CS354 Computer Graphics
Computational Photography II

Qixing Huang

April 25th 2018

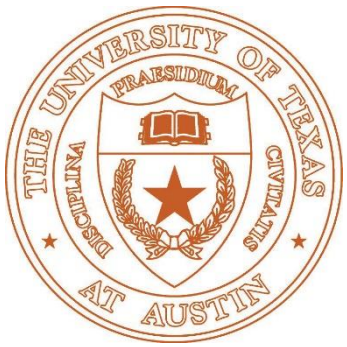
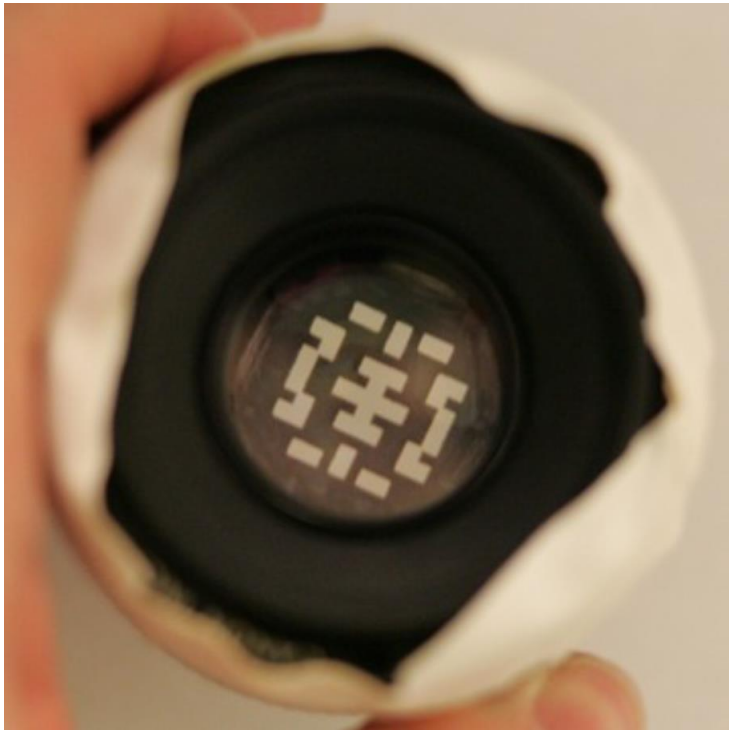


Image and Depth from a Conventional Camera with a Coded Aperture
Levin et al. (SIGGRAPH 2007)

conventional aperture



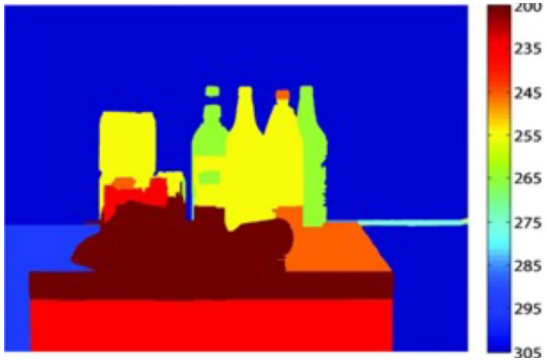
coded aperture

Slide from https://groups.csail.mit.edu/graphics/CodedAperture/CodedAperture-LevinEtAl-SIGGRAPH07.ppt

Image and Depth from a Conventional Camera with a Coded Aperture
Levin et al. (SIGGRAPH 2007)

input
(blurred)

output
(blurred)



depthmap

Lens and Defocus

Lens' aperture

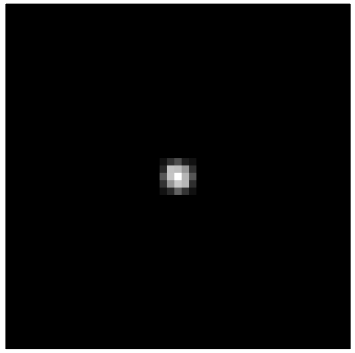
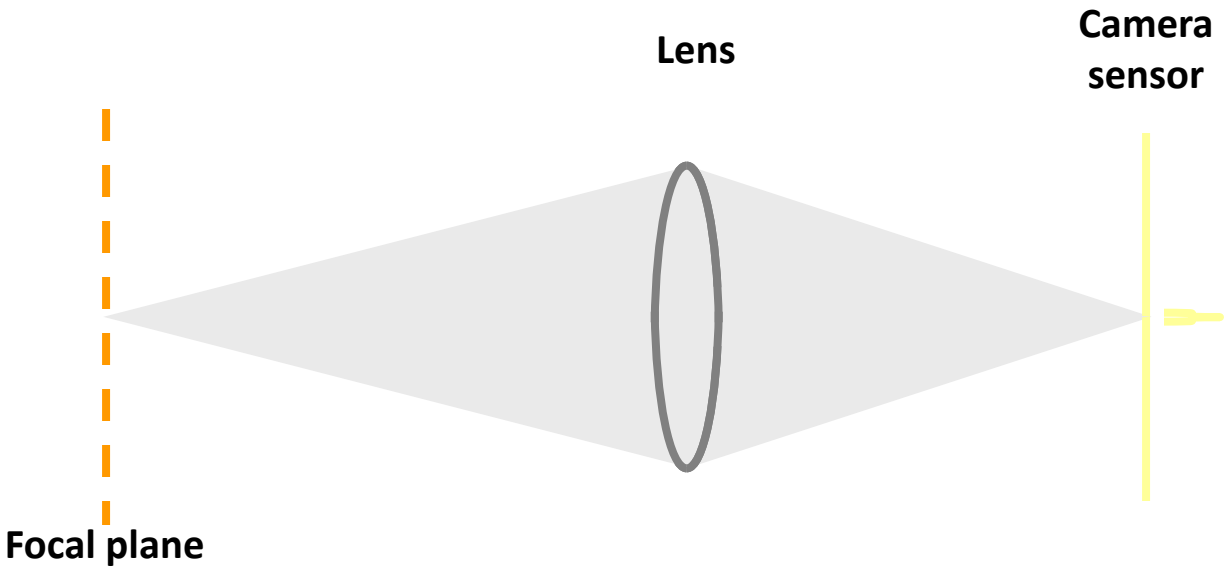


Image of a point light source



Lens and Defocus

Lens' aperture

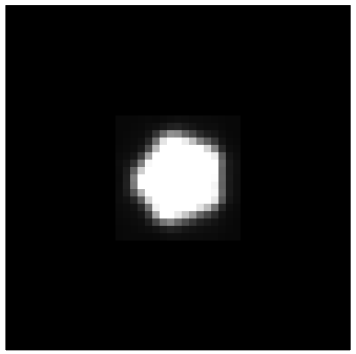
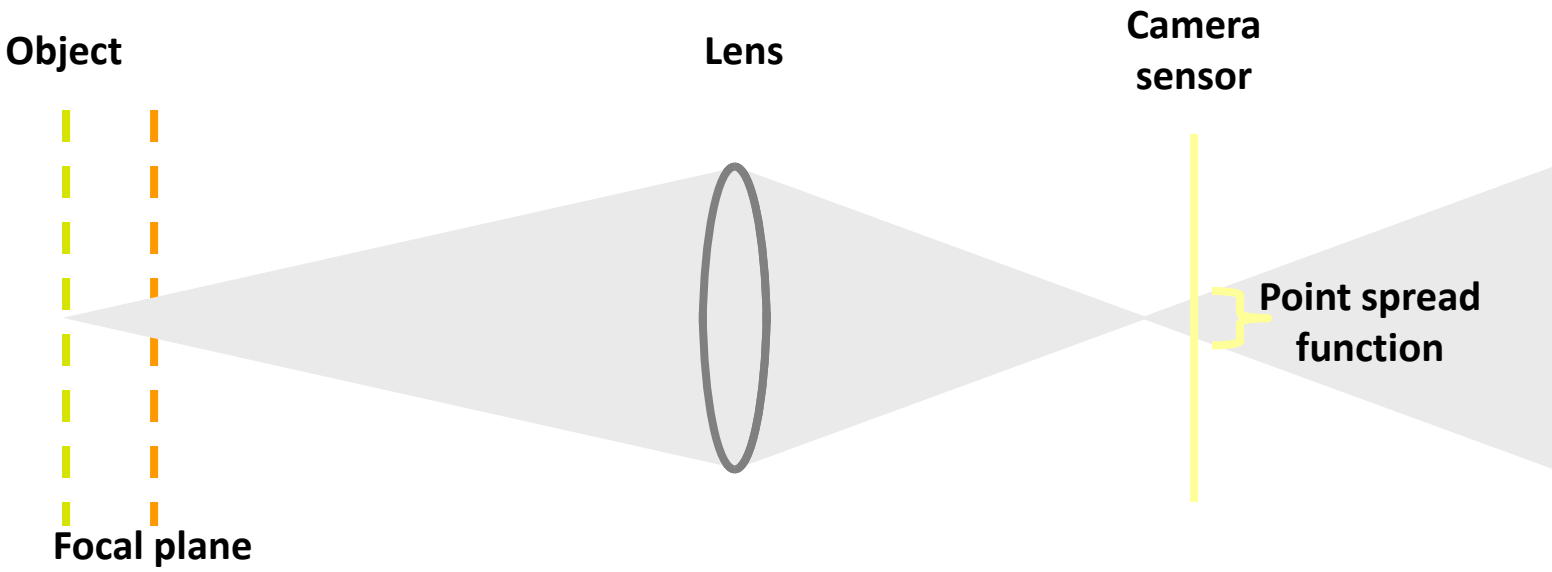


Image of a defocused point light source



Lens and Defocus

Lens' aperture

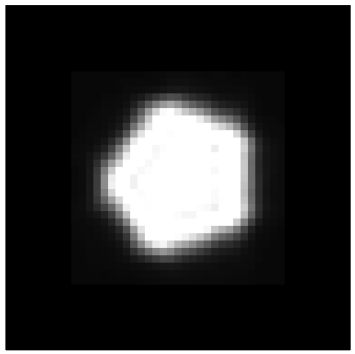
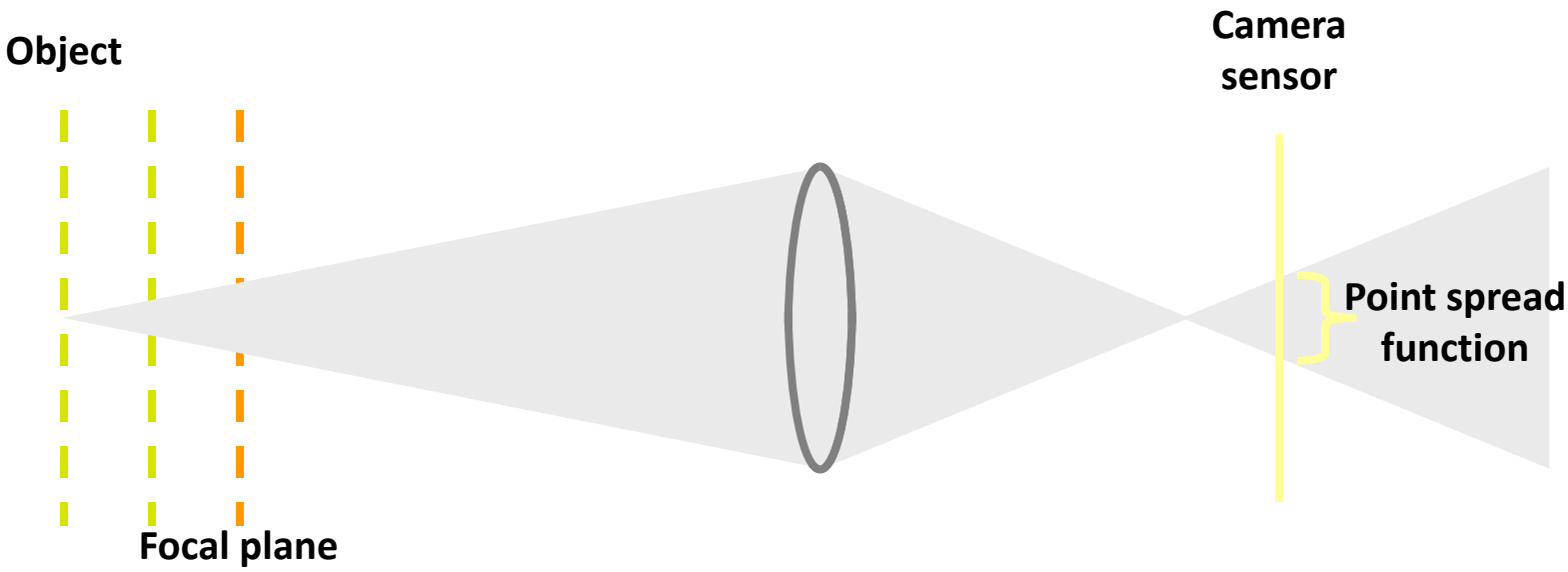


Image of a defocused point light source



Lens and Defocus

Lens' aperture

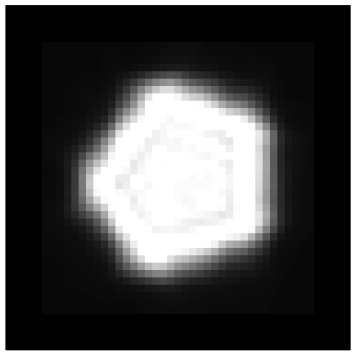
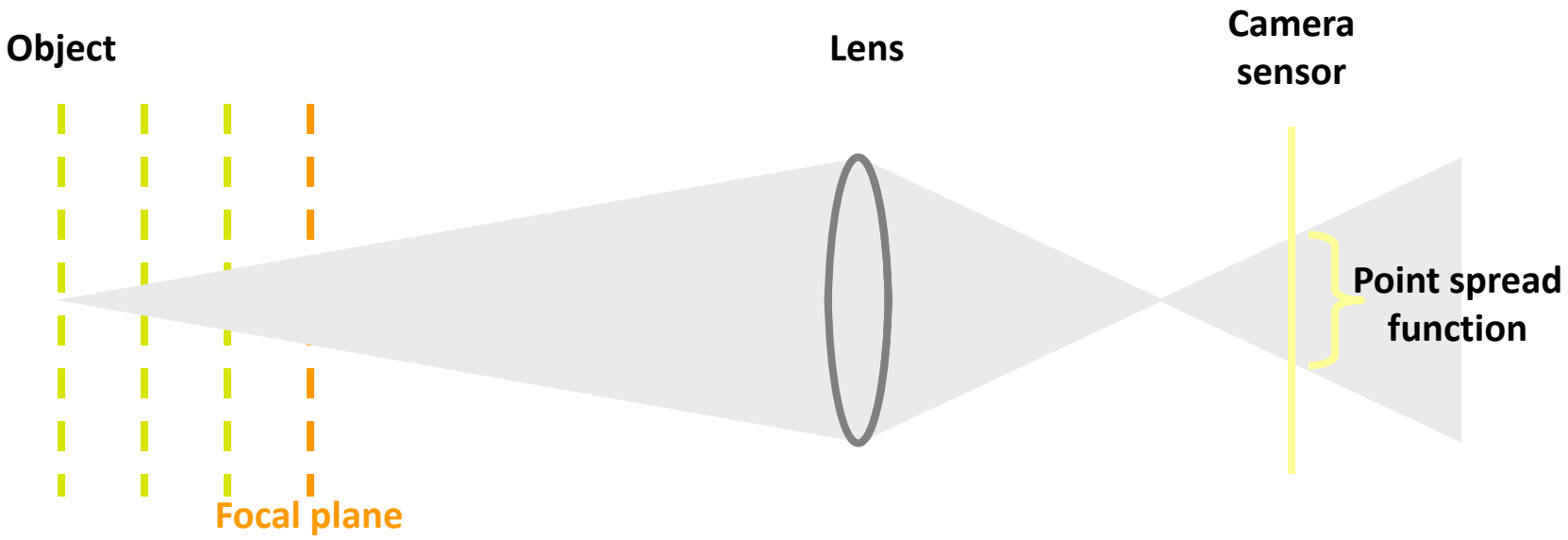


Image of a defocused point light source



Lens and Defocus

Lens' aperture

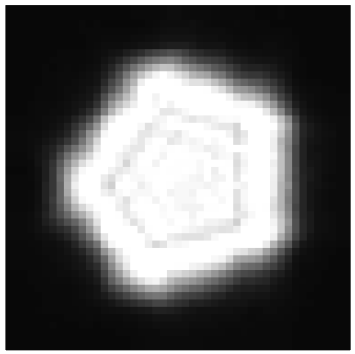
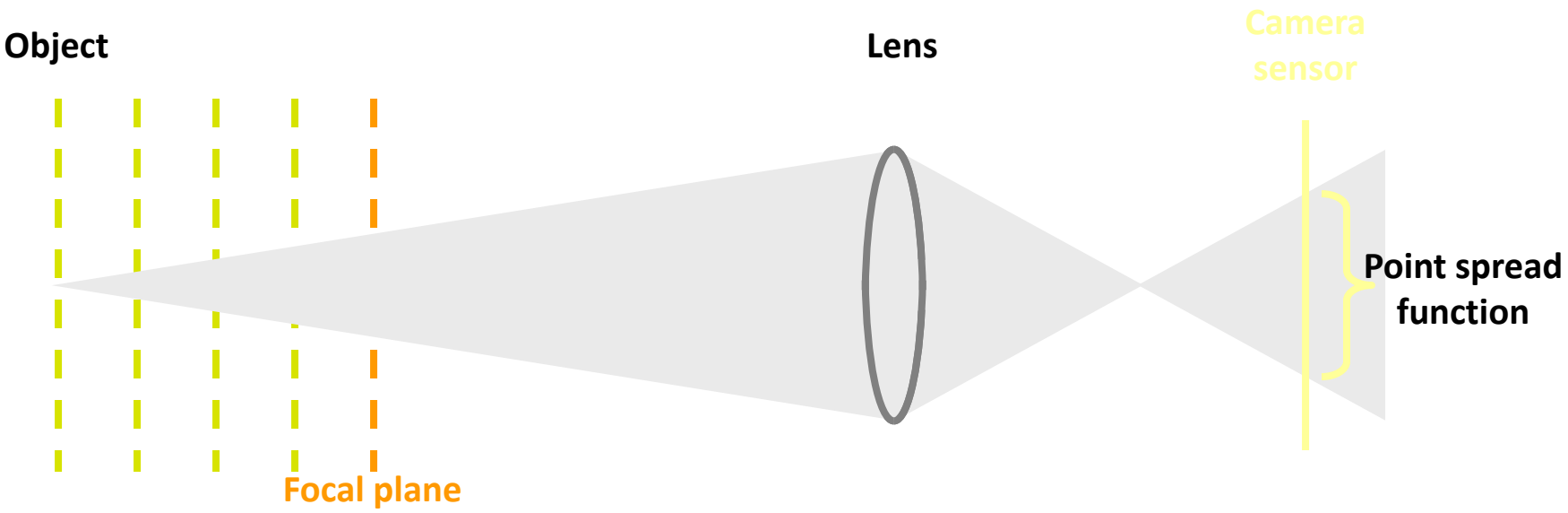


Image of a defocused point light source



Depth and defocus

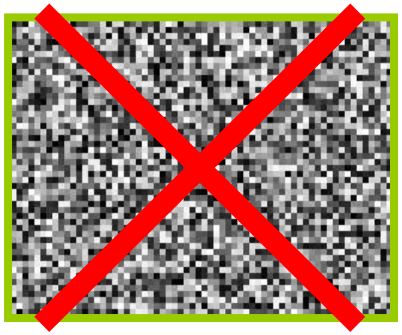
ill posed

Depth from defocus:

Infer depth by analyzing local scale of defocus blur

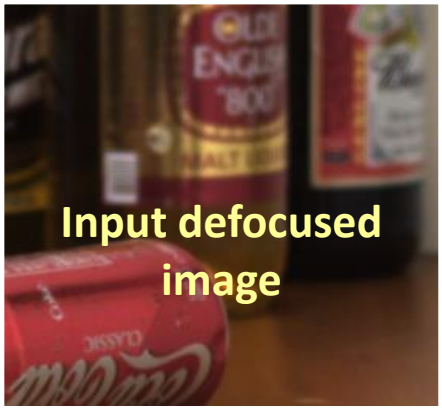
Key contributions

- Exploit prior on natural images
  - Improve deconvolution
  - Improve depth discrimination

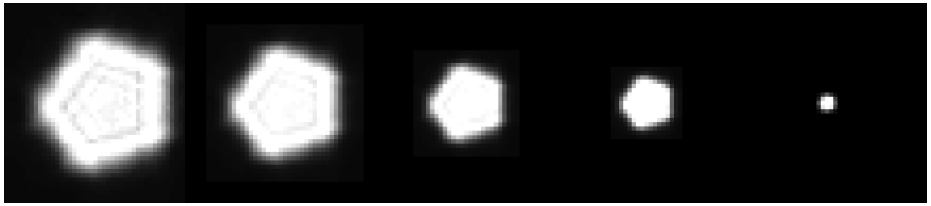


- Coded aperture (mask inside lens)
  - make defocus patterns different from
  - natural images and easier to discriminate

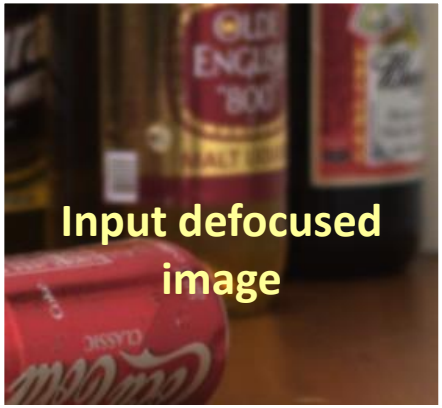
Defocus as local convolution



Calibrated blur kernels at different depths



Defocus as local convolution



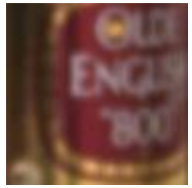
Local sub-window

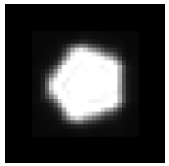
Calibrated blur kernels at depth k

Sharp sub-window

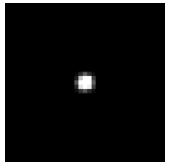
Depth k=1:

Depth k=2:



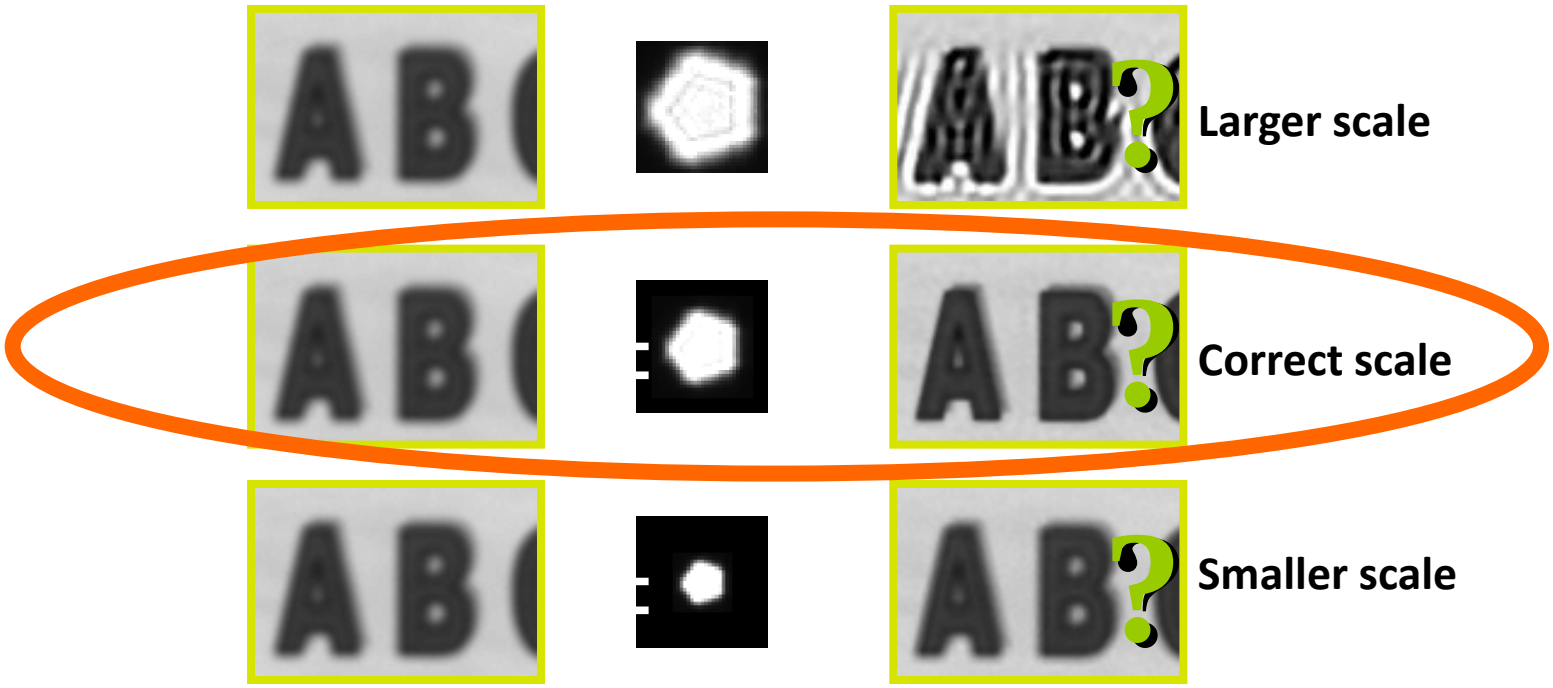


Depth k=3:



Overview

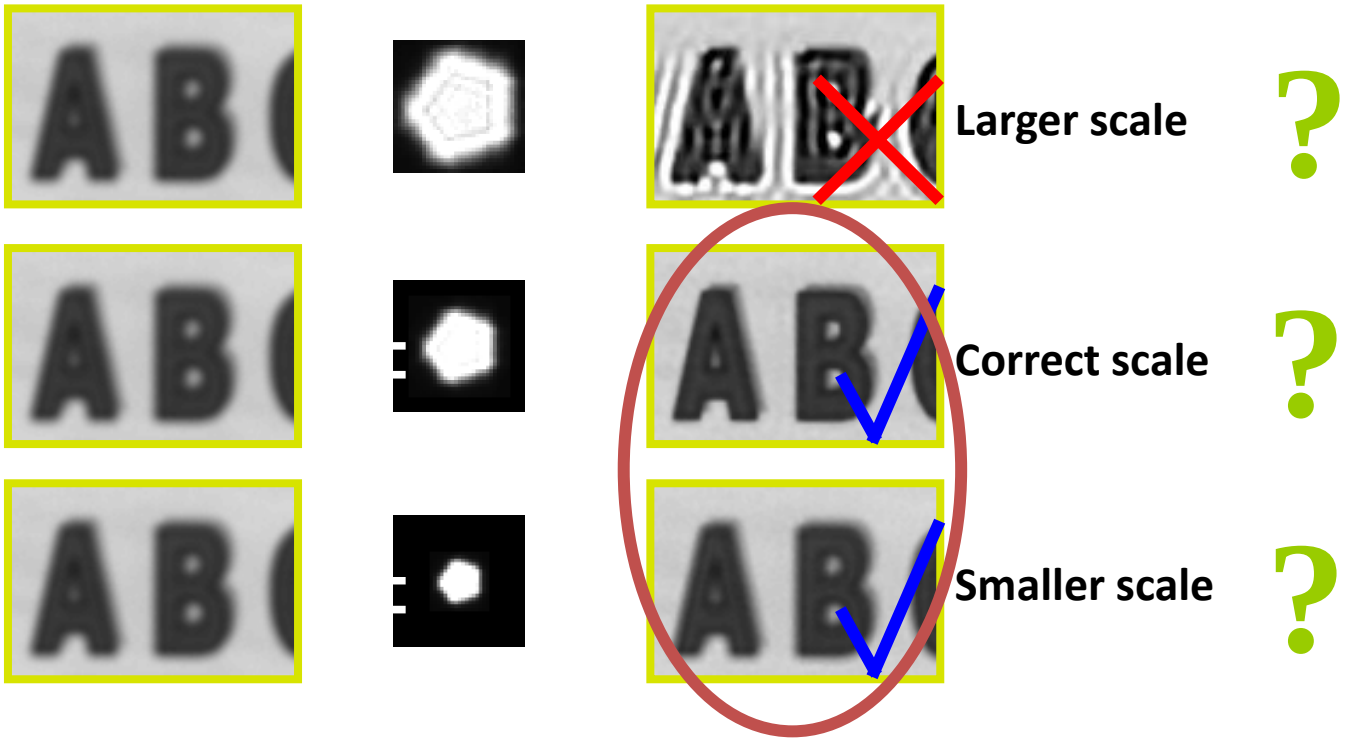
Try deconvolving local input windows with different scaled filters:



Somehow: select best scale.

Overview

Try deconvolving local input windows with different scaled filters:



Somehow: select best scale.

Challenge: smaller scale not so different than correct

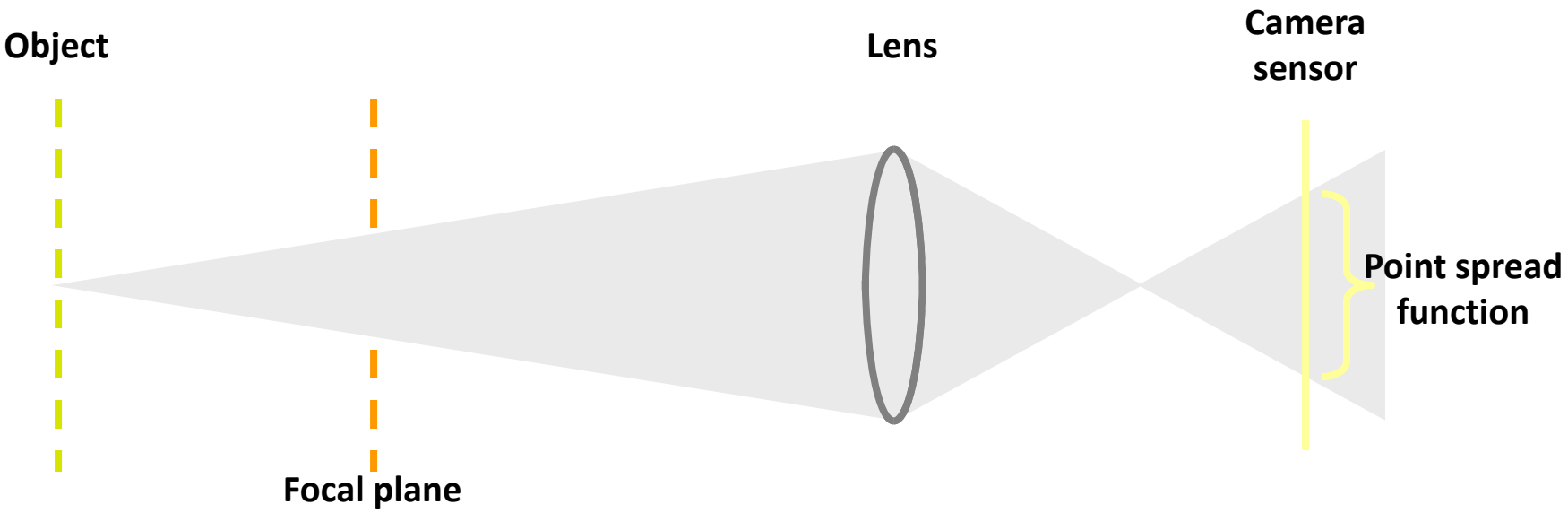
Coded Aperture

- Mask (code) in aperture plane
  - make defocus patterns different from
  - natural images and easier to discriminate

Conventional aperture

Our coded aperture

Solution: lens with occluder



Solution: lens with occluder

Aperture pattern

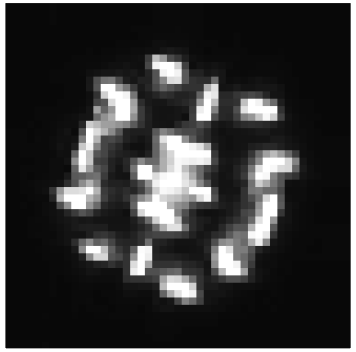
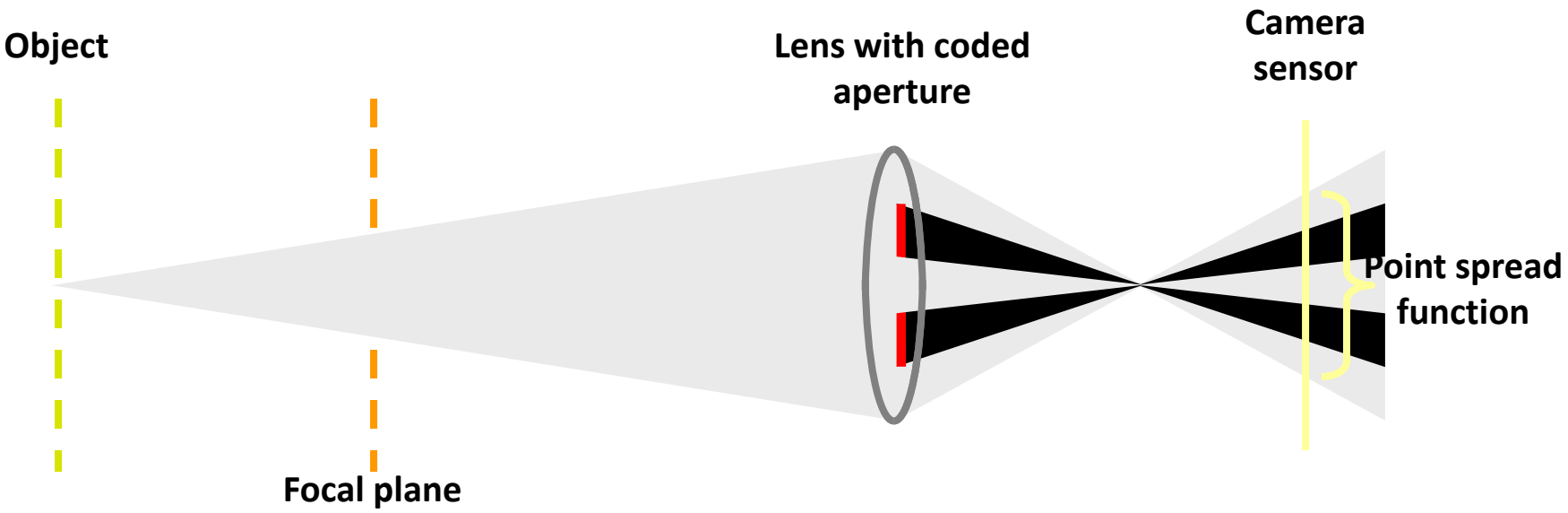
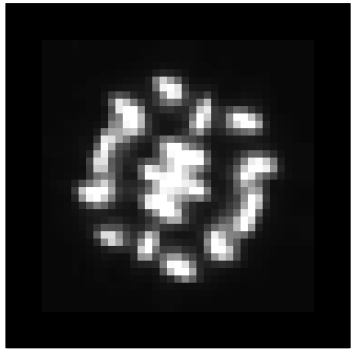


Image of a defocused point light source



Solution: lens with occluder

Aperture pattern



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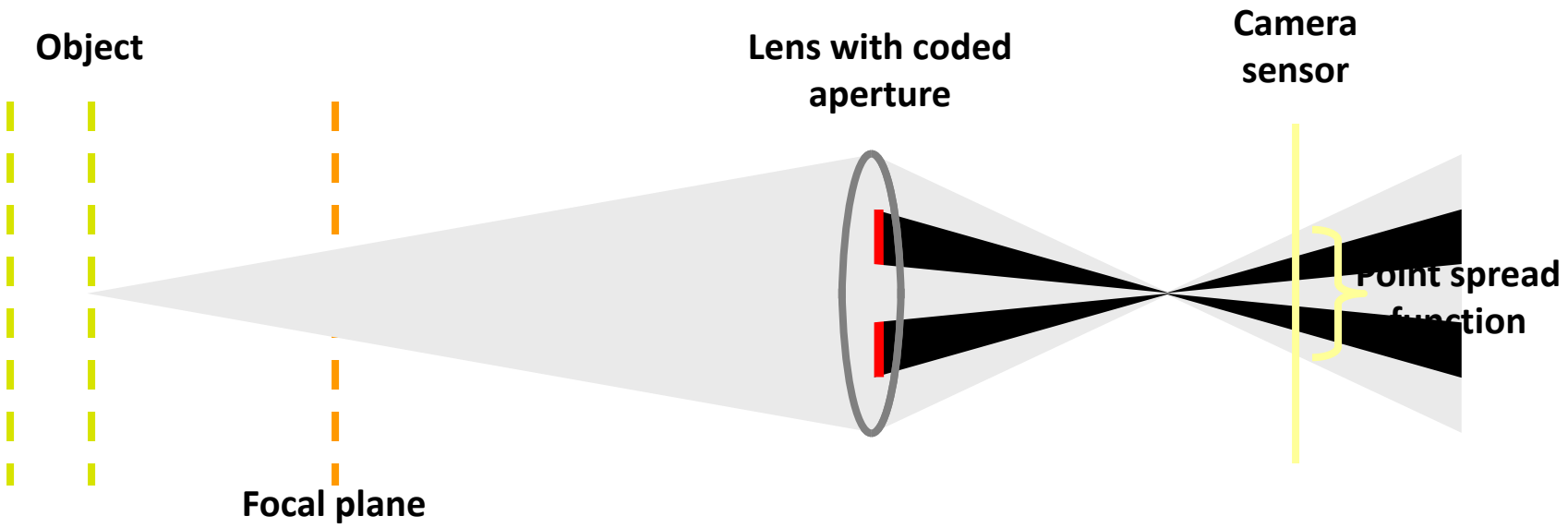
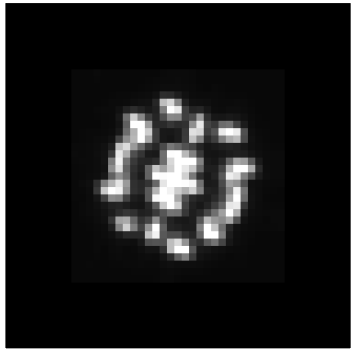


Solution: lens with occluder

Aperture pattern



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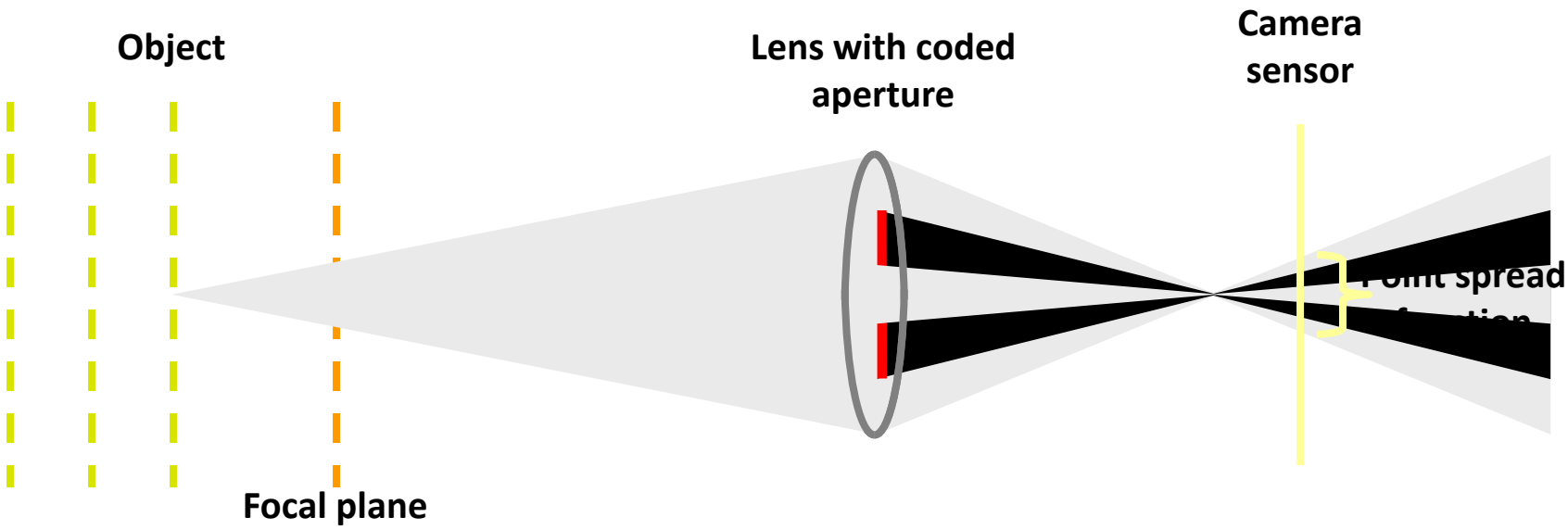
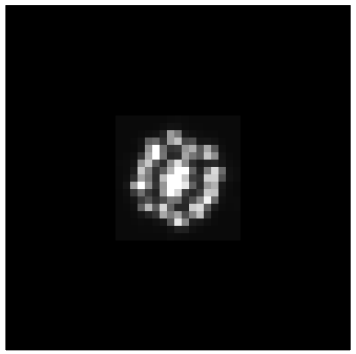


Solution: lens with occluder

Aperture pattern



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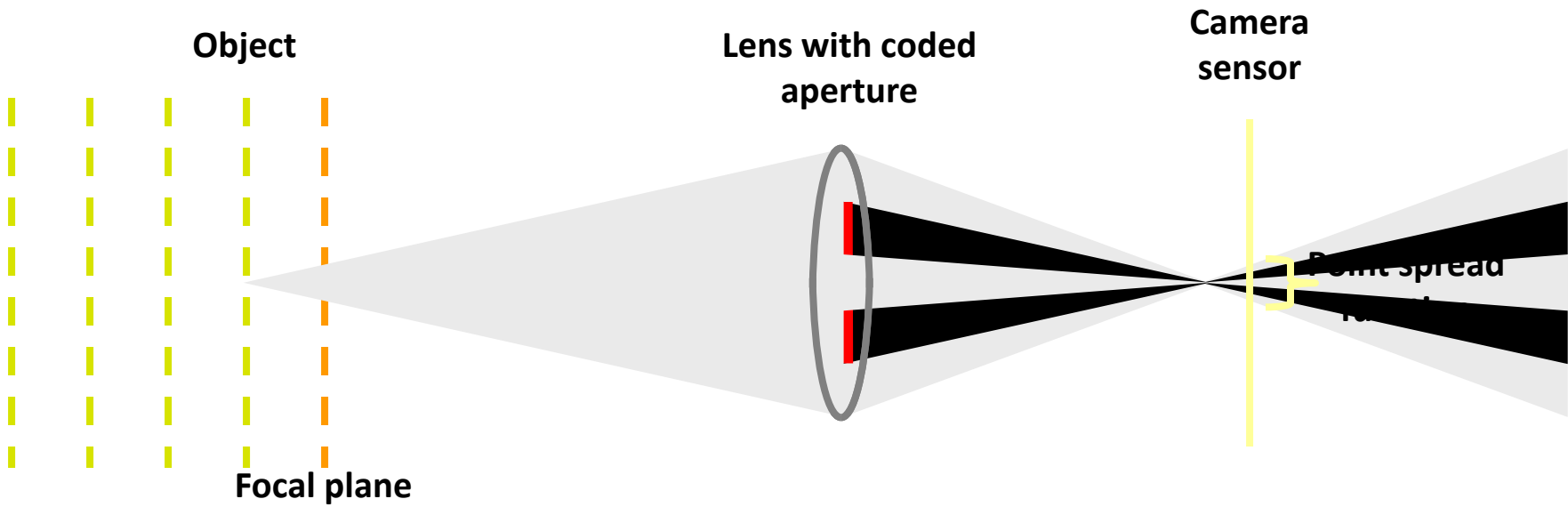


Solution: lens with occluder

Aperture pattern

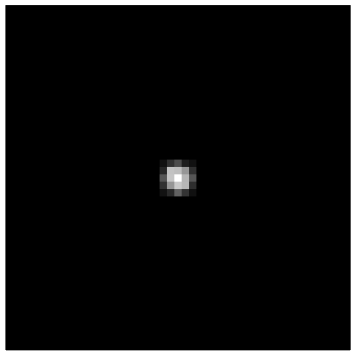
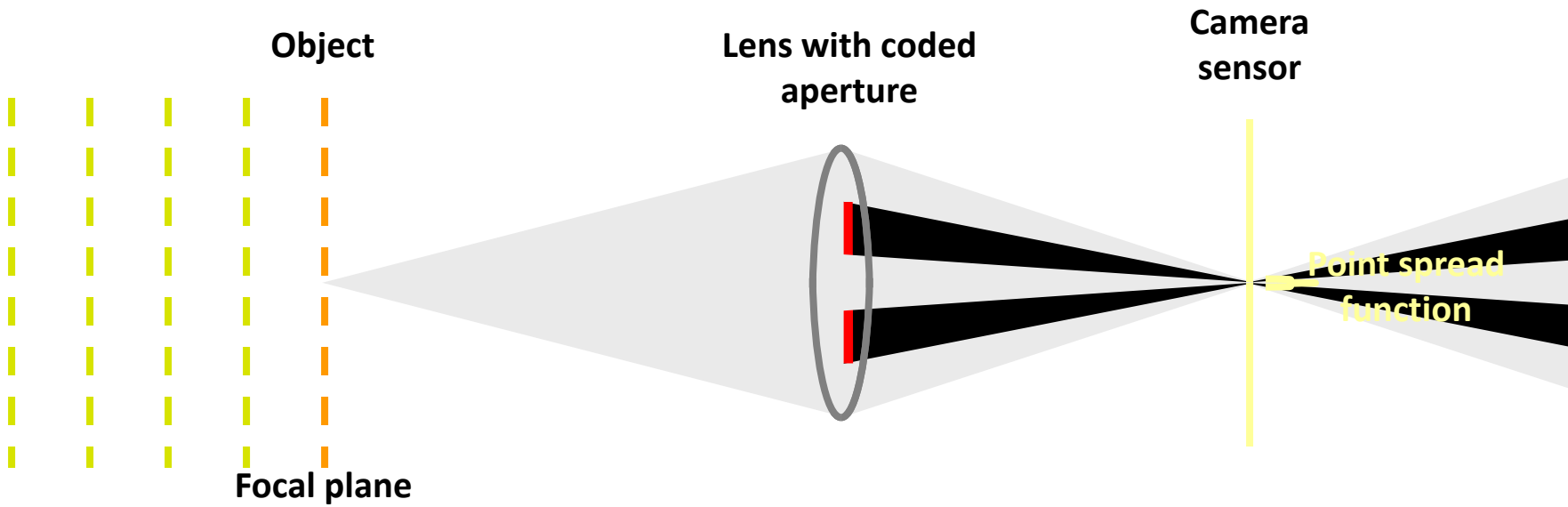
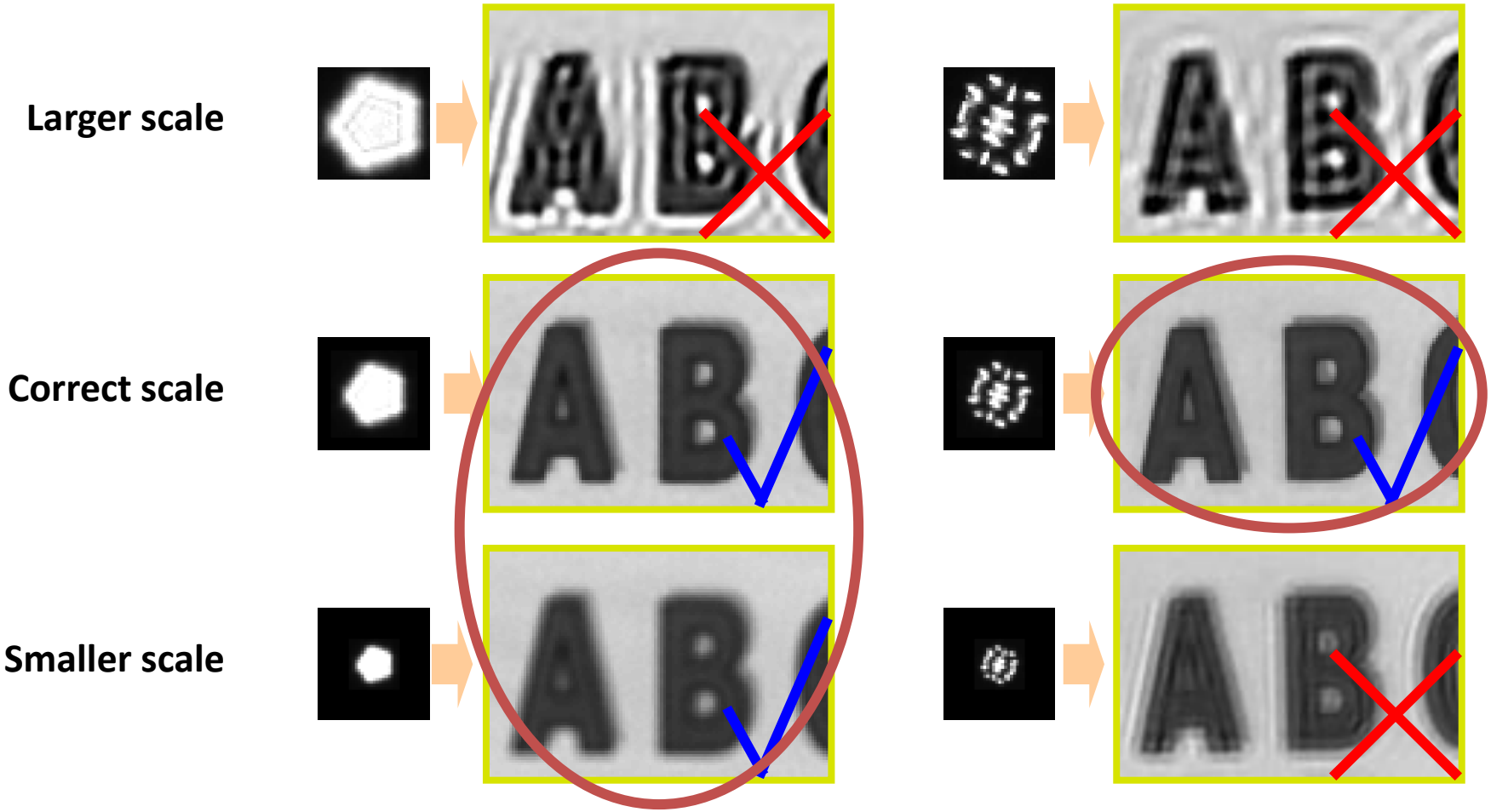


Image of a defocused point light source



Why coded?

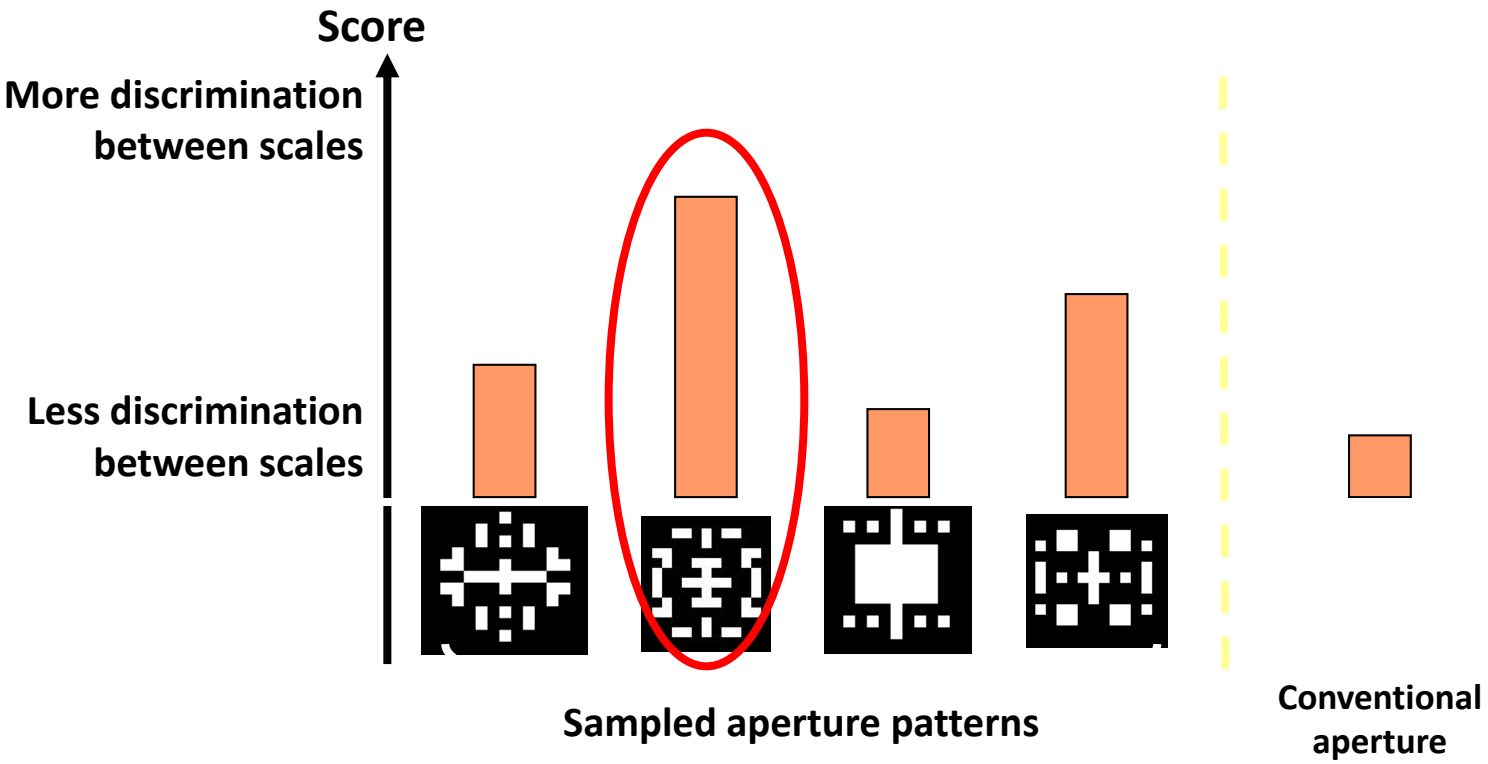
Coded aperture- reduce uncertainty in scale identification



Filter Design

Analytically search for a pattern maximizing discrimination between images at different defocus scales (*KL-divergence*)

Account for image prior and physical constraints

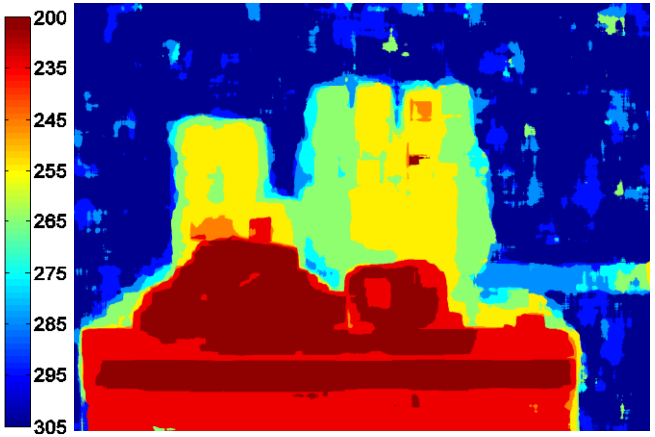


Regularizing depth estimation

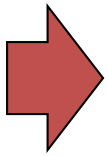
Try deblurring with 10 different aperture scales

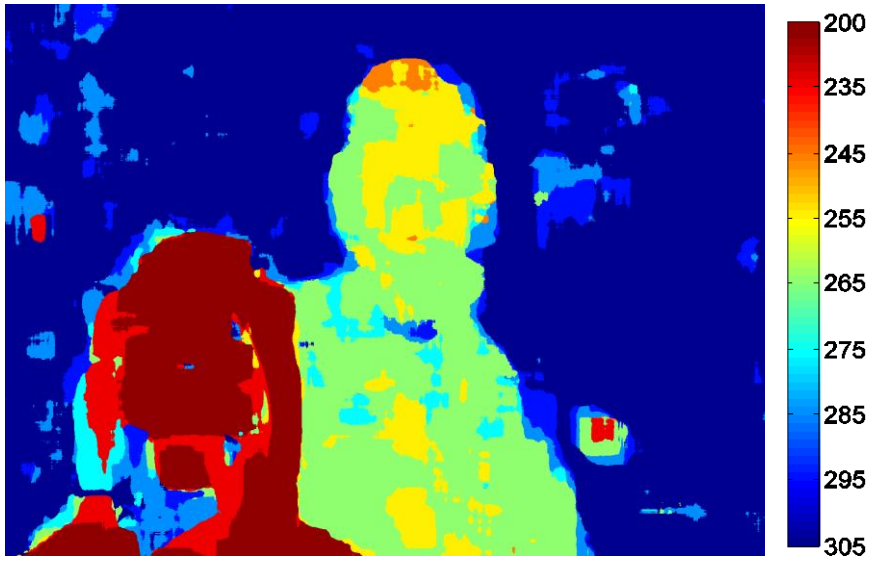
$$x = \arg\min |f \otimes x - y| + \lambda \sum_i \rho(\nabla x_i)$$

Keep minimal error scale in each local window + regularization



Input **Local depth estimation** **Regularized depth**





Local depth estimation

Regularized depth

Computational Illumination

Digital Photography with Flash and No-Flash Image Pairs
Petschnigg et al. (SIGGRAPH 2004)

Flash No-Flash

Digital Photography with Flash and No-Flash Image Pairs
Petschnigg et al. (SIGGRAPH 2004)

Flash No-Flash Combined

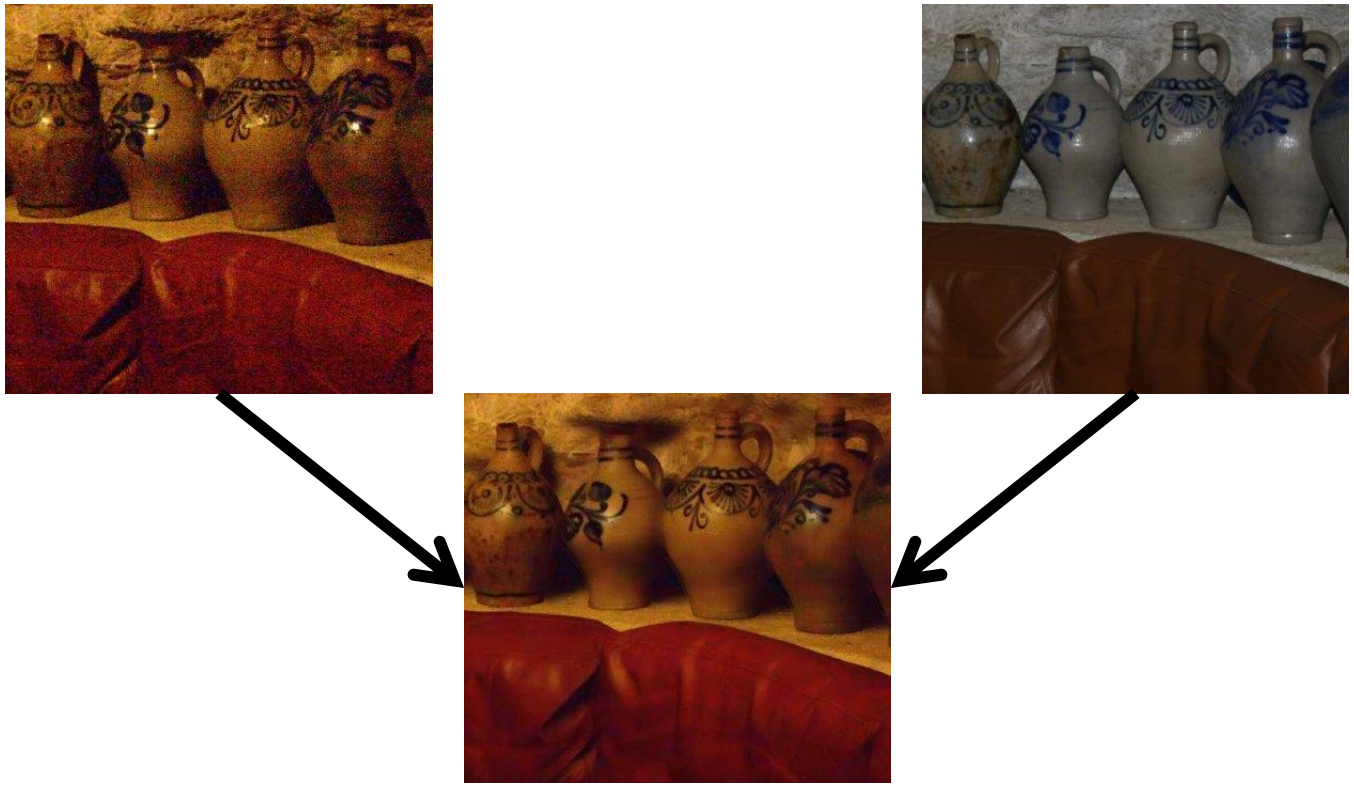
The Dilemma: to Flash or not to flash?

- Natural lighting
- Low signal-to-noise ratio (SNR)
- Loss of details
- Longer exposure – motion blur

- Harsh, unnatural lighting
- High SNR
- More details
- May cause unwanted artifacts (red eye, shadows, specularities)

Why not both?

- **The idea:** use the good features of each photo to create a better image

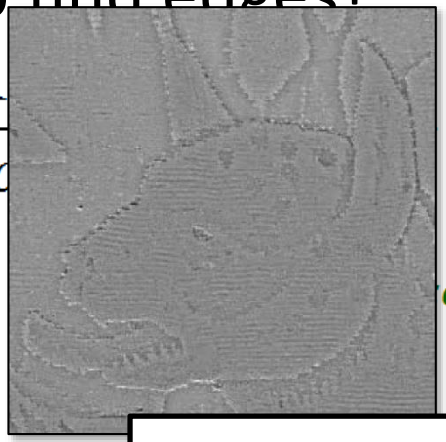


Improvement: Joint Bilateral Filter

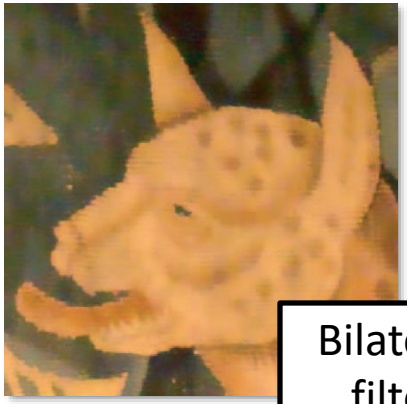
- In the flash image there are much more details
- Why not use F to find edges?

$$A^{NR}_{p(col)} = \frac{1}{k(p(c} \qquad p'|)$$

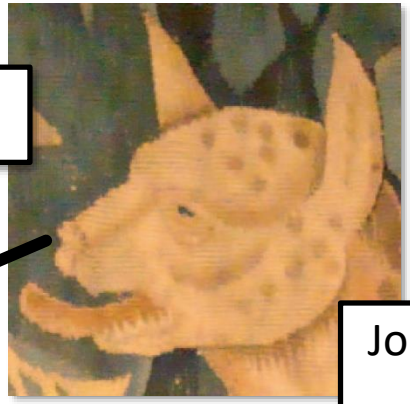
$$ol) - F_{p'(col)})A_{p'(col)}$$



The difference



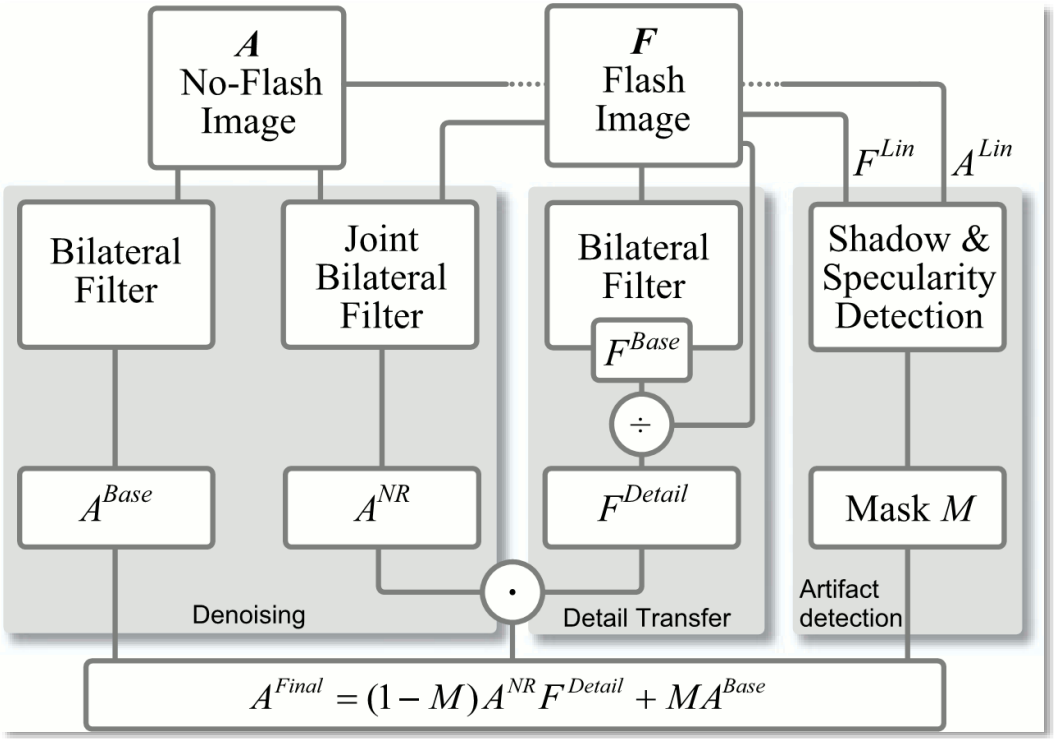
Bilateral filter



Joint Bilateral filter

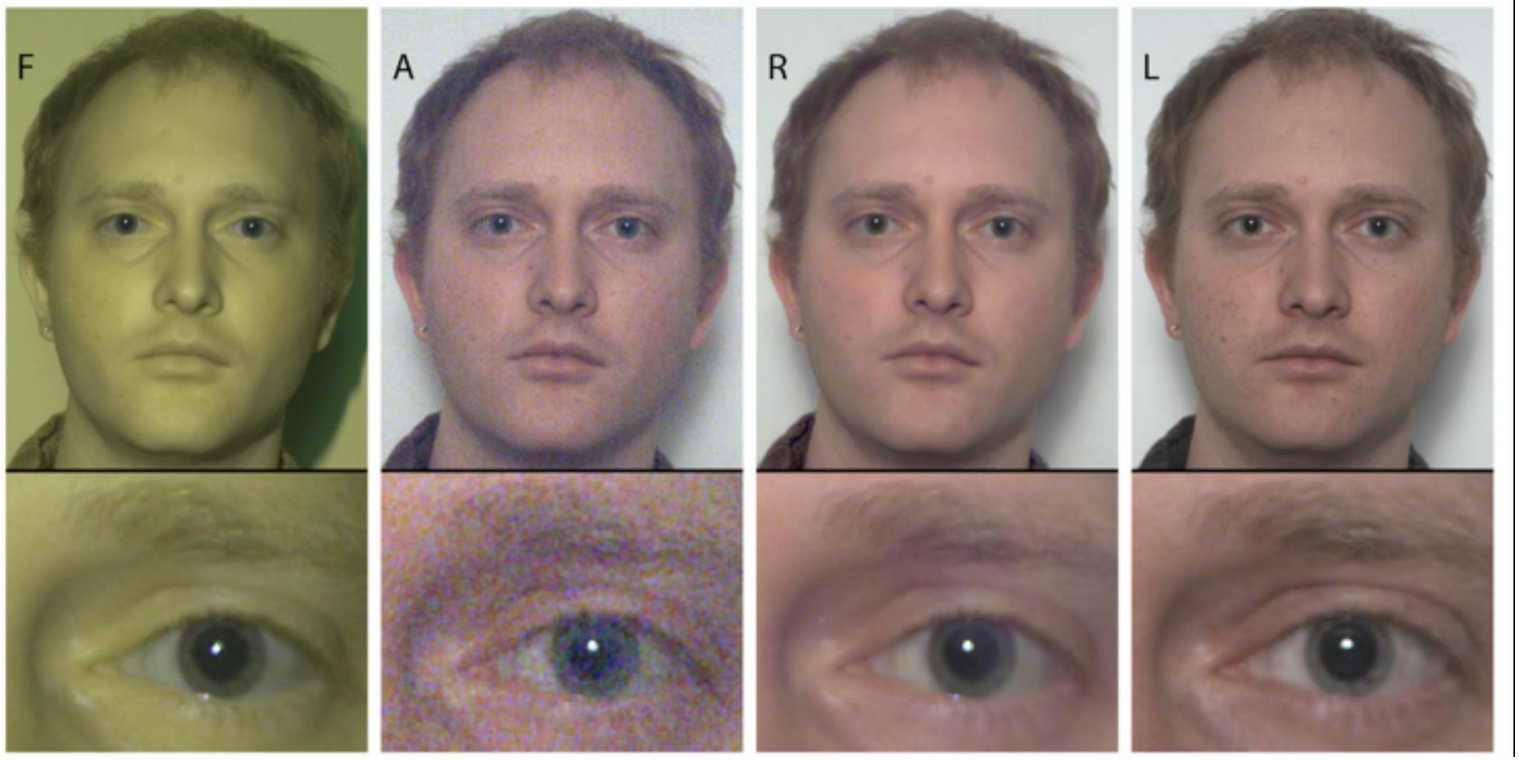
More details

- Denoising + detail transfer + masking shadows and specularities



More Examples

Dark Flash Photography
Krishnan, Fergus (SIGGRAPH 2009)



Dark Flash image | Ambient image | Combined | Groundtruth

Dark flash is ~200 times dimmer than conventional

Computational Stereo

Computational Stereo

Computer

Left 2D image

Right 2D image

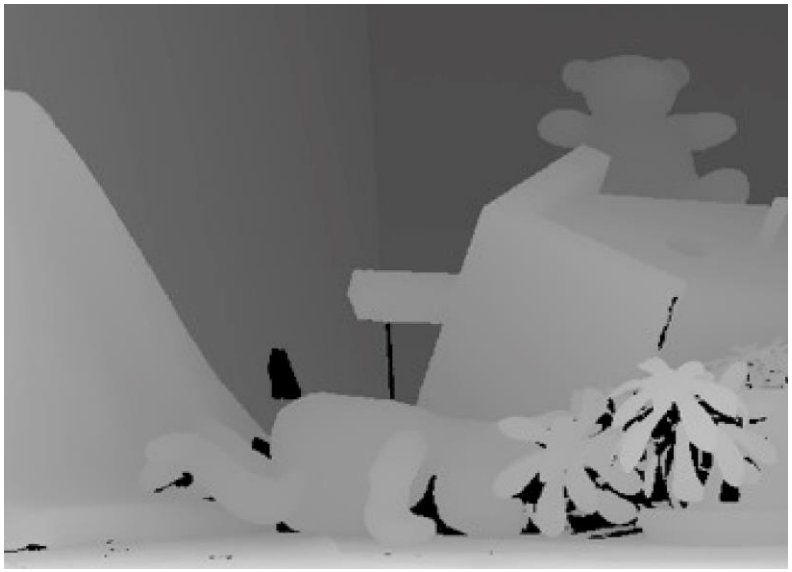
3D image

What is Disparity?

The amount to which a single pixel is displaced in the two images is called disparity

A pixel's disparity is inversely proportional to its depth in the scene

Disparity Encoding

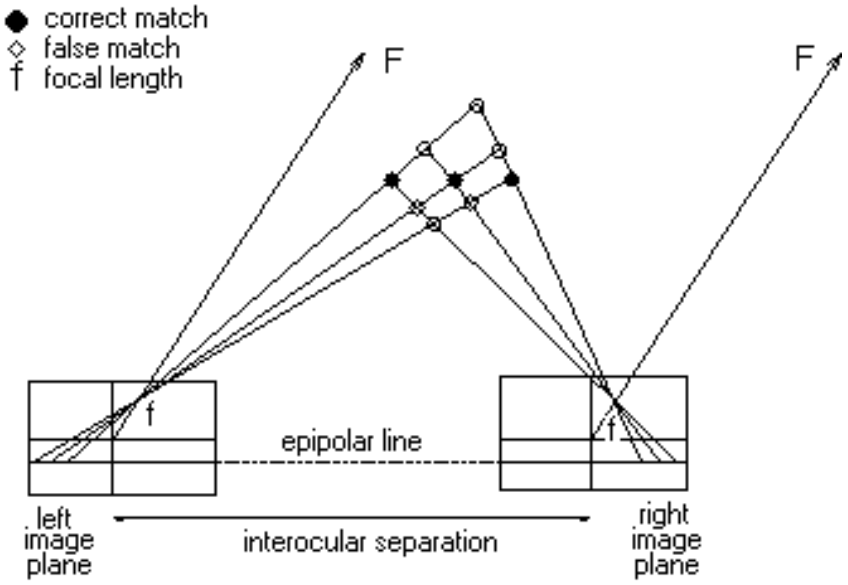


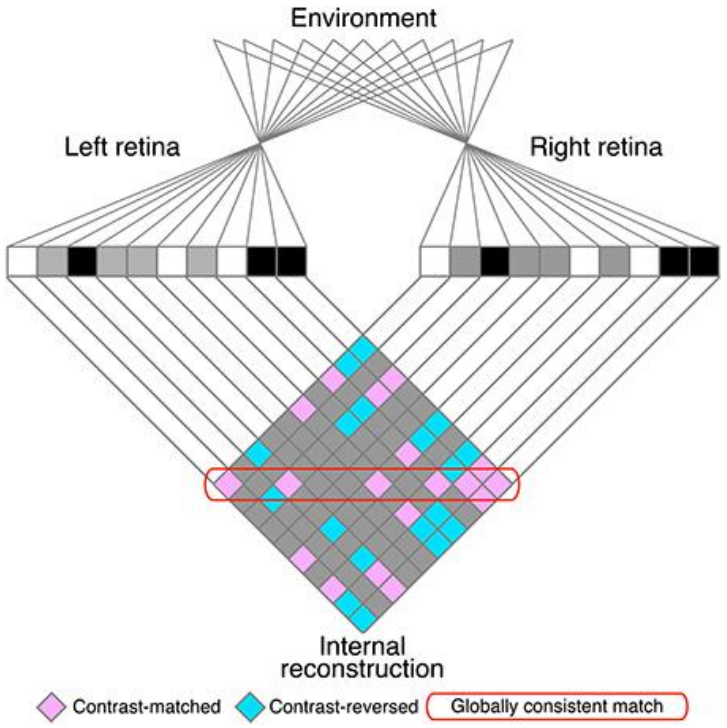
The disparity of each pixel is encoded by a gray value
Light gray values represent high disparities
and dark gray values small disparities
The resulting image is called disparity map

Disparity and Depth

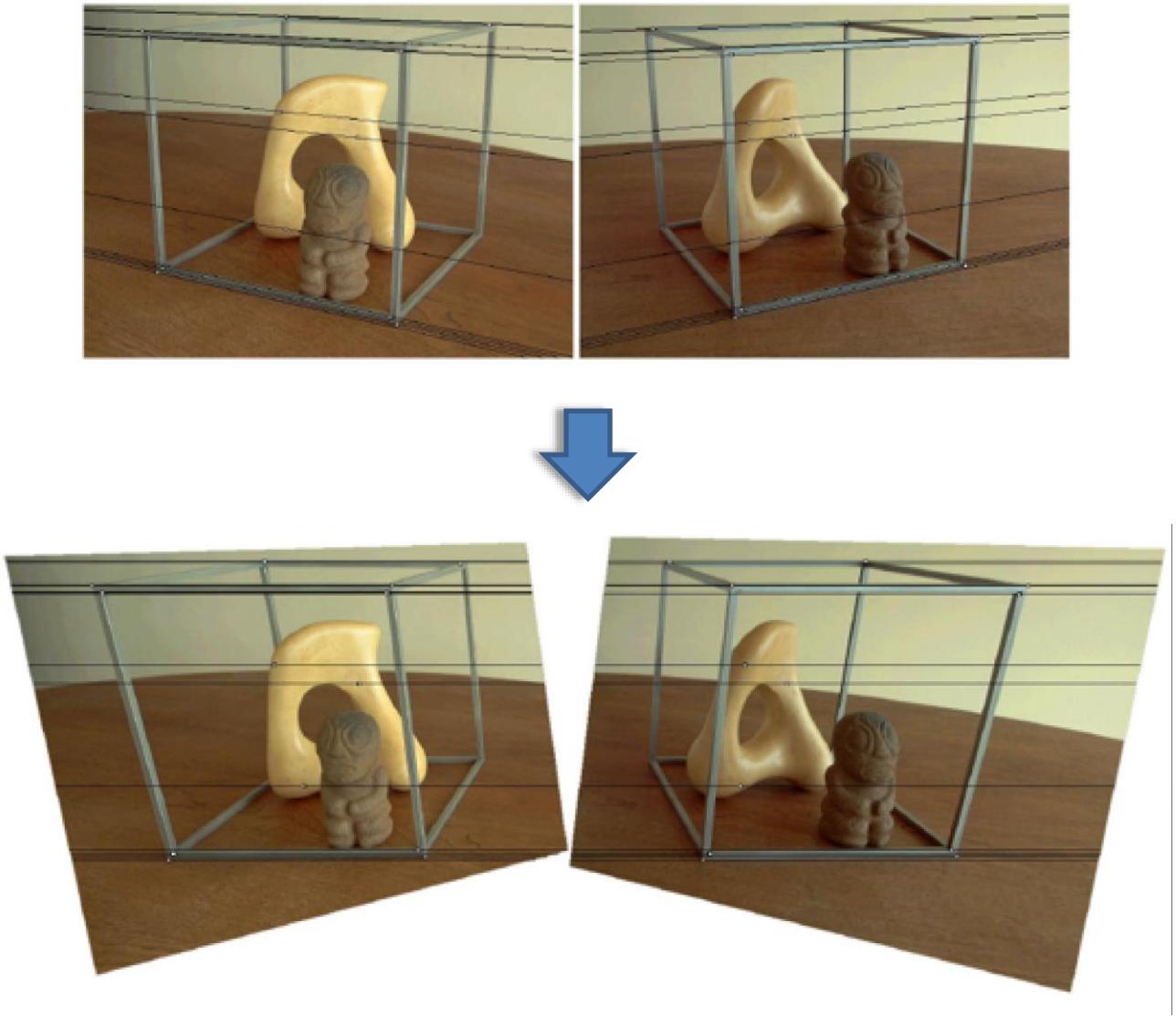
The disparity map contains sufficient information for generating a 3D model

Stereo Correspondence





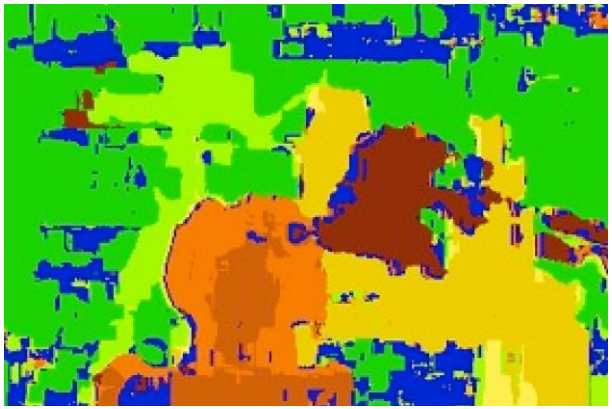
Stereo Rectification



Correspondence problem is hard

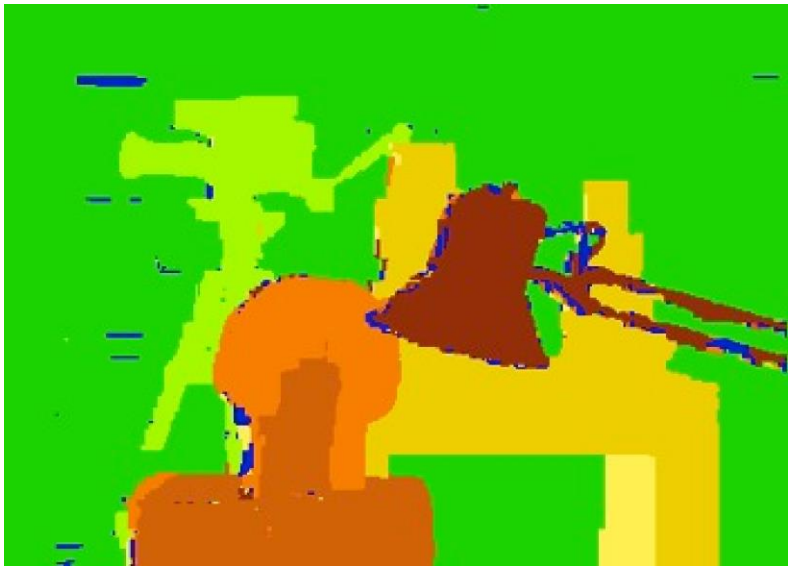
Data

Window-based matching



Ground-truth

Correspondence is hard

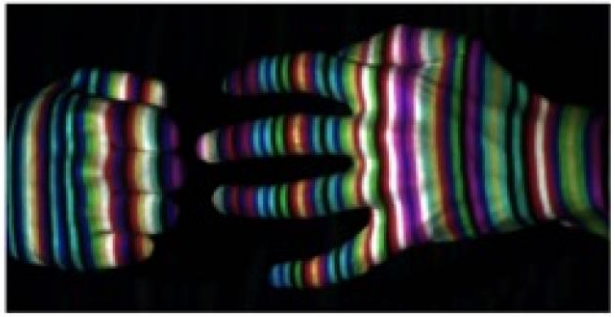


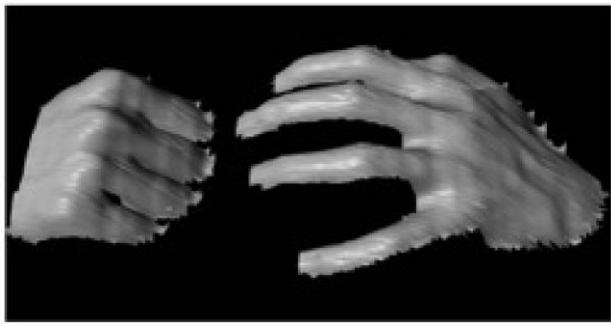
Graph cut

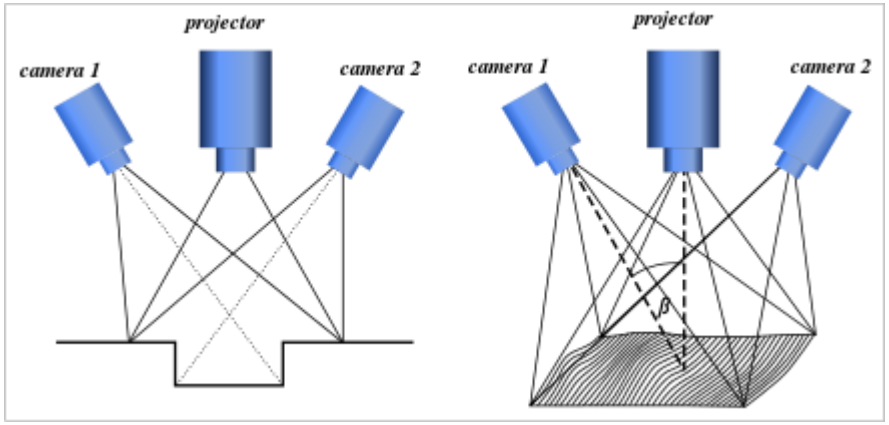
Ground-truth

Y. Boykov, O. Veksler, and R. Zabih, Fast Approximate Energy Minimization via Graph Cuts, PAMI 2001

Active stereo with structured light

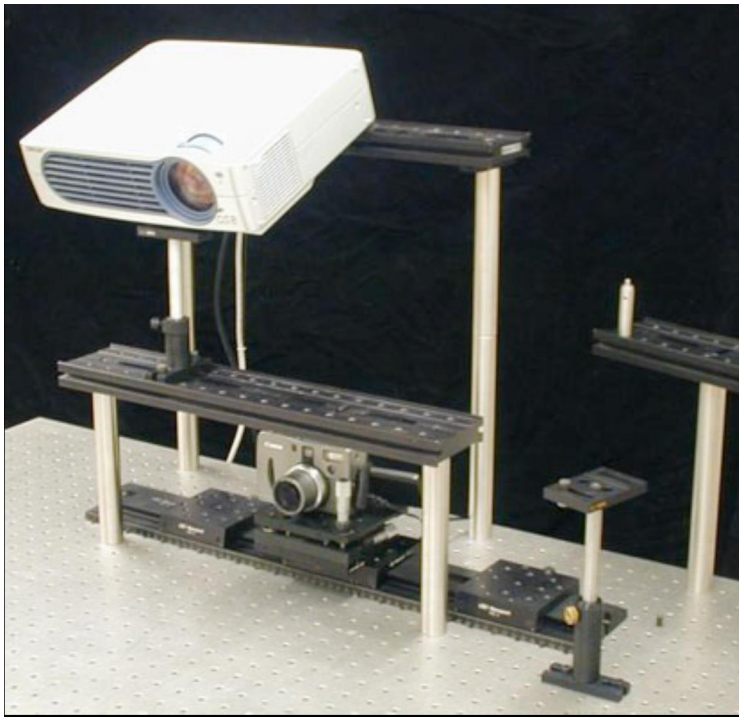


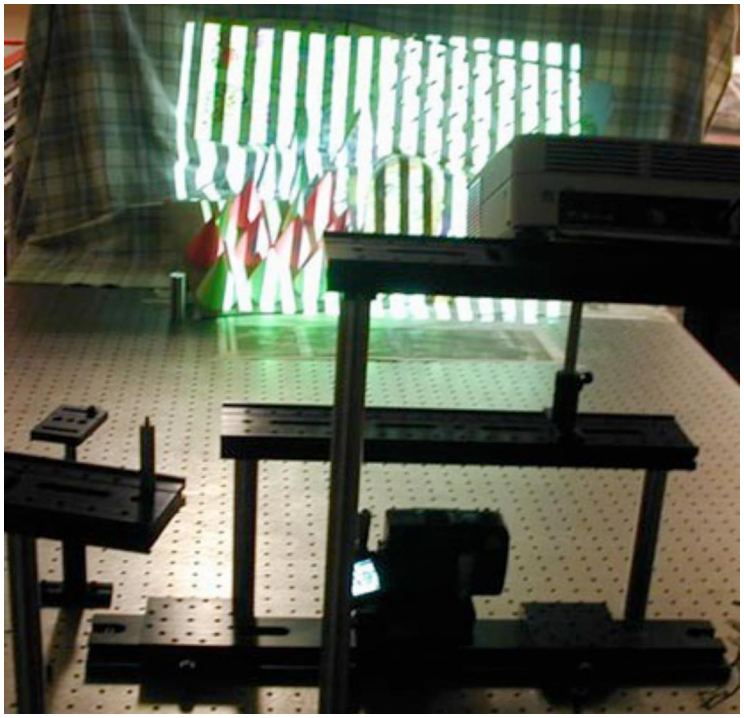




Project “structured” light patterns onto the object
simplifies the correspondence problem

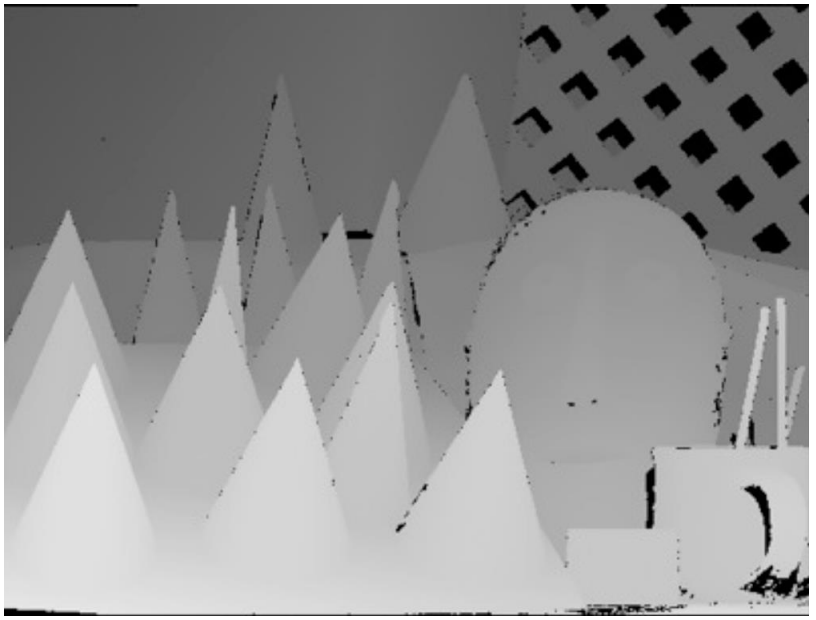
High Accuracy Stereo Depth Map using Structured Light
Scharstein, Szeliski (CVPR 2003)





High Accuracy Stereo Depth Map using Structured Light
Scharstein, Szeliski (CVPR 2003)

scene



depth map

Discussion