

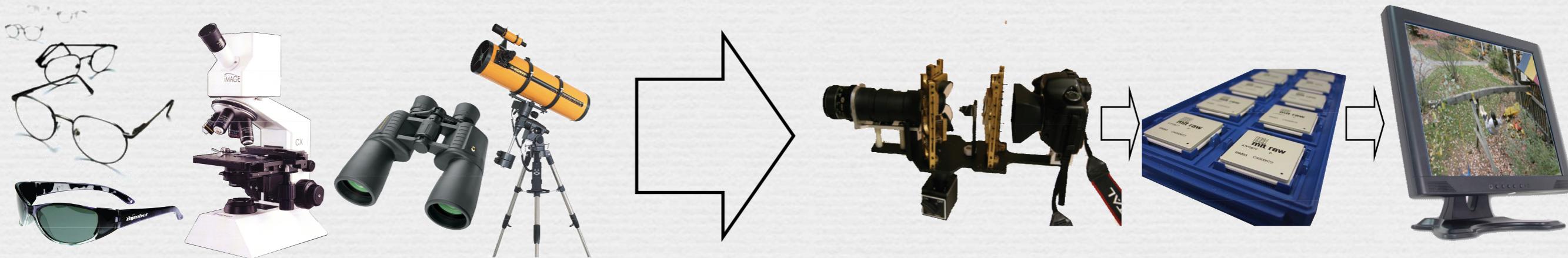
Computational Photography

Frédo Durand
MIT CSAIL



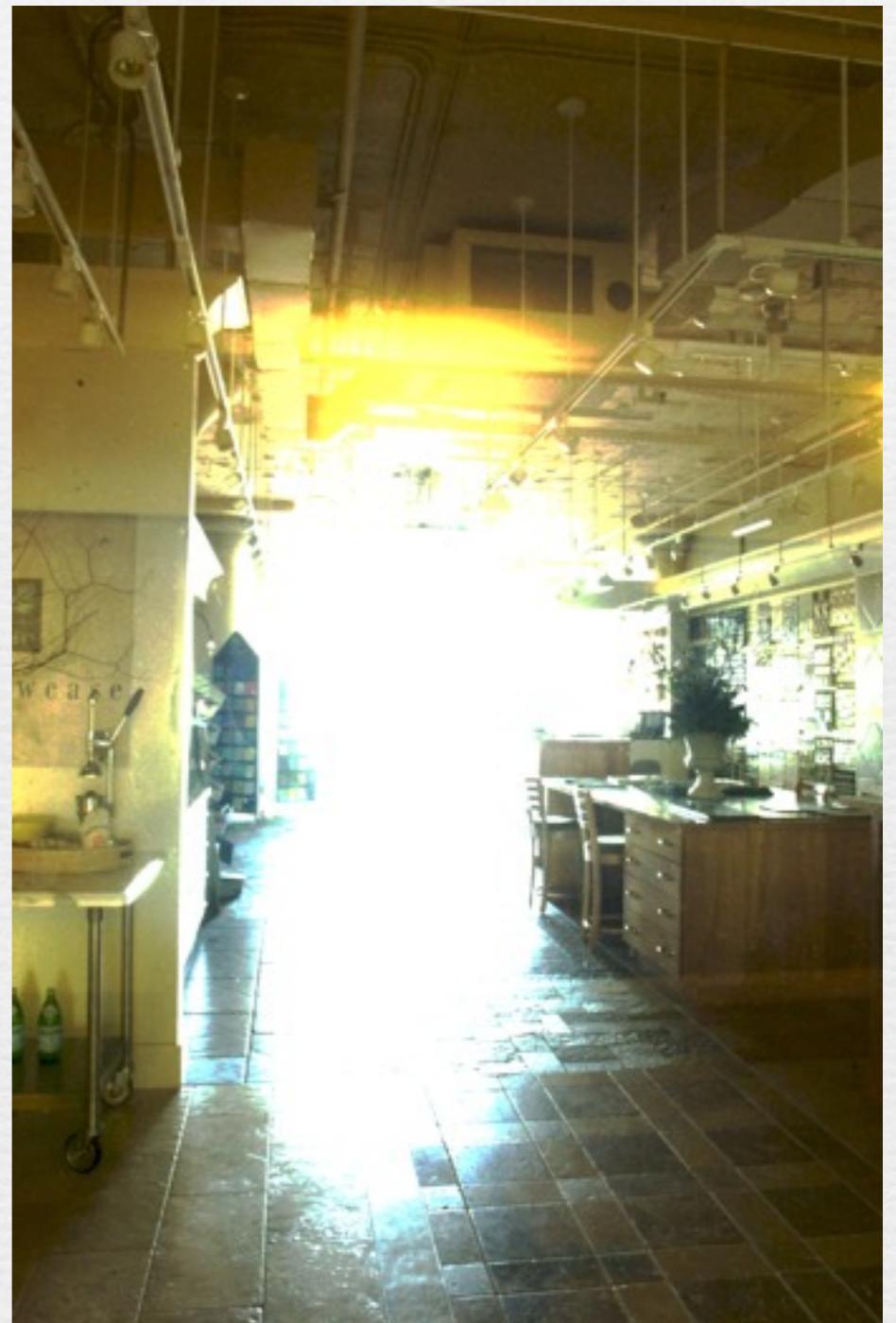
Computation is the new optics

- ♦ See the world better
- ♦ Capture richer visual information
- ♦ Computation is more than a post-process:
it is becoming inherent in image formation
- ♦ What follows is mostly other people's work



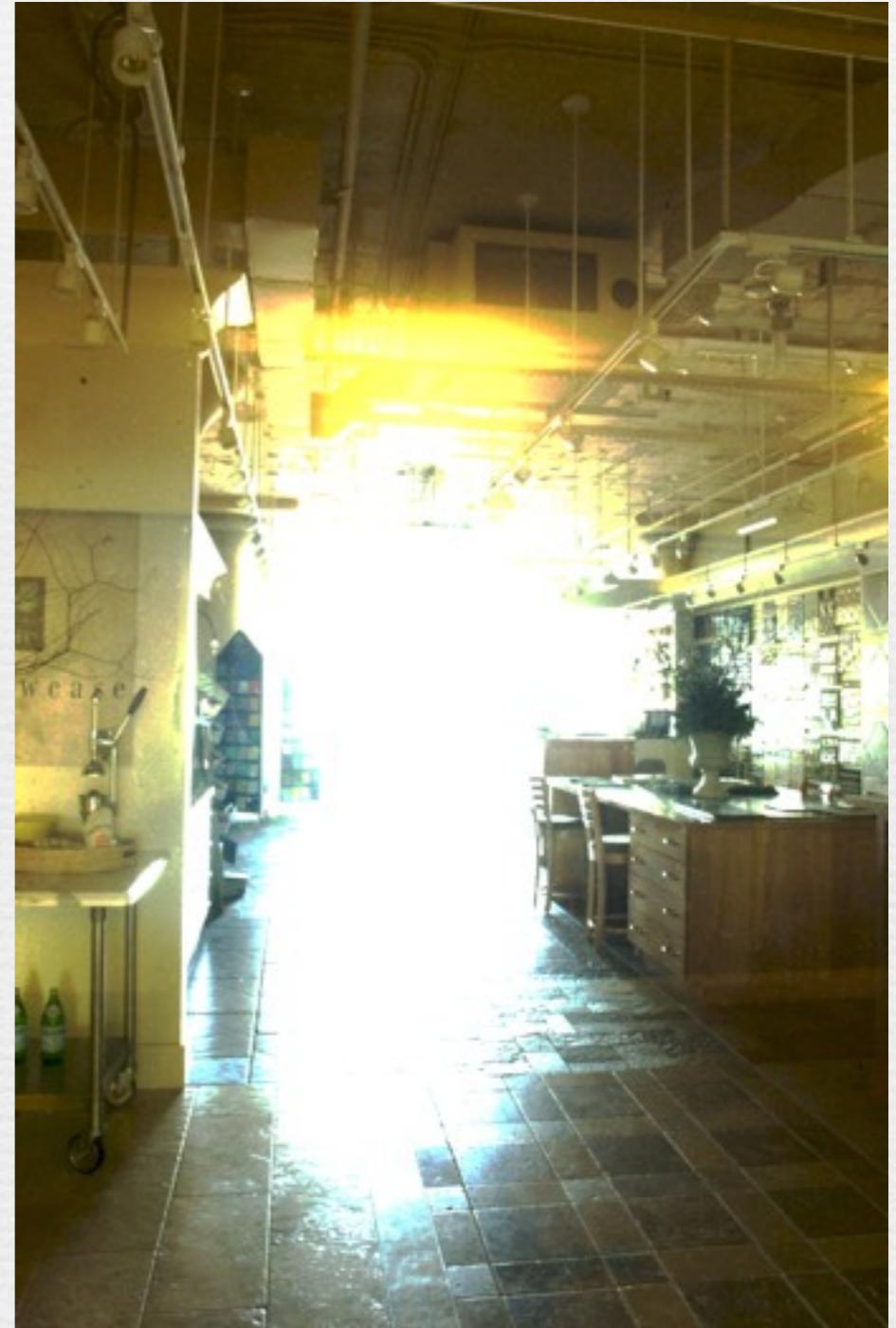
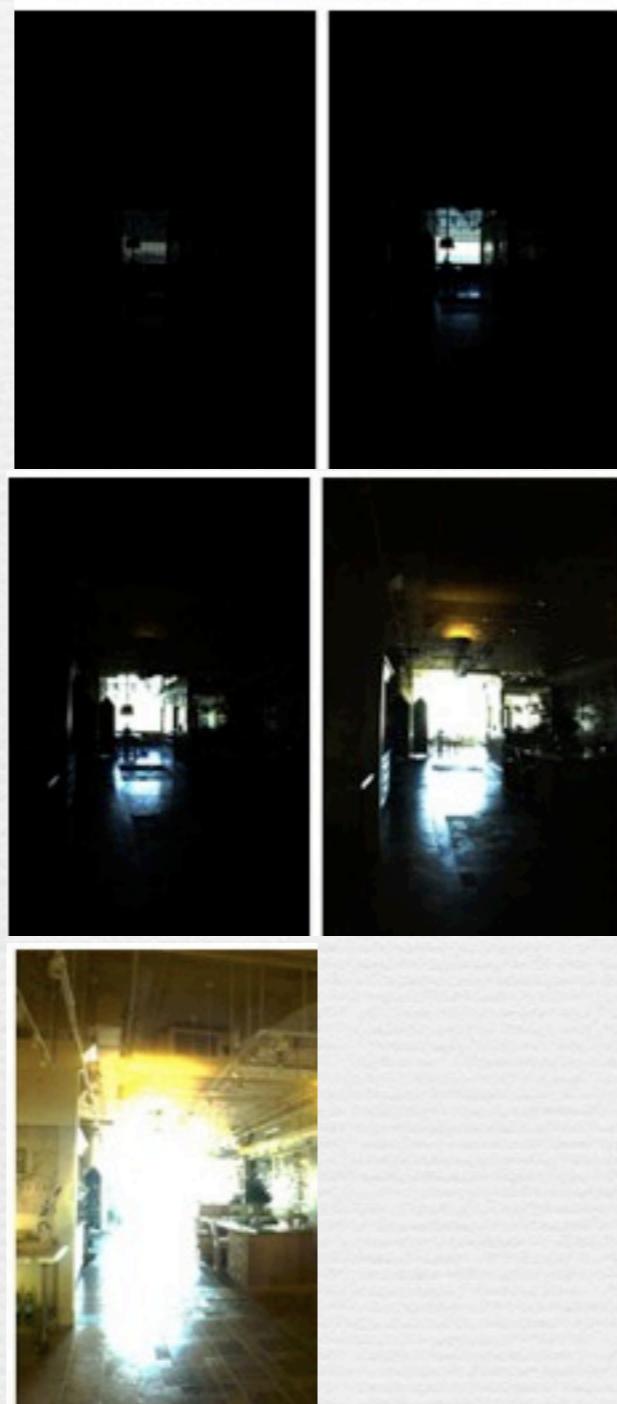
Combine multiple images

- ♦ Problem:
Contrast in the
scene is too high



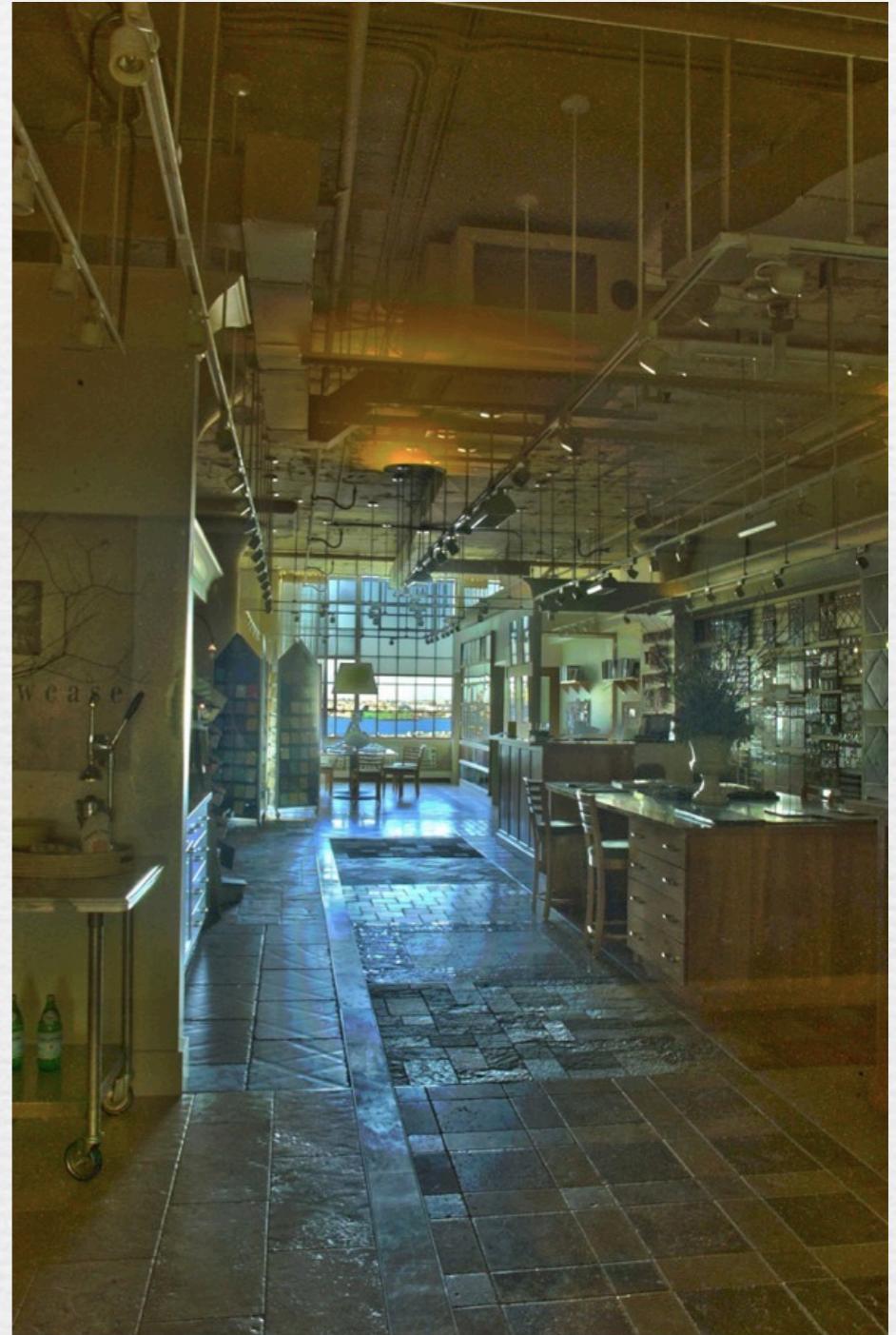
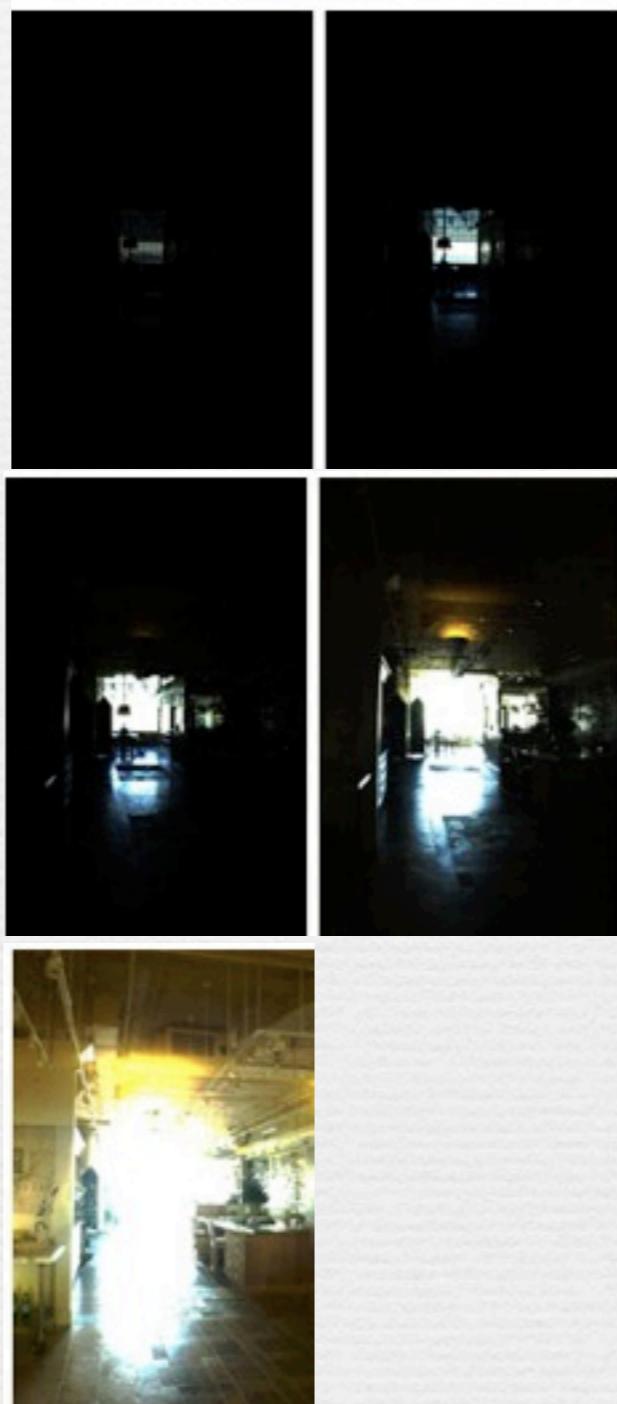
Combine multiple images

- ◆ Problem:
Contrast in the scene is too high
- ◆ Take different exposures
- ◆ Combine and reduce contrast computationally
- ◆ Pioneered by Steve Mann at MIT



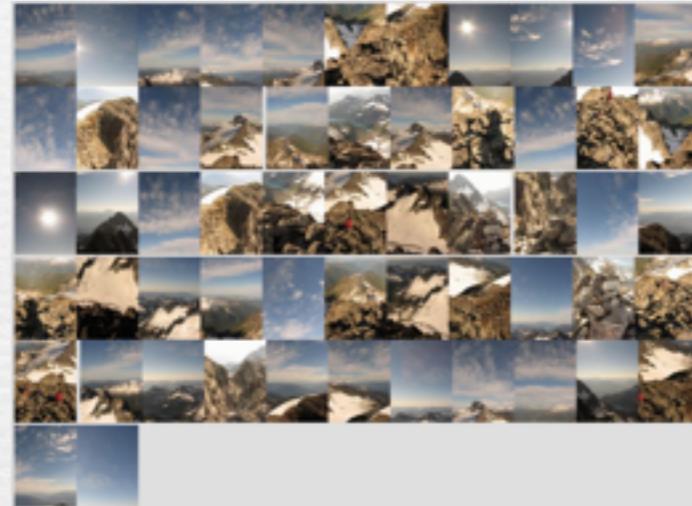
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Combine multiple images

- ♦ Panorama stitching



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[Brown and Lowe]



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Combine large image collections

[Snavely et al.]

Combine large image collections

Photo Tourism Exploring photo collections in 3D

Noah Snavely Steven M. Seitz Richard Szeliski
University of Washington *Microsoft Research*

SIGGRAPH 2006

[Snavely et al.]

Remove optical artifacts

- ♦ Calibrate lenses and remove blur
- ♦ e.g. DXO



Remove optical artifacts

- ♦ **Unknown** camera shake blur

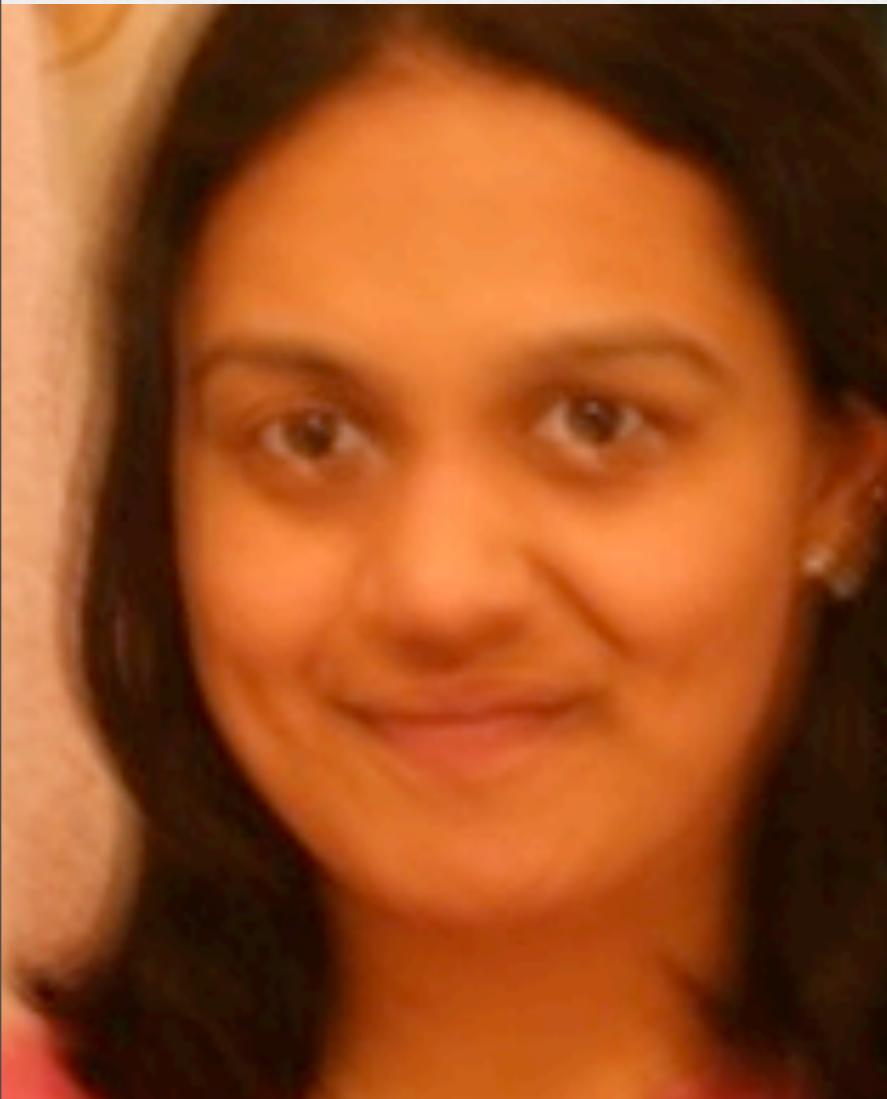
Blurry Original



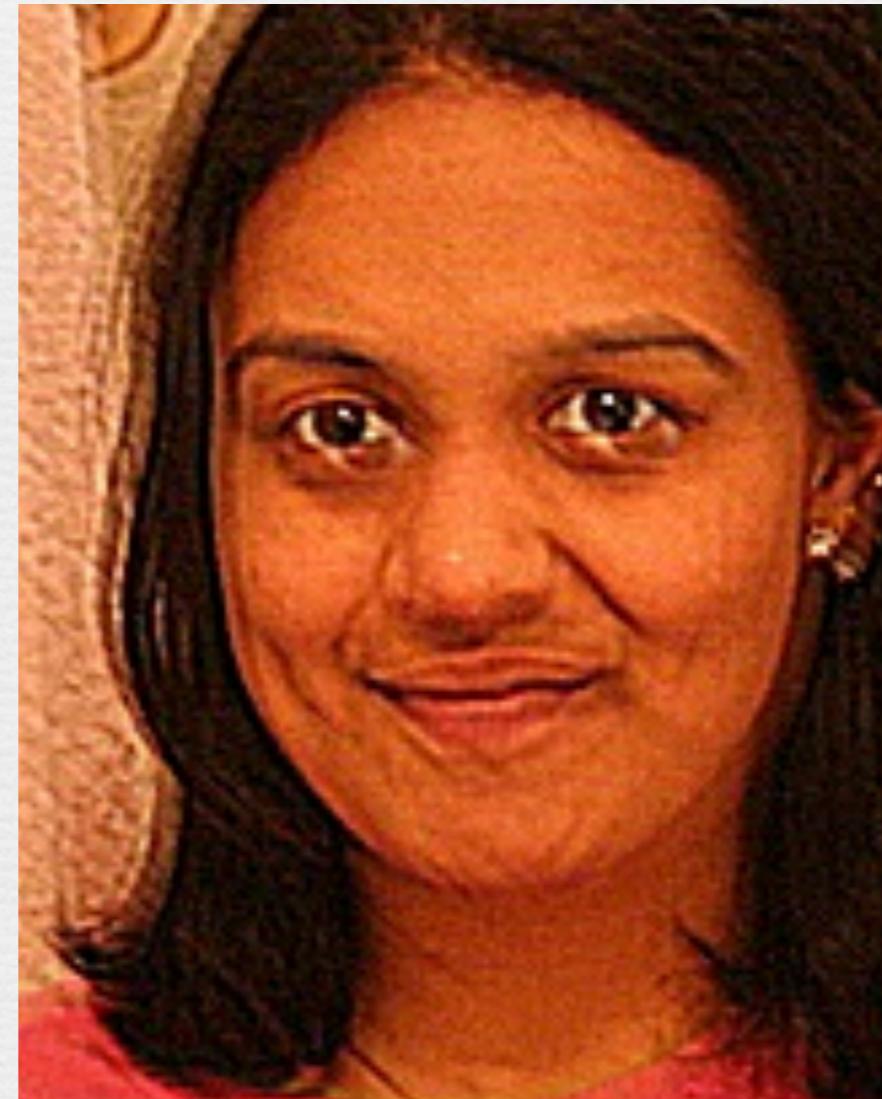
Remove optical artifacts

- ♦ Unknown camera shake blur

Blurry Original



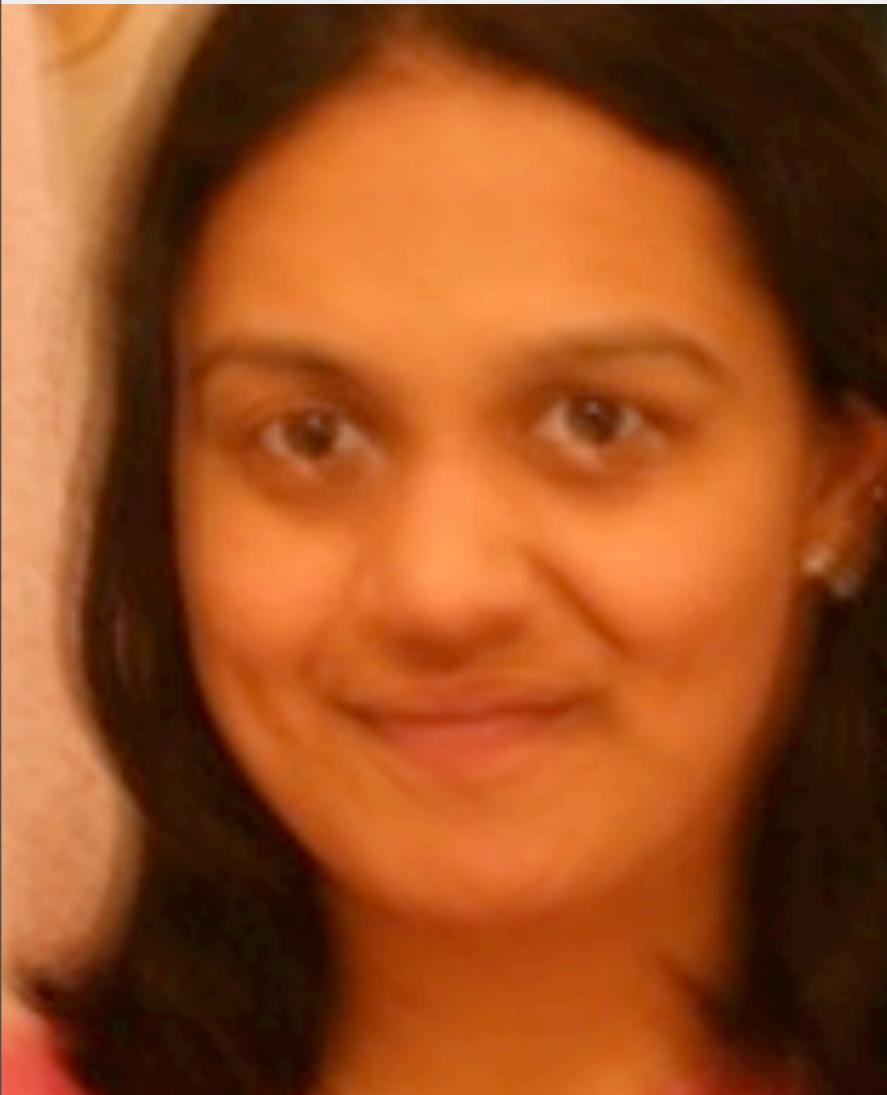
Naïve Sharpening



Remove optical artifacts

- ♦ Unknown camera shake blur

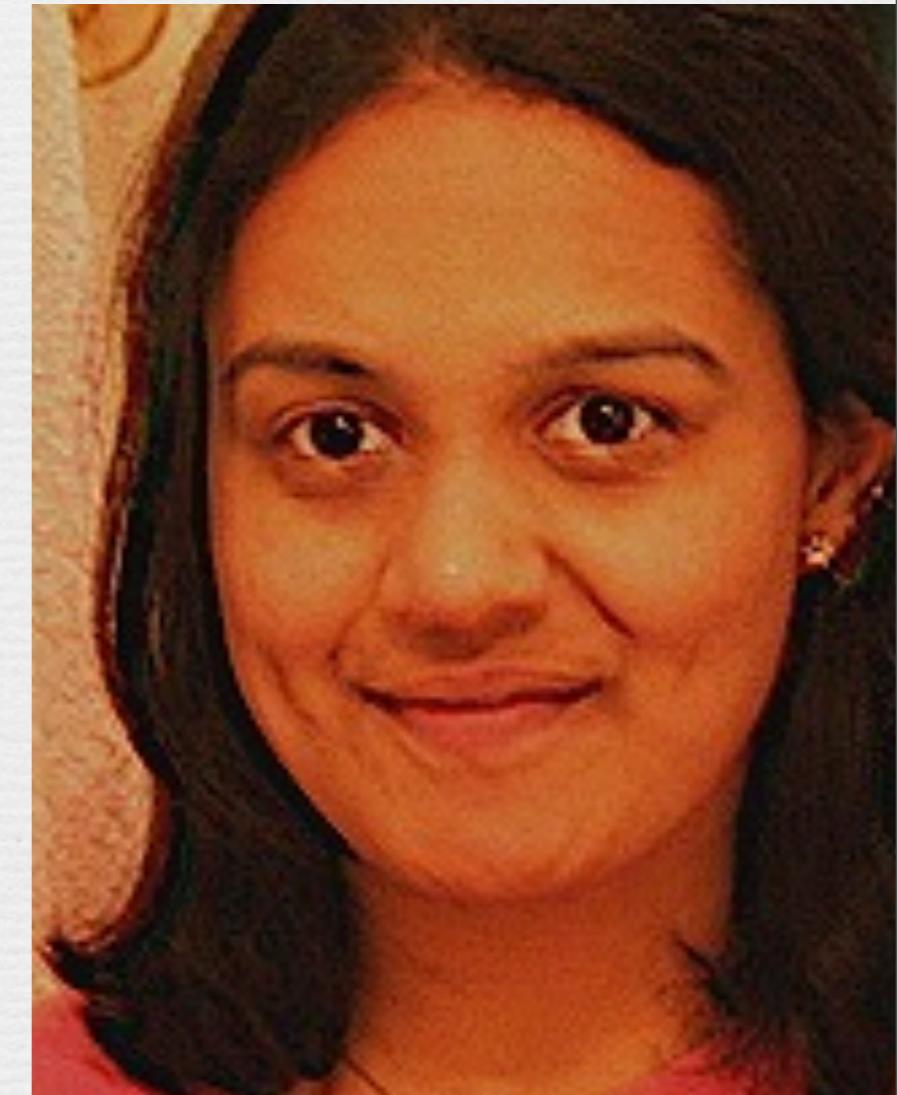
Blurry Original



Naïve Sharpening



Fergus et al.'s
algorithm



Co-design optics & computation

- ♦ Problem: depth of field

Traditional Optical System Image



Co-design optics & computation

- ♦ Problem: depth of field
- ♦ Lens that is blurry at all distances
- ♦ But blur is easy to remove

Traditional Optical System Image



Intermediate Extended Depth of Field Image



Co-design optics & computation

- ◆ Problem: depth of field
- ◆ Lens that is blurry at all distances
- ◆ But blur is easy to remove

Traditional Optical System Image



Intermediate Extended Depth of Field Image

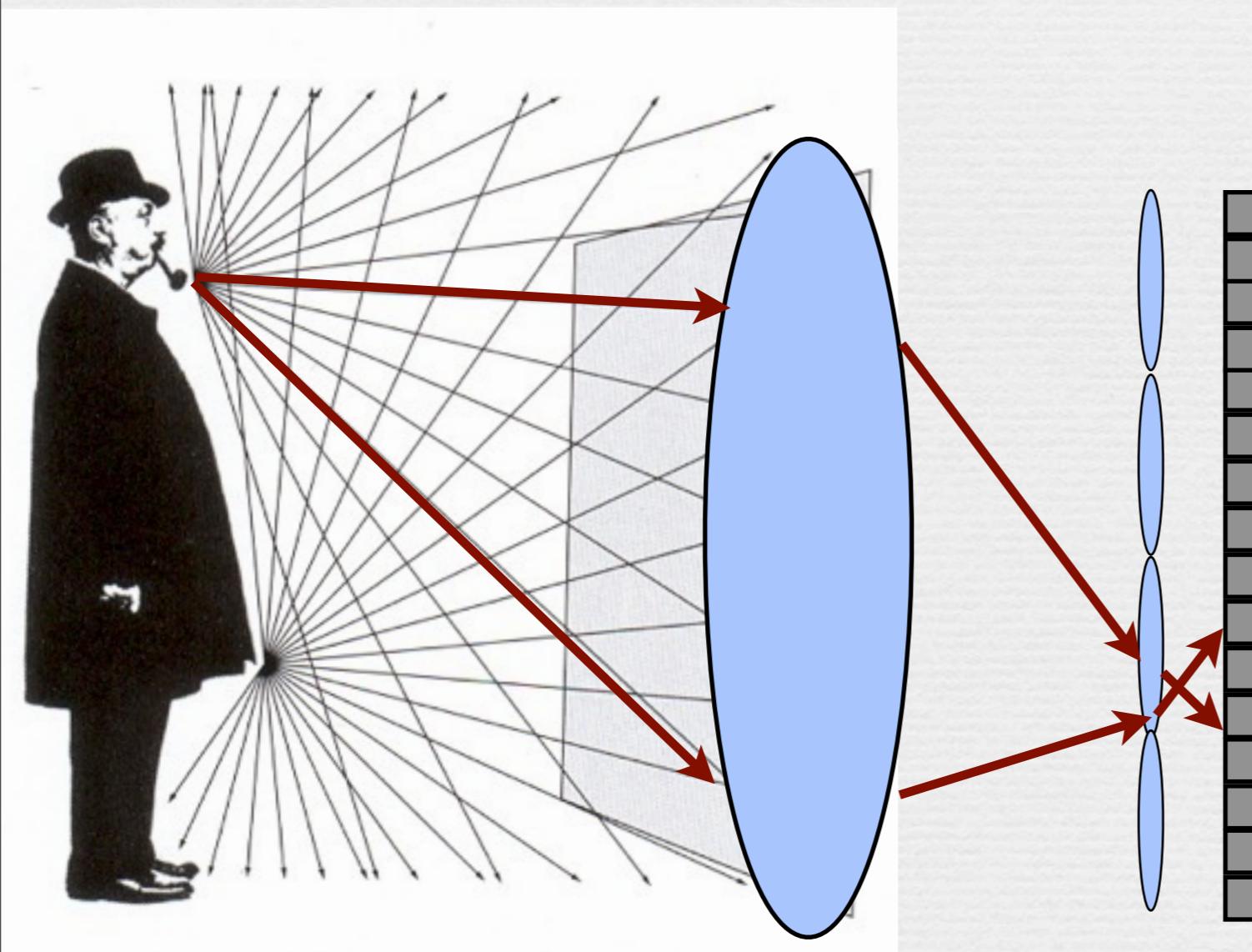


Final Wavefront Coded™ Image



Form images as a post-process

- ♦ Record full 4D set of light rays reaching a lens
 - [Adelson & Wang, Ng et al.]
- ♦ Enables refocusing from a single shot



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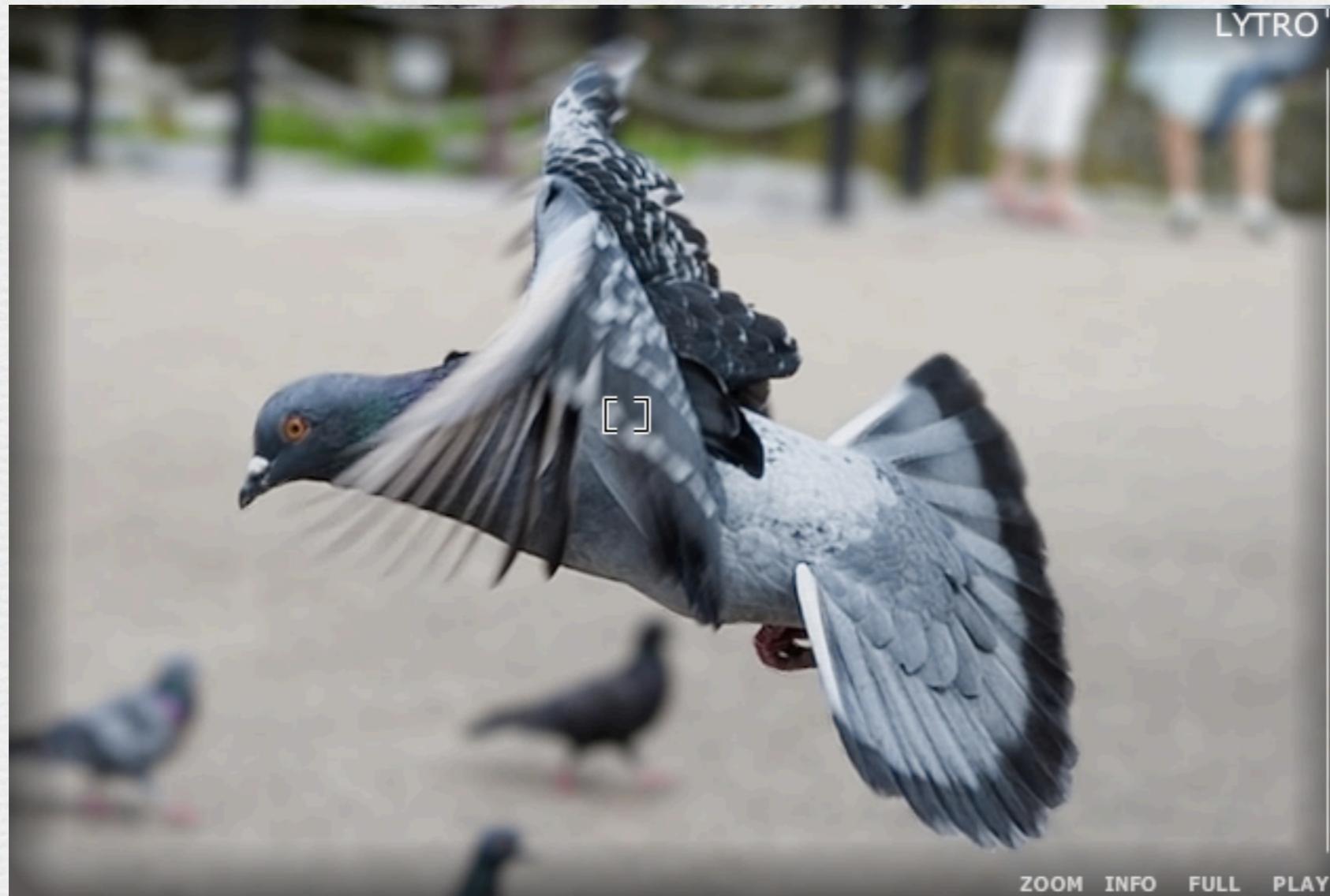


Results by Ren Ng &
Lytro

winner of ACM
dissertation award
2007

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Make invisible things visible

- ◆ [Liu, et al. 2005]
- ◆ Analyze motion in video
- ◆ Magnify motion that is hard to see



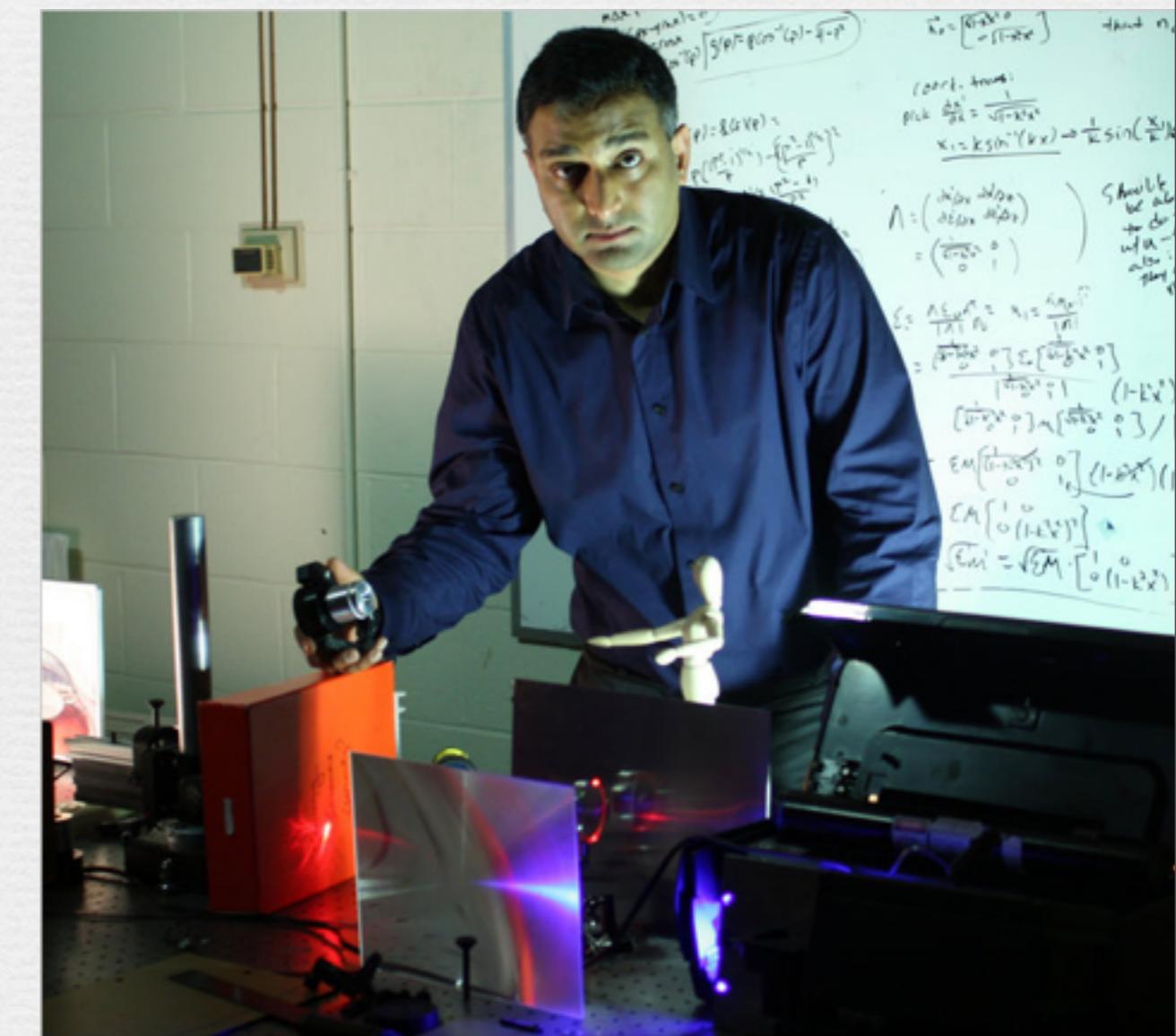
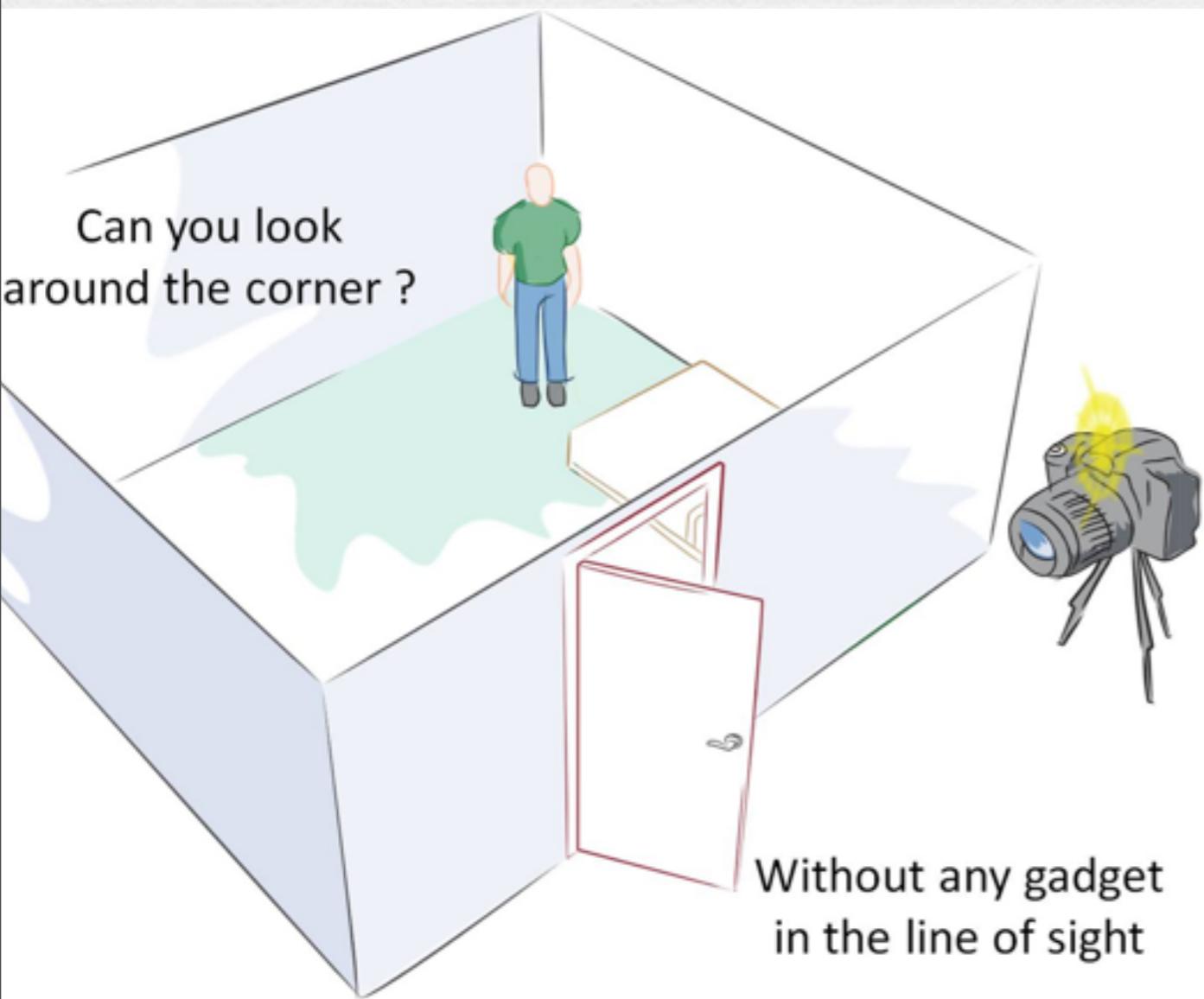
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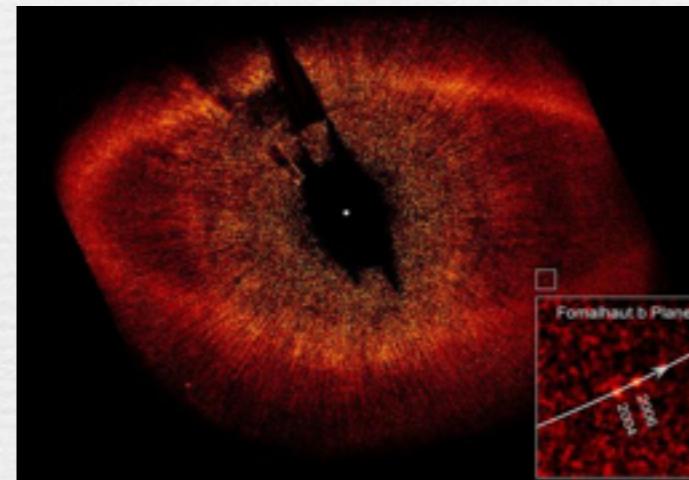
Seeing behind the corners

- ◆ [Raskar et al.]
- ◆ Femtosecond imaging



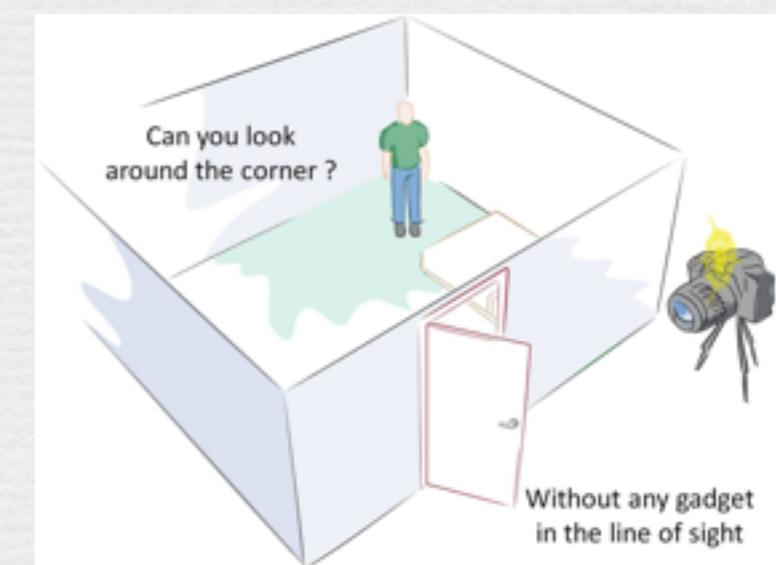
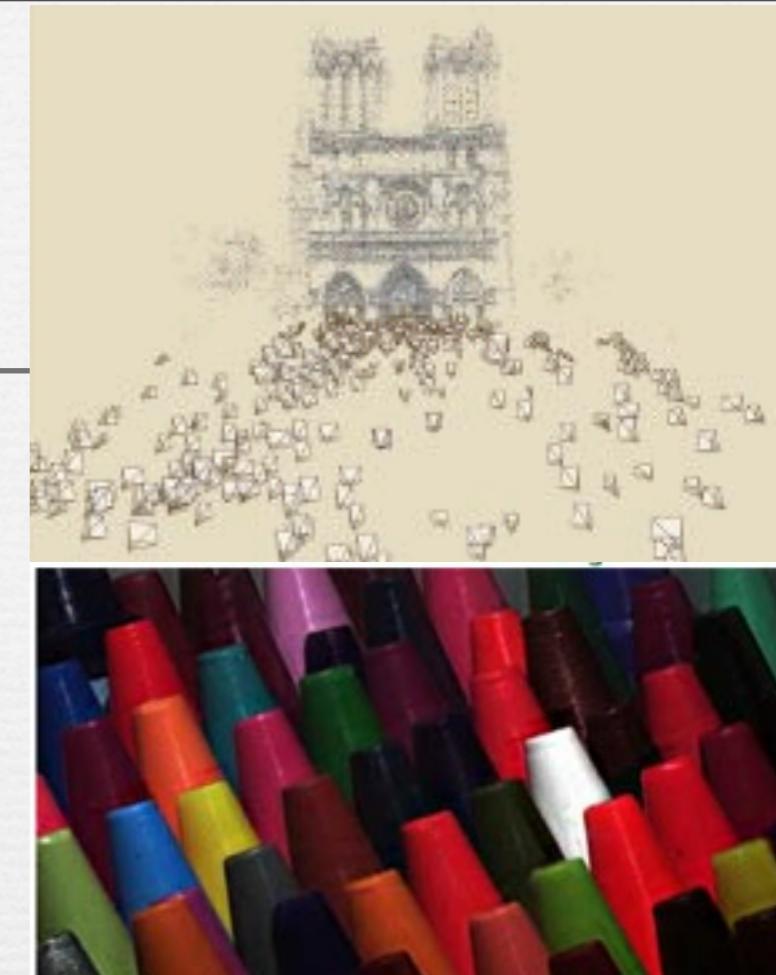
Related areas

- ◆ Radar
- ◆ Microscopy
- ◆ Astronomy
- ◆ Medical Imaging
- ◆ Sound
- ◆ ...
- ◆ **Computation is an inherent part of image formation**



Summary

- ♦ Combine multiple images
 - large collections
- ♦ Correct optical aberration
 - co-design optics & computation
- ♦ Form images as a post-process
 - 4D capture & refocusing
- ♦ Make the invisible visible
 - motion magnification
 - seeing behind the corner



Links to discussed work

- ◆ <http://citeseer.ist.psu.edu/viewdoc/summary?doi=10.1.1.21.3141>
- ◆ <http://ict.debevec.org/~debevec/Research/HDR/>
- ◆ <http://people.csail.mit.edu/fredo/PUBLI/Siggraph2002/>
- ◆ <http://cvlab.epfl.ch/~brown/autostitch/autostitch.html>
- ◆ <http://phototour.cs.washington.edu/>
- ◆ [http://www.dxo.com/us/photo/dxo optics pro/optics geometry corrections](http://www.dxo.com/us/photo/dxo_optics_pro/optics_geometry_corrections)
- ◆ <http://www.cs.nyu.edu/~fergus/research/deblur.html>
- ◆ http://stuff.mit.edu/afs/athena/course/2/2.717/www/ao_41_6080_wvfcode.pdf
- ◆ <http://lytro.com/about/index.html>
- ◆ <http://graphics.stanford.edu/papers/lfcamera/>
- ◆ <http://people.csail.mit.edu/celiu/motionmag/motionmag.html>
- ◆ <http://web.media.mit.edu/~raskar//femto/>

Computational photography courses

- ♦ <http://stellar.mit.edu/S/course/6/sp11/6.815/>
- ♦ <http://web.media.mit.edu/~raskar/#courses>
- ♦ http://graphics.cs.cmu.edu/courses/15-463/2010_fall/