Distributed Ray Tracing
Anti-Aliasing

• Graphics as signal processing
  – Scene description: continuous signal
  – Sample
  – digital representation
  – Reconstruction by monitor
Anti-Aliasing

• Represent any function as sum of sinusoidals
• Sampling
  – Spatial: multiply function by comb function
  – Frequency: convolve function by comb function
• Nyquist limit
• Reconstruction
  – Spatial: convolve with filter
  – Frequency: multiply by filter

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Typical anti-aliasing

• Increase sampling frequency
  – Doesn’t solve problem
  – Increases frequencies handled (Nyquist limit)

• Average values after sampling
  – Doesn’t address problem
  – Blurs bad results
Ideal sampling and reconstruction

- Sample at greater than Nyquist frequency
- Reconstruct using sinc (box) filter
- Given sampling frequency, remove all frequencies higher than Nyquist limit
- Filter first, then sample
  - or do both at the same time
Illumination is Integration

• “The intensity of reflected light at a point on a surface is an integral over the hemisphere above the surface of an illumination function L and a reflections function R.”

Usually referred to as “Kajia’s Rendering Equation”

$$L_o(x, w, \lambda, t) = L_e(x, w, \lambda, t) + \int_{\Omega} f_r(x, w', w, \lambda, t) L_i(x, w', \lambda, t)(-w' \cdot n)dw'$$

• The shading function may be too complex to compute analytically

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Monte Carlo Integration

- Determine area under the curve
- Non analytic function so can’t integrate
- Can tell if point is above or below curve
- Generate random samples
- Count fraction below curve
- Accurate in the limit
Supersampling

- Multiple samples per pixel
- Average together using uniform weights (box filter)
- Average together using a pyrimid filter or a truncated Gaussian filter

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Adaptive Supersampling

• Trace rays at corner of pixels: initial area
• Trace ray (sample) at center of area
• If center is ‘different’ from corners,
  – Subdivide area into 4 sub-areas
  – Recurse on sub-areas
Poison Distribution

- Similar to distribution of vision receptors
- Random with minimum distance between samples
Regular Sampling
Poison Distribution
Jittered Sampling

Frequencies above Nyquist limit are converted to noise instead of incorrect patterns

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Gloss

• Mirror reflections calculated by tracing rays in the direction of reflection
• Gloss is calculated by distributing these rays about the mirror direction
  – The distribution is weighted according to the same distribution function that determines highlights.
Gloss

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Translucency

• Analogous to the problem of gloss
• Distribute the secondary rays about the main direction of the transmitted rays

The distribution of transmitted rays is defined by a specular transmittance function
Translucency
Penumbras

• Consider the light source to be an area, not a point
• Trace rays to random areas on the surface of the light source
• Distribute rays according to areas of varying intensity of light source (if any)
• Use the fraction of the light intensity equal to the fraction of rays which indicate an unobscured light source
Penumbras
Motion Blur

Post-process blurring can get some effects, but consider:

- Two objects moving so that one always obscures the other
  - Can’t render and blur objects separately
- A spinning top with texture blurred but highlights sharp
  - Can’t post-process blur a rendered object
- The blades of a fan creating a blurred shadow
  - Must consider the movement of other objects
Temporal Jittered Sampling

- Jitter in time
- Jitter in space
Temporal Jittered Sampling

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Importance Sampling

- Sample uniformly and average samples according to distribution function

OR

- Sample according to distribution function and average samples uniformly
Pinhole Camera

Image plane

Perfect focus - low light
Lens Camera - more light

\[ \frac{a}{n} = F \]

\[ n = f\text{-stop} \]

\[ F = \text{Focal length} \]
Use of lens - more light

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

Image plane

lens

Focal plane

s

\[d\]
Circle of Confusion: depth of field

c = circle of confusion $\approx 0.33\text{mm}$

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Depth of Field

Given pixel, s, d

1. Construct ray from pixel through lens center to point p on focal plane
2. Randomly generate point q on 2D lens
3. Trace ray from q through p
Summary

Random on refraction direction

Space-time jitter subsample

Random on lens

Random on refraction direction

Random on area light source

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