

# GAMES 204

## Computational Imaging

Lecture 16: Computational Illumination I



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香港中文大学（深圳）

点昀技术（Point Spread Technology）



## Today's Topic

- Duration and Intensity
- Light Position and Orientation
- Programmable Dome (image re-lighting and matting)
- Multi-flash for Depth Edges



# 'Smarter' Lighting Equipment



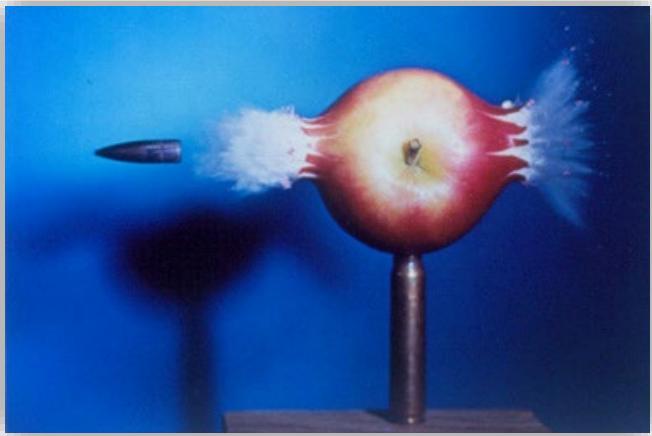
What Parameters Can We Change ?

- Duration and Intensity
- Position and Orientation
- Presence or Absence of Auxiliary Lighting
- Color, Wavelength, Polarization
- Modulation in Space and Time

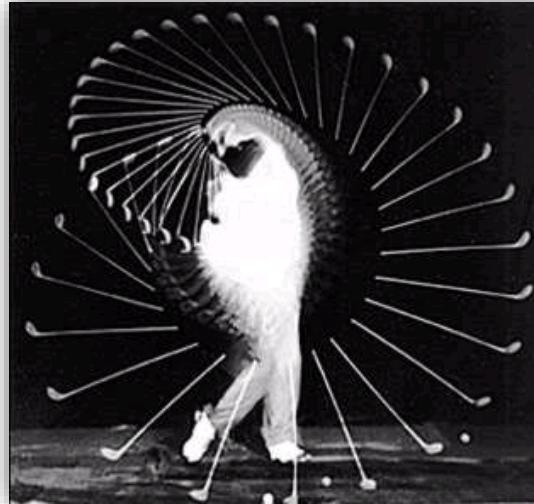
# Duration and Intensity



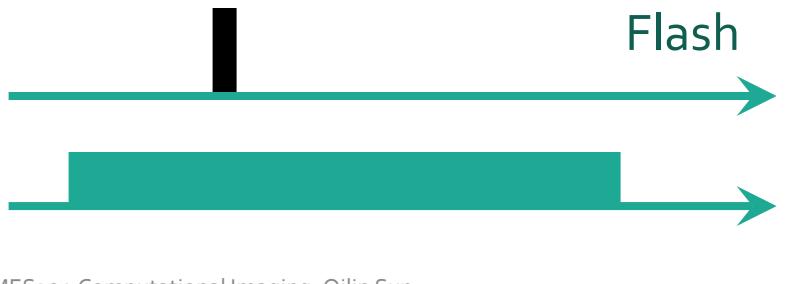
## Duration and Intensity



Stroboscope (Electronic Flash)



Multi-flash Sequential Photography



# Duration and Intensity: Applications

Flash/No-flash Photography——Denoise no-flash image using flash image



No-flash



Result



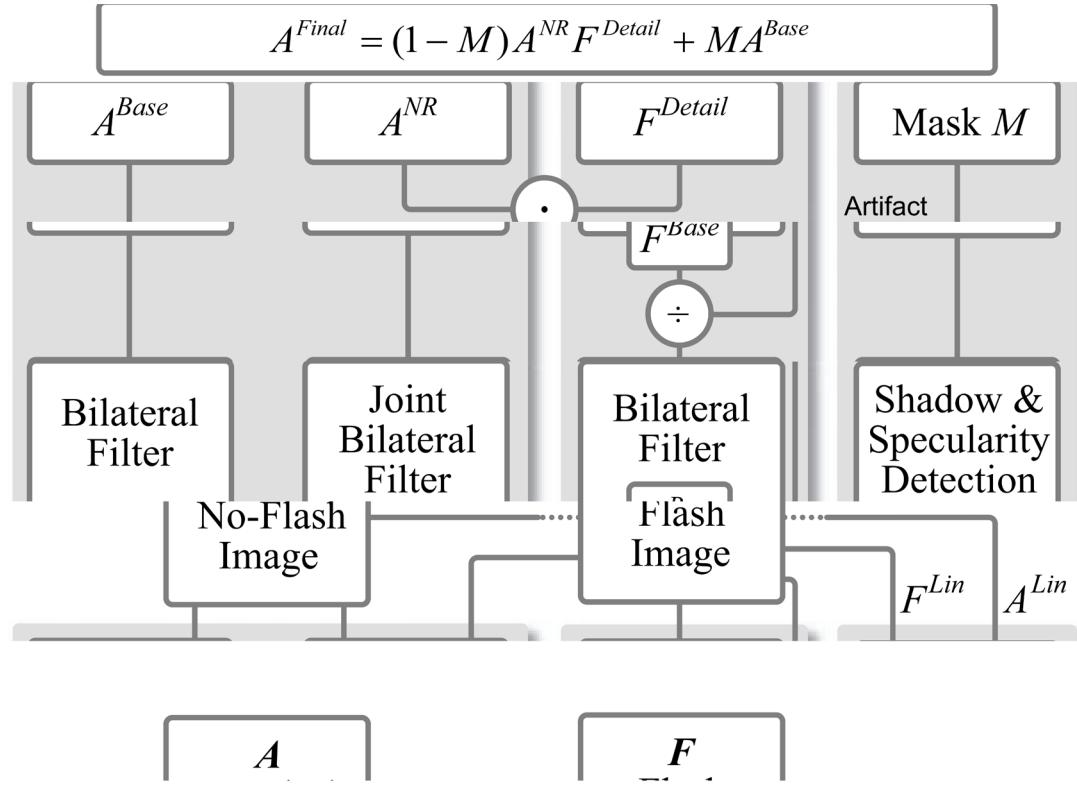
Flash

[Elmar Eisemann](#) and [Frédo Durand](#), Flash Photography Enhancement via Intrinsic Relighting  
Georg Petschnigg, Maneesh Agrawala, Hugues Hoppe, Richard Szeliski, Michael Cohen,  
Kentaro Toyama. [Digital Photography with Flash and No-Flash Image Pairs](#)



# Duration and Intensity: Applications

Flash/No-flash Photography——Denoise no-flash image using flash image





## Duration and Intensity: Applications

Flash/No-flash Photography——Denoise no-flash image using flash image



Intensity



Large-scale



Detail



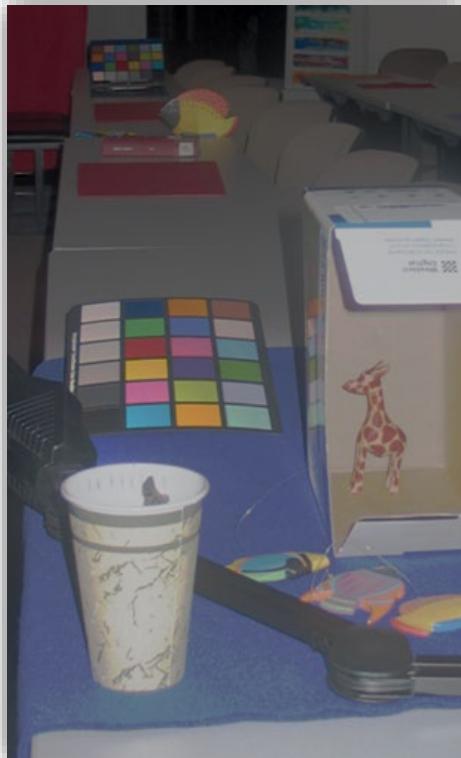
# Duration and Intensity: Applications

## Flash/No-flash Photography——Flash HDR Imaging

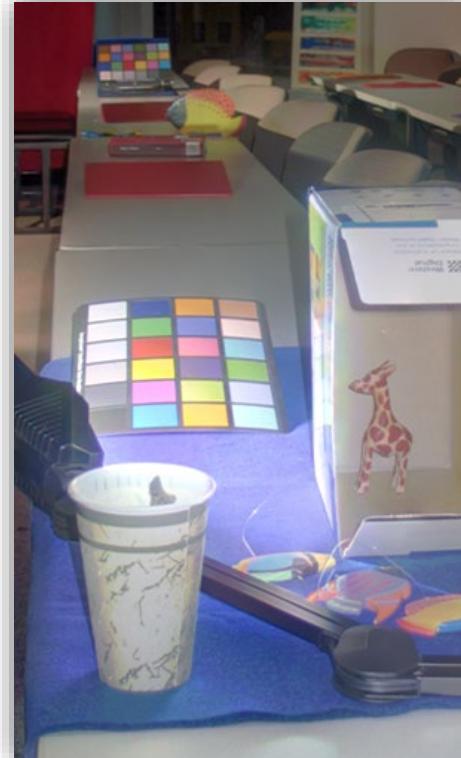
Varying Exposure time



Varying Flash brightness



Varying both

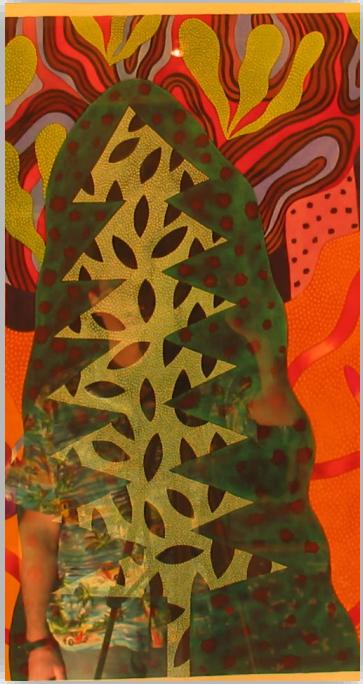




# Auxiliary Lighting

## Flash/No-flash Photography——Removing Artefacts from a Flash Image

Ambient



Flash



Result



Reflection Layer



# Light Position and Orientation



# Synthetic Lighting



Paul Haeberli,  
Jan 1992

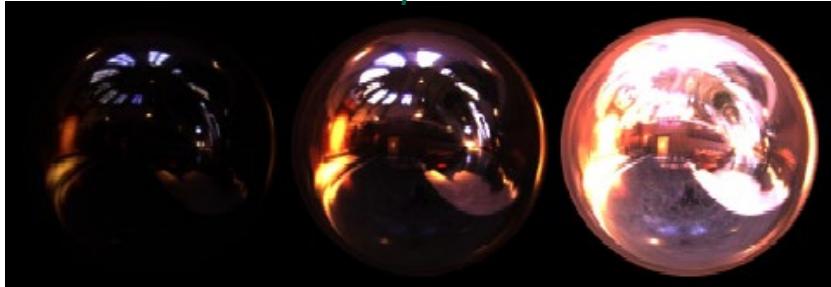


# Debevec et al. 2002: 'Light Stage 3'



# Image-Based Actual Re-lighting

Debevec et al., SIGG2001



Light the actress in Los Angeles



Matched LA and Milan lighting.



Film the background IN Milan, Measure incoming light,

Matte the background

# Image-Based Actual Re-lighting



Photomontage

courtesy of A Agrawala

courtesy of P. Debevec



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The Chinese University of Hong Kong, Shenzhen



# Image-Based Actual Re-lighting



# Table-top Computed Lighting for Practical Digital Photography



Bobby Bodenheimer  
Vanderbilt University



Ankit Mohan, Jack Tumblin  
Northwestern University

Cindy Grimm, Reynold Bailey  
Washington University in St. Louis

# Table-top Computed Lighting for Practical Digital Photography



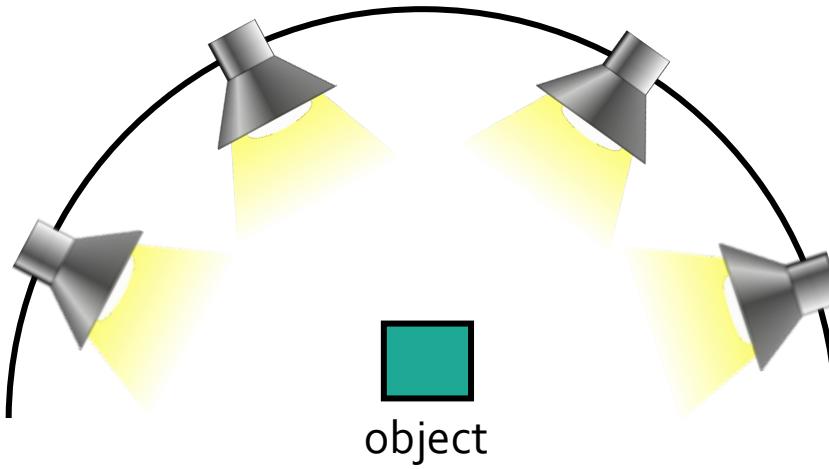
# Sketch Your Desires, Optimize





# Acquisition for Relighting

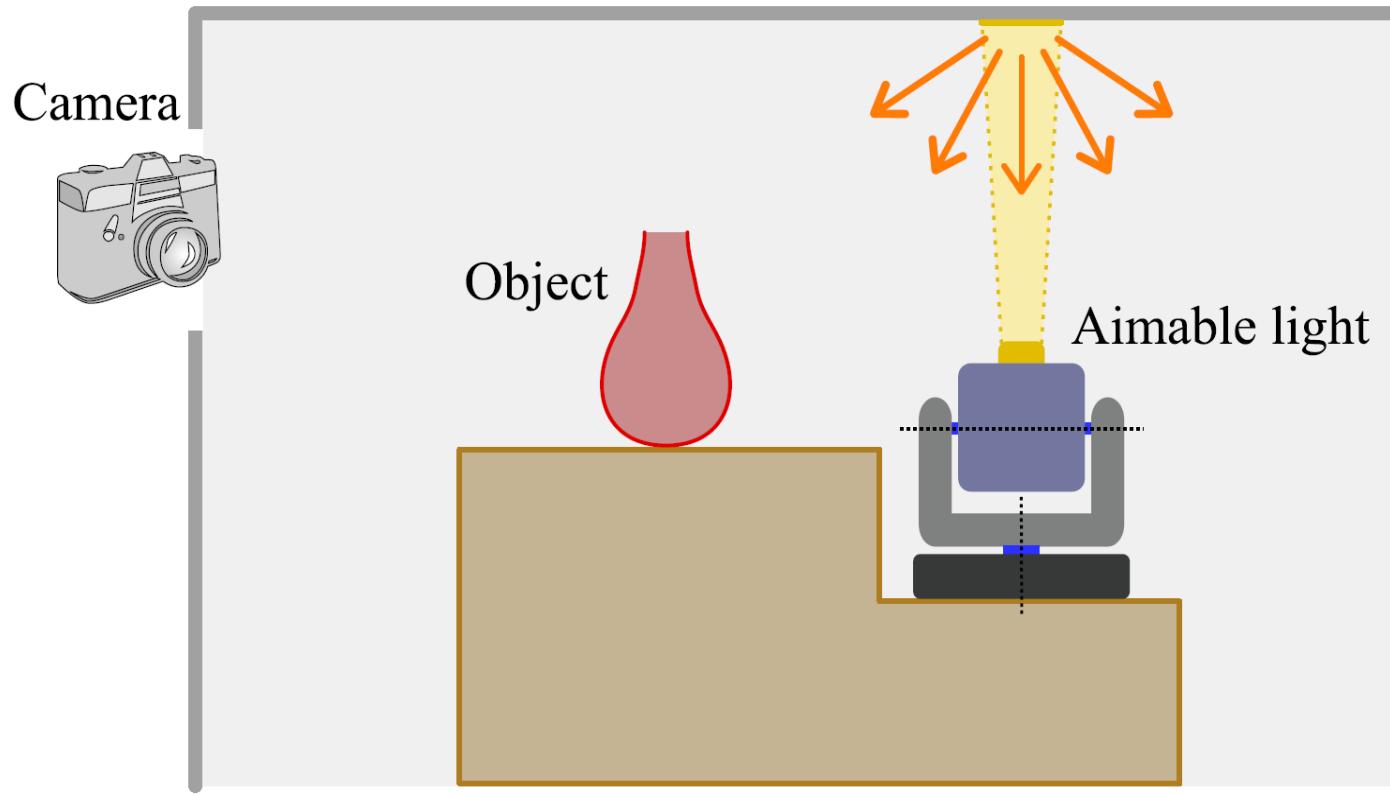
- Uniquely lit basis images
- Known light-positions





# 'Aimed Spot': Low-risk Movement

Diffuse reflective enclosure





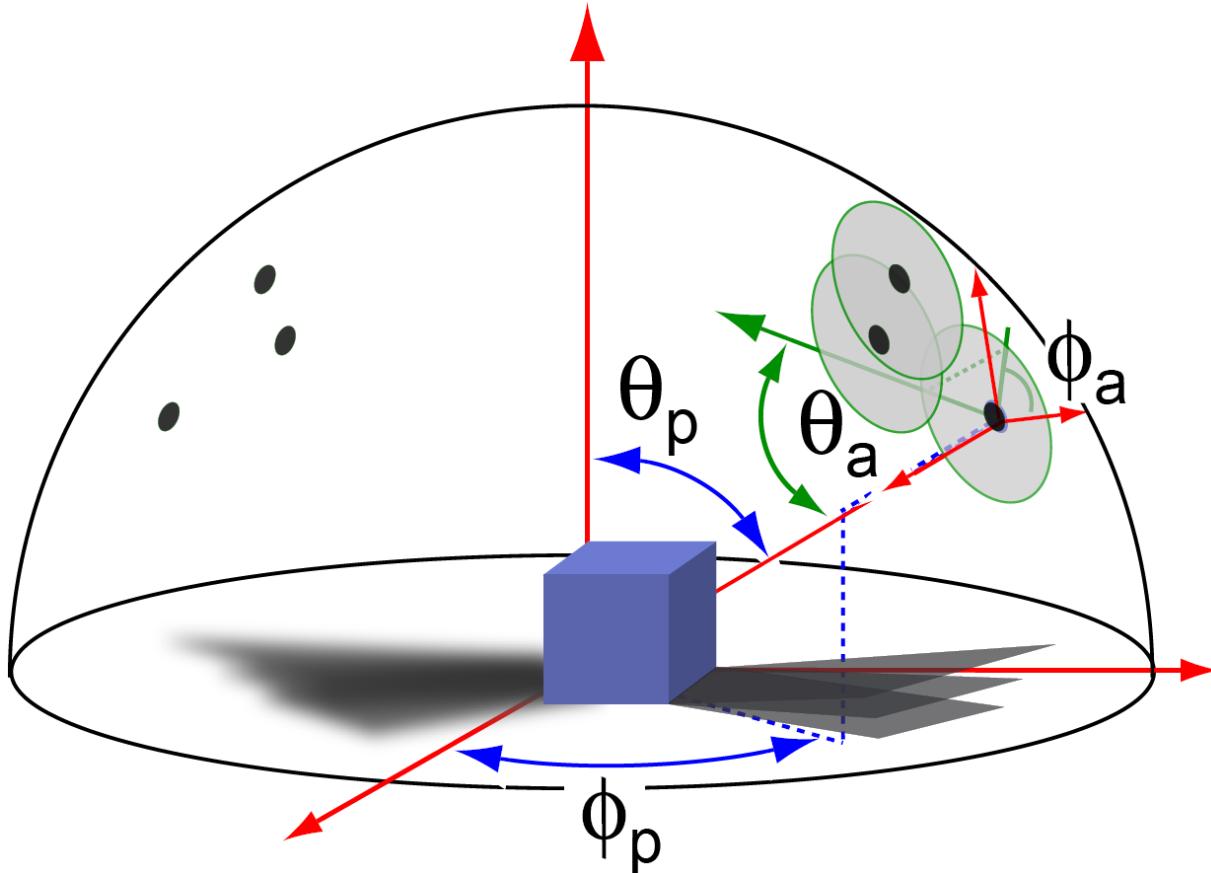
# 'Aimed Spot': low-risk movement



From Jack Tumblin



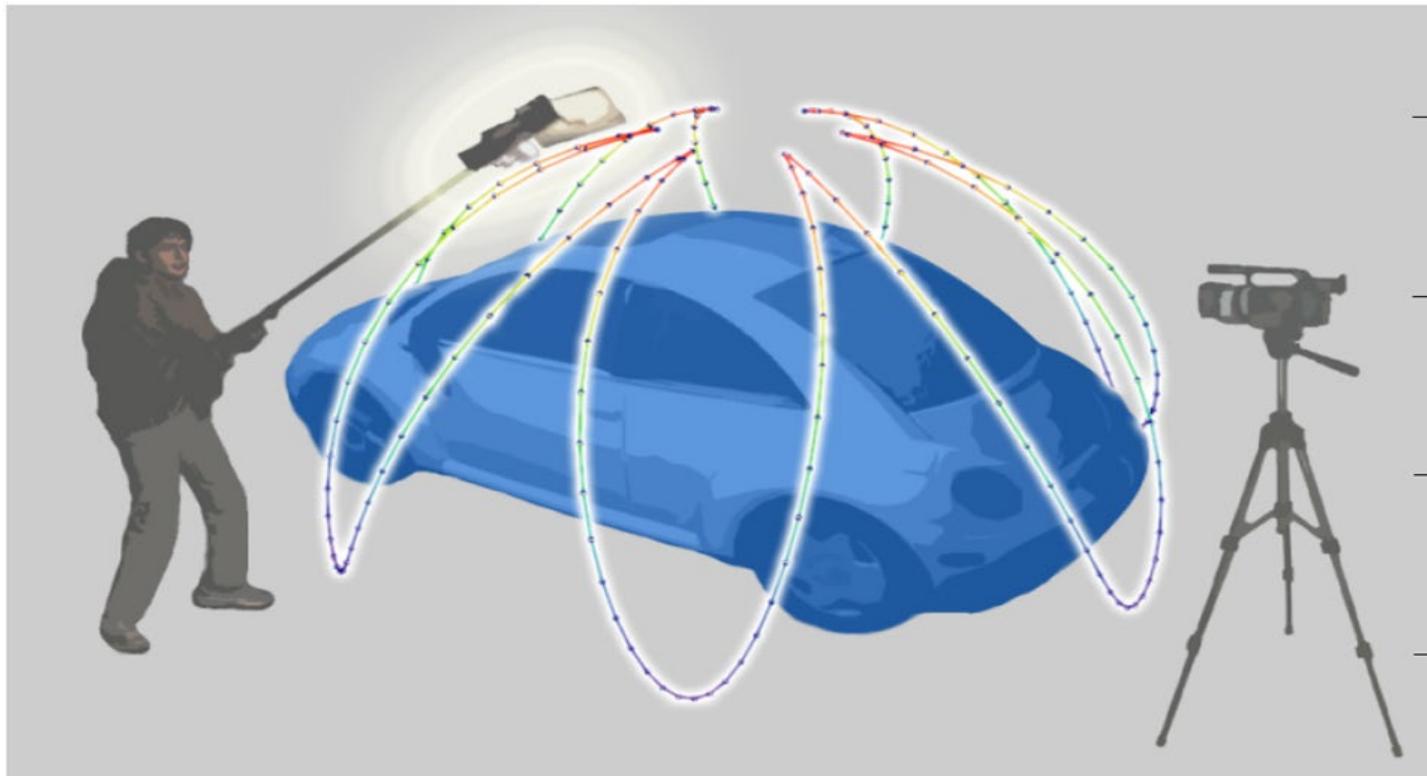
# Overlapped Spots Avoid Aliasing





# “Light Waving”

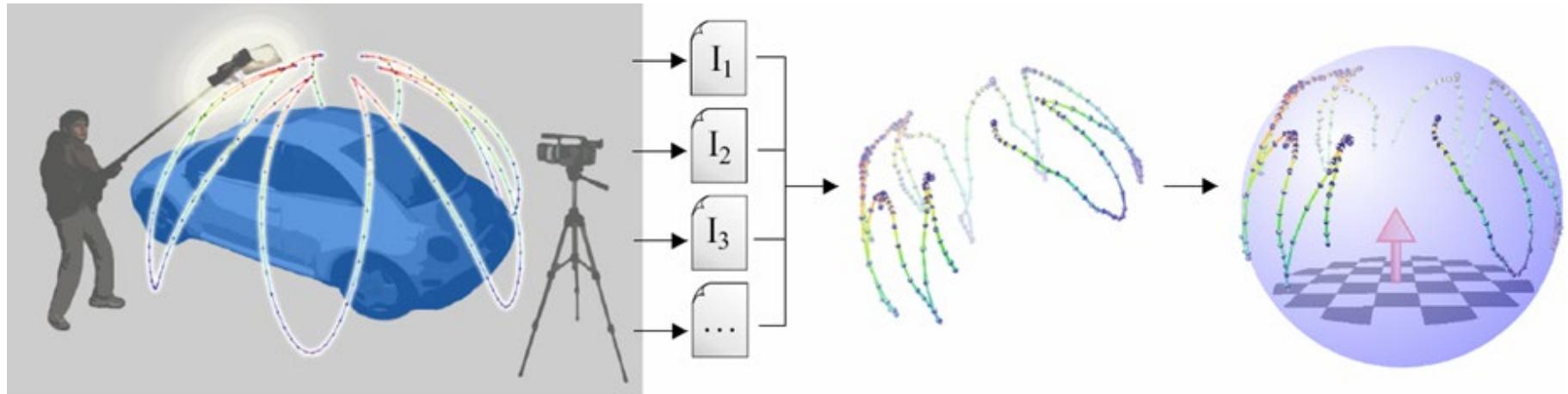
Tech Sketch (Winnemoller, Mohan, Tumblin, Gooch)





# “Light Waving”

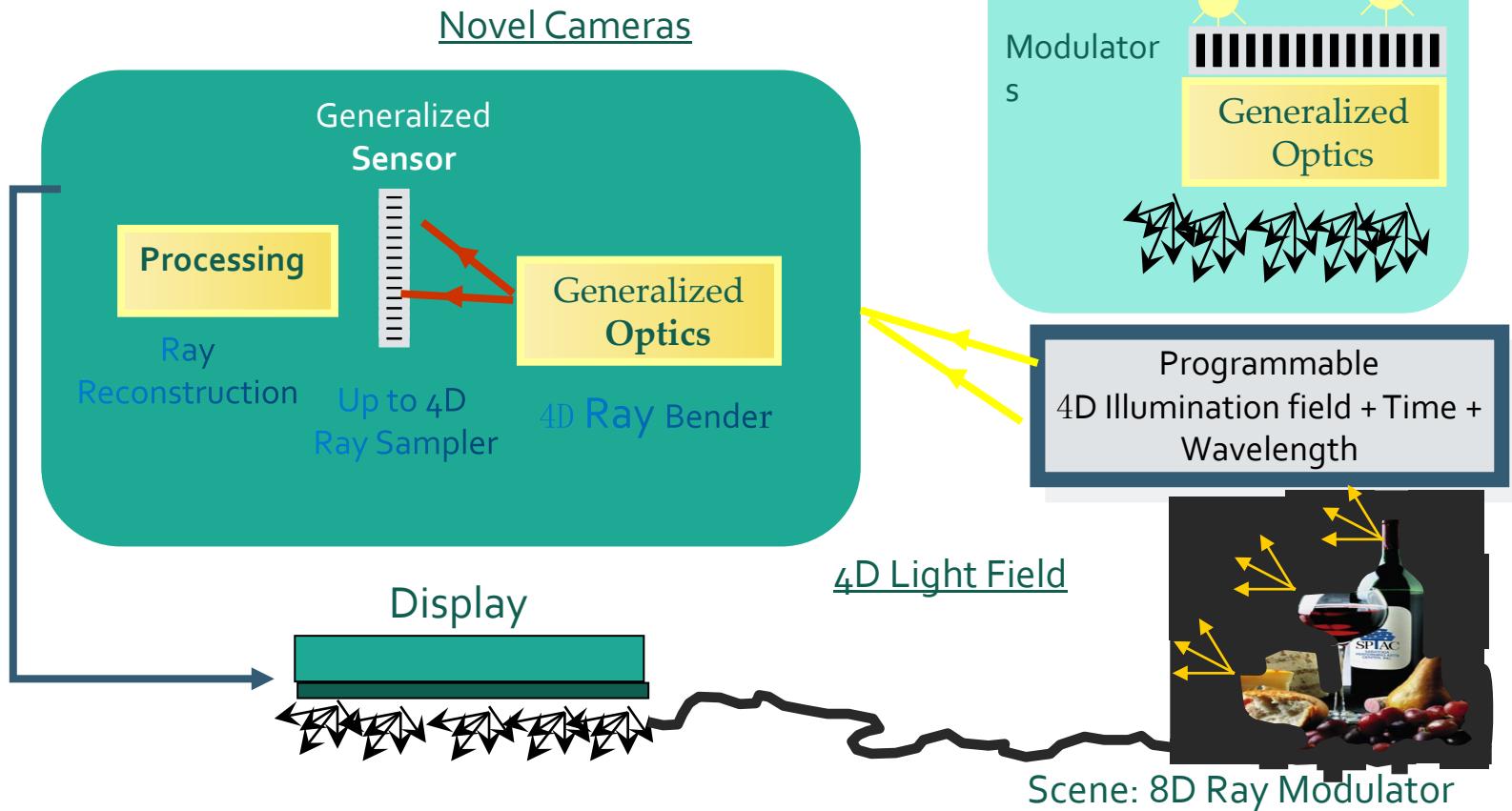
## Light Waving: Estimating Light Positions From Photographs Alone



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



# Computational Illumination Quest for 4D Illumination





# A 4-D Light Source



[Debevec et al. 2000]



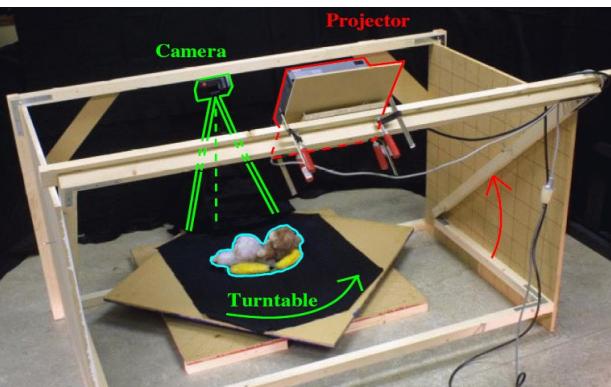
[Masselus et al. 2002]



[Matusik et al. 2002]



[Debevec et al. 2002]



[Masselus et al. 2003]

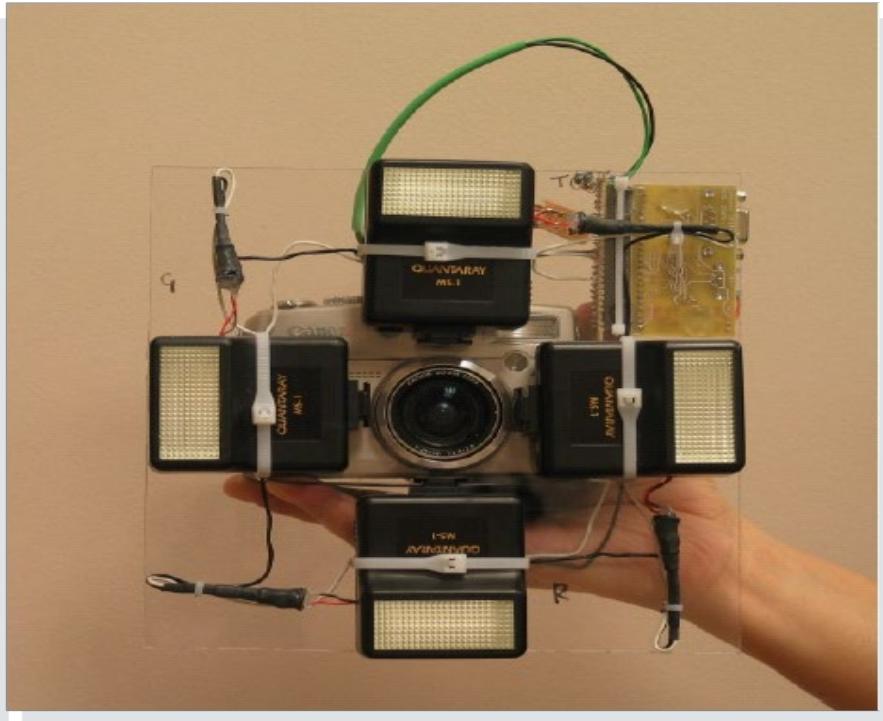
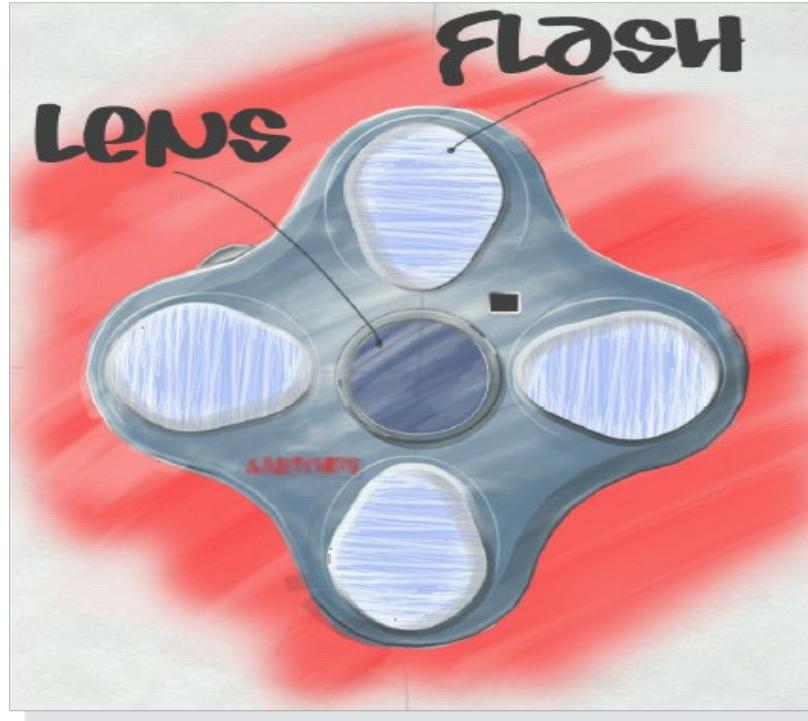


[Malzbender et al. 2002]



# Non-photorealistic Camera

## Depth Edge Detection and Stylized Rendering using Multi-Flash Imaging



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

Mitsubishi Electric Research Labs (MERL), Cambridge, MA, U of California at Santa Barbara, U of North Carolina at Chapel Hill



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# Depth Edge Camera



# Depth Edge Camera



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# Depth Edge Camera





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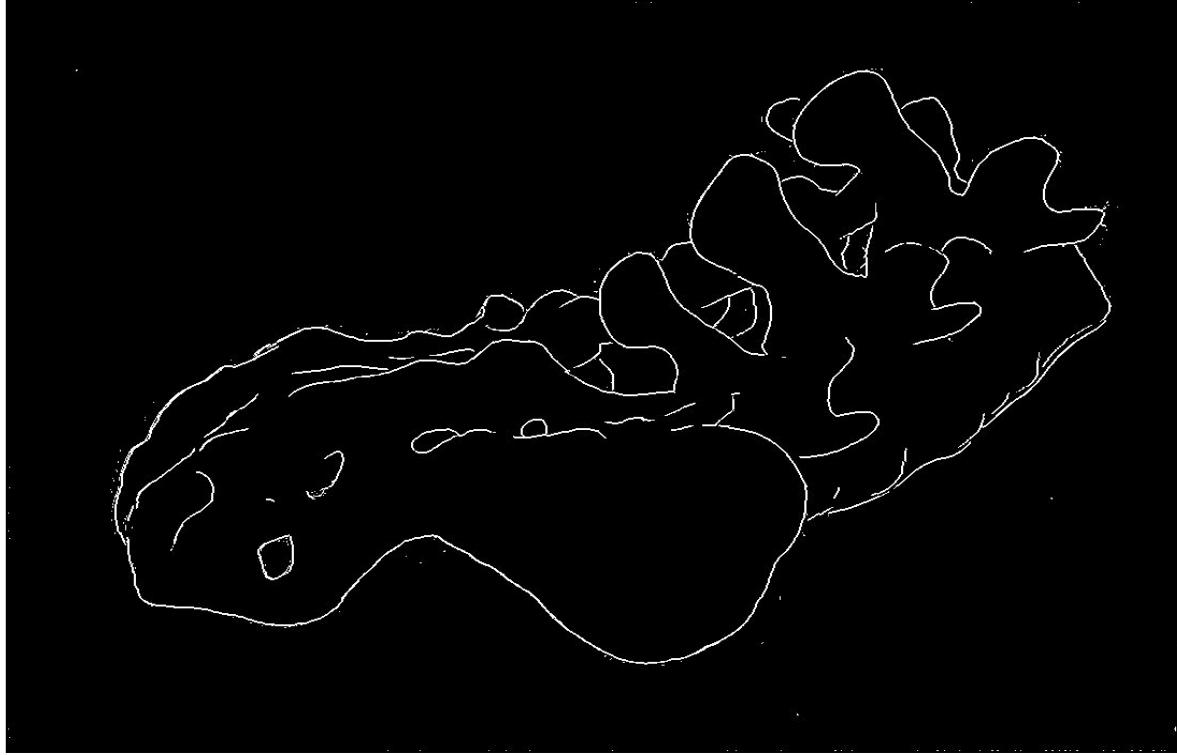


# Depth Edge Camera





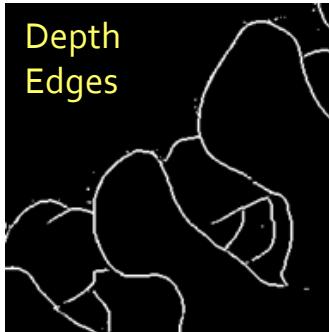
# Depth Discontinuities



Internal and external  
Shape boundaries, Occluding contour, Silhouettes



# Depth Discontinuities



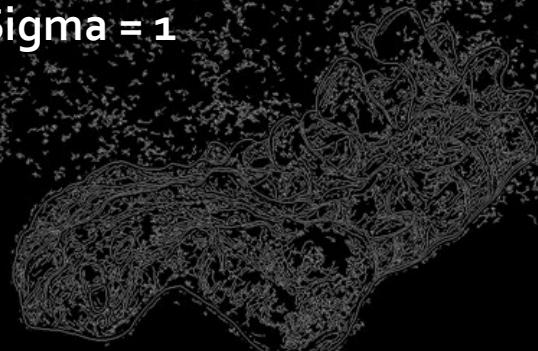
# Depth Discontinuities

Sigma = 9



Canny Intensity Edge Detection

Sigma = 1

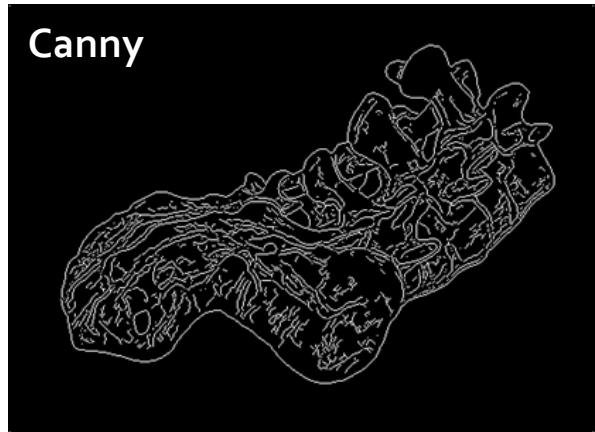
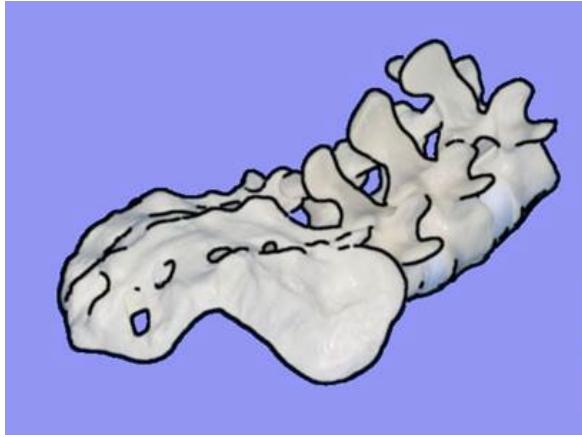


Sigma = 5



captures shape edges

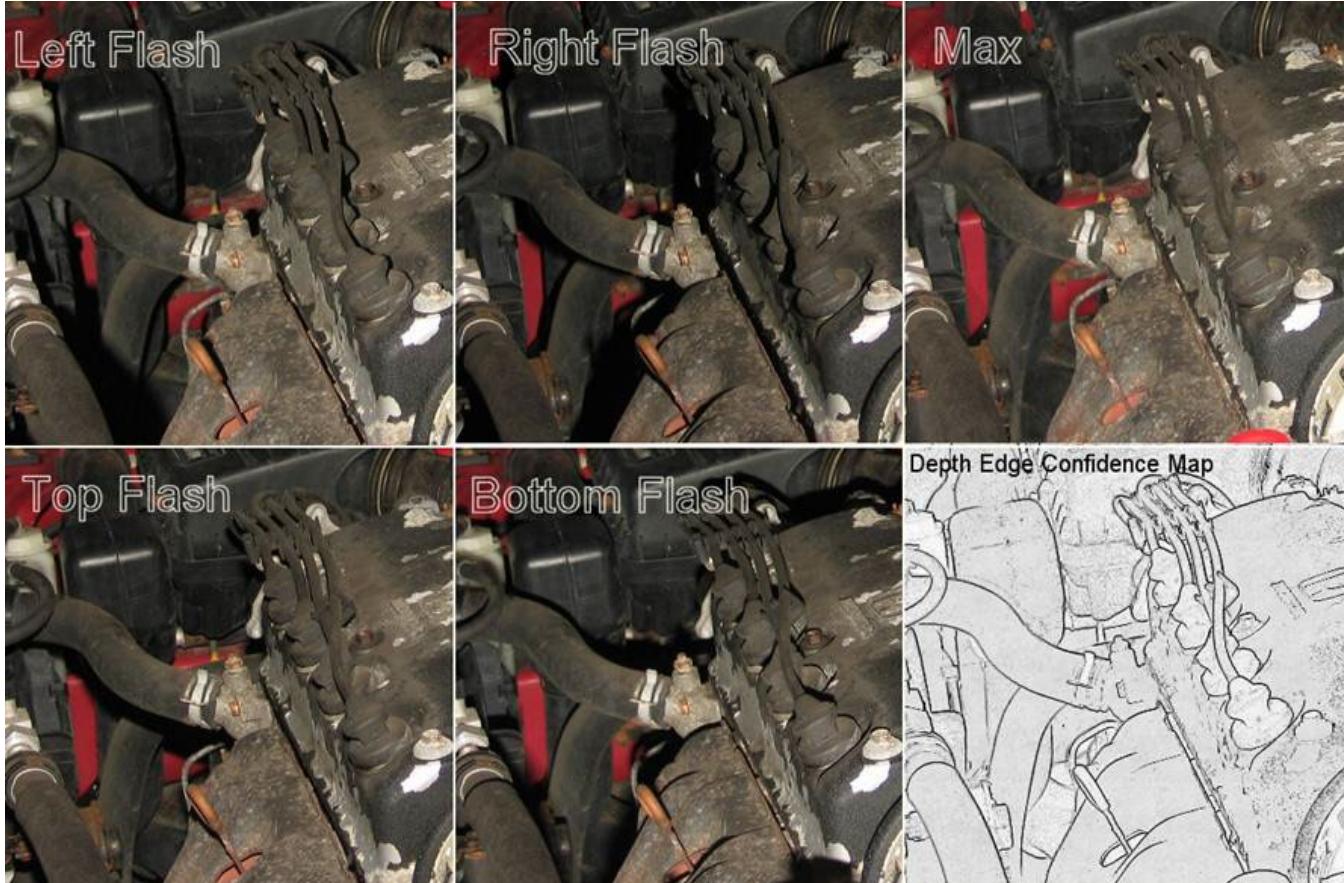
# Depth Discontinuities



# Depth Edge Camera



# Depth Edge Camera



# Depth Edge Camera



Shadows

Clutter

Many Colors

Highlight Shape Edges

Mark moving parts

Basic colors

# Depth Edge Camera

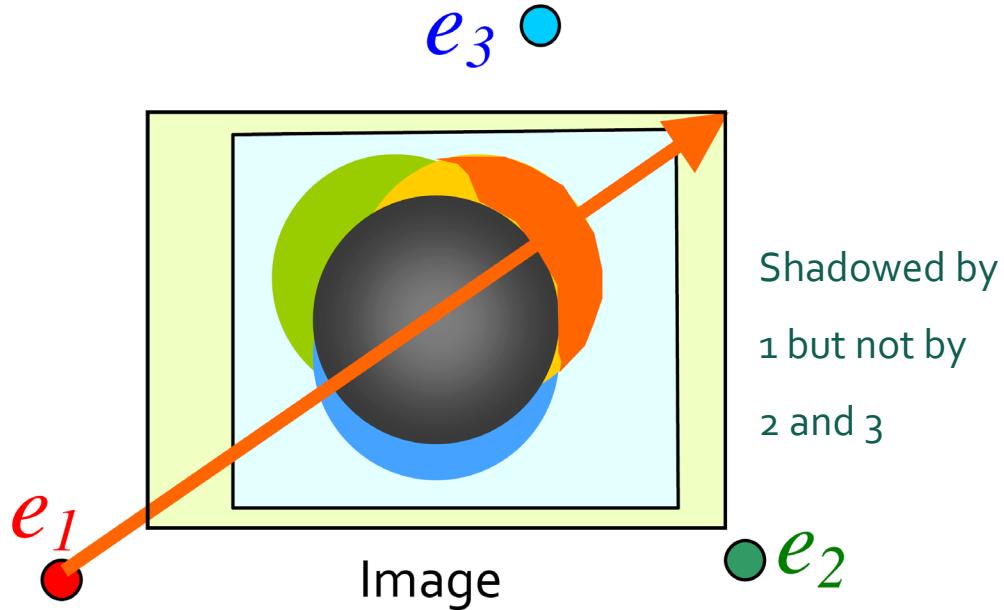
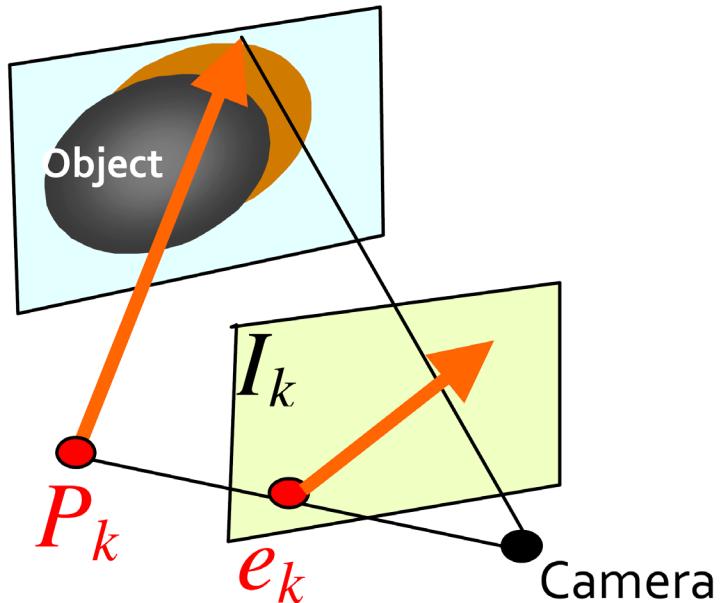


# Depth Edge Camera



# Imaging Geometry

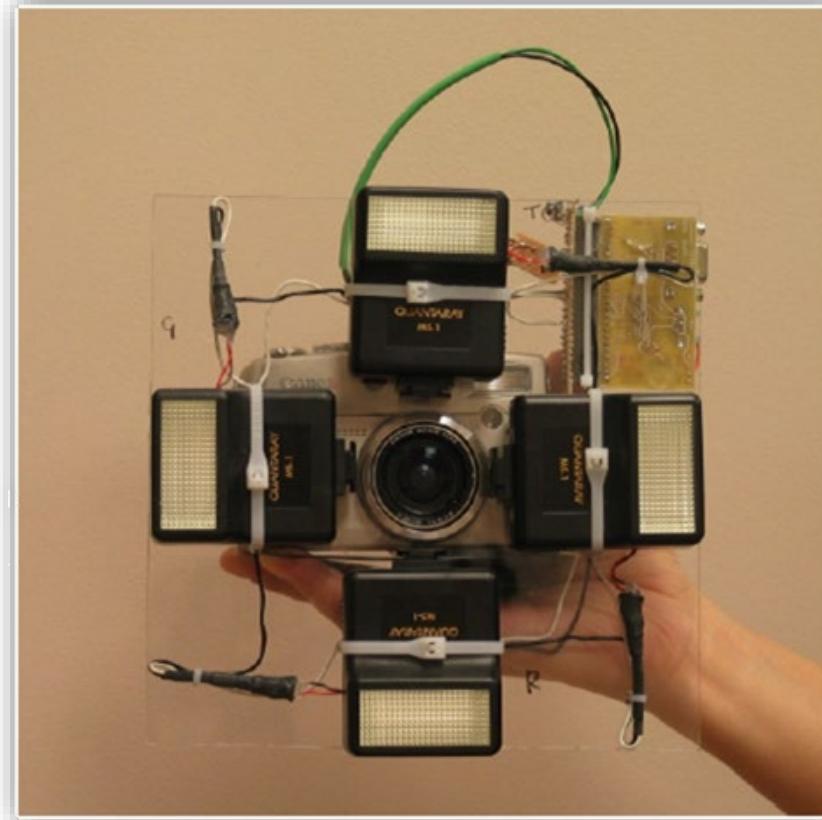
## Shadow



**Shadow lies along epipolar ray,  
Epipole and Shadow are on opposite sides of the edge**



# Depth Edge Camera



Light epipolar rays are horizontal or vertical



# Depth Edge Camera

Input

Left Flash



Right Flash



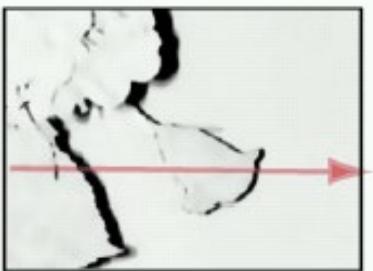
# Depth Edge Camera

Input



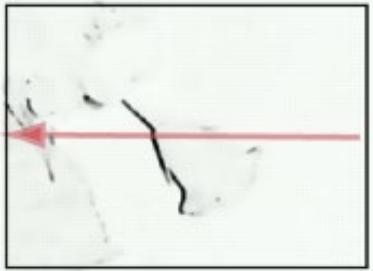
Left Flash

Normalized



Right Flash

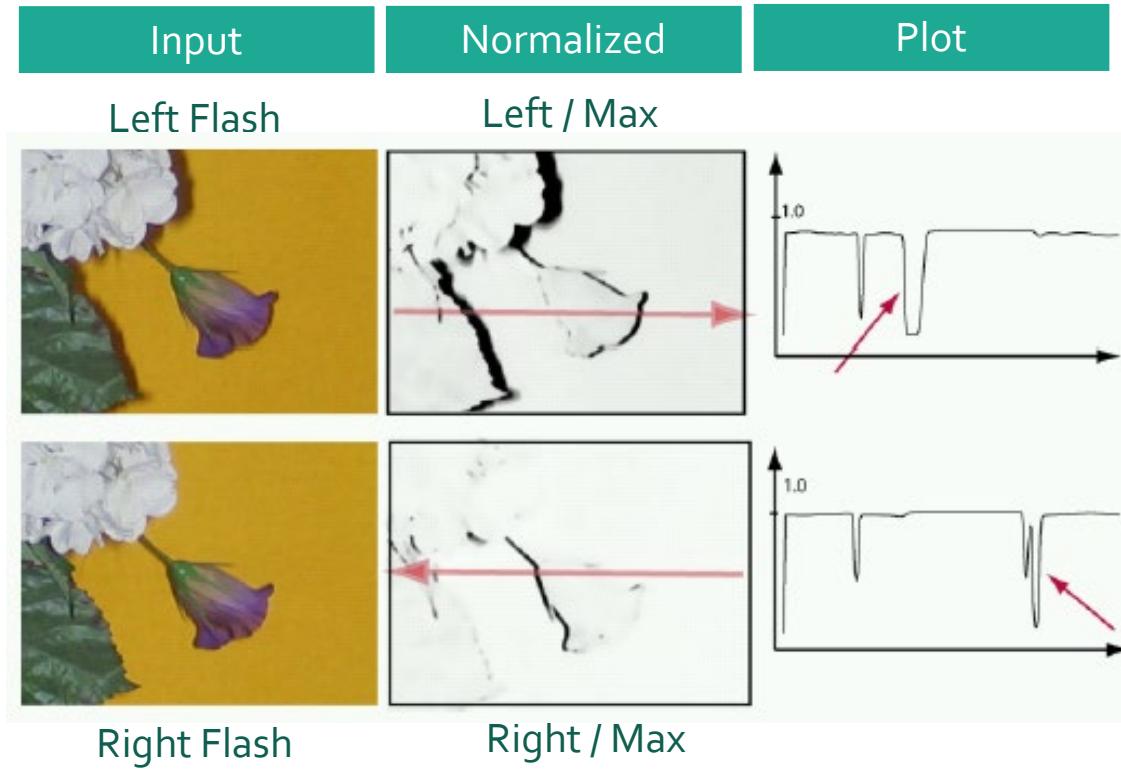
Left / Max



Right / Max



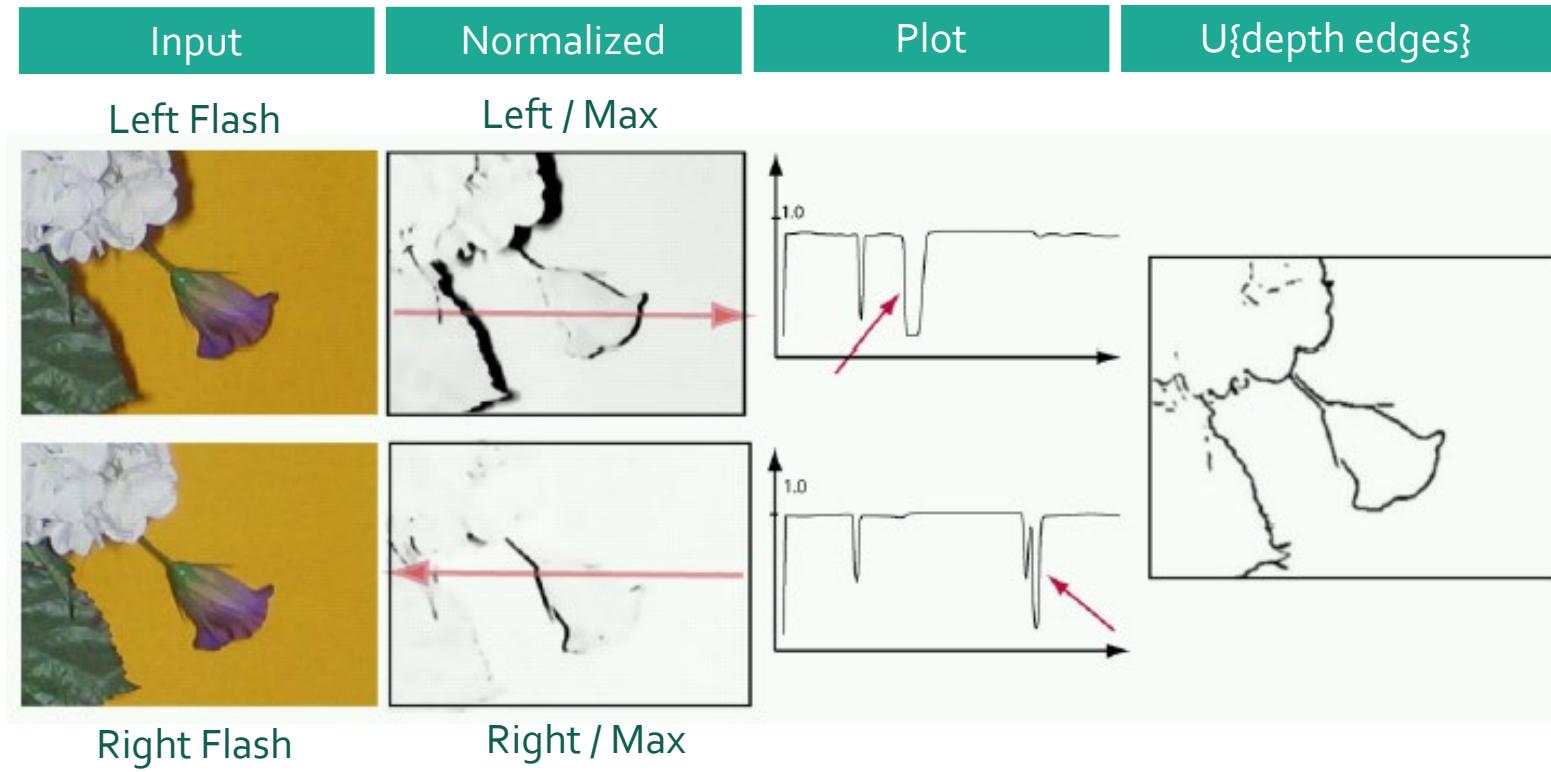
# Depth Edge Camera



Negative transition along epipolar ray is depth edge



# Depth Edge Camera





# 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



# Change Detection

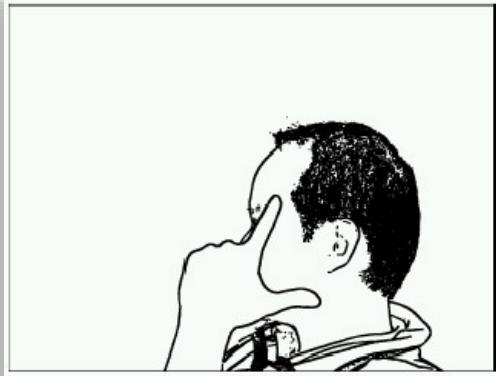


Before

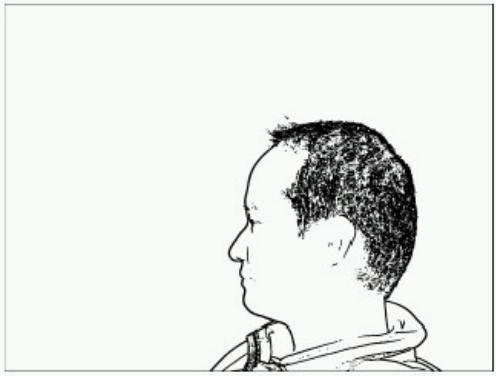
After



# Change Detection



(a)



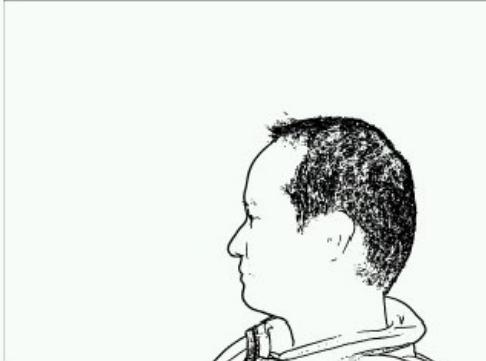
(b)



# Change Detection

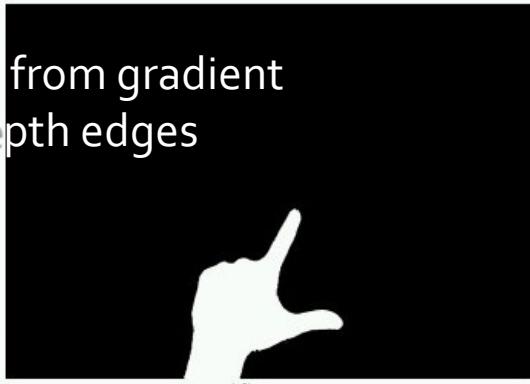


(a)



(b)

Reconstructed from gradient  
field of new depth edges





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## Thank You!



Qilin Sun (孙启霖)

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点昀技术（Point Spread Technology）