Advanced Rendering

CS 4620 Lecture 37
Announcements

• Welcome back!

• A5 grading today
• A6 grading will not have demos
• A7 due later this week

• Prelim next Thu: Dec 10th, 7pm
The Blue Umbrella

- Pixar short
- Made partly to showcase new more photorealistic rendering
  - much of it based on the ideas in this lecture

worth a look:
https://vimeo.com/131090328
http://rainycitytales332.tumblr.com
Basic ray tracing

- Basic ray tracer: one sample for everything
  - one ray per pixel
  - one shadow ray for every point light
  - one reflection ray per intersection
    - one refraction ray (if necessary) per intersection
- Many advanced methods build on the basic ray tracing paradigm
Discontinuities in basic RT

- Perfectly sharp object silhouettes in image
  - leads to aliasing problems (stair steps)
- Perfectly sharp shadow edges
  - everything looks like it’s in direct sun
- Perfectly clear mirror reflections
  - reflective surfaces are all highly polished
- Perfect focus at all distances
  - camera always has an infinitely tiny aperture
- Perfectly frozen instant in time (in animation)
  - motion is frozen as if by strobe light
Antialiasing in ray tracing

aliased image
Antialiasing in ray tracing

aliased image

one sample per pixel
Antialiasing in ray tracing

antialiased image

diagram showing four samples per pixel
Antialiasing in ray tracing

one sample/pixel

9 samples/pixel
Details of supersampling

- For image coordinates with integer pixel centers:

```java
// one sample per pixel
for iy = 0 to (ny-1) by 1
  for ix = 0 to (nx-1) by 1 {
    ray = camera.getRay(ix, iy);
    image.set(ix, iy, trace(ray));
  }

// ns^2 samples per pixel
for iy = 0 to (ny-1) by 1
  for ix = 0 to (nx-1) by 1 {
    Color sum = 0;
    for dx = -(ns-1)/2 to (ns-1)/2 by 1
      for dy = -(ns-1)/2 to (ns-1)/2 by 1 {
        x = ix + dx / ns;
        y = iy + dy / ns;
        ray = camera.getRay(x, y);
        sum += trace(ray);
      }
    image.set(ix, iy, sum / (ns*ns));
  }
```
Soft shadows
Cause of soft shadows

point lights cast hard shadows
Cause of soft shadows

area lights cast soft shadows
Creating soft shadows

• For area lights: use many shadow rays
  – and each shadow ray gets a different point on the light

• Choosing samples
  – general principle: start with uniform in square
Creating soft shadows

**Figure 13.13.** Left: an area light can be approximated by some number of point lights; four of the nine points are visible to $p$ so it is in the penumbra. Right: a random point on the light is chosen for the shadow ray, and it has some chance of hitting the light or not.
Generating direct paths

• Pick surface points $y_i$ on light source
• Evaluate direct illumination integral

\[
\langle L(x \rightarrow \Theta) \rangle = \frac{1}{N} \sum_{i=1}^{N} \frac{f_r(...)L(...)G(x, y_i)}{p(y_i)}
\]
Applied to direct illumination

\[ p(y) = \frac{1}{\text{Area}_{\text{source}}} \]

\[ E(x) = \text{Area}_{\text{source}} L_{\text{source}} f_r \frac{\cos \theta_x \cos \theta_{\bar{y}}}{r_{x\bar{y}}^2} \text{Vis}(x, \bar{y}) \]
More points ...

\[ E(x) = \frac{\text{Area}_{\text{source}} f_r L_{\text{source}}}{N} \sum_{i=1}^{N} \frac{\cos \theta_x \cos \theta_{\bar{y}_i}}{r_{x\bar{y}_i}^2} \text{Vis}(x, \bar{y}_i) \]
Even more points ...
Glossy reflection
Cause of glossy reflection

smooth surfaces produce sharp reflections
Cause of glossy reflection

rough surfaces produce soft (glossy) reflections
Creating glossy reflections

• Jitter the reflected rays
  – Not exactly in mirror direction; add a random offset
  – Can work out math to match Phong exactly
  – Can do this by jittering the normal if you want
Depth of field

\[ \frac{1}{z} + \frac{1}{f} = \frac{1}{d} \]

REAL CAMERAS
Cause of focusing effects

point aperture produces always-sharp focus
Cause of focusing effects

what lenses do (roughly)
Cause of focusing effects

finite aperture produces limited depth of field
Depth of field

- Make eye rays start at random points on aperture
  - always going toward a point on the focus plane
Motion blur
Cause of motion blur

moving object

image point sees different object points at different times

single image point
Motion blur

- Caused by finite shutter times
  - strobing without blur
- Introduce time as a variable throughout the system
  - object are hit by rays according to their position at a given time
- Then generate rays with times distributed over shutter interval
Pixar—Monsters University (2013)
Lightcuts

Direct only (relative cost 1x)
Direct+Indirect (1.3x)
Direct+Indirect+Fog (1.8x)
Direct+Indirect+Fog+Motion (2.2x)
Images and Displays
Representative display technologies

Direct-view displays
- Raster CRT display
- LCD display
- LED display

Printers
- Laser printer
- Inkjet printer
Cathode ray tube

- First widely used electronic display
  - developed for TV in the 1920s–1930s
Raster CRT display

- Scan pattern fixed in display hardware
- Intensity modulated to produce image
- Originally for TV
  - (continuous analog signal)
- For computer, intensity determined by contents of framebuffer
LCD flat panel display

• Principle: block or transmit light by twisting its polarization
• Illumination from backlight (either fluorescent or LED)
• Intermediate intensity levels possible by partial twist
• Fundamentally raster technology
• Fixed format
LED Displays