Computational Photography

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http://www.cs.pdx.edu/~fliu/courses/cs510/

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Last Time

☐ Course overview
  ■ Admin. Info
  ■ Computational Photography
Today

- Digital Camera
  - History of Camera
  - Controlling Camera
- Photography Concepts
The first camera

- 5th B.C. Aristotle, Mozi (Chinese: 墨子)
- How does the aperture size affect the image?

http://en.wikipedia.org/wiki/Pinhole_camera

Modified from slides provided by L. Zhang
Shrinking the aperture
Shrinking the aperture

- Why not make the aperture as small as possible
  - Less light gets through
  - *Diffraction* effects

Slide credit: L. Zhang
Shrinking the aperture

Slide credit: L. Zhang
First production camera?

- 1839. Daguerrotype

Slide credit: F. Durand
Beginning of hobby photography?

- 1900 Kodak Brownie

Slide credit: F. Durand
Color photography

- Who did the first color photography?
  - Maxwell
    (yes, the same from the EM equations)
- When? 1861
- Oldest color photos still preserved: Prokudin-Gorskii

[Link to exhibit](http://www.loc.gov/exhibits/empire/)

Slide credit: F. Durand
Prokudin-Gorskii

- Digital restoration

http://www.loc.gov/exhibits/empire/

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Prokudin-Gorskii

Slide credit: F. Durand
Prokudin-Gorskii

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Flash bulb?

- As opposed to powder systems
- Boutan-Chauffour - 1893
- For underwater photography

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Instant photography?

- 1947, Edwin Land (Polaroid founder)

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Auto Focus

- 1978, Konica

- 1981 Pentax ME-F.

- Canon T80 1985
  - Canon AL1 had focus assist but no actuator

- Minolta Maxxum 1985 (AF in body)
First microprocessor in a camera

- Canon AE-1 1976

Slide credit: F. Durand
First scanned photo?

- 1957, Russell A. Kirsch of the National Bureau of Standards, 176x176

Slide credit: F. Durand
CCD technology?

- 1969, Willard S. Boyle and George E. Smith, Bell Laboratories
CCD in astronomy

- 1979, 1-meter telescope at Kitt Peak National Observatory, 320x512, great for dim light
- Nitrogen cooled

Slide credit: F. Durand
Computer Graphics?

Computers to create image

- Sketchpad, 1961, Ivan Sutherland, Turing Awardee at PSU now

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Paint program

- Dick Shoup: SuperPaint [1972-73]
  - 8 bits

- Alvy Ray Smith (Pixar co-founder): Paint [1975-77]
  - 8 bits then 24 bits
  - [http://www.alvyray.com/Awards/AwardsMain.htm](http://www.alvyray.com/Awards/AwardsMain.htm)

- Tom Porter: Paint

Slide credit: F. Durand
Photoshop

- Thomas Knoll and John Knoll began development in 1987
- Version 1.0 on Mac: 1990

- http://en.wikipedia.org/wiki/Photoshop#Development

Slide credit: F. Durand
First digital camera?

- 1975, Steve Sasson, Kodak
- Uses ccd from Fairchild semiconductor, A/D from Motorola, .01 megapixels, 23 second exposure, recorded on digital cassette
Completely Digital Commercial camera

- 1991 first completely digital Logitech Dycam 376x240

http://www.g4tv.com/

Slide credit: F. Durand
Digital

- 1994 Apple quicktake, first mass-market color digital camera, 640 x 480 (commercial failure)
Digital SLR?

- 1992 Kodak DCS 200, 1.5 Mpixels, based on Nikon body

Slide credit: F. Durand
Consumer digital SLR?

- Canon D30, 2000 3MPixels

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Camera phone?

- In November 2000 Sharp and J-Phone introduced the first camera-phone in Japan

Slide credit: F. Durand
Outline

- History of Camera
- Controlling Camera
Camera specifics

- Focal length
- Shutter
- Aperture
- Reciprocity
- Depth of field (focal)
- Motion
- ISO
- Metering
Pinhole imaging

Slide credit: F. Durand
Focal length: pinhole optics

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Film/sensor  pinhole  scene

Slide credit: F. Durand
Field of View

Slide credit: F. Durand
Focal length: pinhole optics

What happens when the focal length is doubled?

- Projected object size
- Amount of light gathered

Slide credit: F. Durand
Perspective vs. viewpoint

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

Slide credit: F. Durand
Perspective vs. viewpoint

- Telephoto makes it easier to select background (a small change in viewpoint is a big change in background.)
Perspective vs. viewpoint

- Portrait: distortion with wide angle
- Why?

Wide angle  Standard  Telephoto

Slide credit: F. Durand
Most of the time, the film/sensor is protected from light

When we take a picture, the shutter opens and closes, thereby exposing the film.

Exposure is proportional to the time the shutter is open

Expressed in fraction of a second (1/60s, 1/125s, 1/250s, 1/500s, etc.)
Effect of shutter speed

- Longer shutter speed => more light, but more motion blur
- Faster shutter speed freezes motion
Effect of shutter speed

- Longer shutter speed => more light, but more motion blur
- Faster shutter speed freezes motion

Slide credit: F. Durand
Effect of shutter speed

- Freezing motion

Walking people  
1/125

Running people  
1/250

Car  
1/500

Fast train  
1/1000

Slide credit: F. Durand
Shutter speed and focal length

- Because telephoto “magnify”, they also magnify your hand shaking
- Telephotos therefore require faster shutter speed
- Rule of thumb:
  - The slowest shutter speed where normal human can hand-hold and get a sharp picture is $1/f$
  - E.g., a 500mm requires $1/500$ s or higher.
- Solution: Image stabilization
  - mechanically compensates for vibration
  - Can gain 2 or 3 shutter speeds (1/125 or 1/60 for a 500mm)

Slide credit: F. Durand
Your best friend

- Use a tripod! It will always enhance sharpness

Slide credit: F. Durand
Exposure

- Two main parameters:
  - Shutter speed
  - Aperture (in f stop)

Slide credit: F. Durand
Aperture

- Diameter of the lens opening (controlled by diaphragm)
- Expressed as a fraction of focal length, in f-number
  - f/2.0 on a 50mm means that the aperture is 25mm
  - f/2.0 on a 100mm means that the aperture is 50mm
- Disconcerting: small f number = big aperture
- What happens to the area of the aperture when going from f/2.0 to f/4.0?
- Typical f numbers are
  - f/2.0, f/2.8, f/4, f/5.6, f/8, f/11, f/16, f/22, f/32

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Exposure

Two main parameters:
- Aperture (in f stop)
- Shutter speed (in fraction of a second)

Reciprocity
- The same exposure is obtained with an exposure twice as long and an aperture area half as big
- Reciprocity can fail for very long exposures

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Exposure & metering

- The camera metering system measures how bright the scene is.
- In Aperture priority mode, the photographer sets the aperture, the camera sets the shutter speed.
- In Shutter-speed priority mode, the photographer sets the shutter speed and the camera deduces the aperture.
  - In both cases, reciprocity is exploited.
- In Program mode, the camera decides both exposure and shutter speed (middle value more or less).
- In Manual, the user decides everything (but can get feedback).

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Pros and cons of various modes

- **Aperture priority**
  - Direct depth of field control
  - Cons: can require impossible shutter speed (e.g. with f/1.4 for a bright scene)

- **Shutter speed priority**
  - Direct motion blur control
  - Cons: can require impossible aperture (e.g. when requesting a 1/1000 speed for a dark scene)
    - Note that aperture is somewhat more restricted

- **Program**
  - Almost no control, but no need for neurons

- **Manual**
  - Full control, but takes more time and thinking

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Metering

- Photosensitive sensors measure scene luminance
- Most cameras then use a center-weighted average
  - Can fail if scenes are very white or very black
  - Nikon has a more advanced system (3D matrix)
Main effect of aperture

- Depth of field

Large aperture opening

Small aperture opening

Slide credit: F. Durand

From Photography, London et al.
Depth of field

Slide credit: F. Durand
Depth of field

- We allow for some tolerance

Depth of field

Point in focus

Object with texture

Max acceptable circle of confusion

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What happens when we close the aperture by two stop?

- Aperture diameter is divided by two
- Depth of field is doubled
Depth of field

Slide credit: F. Durand

From Photography, London et al.
Depth of field & focusing distance

- What happens when we divide focusing distance by two?
  - Similar triangles => divided by two as well
What happens when we divide focusing distance by two?

- Similar triangles => divided by two as well
Sensitivity (ISO)

- Third variable for exposure
- Linear effect (200 ISO needs half the light as 100 ISO)
- Film photography: trade sensitivity for grain
- Digital photography: trade sensitivity for noise

Slide credit: Y. Chuang
Next Time

☐ Filter