6.A44 Computational Photography

Frédo Durand

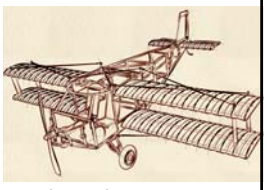
My Background

- **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**

Computer Graphics - Frédo Durand

Real-time & Realistic Rendering

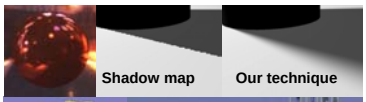
Non-Photorealistic Rendering

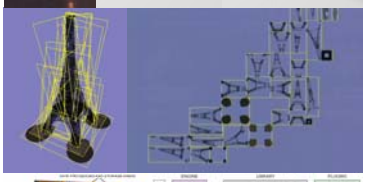


Computational Photography

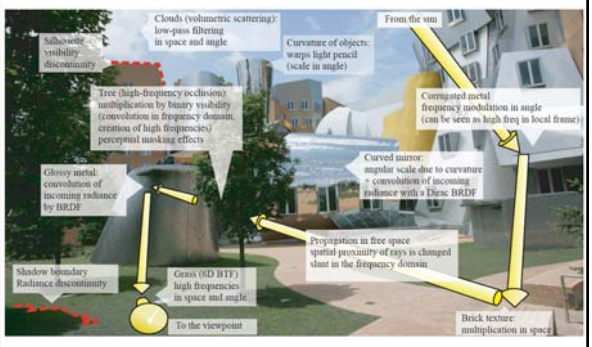
Real-time and realistic rendering (Frédo Durand)

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

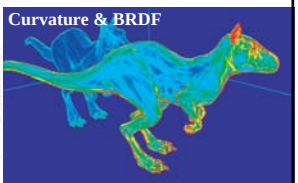


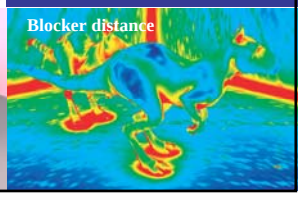


Frequency analysis of light transport



Ray tracing with bandwidth prediction





Non-Photorealistic Drawing (Frédo Durand)

Computational photography
Frédo Durand

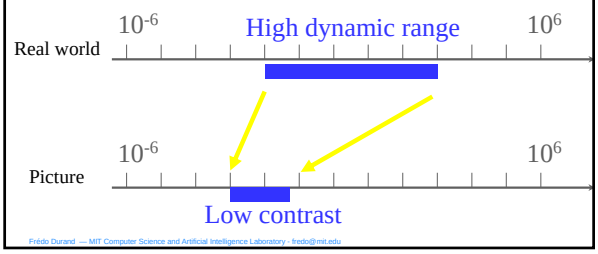
- *1st digital revolution (done!)*
  Ease of taking and sharing pictures
- *2nd digital revolution (just starting!)*
  Image quality enhancement
  exploiting power of digital processing

Tonal management

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

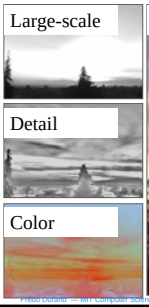
High Dynamic Range

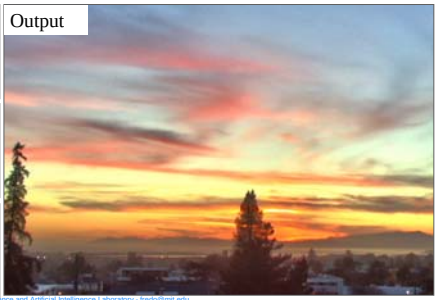
- **Real-world contrast is high**
- **Display contrast is low**



Our approach

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





Flash Photography (Elmar Eisemann)

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

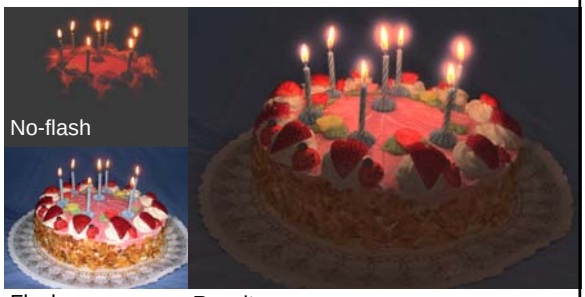
Flash Photography (Elmar Eisemann)

- 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)



Flash Result

Non-Photorealistic Drawing (Frédo 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

Results – Hotel Lobby

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

Motion magnification

Photography hobby

Photoshop

Who you are

Brainstorming: seminar content

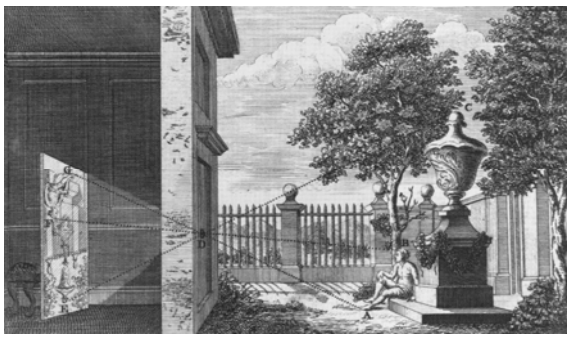
Seminar format

Books

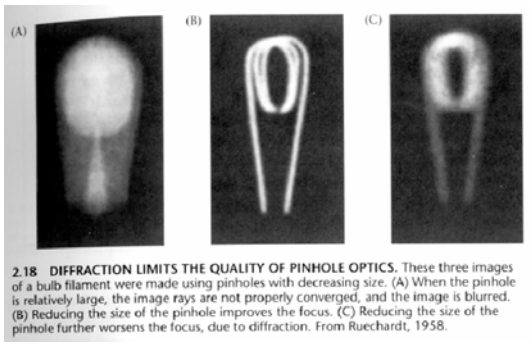
- **No required textbook**
- **I will use many books and web resources**

Museum of Fine Arts exhibit

Pinhole imaging



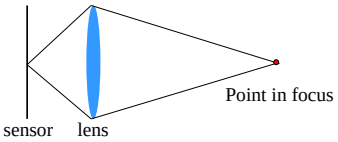
Pinhole limit



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.

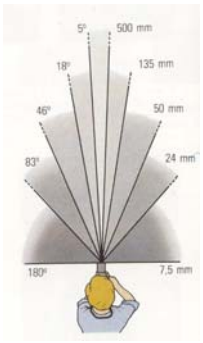
Lens

- **Gather more light!**



- **Two new important issues:**
  - Aperture size
  - Focusing distance

Lenses



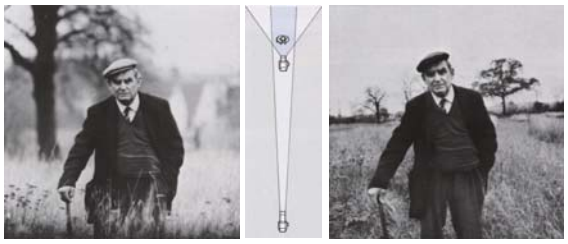
24mm

50mm

135mm

Perspective vs. viewpoint

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



Snapshot-Perspective-Speed, aperture-Filter-Lighting-Processing & Print-Make up-Retouching

Perspective vs. viewpoint

- **Martin Scorcese, Good Fellas**

Snapshot-Perspective-Speed, aperture-Filter-Lighting-Processing & Print-Make up-Retouching

Perspective vs. viewpoint

- **Portrait: distortion with wide angle**

Wide angle Standard Telephoto

Snapshot-Perspective-Speed, aperture-Filter-Lighting-Processing & Print-Make up-Retouching

Exposure

- **Two main parameters:**
  - Aperture (in f stop)

  - Shutter speed (in fraction of a second)

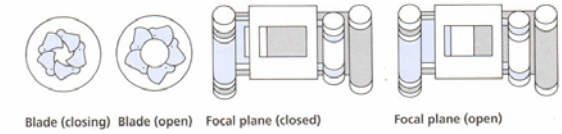
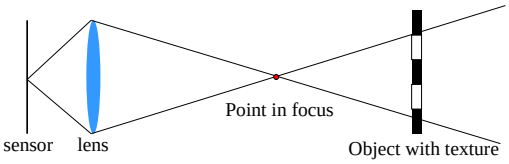


Figure 6-6. Jacques Henri Lartigue, *Grand Prix of the Automobile Club of France*, 1912. This classic photograph provides an exaggerated example of the distortion that can be caused by a focal-plane shutter. The oval shape of the automobile tire is caused by the motion of the car between the time the 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.)

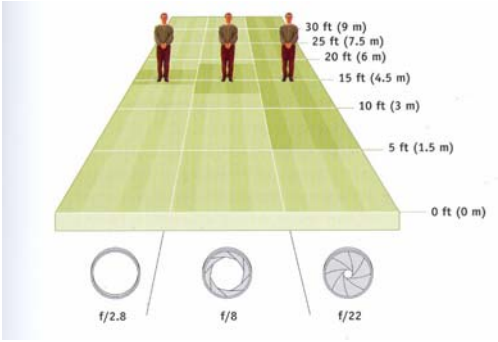
Exposure

- **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 wit 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

Depth of field

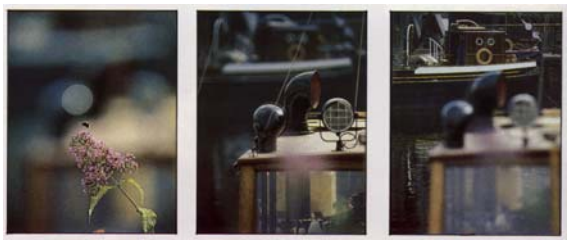


Depends on aperture



Depth of field

- **Depends on aperture and lens**
- **Selective focus**

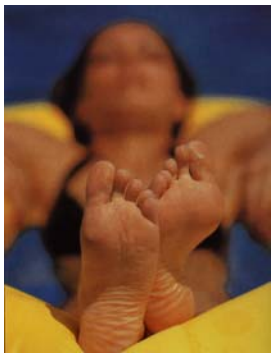


Depth of field

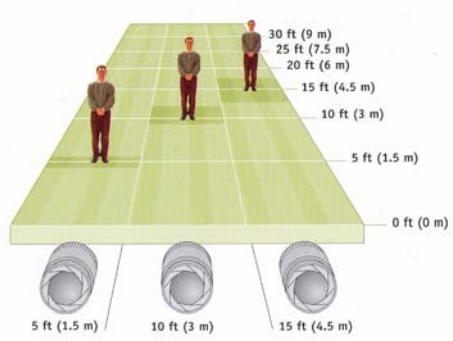
- Complete focus
- Never happens for human vision

Depth of field

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

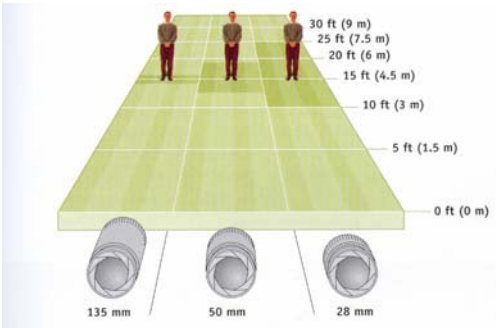


Depends on focusing distance



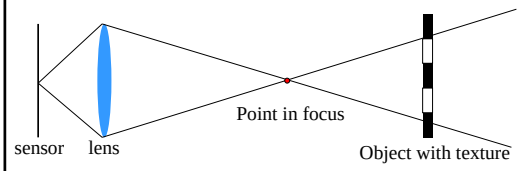
Depends on focal length

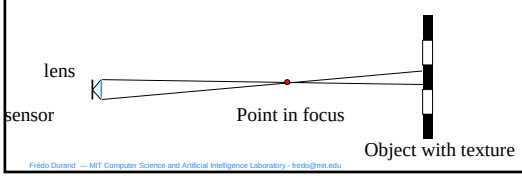
- Remember definition of f stop



Depth of field

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

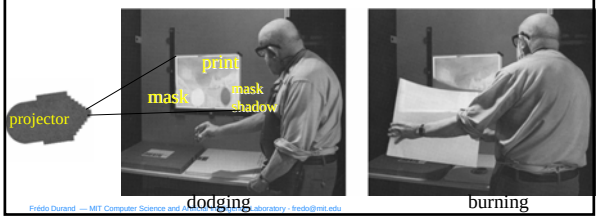




The Print

Traditional craft: dodging and burning

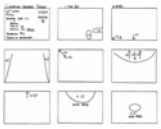
- **Negative has more range than print (data-rich!)**
- **Locally darken or lighten**
- **Mask to expose some areas less**
- **Has to be done for each print!**
- **Risk of halo artifacts**



dodging burning

Traditional craft: dodging and burning

- ***Clearing Winter Storm***
  by Ansel Adams



Straight print After dodging and burning

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

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**