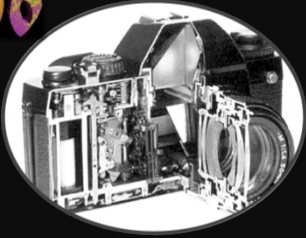



Computational Photography



Adam Finkelstein
for Tom Funkhouser
Princeton University
COS526, Fall 2014

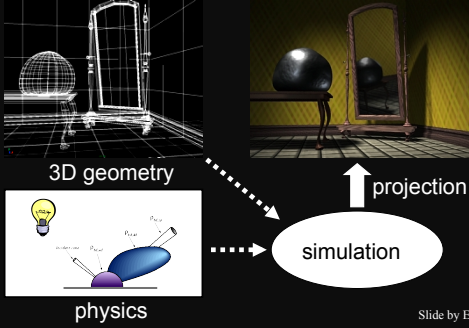
Slides from Durand, Efros, Freeman, Lazechnik, Seitz

What is Computational Photography?

Definition 1: the use of photographic imagery to create content for computer graphics

Slide by Lazechnik

Traditional Computer Graphics



3D geometry


physics

simulation

projection

Slide by Efros


State of the Art



Amazingly real ... but sterile, lifeless, *futuristic*

Slide by Efros

The richness of our everyday world



Pavia, Italy

Slide by Efros

Beauty in complexity



Blue Mountains, Australia

Slide by Efros

What's so hard to model?



Slide by Efros

Urban Scenes



Virtual LA (SGI)



Slide by Efros

Nature



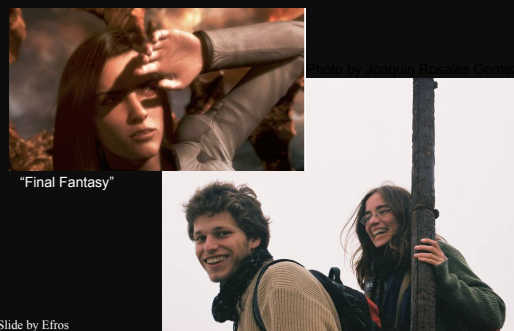
Slide by Efros

People



Slide by Efros

Faces / Hair



"Final Fantasy"

Slide by Efros

Slide by Lazebnik

What is Computational Photography?

Definition 2: The use of computational techniques to overcome limitations of traditional photography

Traditional Photography

Camera controls:

- Viewpoint
- Lens
- Shutter speed
- Aperture
- Sensor

Slide by Freeman and Durand

Traditional Photography

Pin-hole camera:

From Photography, London et al.

Traditional Photography

Pin-hole size?

From Photography, London et al.

Traditional Photography

Pin-hole size?

- Smaller produces sharper image (up to limits of diffraction)
- Larger lets in more light

2.18 DIFFRACTION LIMITS THE QUALITY OF PINHOLE OPTICS. These three images of a bulb filament were made using pinholes with decreasing size. (A) When the pinhole is relatively large, the image rays are not properly converged, and the image is blurred. (B) Reducing the size of the pinhole improves the focus. (C) Reducing the size of the pinhole further worsens the focus, due to diffraction. From Ruedardt, 1958.

From Wandell

Traditional Photography

Lenses

Slide by Freeman and Durand

Traditional Photography

Lenses


$$\frac{1}{D'} + \frac{1}{D} = \frac{1}{f}$$

Slide by Freeman and Durand

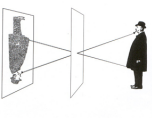
Traditional Photography

Lenses
 + More light
 + Sharp ...
 - at one depth

Photograph made with small pinhole




To make this picture, the lens of a camera was replaced with a thin metal disk pierced by a tiny pinhole, equivalent in size to an aperture of f/162. Only a few rays of light from each point on the

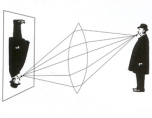


subject get through the tiny opening, producing a soft but acceptably clear photograph. Because of the small size of the pinhole, the exposure had to be 6 sec long.

Photograph made with lens



This time, using a simple convex lens with an f/16 aperture, the scene appeared sharper than the one taken with the smaller pinhole, and the exposure time was much shorter: only 1/100 sec.



The lens opening was much bigger than the pinhole, letting in far more light, but it focused the rays from each point on the subject precisely so that they were sharp on the film.

From Photography, London et al.

Limitations of traditional photography

Single depth of focus



Slide by Lazebnik

Limitations of traditional photography

Limited resolution



Slide by Lazebnik

Limitations of traditional photography

Bad color / no color








Slide by Lazebnik

Limitations of traditional photography


Limited dynamic range

Slide by Lazebnik

Limitations of traditional photography

Single viewpoint



NFL

Limitations of traditional photography

Static scene



Slide by Lazebnik

Limitations of traditional photography

Blur, camera shake, noise, damage



Slide by Lazebnik

Limitations of traditional photography

Unfortunate expressions



Slide by Lazebnik

Limitations of traditional photography

Unwanted objects



Slide by Lazebnik



What is Computational Photography?

Definition 1: the use of photographic imagery to create graphics content

Definition 2: The use of computational techniques to overcome limitations of traditional photography

Slide by Lazebnik

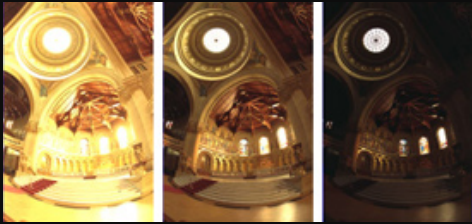
Computational Photography

Computer Graphics	Computational Photography	Photography
 <ul style="list-style-type: none"> + easy to manipulate objects/viewpoint - hard to acquire/create - hard to make realistic 	<p>Realism Manipulation Ease of capture</p>	 <ul style="list-style-type: none"> - hard to manipulate objects/viewpoint + easy to acquire + instantly realistic

Slide by Efos

Computational Photography


Example: high-dynamic range



Debevec

Computational Photography


Example: deblurring



Fergus

Computational Photography

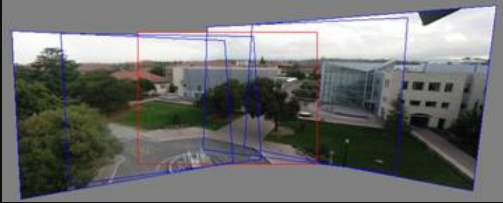
Example: super-resolution



Hertzmann


Computational Photography

Example: creating panorama



Computational Photography


Example: gigapixel images



Kopf

Computational Photography

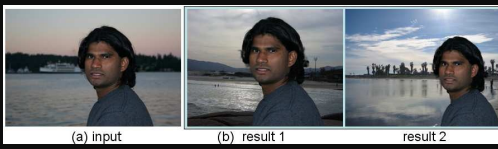
Example: color harmonization



Cohen-Or

Computational Photography

Example: background replacement

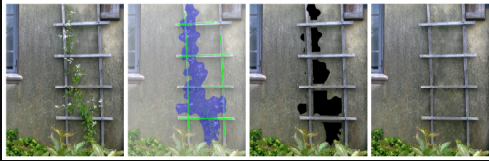


(a) input (b) result 1 result 2

Preliminary results by Sashi Kumar Penta

Computational Photography

Example: image completion




Sun et al. (2005)

Sun

Computational Photography


Example: image completion



Efros

Computational Photography

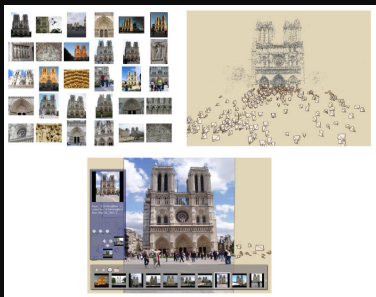
Example: tour into the picture



Horry

Computational Photography

Example: photo tourism



Snaveley

Next...

Texture synthesis