


6.A44 Computational Photography


Frédo Durand




My Background

- **Mathematics & CS**
- **PhD in Computer Science, 3D computer graphics**
 - Grenoble University, France
 - Theory & applications
- **Read a lot about visual perception**
- **A little bit about art history**
- **A little bit about photography**

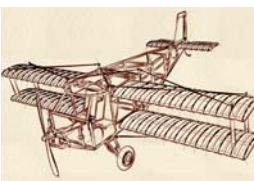
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Computer Graphics - Frédo Durand



**Real-time & Realistic
Rendering**




**Non-Photorealistic
Rendering**




**Computational
Photography**

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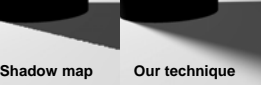


Real-time and realistic rendering (Frédo Durand)


- **Better**
 - Appearance
 - Lighting
 - Shadows
- **Faster**
 - Visibility
 - Simplification
- **New real-time architectures**
 - Software & Hardware




Shadow map



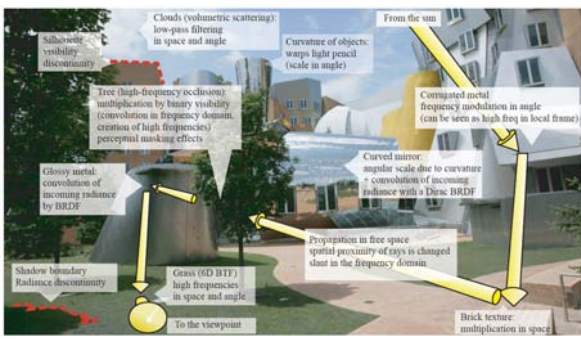
Our technique



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Frequency analysis of light transport




Labels in diagram:

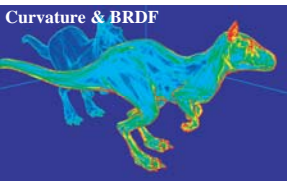
- Substrate visibility (discontinuity)
- Clouds (volumetric scattering): low-pass filtering in space and angle
- Curvature of objects: warps light pencil (scale in angles)
- From the sun
- Tree (high-frequency occlusion): multiplication by binary visibility (convolution in frequency domain, creation of high frequencies), perceptual masking effects
- Glossy metal: convolution of incoming radiance by BRDF
- Curved mirror: angular scale due to curvature + convolution of incoming + balance with a Dirac BRDF
- Corrugated metal: frequency modulation in angle (can be seen as high freq in local frame)
- Propagation in free space: spatial proximity of rays is changed, blur in the frequency domain
- Shadow boundary: Radiance discontinuity
- Grass (GD RT): high frequencies in space and angle
- To the viewpoint
- Brick texture: multiplication in space

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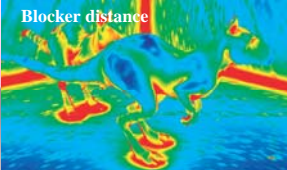
Ray tracing with bandwidth prediction





Curvature & BRDF





Blocker distance



Computational photography
Frédo Durand

- 1st digital revolution (done!)
Ease of taking and sharing pictures
- 2nd digital revolution (just starting!)
Image quality enhancement
exploiting power of digital processing

Before

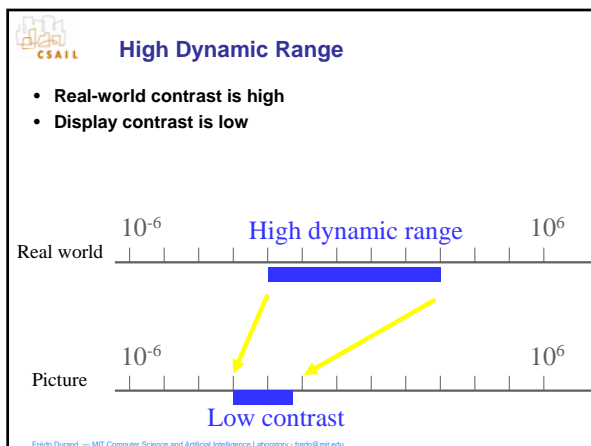
After

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CSAIL **Tonal management**

- Over and under-exposure is the largest cause of bad photographs
- Both for professional and consumers

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CSAIL **Our approach**

- Reduce contrast of large scale; preserve local detail
- Non-linear image decomposition


Large-scale

Detail


Color

Output

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 **Flash Photography** (Elmar Eisemann)

- Available light is not always enough, image is blurry/noisy



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- Available light is not always enough, image is blurry/noisy
- Flash photos look harsh, ambiance is not nice




 **Flash Photography** (Elmar Eisemann)

- Available light is not always enough, image is blurry/noisy
- Flash photos look harsh, ambiance is not nice
- Our work combines the two to get the best of both



 **Flash Photography** (Elmar Eisemann)





No-flash


Flash

Result


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 **Non-Photorealistic Drawing** (Frédéric Durand)



 **Image-based modeling and photo editing**

- With Byong Mok Oh, Max Chen and Julie Dorsey
- 3D model from single photograph
 - User-driven
- Photo editing with power of 3D
 - Change objects, texture, lighting



Input image

New viewpoint

Relighting

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CSAIL Results – Hotel Lobby



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CSAIL Style & 2D from 3D: Fun with Salvador Dali



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CSAIL Motion magnification

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CSAIL Photography hobby

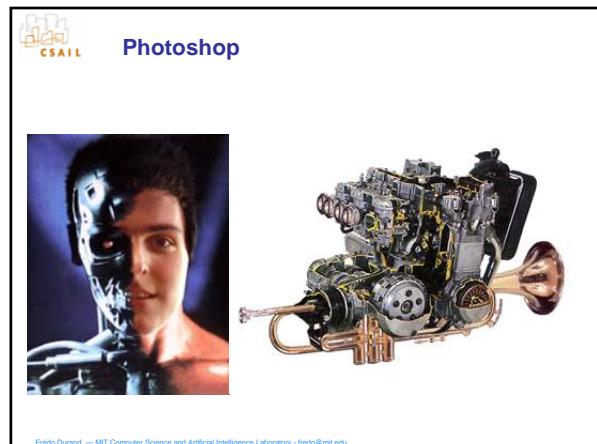
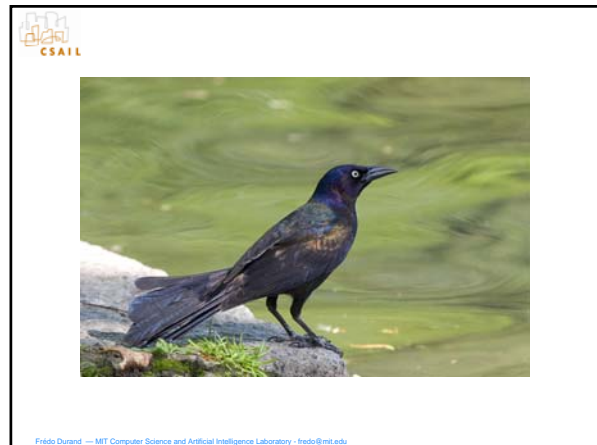
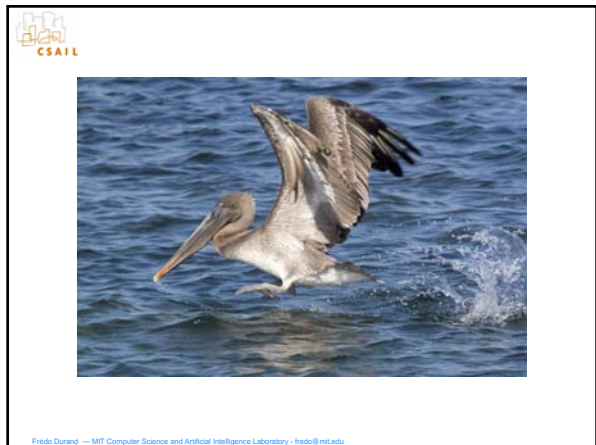
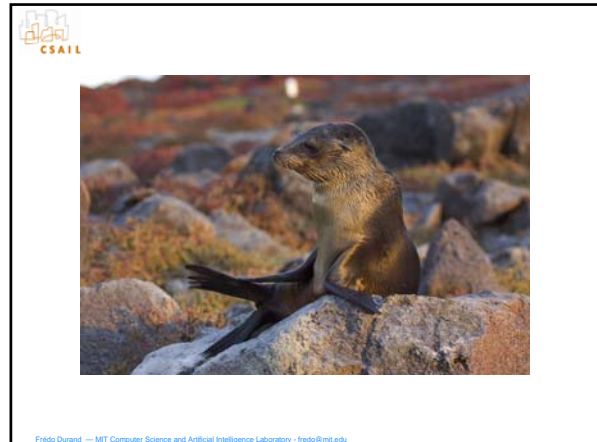


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CSAIL



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Who you are

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Brainstorming: seminar content

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Seminar format

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Books

- No required textbook
- I will use many books and web resources

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Museum of Fine Arts exhibit



ANSEL ADAMS
August 21 - December 31, 2009

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Pinhole imaging



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Pinhole limit

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 Ruechardt, 1958.

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Lens

- Gather more light!

Two new important issues:

- Aperture size
- Focusing distance

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Lenses

24mm
50mm
135mm

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Perspective vs. viewpoint

- Focal lens does NOT ONLY change subject size
- Same size by moving the viewpoint
- Different perspective (e.g. background)

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Perspective vs. viewpoint

- Martin Scorsese, Good Fellas

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Perspective vs. viewpoint

- Portrait: distortion with wide angle

Wide angle Standard Telephoto

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Exposure

- Two main parameters:
 - Aperture (in f stop)
 - Full aperture
 - Medium aperture
 - Stopped down
 - Shutter speed (in fraction of a second)
 - Blade (closing)
 - Blade (open)
 - Focal plane (closed)
 - Focal plane (open)

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Exposure

Figure 6-6. Jacques Henri Lartigue, *Grand Prix of the Automobile Club of France, 1912*. This classic photograph provides an exaggerated example of the distortion that can be caused by a focal-plane shutter. The oval shape of the automobile tire is caused by the motion of the car between the time the bottom of the tire was exposed and the top. (Remember—the image is upside-down on the negative.) The same principle caused the leaning appearance of the spectators. Lartigue turned the camera to follow the automobile (panning), and thus the image of the spectators moved at the film plane during the exposure. (Courtesy International Museum of Photography at George Eastman House.)

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Exposure

- Two main parameters:
 - Aperture (in f stop)
 - Expressed as a fraction of the focal length
 - E.g. : $f/2.0$ for a 50mm lens means an aperture of 25mm
 - Longer lenses need bigger aperture
 - Shutter speed (in fraction of a second)
- Reciprocity
 - The same exposure is obtained with an exposure twice as long and an aperture half as big
 - Hence square root of two progression of f stops
 - Reciprocity can fail for very long exposures

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Depth of field

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Depends on aperture

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Depth of field

- Depends on aperture and lens
- Selective focus

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CSAIL **Depth of field**

- Complete focus
- Never happens for human vision



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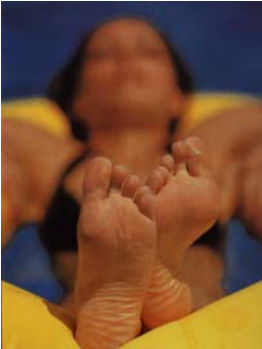
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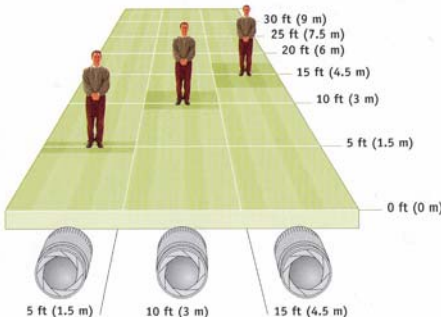
CSAIL **Depth of field**

- Selective focus
- In reality, we would be able to shift focus
- This is refused to us
- The photographer rules



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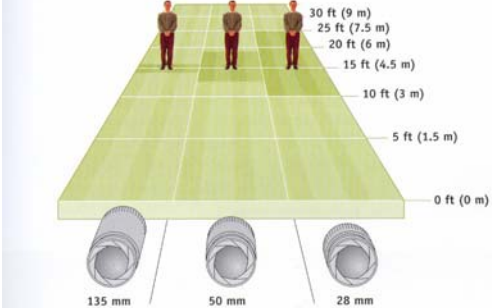
CSAIL **Depends on focusing distance**



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CSAIL **Depends on focal length**

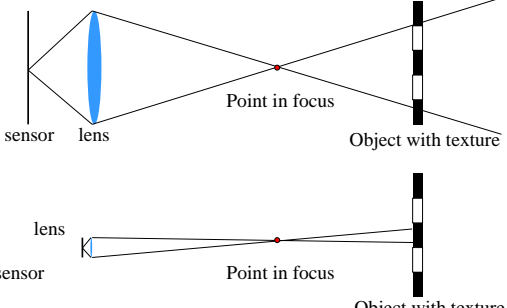
- Remember definition of f stop



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CSAIL **Depth of field**

- It's all about the size of the lens aperture



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CSAIL **The Print**

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CSAIL **Traditional craft: dodging and burning**

- Negative has more range than print (data-rich!)
- Locally darken or lighten
- Mask to expose some areas less
- Has to be done for each print!
- Risk of halo artifacts

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CSAIL **Traditional craft: dodging and burning**

- **Clearing Winter Storm** by Ansel Adams

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CSAIL **Assignment 1: Aperture/Speed**

- **Four pictures**
 - Shallow depth of field to isolate the subject
 - Long depth of field to relate elements at different depths
 - Fast shutter speed to freeze motion
 - Slow shutter speed for motion blur

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CSAIL **Plan**

- **Image formation**
 - Anatomy of an SLR
 - Speed & aperture
 - Metering
 - Focusing
 - AF
 - Depth of field
 - Film
 - Types of lenses
 - * Difference zoom viewpoint
 - Types of camera
- **Processing & printing**
- **Digital vs. Film**
- **Computational vs. digital**

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