Lecture 2 – Light, Eyes, Displays

Objectives

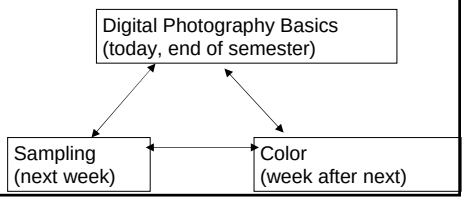
- Light, forming images on 2D surfaces
- Sensor systems
- Image plane measurements (cameras, eyes)
- Resolution
- What the eye does
- Sensitivity/Intensity of the Eye
- Gamma Correction
- Quantization / Halftoning

What do we see? What is an Image?

- Basics of Light
  - Electromagnetic radiation
    - Waves, frequencies (later)
  - Particle model
    - Travels from source to receiver
- Source to Viewer?
  - Not known until around 1000
    - Euclid and Ptolemy PROVED otherwise
  - Ibn Al-Haythan (Al-hazen) around 985
    - Triumph of the scientific method
      - Proof by observation – not authority
    - Experiment – stare at sun, burns eyes, …
    - Also figured out light travels in straight lines

Why is this lecture hard?

- Learning to give 50 minute lectures!
- Cut some "fun" topics (get back at end of semester)
- Interdependence



Back to basics

- Graphics is how computers create what we see
- See (eyes)
- Light

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Depth and Distance

- Light travels in straight lines
  - Except in weird cases that only occur in theoretical physics
- Doesn't matter how far away
  - Can't tell where photon comes from
  - Photons leaving source might not all make it to eye
  - Photons might bounce around on stuff
    - Longer distance, more chance of hitting something

Looking at things

- Light leaves source
- Light bounces off object
- Light goes to receiver
  - Eye, Camera
- Receiver is 2D, process is 3D
- Mathematics later

- Could be a picture (per eye)

Be sure to put plane in picture

Images

- Dictionary: a reproduction of the form of a person or object, especially a sculptured likeness
- Math: the range of a function

- A picture (2D)
- A sampled representation of a spatial thing

Image Sensors and Displays

- 2D – but not necessarily flat
  - Back of the eye
  - I will use the term "image plane" anyway

- Sensor measure what hits an image plane
- Display sends light out from image plane

- Talk about light on the plane f(x,y)

Measuring on the image plane

- Want to measure / record the light that hits the image plane
- At every position on the image plane (in the image) we can measure the amount of light
  - Continuous phenomenon (move a little bit, and it can be different)
  - Can think of an image as a function that given a position (x,y) tells "amount" of light at position
    i = f(x,y)
  - For now, simplify "amount" as just a quantity, ignoring that light can be different colors

Measuring on the image plane

- i = f(x,y)
- Continuous quantities
  - Continuous in space
  - Continuous in value
- Computers (and measuring in general) is difficult with continuous things
- Major issue
  - Limits to how much we can gather
  - Reconstruct continuous thing based on discrete set of observations
  - Manipulate discrete representations

Sampling

- Discrete set of measurements
- Concept of resolution (megapixels)
- How do we reconstruct what happens?
- How do we resample
- Sampling theory – next week

Measuring on the image

- Water/rain analogy
- Put a set of buckets to catch water
- Wait over a duration of time
  - Use a shutter to control the amount of time
- Resolution is the number of buckets
- Measurement depends on
  - Amount of light
  - Size of aperature (how much of the light we let through)
  - Duration

Types of "buckets"

- Film
  - silver halide crystals change when exposed to light
- Electronic
  - Old analog ways – vidicon tubes
    - Store the charge on a plate, scan the plate to read
    - http://www.answers.com/topic/video-camera-tube
  - New ways: use an MOS transistor as a bucket
- Biological
  - Chemicals (photo-pigments) store the photon and release it as electricity
  - Isn't really a shutter

Similarities

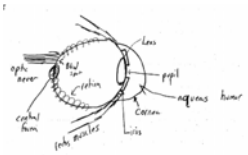
- Low light levels are hard
  - Need to get enough photons to measure
  - Small counting errors (noise) – are big relative to small measurements
- Tradeoffs on bucket sizes
  - Big buckets are good (lower noise in low light)
  - Lots of buckets are good (sense more places)
  - For a fixed area, there is a tradeoff
    - Especially in digital cameras/videocameras

Practical Image Sensing How good is your digital camera?

- Number of Measurements
- Quality of those measurements
  - Talk about how sensors work later
- How well formed is the image on the sensor
  - Talk about optics later
- Megapixels = number of buckets
  - 7 or 8 million buckets in a consumer camera
- But…
  - How big are the sensors?
    - Same size / more megapixels = smaller buckets = more noise
    - (unless the sensor technology gets better)
  - How good is the lens?
    - Smaller buckets don't do you any good if the lens can't aim it into the right bucket

Eye

- Pupil – hole in the eye
- Lens
- Iris
  - round muscle – size of pupil
- Cornea
  - Clear protective coating
- Fluid filled spaces – acts as lens
  - Aqueous humor
  - Vitreous humor
- Rectus Muscles
  - Change shape of eyeball to focus
- Optic Nerve
  - Carries information away
- Blind Spot
  - Where the optic nerve is
- Central Fovea



Retina – the "image plane" of the eye

- Only place on body to see blood vessels directly
- Has photoreceptors
  - Cells sensitive to light
- Photopigments
  - chemicals that change when exposed to light
  - Different photoreceptors have different pigments
  - Different pigments behave differently
    - Sensitivity, color selectivity, regeneration speed
- Types of photoreceptors

Persistence of Vision

- Photopigments take some time to regenerate
- If you see a flash, you sense it for a while afterwards
- This is NOT how you fuse movie frames together in order for it to seem continuous
  - This is actually hard psychological science that is not well understood
  - Integration happens as a higher level process in the brain
  - Many other effects

"Flicker-based Displays"

- If something flashes fast enough, it seems to be continuous
  - Flicker frequency – approx 40-45 hz in a dim/dark room
  - Sensitivity varies with age and ambient brightness
- Used to create different types of displays
  - CRT
  - Movies