CS 563 Advanced Topics in Computer Graphics
Summary and Conclusion

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Appel 1968 – Ray casting

1. Generate an image by sending one ray per pixel
2. Check for shadows by sending a ray to the light
- Whitted 1979
  Recursive ray tracing (reflection and refraction)
PBRT Architecture

Diagram showing the flow of data from Sampler to Camera to Scene::Render() to Integrators to Film.
Table 1.1: Plug-ins. PBRT supports 13 types of plug-in objects that can be loaded at run time based on the contents of the scene description file. The system can be extended with new plugins, without needing to be recompiled itself.

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- **Primitive**: a shape with its appearance properties such as material properties. It is the bridge between the geometry processing and shading subsystem.

- **Primitives**
  1. Basic geometric primitive
  2. Primitive instance
     - Reuses transformed copies of a single collection of geometry at multiple positions
  3. Aggregate( collection )
     - Treat collections just like basic primitives
     - Incorporate acceleration structures into collections
     - May nest accelerator of different types

Types: grid.cpp kdtree.cpp
Uniform grid

Preprocess scenes
  1. Find bounding box
  2. Determine resolution
  3. Place object in cell if object overlaps cell

Traverse grid
- Spatial Hierarchies

- Letters correspond to planes (A, B, C, D)
- Point location by recursive search
Accelerator

- Variations

- Kd-tree recursively split along one coordinate axe
- OCT-tree use 3 axis-perpendicular planes to split to 8 regions
- BSPtree adaptively subdivide space into irregularly sized regions
Radiometry

- Basic quantities
- Flux: power, energy per unit time (J/s) or (W), symbol $\Phi$
- Irradiance: area density of flux (W/m$^2$), $E$
  \[ E(x) = \frac{d\Phi_i}{dA} \]
- Intensity: power per unit solid angle
  \[ I(\omega) = \frac{d\Phi}{d\omega} \]
- Radiance: the flux density per unit area per unit solid angle
  \[ L = \frac{d\Phi}{d\omega dA} \]
Incident and Exitant Radiance functions

- Incident Radiance, distribution of radiance arriving at the point $L_i(p, w)$
- Exitant Radiance: outgoing reflected radiance from the surface $L_o(p, w)$

$\text{Li}(p, w) \neq \text{Lo}(p, w)$

Radiometrical Integrals

$$E(p, n) = \int_\Omega L_i(p, \omega) \mid \cos \theta \mid d\omega$$

Scattering equation

$L_o(p, w_0) = \int s \cdot 2f(p, w_0, w_i) L_i(p, w_i) \mid \cos \theta_i \mid dw_i$
Camera Model

- Projective Camera Models
  Project a 3D scene onto a 2D image
- Orthographic projection model
- Perspective projection model
- Depth of field
  blurriness in the out-of-focus regions
  Cause: aperture has finite area
As the size of the lens aperture increases, more blur
The sampling and reconstruction process
- Real world: continuous
- Digital world: discrete

Basic signal processing
- Fourier transforms
- The convolution theorem
- The sampling theorem

Aliasing and antialiasing
- Uniform supersampling
- Nonuniform supersampling
Sampling and reconstruction

- Fourier Transforms
  Each function has two representations
  Spatial domain-normal representation
  Frequency domain-spectral representation
  Spectral representation treats the function as a weighted sum of sines and cosines

\[
\begin{align*}
  \mathcal{F}(\omega) &= \int_{-\infty}^{\infty} f(x) e^{-i\omega x} \, dx \\
  f(x) &= \frac{1}{2\pi} \int_{-\infty}^{\infty} \mathcal{F}(\omega) e^{i\omega x} \, d\omega
\end{align*}
\]
- Spatial Domain

- Frequency Domain
Convolution

\[ h(x) = f \otimes g = \int f(x')g(x - x') \, dx' \]

Convolution Theorem: Multiplication in the frequency domain is equivalent to convolution in the space domain.

\[ f \otimes g \leftrightarrow F \times G \]
- **Ideal Sampling**

\[ III_T(x) = T \sum \delta(x - iT) \]

\[ III_T(x)f(x) = T \sum_i \delta(x - iT)f(iT) \]

- The multiplication yields an infinite sequence of values of the function at equally spaced points;

- **Ideal reconstruction**

Computing the convolution between the sample values above and a filter function

\[ (III_T(x)f(x)) \otimes r(x) \]
**Underasampling and Aliasing**

- The left: when the sampling rate is too low, the copies of the function’s spectrum overlap.
- The right: resulting in aliasing when reconstruction is performed.
- Antialiasing = preventing aliasing
- 1. Analytically prefilter the signal
   Filter the original function so that no high frequencies remain
- 2. Uniform supersampling and resample
   Increasing the sampling rate;
- 3. Nonuniform or stochastic sampling
   Varying the spacing between samples in a nonuniform way.
Reflection Models

- BRDF
  Bidirectional reflectance distribution function
- BTDF
  Bidirectional transmission distribution function
- BSDF
  Bidirectional scatter distribution function

Combine the above two functions
- Types of reflection functions
  Ideal specular
  Reflection law
  Mirror
  Ideal diffuse
  Lambert’s law
  Specular
  Glossy
  Directional diffuse
Reflection equation

\[ L_r(x, \omega_r) = \int_{H^2} f_r(x, \omega_i \rightarrow \omega_r) L_i(x, \omega_i) \cos \theta_i \, d\omega_i \]
- Reflection and refraction
- Laws
- \( L_r = k d L \cos \theta \)
- \( \sin \theta_i = \sin \theta_t \)
- Microfacet models
  Distribution of facets + BRDF from individual microfacets.
Self-shadowing

- shadows on rough surface