Distributed Ray Tracing

Anti-Aliasing

- Graphics as signal processing
  - Scene description: continuous signal
  - Sample
  - Digital representation
  - Reconstruction by monitor

- Represent any function as sum of sinusoids
- Sampling
  - Spatial: multiply function by comb function
  - Frequency: convolve function by comb function
- Nyquist limit
- Reconstruction
  - Spatial: convolve with filter
  - Frequency: multiply by filter

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”

\[
L_i(x,\omega,\lambda,t) = L_i(x,\omega,\lambda) = \int f(x,\hat{\omega'},\lambda,t)L_i(x,\hat{\omega'},\lambda,t)\,d\omega'
\]

- The shading function may be too complex to compute analytically

**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 pyramid filter or a truncated Gaussian filter
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
Jittered Sampling

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

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

- 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
Translucency

Penumbra

• 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

<table>
<thead>
<tr>
<th></th>
<th>7</th>
<th>11</th>
<th>3</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>15</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>1</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

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

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

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

Use of lens - more light

Circle of Confusion: depth of field

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

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

Random on lens

Random on area light source

Space-time jitter subsample