What will be on the midterm?

CS 178, Spring 2012

Marc Levoy
Computer Science Department
Stanford University

General information

- Monday, 7-9pm, rooms to be assigned by email
- closed book, no notes
- calculators ok, but you won't need them
- on lectures and assigned chapters in London
- list of formulas will be provided on exam sheets
- practice problems in weekly assgns and sections this week
- attached are some review slides to help you study;
  treat these as a non-exhaustive summary of the course
- look also at the applets and the recap slides in each lecture
- emphasis will be on the concepts behind the formulas, and
  on the tradeoffs they imply for the photographer

Image formation

- the laws of perspective
  - especially natural perspective versus linear perspective
- pinhole imaging
  - tradeoff between aperture size and blur
- imaging uses lenses
  - Gauss's ray tracing construction (be able to draw it)
  - tradeoffs between focal length, sensor size, and FOV
  - changing the focal length vrs changing the viewpoint
- exposure
  - tradeoffs between aperture, shutter speed, motion blur, and depth of field (study Eddy's diagrams!)
  - tradeoffs that include ISO and noise covered later

Lenses and apertures

orange lecture slides and items starred (*) here are fair game for extra-credit Q's

- qualitative understanding of the approximations we make
  - geometrical optics instead of physical optics
  - spherical lenses instead of hyperbolic lenses
  - thin lens representation of thick optical systems*
  - paraxial approximation of ray angles*
- the Gaussian lens formula (know it and be able to use it)
  - changing the focal length vrs changing the subject distance
  - understand lens power and transverse magnification
- center of perspective (ignore the other thick lens terms), convex vrs concave lenses, real vrs virtual images
- depth of field formula
  - know its parts, how they vary, and the tradeoffs they imply
  - hyperfocal distance and how to use it

Practical photographic lenses

- aberrations (without the algebra)
  - be able to recognize them by a name or sketch
  - how is each one fixed? which are correctable in software? which are reducible by stopping down the aperture?
- other lens artifacts
  - be able to recognize them by a name or sketch
  - understand the geometry of vignetting, $\cos^4$ falloff*
- diffraction, sharpness, and MTF (qualitatively)
  - what are they, and what factors do they depend on? (some of this was covered in the sampling & pixels lecture)
- special-purpose lenses
  - principles (not detailed derivations) of telephoto, zoom

Autofocus (AF)

- view cameras
  - understand eliminating vanishing points
  - understanding tilting the focal plane
  - understand real versus fake tilt-shift effects
- passive autofocus techniques
  - understand the principle of phase detection
  - understand the principle of contrast detection
  - when are they used? what are the tradeoffs?
  - don't worry about the details of lenslets, ray geometry, etc.
- active autofocus techniques (if I have time to cover it this week)
  - tradeoffs between time of flight and triangulation
  - be able to manipulate the geometry of triangulation, at least for right-angle triangles

Automatic exposure metering (AE)

- what makes metering hard?
  - understand (qualitatively) the dynamic range problem
- gamma correction
  - what is it? when is it applied? what effect does it have?
  - when can you compare intensity levels in image files?
- metering technologies
  - what problems are caused by having few metering zones?
  - tradeoffs between typical shooting modes (A,P,Av,Tv,M)

Sampling and pixels

- frequency representations of images*
- resolution and human perception
  - be able to manipulate FOV, dpi, retinal arc, cycles / degree
- sampling and aliasing
  - what is aliasing? when does it happen? (especially in a camera)
  - how can aliasing be avoided? what is prefiltering?
- definition and uses of spatial convolution
  - understand the integral and summation forms of this equation
  - be able to work out a simple convolution, like two rects
  - no calculus manipulations will be required on the exam
- sampling versus quantization
  - understand how aliasing differs from quantization artifacts

Photons and sensors

- basic concepts (qualitatively)
  - photons, quantum efficiency, blooming, smearing
  - analog to digital conversion
  - relationship of gamma correction to # of bits required
  - don't worry about specific circuits
- how does aliasing and filtering apply to a digital camera?
  - fill factor, per-pixel microlenses, antialiasing filters
  - be able to explain how exposure time is a temporal prefilter
- color sensing technologies
  - be able to recognize them from a name or sketch
  - tradeoffs between the technologies (qualitatively)
  - what is demosaicing?

Noise and ISO

- what are the sources of noise in digital cameras?
  - be able to recognize them by a name or description
  - which ones grow with exposure time, or with temperature?
  - which ones can be fixed in software?
  - benefit of downsizing an image or averaging multiple shots
- signal-to-noise ratio and dynamic range
  - be able to apply the formulas correctly (we'll give you a list)
- ISO
  - what is it, and how is it implemented in digital cameras?
  - tradeoffs between ISO and noise (study Eddy's diagram from the image formation lecture!)

Image stabilization (IS)

- what are the causes of camera shake?
  - and how can you avoid it (without having an IS system)?
- treating camera shake as a 2D convolution of the image
  - understand the geometry of this approximation
- image stabilization systems
  - be able to define mechanical, optical, electronic IS
  - understand the principles of lens-shift vrs sensor-shift IS
  - understanding the ray geometry in detail is not required
  - how much does stabilization help?
  - what is lucky imaging, and how can a photographer use it?

List of important formulas (will be replicated on exam sheets)

$$N = \frac{f}{A}$$

$$\frac{x_i}{x_t} = \frac{\sin\theta_i}{\sin\theta_t} = \frac{n_t}{n_i}$$

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

$$M_T \triangleq \frac{y_i}{y_o} = -\frac{s_i}{s_o}$$

$$FOV = 2\ arctan\ (h\ /\ 2\ f\ )$$

$$D_{TOT} \approx \frac{2NCU^2}{f^2}$$

$$U \geq \frac{f^2}{NC} \triangleq H$$

$$SNR\ (\text{dB}) = 20 \log_{10}\left(\frac{\mu}{\sigma}\right)$$

$$SNR = \frac{\mu}{\sigma} = \frac{P\,Q_e\,t}{\sqrt{P\,Q_e\,t + D\,t + N_r^2}}$$

$$DR = \frac{\text{saturation level - } D\,t}{\sqrt{D\,t + N_r^2}}$$