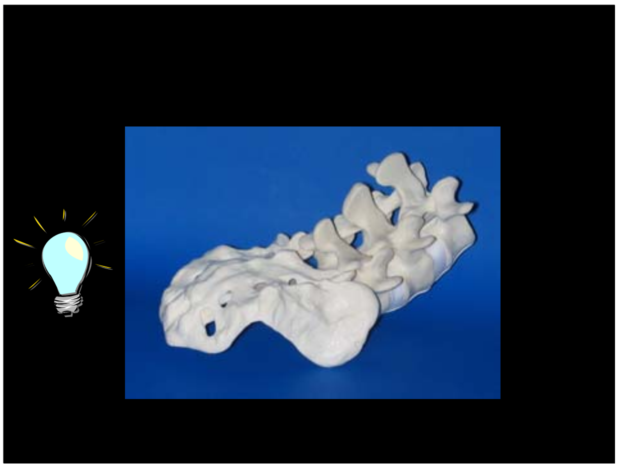

Non-photorealistic Camera:
Depth Edge Detection and Stylized Rendering using Multi-Flash Imaging
FLASH
LENS
Ramesh Raskar, Karhan Tan, Rogerio Feris,
Jingyi Yu, Matthew Turk
Mitsubishi Electric Research Labs (MERL), Cambridge, MA
U of California at Santa Barbara
U of North Carolina at Chapel Hill

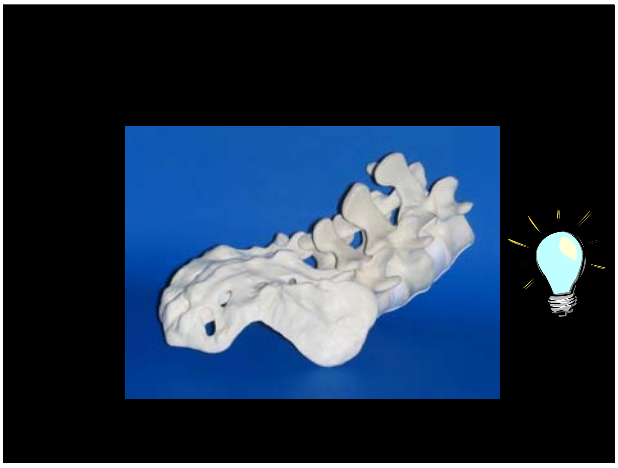

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Depth Edge Camera
FLASH
LENS

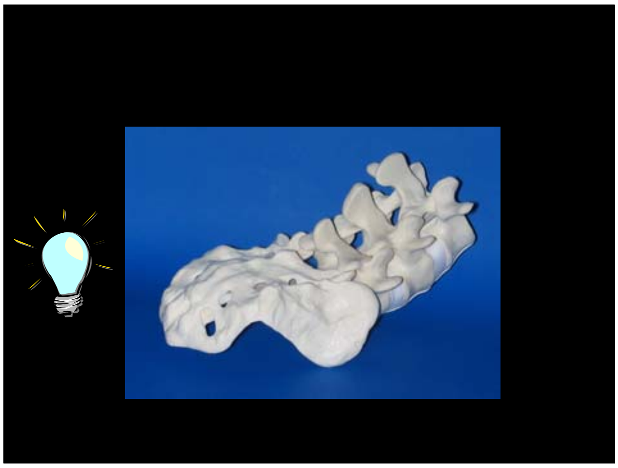


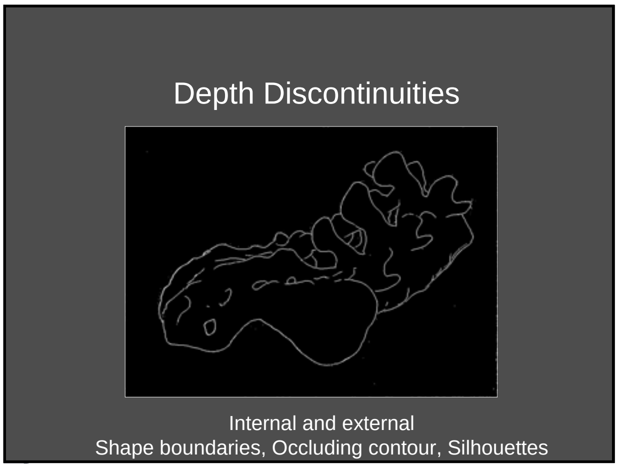


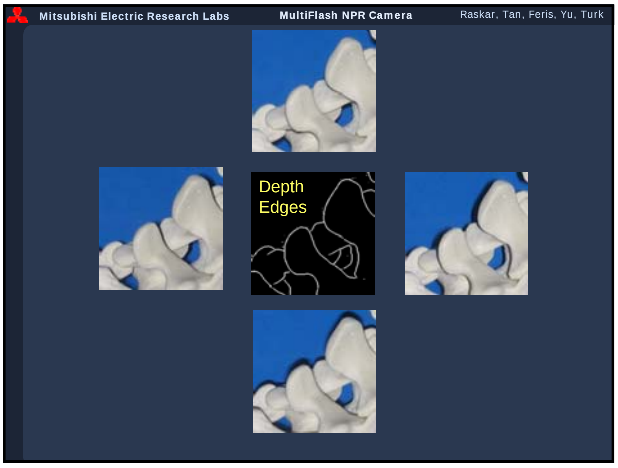


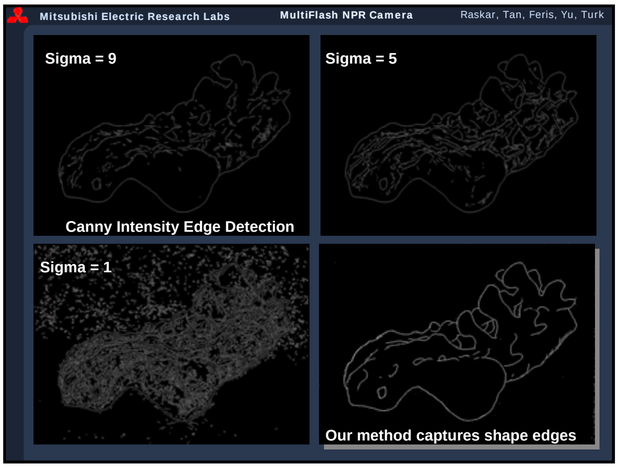


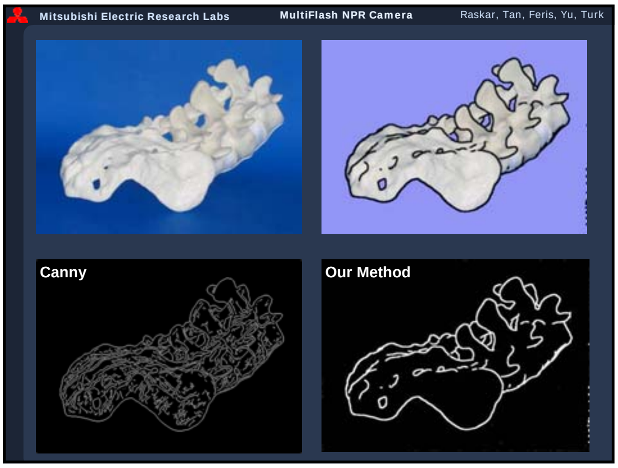


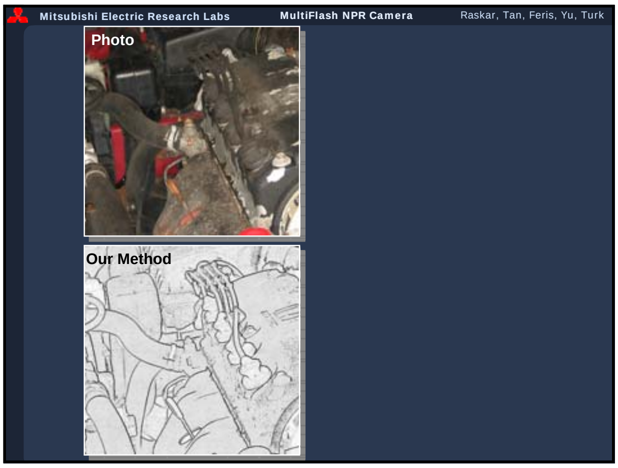



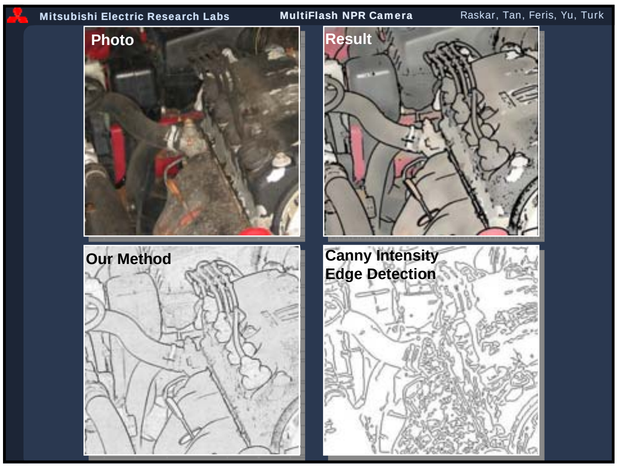

Depth Discontinuities
Internal and external
Shape boundaries, Occluding contour, Silhouettes

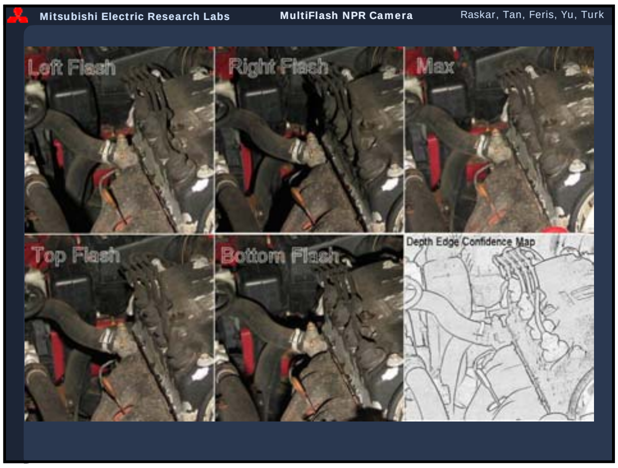

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Depth
Edges

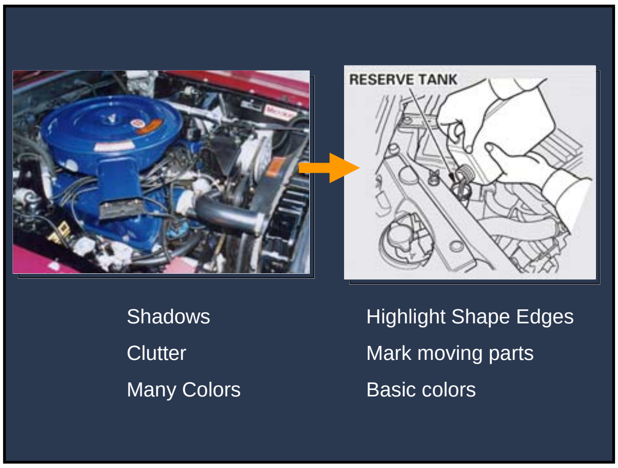

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Sigma = 9
Sigma = 5
Canny Intensity Edge Detection
Sigma = 1
Our method captures shape edges

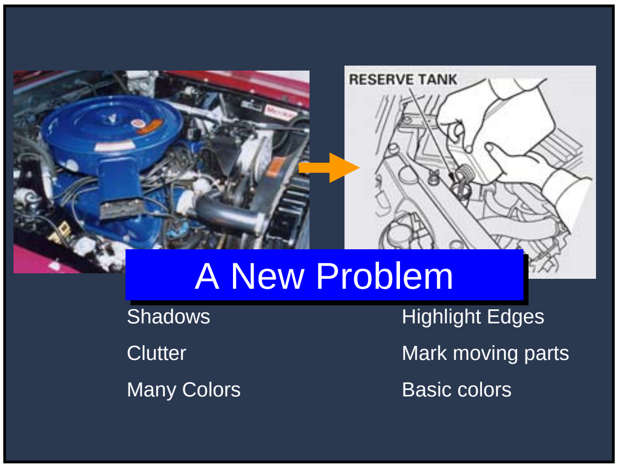

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Canny
Our Method

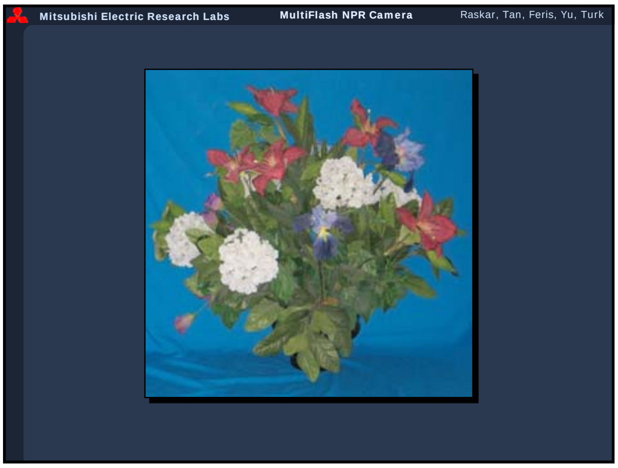

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Photo
Our Method

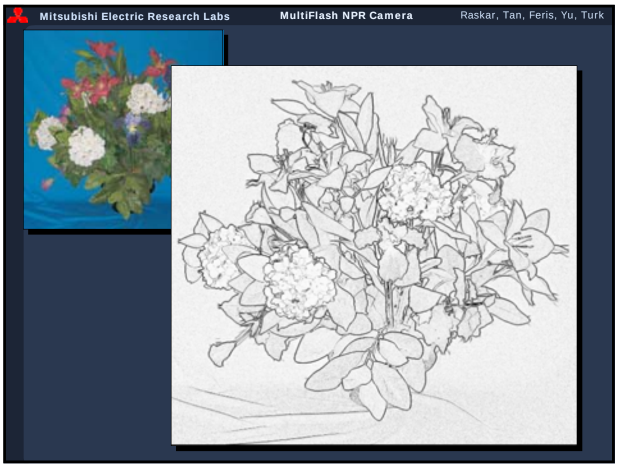

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Photo
Result
Our Method
Canny Intensity
Edge Detection

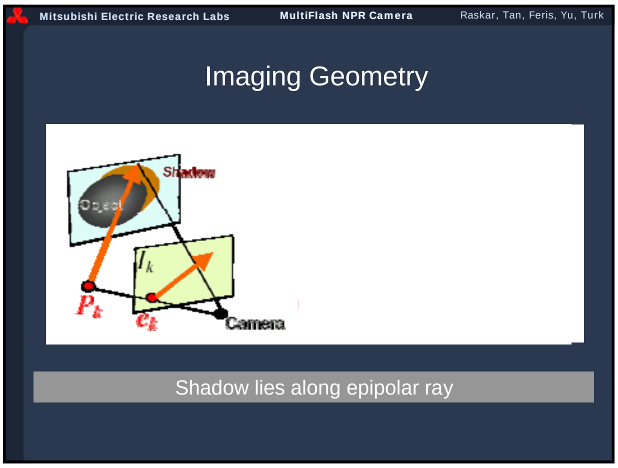

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Left Flash
Right Flash
Max
Top Flash
Bottom Flash
Depth Edge Confidence Map

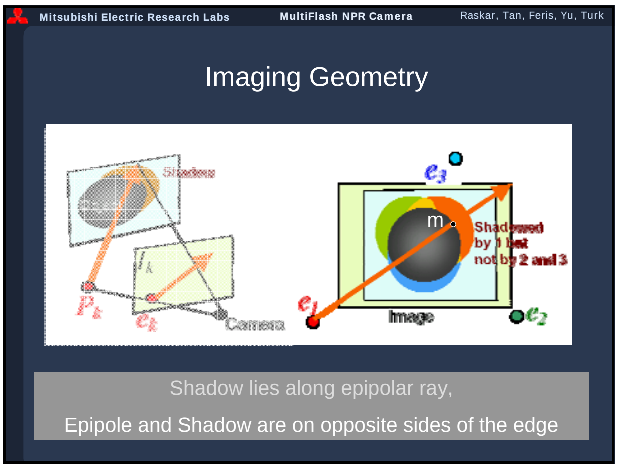

RESERVE TANK
Shadows
Clutter
Many Colors
Highlight Shape Edges
Mark moving parts
Basic colors

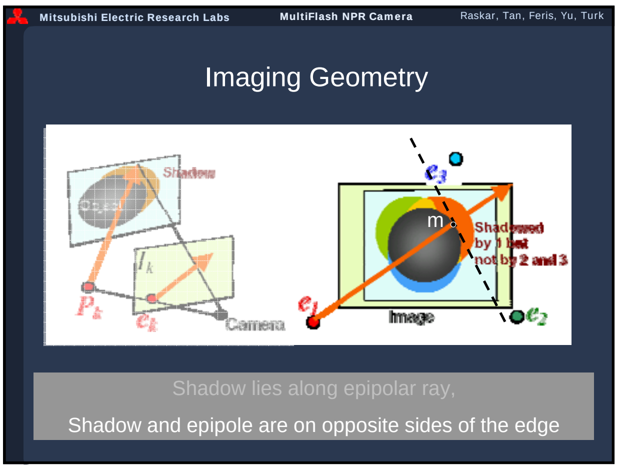

RESERVE TANK
A New Problem
Shadows
Clutter
Many Colors
Highlight Edges
Mark moving parts
Basic colors


Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk

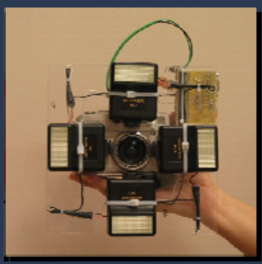

Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk


Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Imaging Geometry
Shadow
Camera
Shadow lies along epipolar ray


Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Imaging Geometry
Shadow
Camera
m
Shadowed by 1 but not by 2 and 3
Image
Shadow lies along epipolar ray,
Epipole and Shadow are on opposite sides of the edge


Mitsubishi Electric Research Labs
MultiFlash NPR Camera
Raskar, Tan, Feris, Yu, Turk
Imaging Geometry
Shadow
Camera
m
Shadowed by 1 but not by 2 and 3
Image
Shadow lies along epipolar ray,
Shadow and epipole are on opposite sides of the edge

Depth Edge Camera



Light epipolar rays are horizontal or vertical

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Input

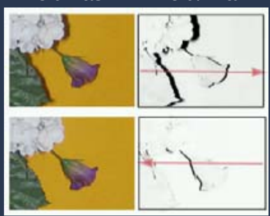
Left Flash

Right Flash

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Input | Normalized

Left Flash Left / Max

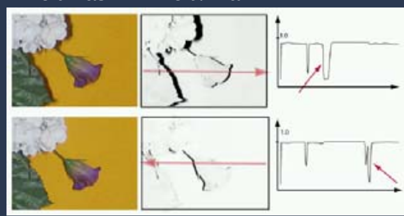


Right Flash Right / Max

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Input | Normalized | Plot

Left Flash Left / Max



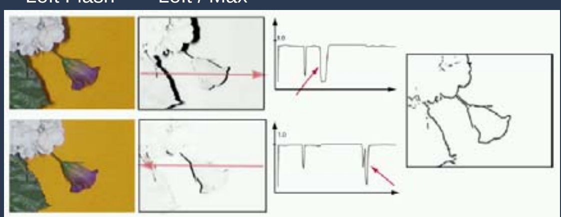
Right Flash Right / Max

Negative transition along epipolar ray is depth edge

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Input | Normalized | Plot | U{depth edges}

Left Flash Left / Max



Right Flash Right / Max

Negative transition along epipolar ray is depth edge

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

```
% Max composite
maximg = max( left, right, top, bottom);

% Normalize by computing ratio images
r1 = left./ maximg;          r2 = top ./ maximg;
r3 = right ./ maximg;        r4 = bottom ./ maximg;

% Compute confidence map
v = fspecial( 'sobel' ); h = v';
d1 = imfilter( r1, v ); d3 = imfilter( r3, v );  % vertical sobel
d2 = imfilter( r2, h ); d4 = imfilter( r4, h ); % horizontal sobel

%Keep only negative transitions
silhouette1 = d1 .* (d1>0);
silhouette2 = abs( d2 .* (d2<0) );
silhouette3 = abs( d3 .* (d3<0) );
silhouette4 = d4 .* (d4>0);

%Pick max confidence in each
confidence = max(silhouette1, silhouette2, silhouette3, silhouette4);
imwrite( confidence, 'confidence.bmp');
```

No magic parameters !

Related Work

- Stylized image processing
  - [Hertzmann 98] [DeCarlo and Santella 02][Waking Life]
    - Relies on segmentation of image,
    - Stylization rather than comprehension
- Shape from shadow
  - Shadow grams [Savarese et al 01]
    - Look at smooth surfaces
  - Building heights [Lin et al 1998]
    - Assumes flat ground and uniform albedo

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Comparison
Less data but more robust

- Traditional stereo (camera pair)
  - Correspondence matching fails at depth edges
  - Requires texture
- Photometric stereo (moving light source)
  - For smooth surfaces, fails at depth edges
  - Large lighting variation required
  - Not a self-contained device
- 3D range scanners
  - Expensive, low resolution, low frame rate

Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Limitations

- Difficult conditions
  - Outdoor, bright scenes
  - Transparent, low albedo, mirror-like surfaces
  - Thin narrow objects
- Issues
  - Baseline between camera and flash
  - Specularities
  - Flash non-uniformity, area light source
- Comprehensibility
  - Sharp edges not captured

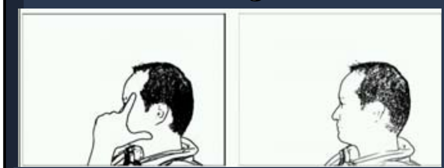
Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Change Detection

Before After

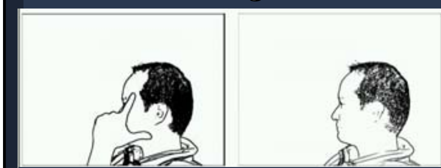
Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

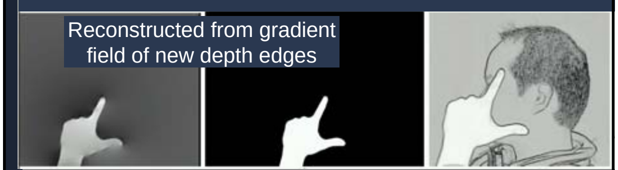
Change Detection



Mitsubishi Electric Research Labs MultiFlash NPR Camera Raskar, Tan, Feris, Yu, Turk

Change Detection





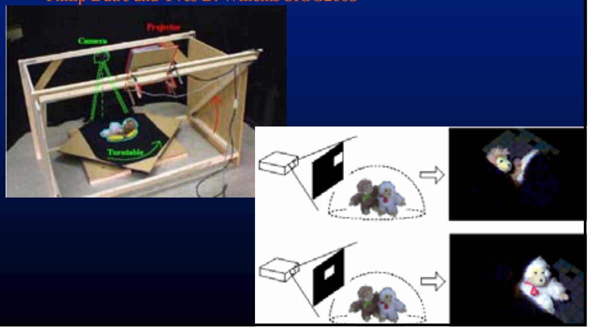
Computational Illumination

- Presence or Absence
  - Flash/No-flash
- Light position
  - Multi-flash for depth edges
  - Programmable dome (image re-lighting and matting)
- Light color/wavelength
- Spatial Modulation (Intra-flash 2D Modulation)
  - Synthetic Aperture Illumination
- Temporal Modulation
  - TV remote, Motion Tracking, Sony ID-cam, RFIG
- General lighting condition
  - Day/Night

Ramesh Raskar, Computational Illumination

6-D Methods and beyond...

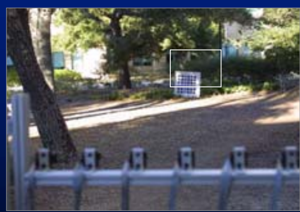
Relighting with 4D Incident Light Fields Vincent Masselus, Pieter Peers, Philip Dutre and Yves D. Willems SIGG2003



Synthetic Aperture Illumination: Comparison with Long-range synthetic aperture photography

- width of aperture 6’
- number of cameras 45
- spacing between cameras 5”
- camera’s field of view 4.5°

The scene



- distance to occluder 110’
- distance to targets 125’
- field of view at target 10’

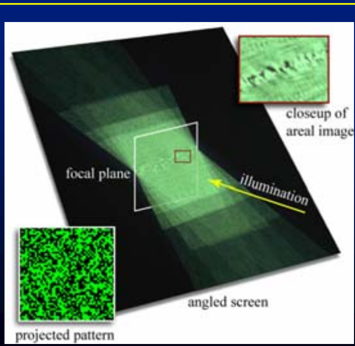
Synthetic aperture photography using an array of mirrors

- 11-megapixel camera (4064 x 2047 pixels)
- 18 x 12 inch effective aperture, 9 feet to scene
- 22 mirrors, tilted inwards → 22 views, each 750 x 500 pixels

Synthetic aperture illumination

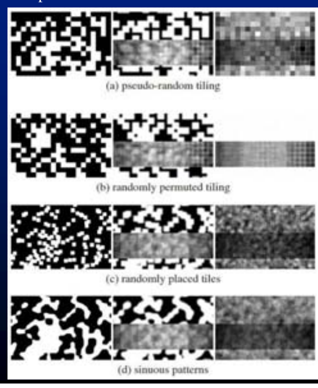
- technologies
  - array of projectors
  - array of microprojectors
  - single projector + array of mirrors

What does synthetic aperture illumination look like?

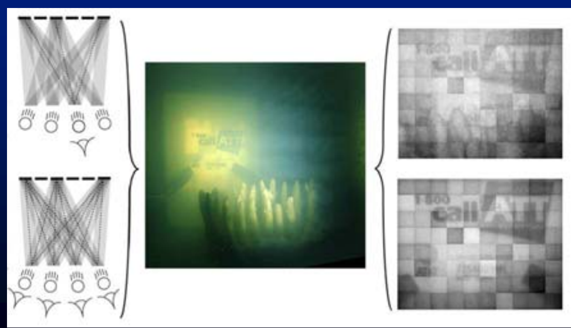


What are good patterns?

pattern | one trial | 16 trials



Underwater confocal imaging with and without SAP

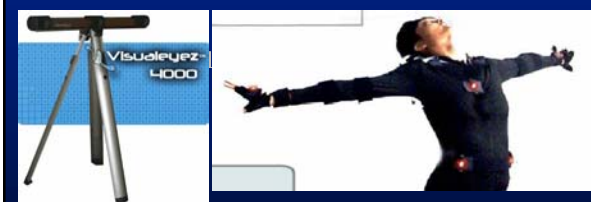


Computational Illumination

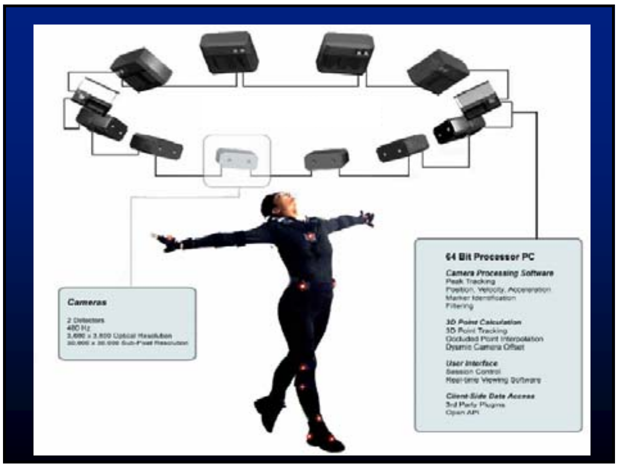
- Presence or Absence
  - Flash/No-flash
- Light position
  - Multi-flash for depth edges
  - Programmable dome (image re-lighting and matting)
- Light color/wavelength
- Spatial Modulation
  - Synthetic Aperture Illumination
- Temporal Modulation
  - TV remote, Motion Tracking, Sony ID-cam, RFIG
- General lighting condition
  - Day/Night

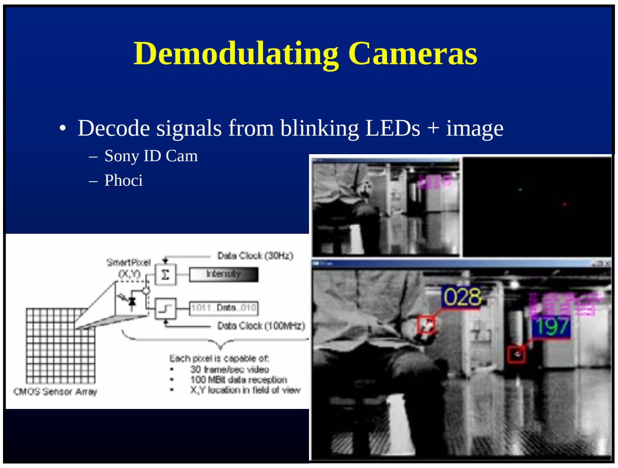
Ramesh Raskar, Computational Illumination

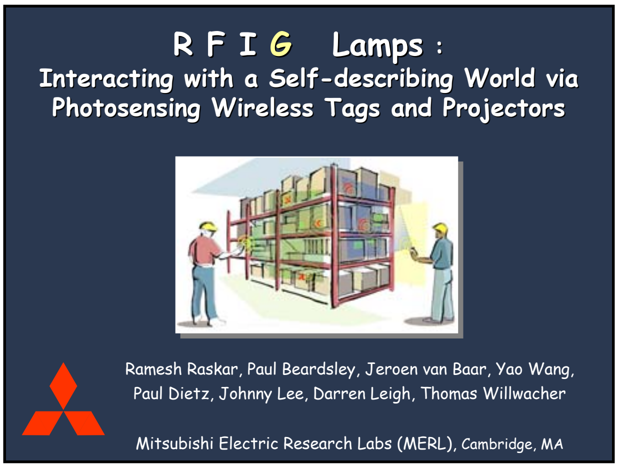
Demodulating Cameras

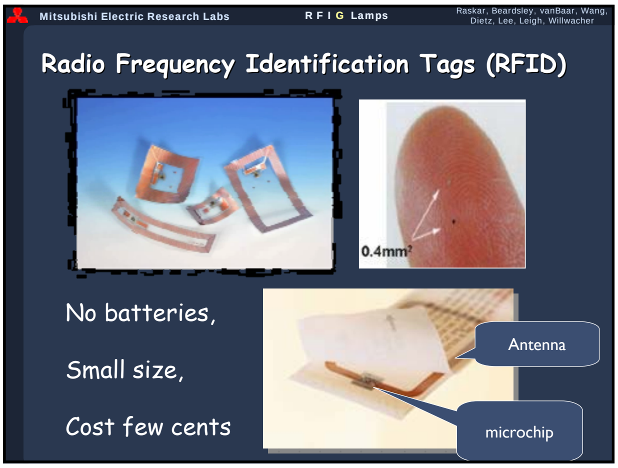


- Motion Capture Cameras
  - Visualeyez™ VZ4000 Tracking System
  - PhaseSpace motion digitizer

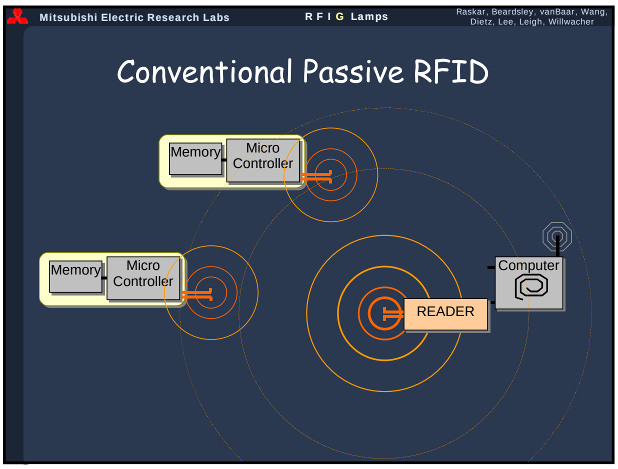

64 Bit Processor PC
Cameras


Demodulating Cameras
• Decode signals from blinking LEDs + image
– Sony ID Cam
– Phoci
SmartPixel
(X,Y)
Intensity
Data Clock (30Hz)
Data Clock (100MHz)
CMOS Sensor Array
Each pixel is capable of:
30 frame/sec video
100 MBit data reception
X,Y location in field of view
028
197


R F I G Lamps :
Interacting with a Self-describing World via
Photosensing Wireless Tags and Projectors
Ramesh Raskar, Paul Beardsley, Jeroen van Baar, Yao Wang,
Paul Dietz, Johnny Lee, Darren Leigh, Thomas Willwacher
Mitsubishi Electric Research Labs (MERL), Cambridge, MA

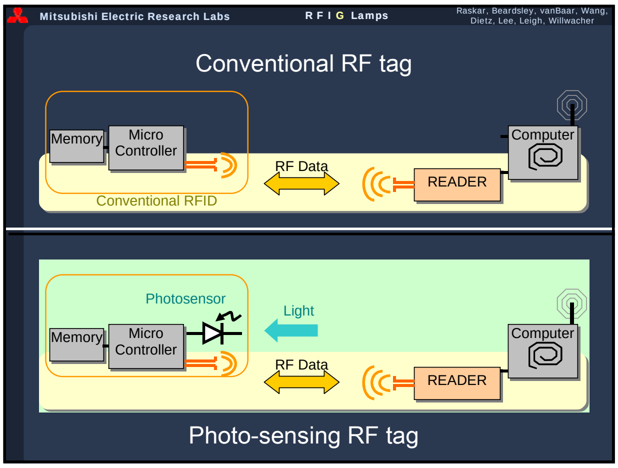

Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Radio Frequency Identification Tags (RFID)
0.4mm²
No batteries,
Small size,
Cost few cents
Antenna
microchip

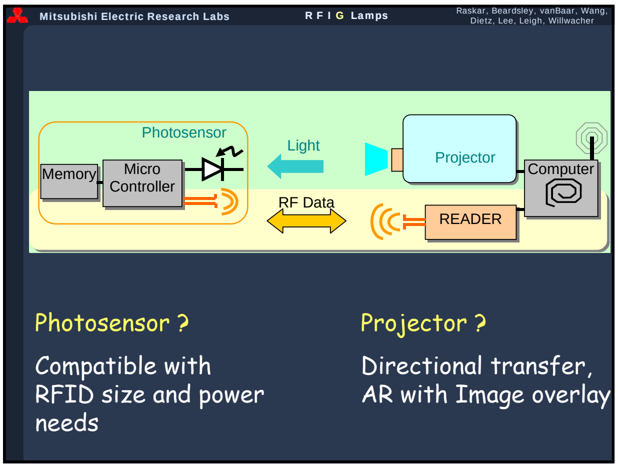

Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Warehousing
Routing
Livestock tracking
Library
Baggage handling
Currency

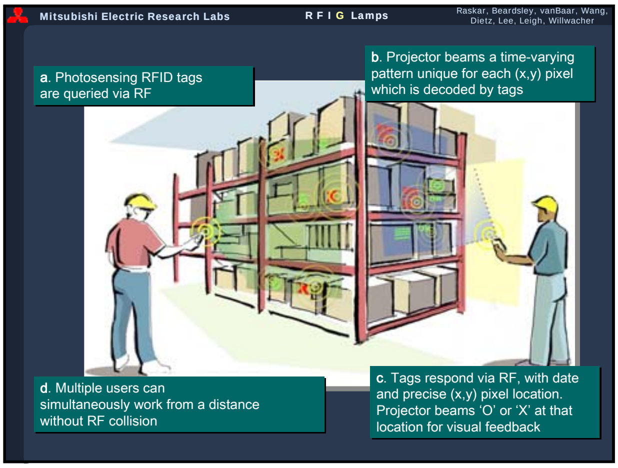

Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Conventional Passive RFID
Memory
Micro Controller
Memory
Micro Controller
READER
Computer


Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Tagged Books in a Library
✓ Id
Easy to get list of books in RF range
✗ No Precise Location Data
Difficult to find if the books in sorted order ?
Which book is upside down ?


Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Where are boxes with
Products close to Expiry Date ?


Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Conventional RF tag
Memory
Micro Controller
RF Data
READER
Computer
Conventional RFID
Photosensor
Memory
Micro Controller
Light
RF Data
READER
Computer
Photo-sensing RF tag


Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Photosensor
Memory
Micro Controller
Light
Projector
Computer
RF Data
READER
Photosensor ?
Compatible with RFID size and power needs
Projector ?
Directional transfer, AR with Image overlay


Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
a. Photosensing RFID tags are queried via RF
b. Projector beams a time-varying pattern unique for each (x,y) pixel which is decoded by tags
d. Multiple users can simultaneously work from a distance without RF collision
c. Tags respond via RF, with date and precise (x,y) pixel location. Projector beams 'O' or 'X' at that location for visual feedback


Mitsubishi Electric Research Labs
R F I G Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher

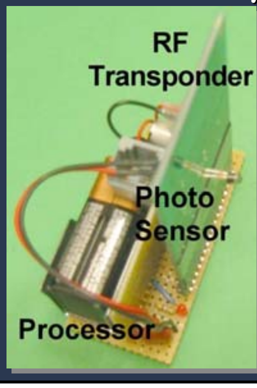
RFID

(Radio Frequency Identification)

RFIG

(Radio Frequency Id and Geometry)

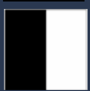
Prototype Tag



RF tag + photosensor

Projected Sequential Frames

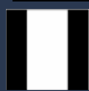
Pattern MSB | Pattern MSB-1 | – – – – | Pattern LSB



- Handheld Projector beams binary coded stripes
- Tags decode temporal code

Projected Sequential Frames

Pattern MSB | Pattern MSB-1 | – – – – | Pattern LSB



- Handheld Projector beams binary coded stripes
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Projected Sequential Frames

Pattern MSB | Pattern MSB-1 | – – – – | Pattern LSB

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Projected Sequential Frames

Pattern MSB | Pattern MSB-1 | – – – – | Pattern LSB

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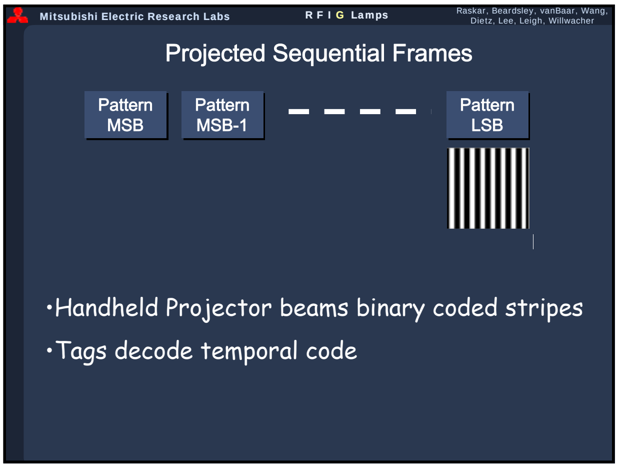
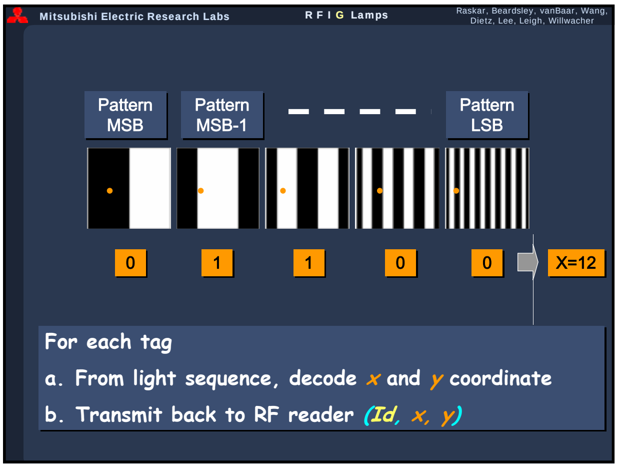
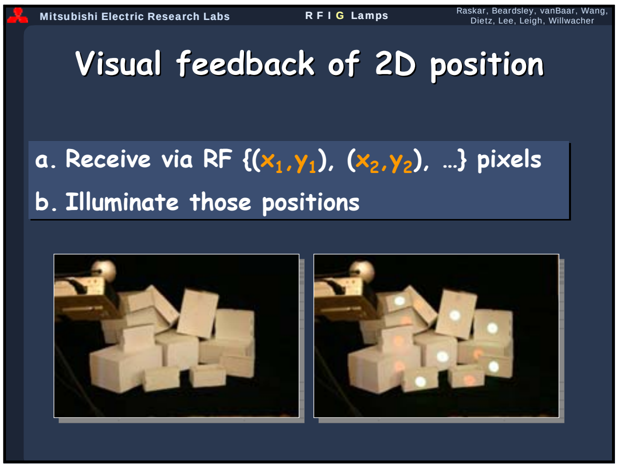
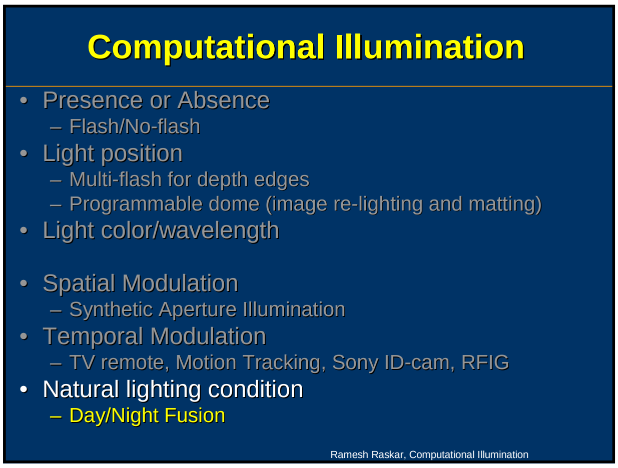
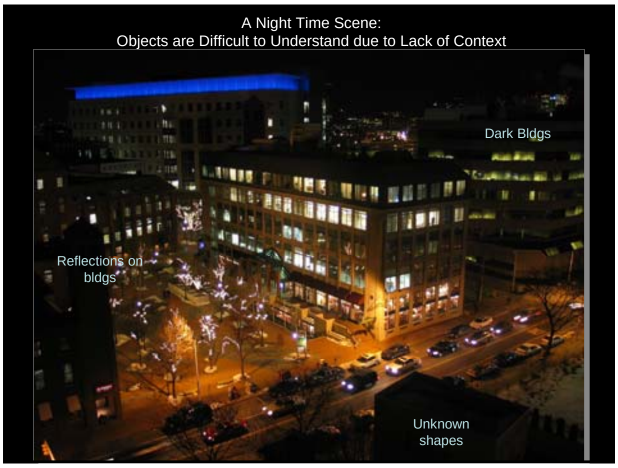

Mitsubishi Electric Research Labs
RFIG Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Projected Sequential Frames
Pattern MSB
Pattern MSB-1
Pattern LSB
•Handheld Projector beams binary coded stripes
•Tags decode temporal code

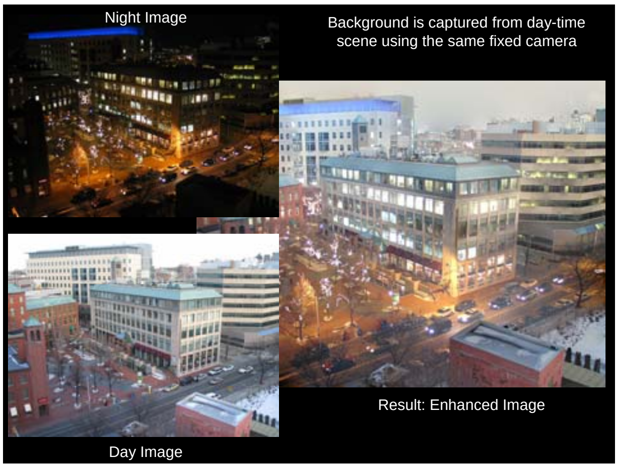

Mitsubishi Electric Research Labs
RFIG Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Pattern MSB
Pattern MSB-1
Pattern LSB
0
1
1
0
0
X=12
For each tag
a. From light sequence, decode x and y coordinate
b. Transmit back to RF reader (Id, x, y)


Mitsubishi Electric Research Labs
RFIG Lamps
Raskar, Beardsley, vanBaar, Wang, Dietz, Lee, Leigh, Willwacher
Visual feedback of 2D position
a. Receive via RF {(x_1,y_1), (x_2,y_2), …} pixels
b. Illuminate those positions


Computational Illumination
• Presence or Absence
– Flash/No-flash
• Light position
– Multi-flash for depth edges
– Programmable dome (image re-lighting and matting)
• Light color/wavelength
• Spatial Modulation
– Synthetic Aperture Illumination
• Temporal Modulation
– TV remote, Motion Tracking, Sony ID-cam, RFIG
• Natural lighting condition
– Day/Night Fusion
Ramesh Raskar, Computational Illumination

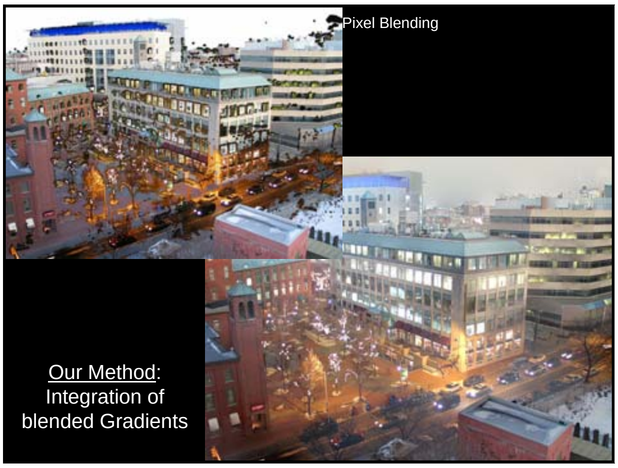

A Night Time Scene:
Objects are Difficult to Understand due to Lack of Context
Dark Bldgs
Reflections on bldgs
Unknown shapes

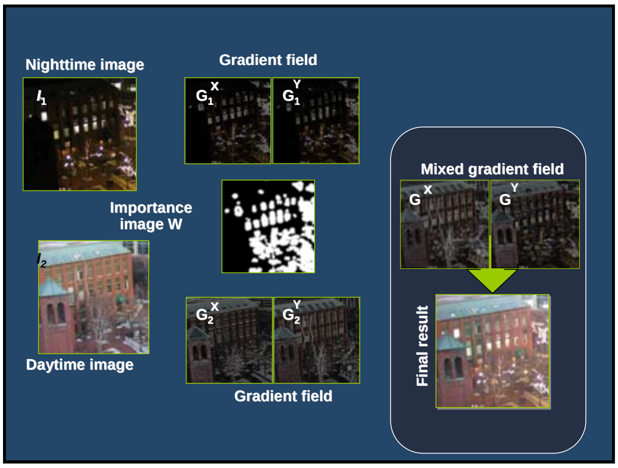

Enhanced Context :
All features from night scene are preserved, but background in clear
'Well-lit' Bldgs
Reflections in bldgs windows
Tree, Street shapes

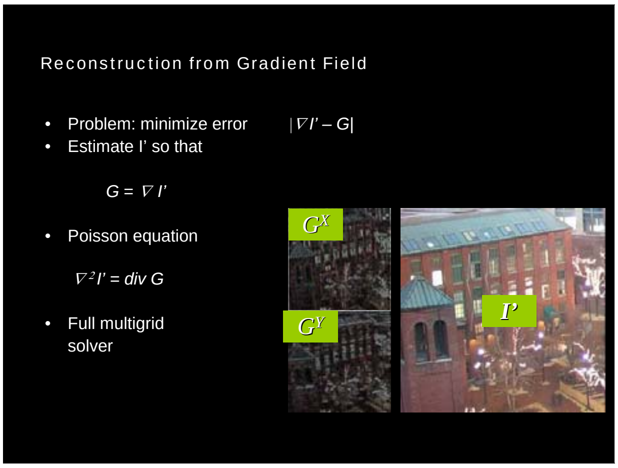

Night Image
Background is captured from day-time scene using the same fixed camera
Result: Enhanced Image
Day Image


Mask is automatically computed from scene contrast


But, Simple Pixel Blending Creates Ugly Artifacts

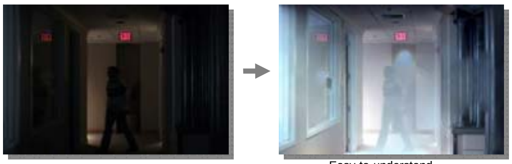

Pixel Blending
Our Method: Integration of blended Gradients


Nighttime image
Gradient field
Importance image W
Daytime image
Gradient field
Mixed gradient field
Final result


Reconstruction from Gradient Field
Problem: minimize error |∇I' – G|
Estimate I' so that
G = ∇I'
Poisson equation
∇²I' = div G
Full multigrid solver
G^X
G^Y
I'

Video Enhancement using Fusion

- Video from fixed cameras
  - Improve low quality InfraRed video using high-quality visible video
  - Fill in dark areas, enhance change in intensity
  - Output style: better context
- Current Demo
  - Fusion of Night video and Daytime image

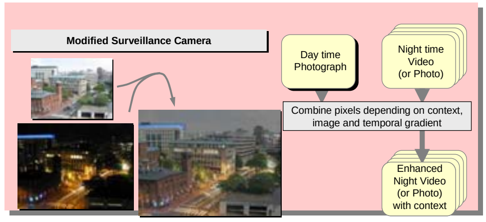


Original Video Frame

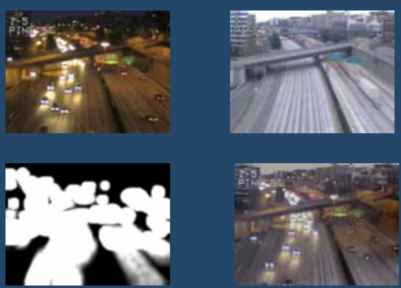
Easy-to-understand
Non-photorealistic (NPR)
Image or Video

Details

- Combine day and night time images
  - Night videos have low contrast, areas with no detail
  - Same camera during day can capture static information
  - Dark areas of night video are replaced to provide context
  - Moving object (from night) + Static scene (from day)



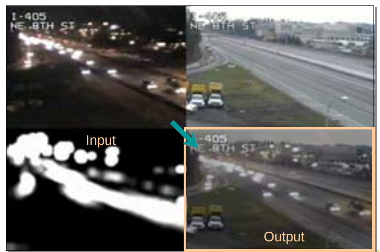
Video Enhancement



Overview of Process

Original night time traffic camera 320x240 video

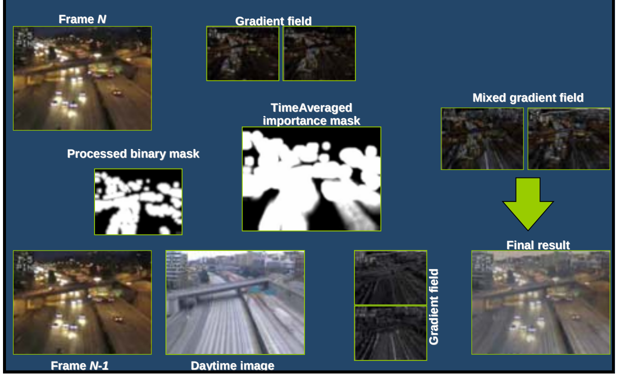
Day time image: By averaging 5 seconds of day video



Mask frame (for frame above): Encodes pixel with intensity change

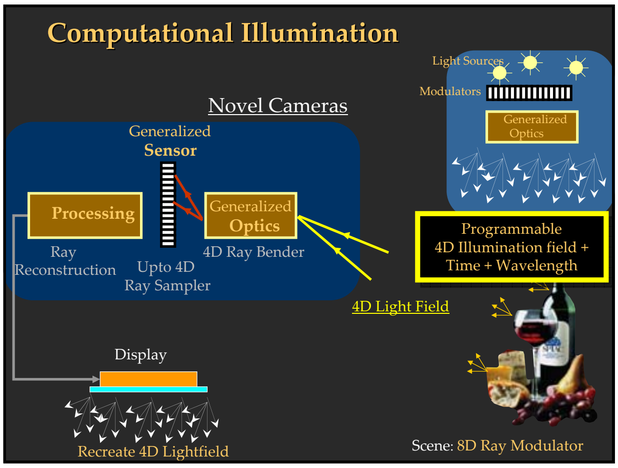
Enhanced video
Note: exit ramp, lane dividers, buildings not visible in original night video, but clearly seen here.

Algorithm



‘Smarter’ Lighting Equipment

Programmable Parameters



Computational Illumination:

Programmable 4D Illumination Field + Time + Wavelength

- Presence or Absence, Duration, Brightness
  - Flash/No-flash
- Light position
  - Multi-flash for depth edges
  - Programmable dome (image re-lighting and matting)
- Light color/wavelength
- Spatial Modulation
  - Synthetic Aperture Illumination
- Temporal Modulation
  - TV remote, Motion Tracking, Sony ID-cam, RFIG
- Exploiting (uncontrolled) natural lighting condition
  - Day/Night Fusion

Course WebPage :
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