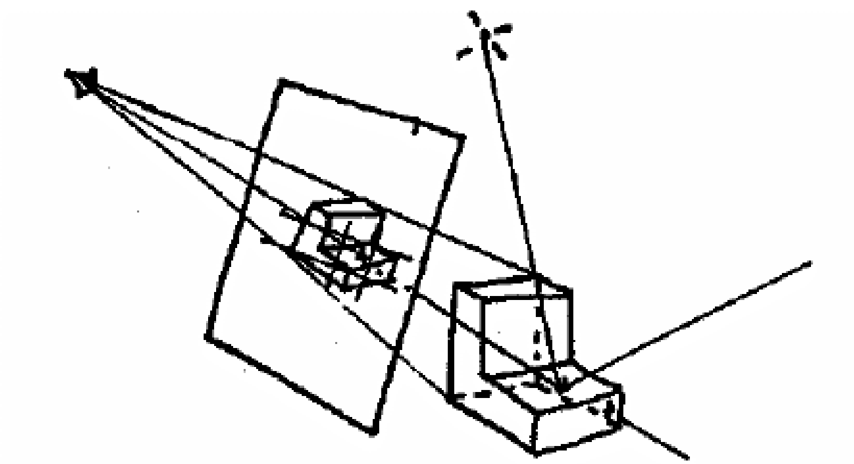
CS 563 Advanced Topics in Computer Graphics
Summary and Conclusion

by Juan Li

Ray Tracing

- Appel 1968 – Ray casting

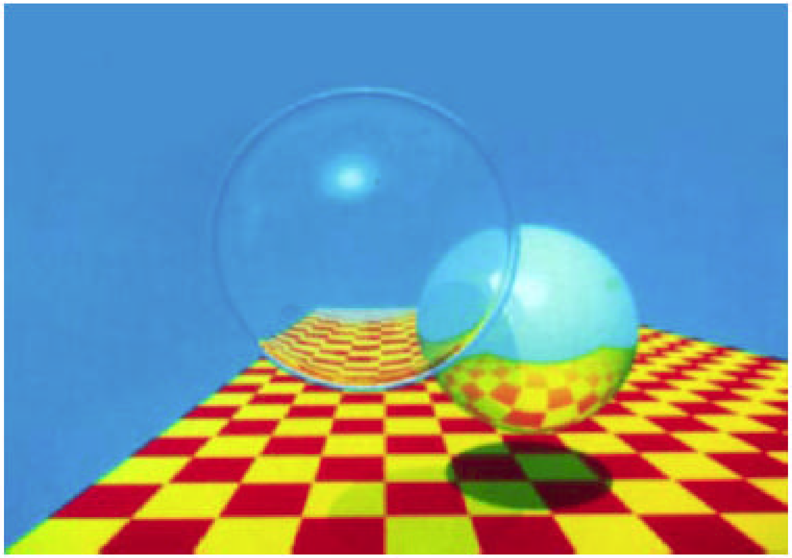
1. Generate an image by sending one ray per pixel
2. Check for shadows by sending a ray to the light



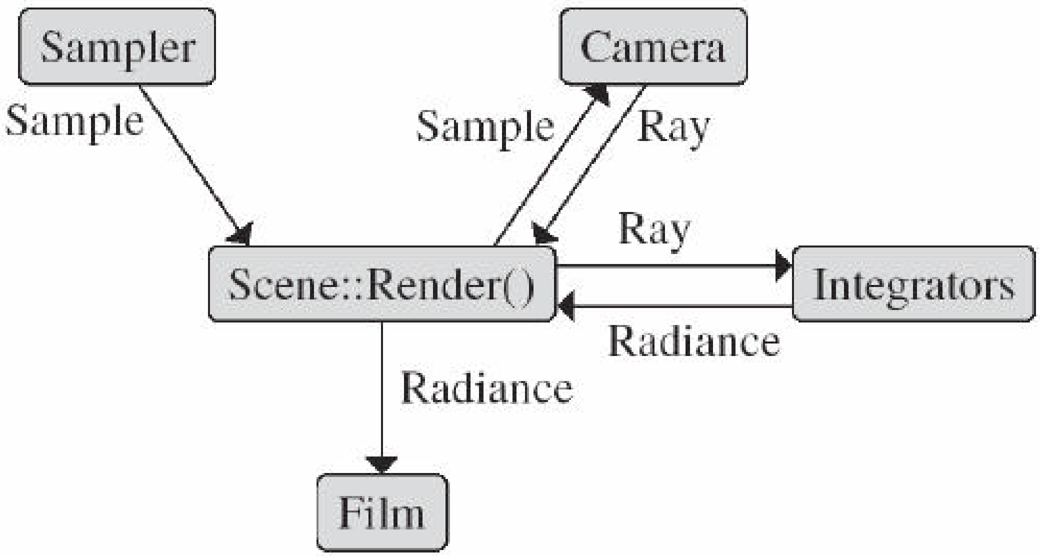
Ray Tracing

- Whitted 1979

  Recursive ray tracing(reflection and refraction)



PBRT Architecture



PBRT Organization

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 plug-ins, without needing to be recompiled itself.

Base class	Directory	Section
Shape	shapes/	3.1
Primitive	accelerators/	4.1
Camera	cameras/	6.1
Film	film/	8.1
Filter	filters/	7.6
Sampler	samplers/	7.2
ToneMap	tonemaps/	8.4
Material	materials/	10.2
Texture	textures/	11.3
VolumeRegion	volumes/	12.3
Light	lights/	13.1
SurfaceIntegrator	integrators/	16
VolumeIntegrator	integrators/	17

Primitive

- 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

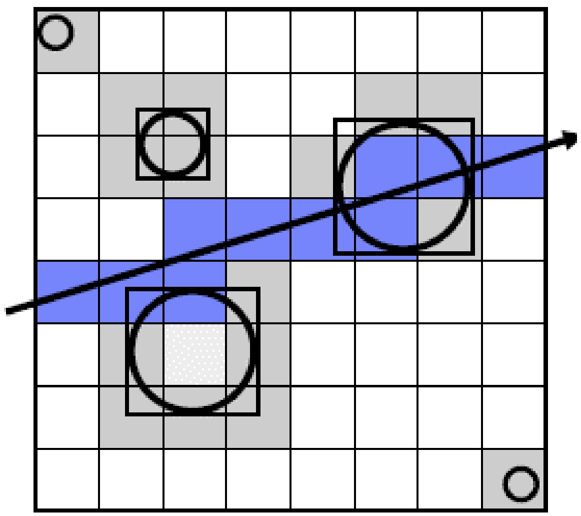
   Incorporate acceleration structures into collections

   May nest accelerator of different types

   Types:grid.cpp kdtree.cpp

Accelerator

- Uniform grid



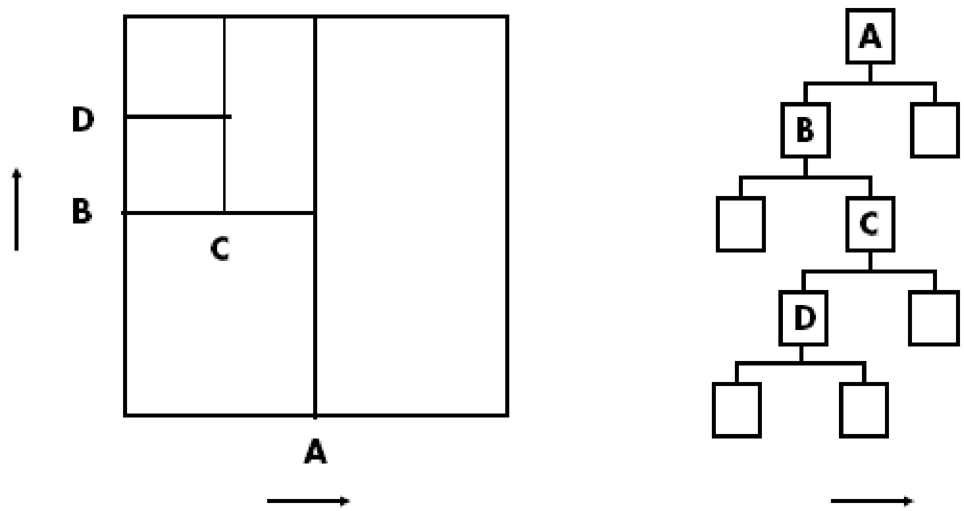
Preprocess scenes

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

Traverse grid

Accelerator

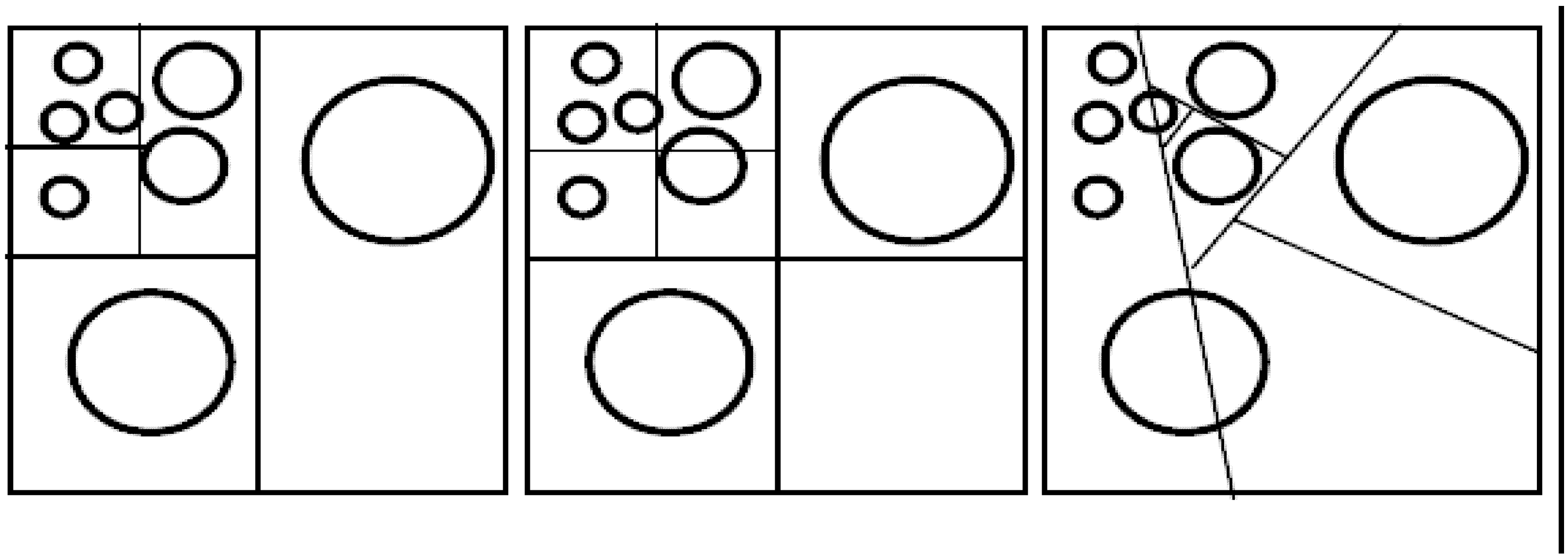
- Spatial Hierarchies



- 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 Φ
- Irradiance :area density of flux(W/m^2) E

$$E(x) \equiv \frac{d\Phi_i}{dA}$$

- Intensity: power per unit solid angle

$$I(\omega) \equiv \frac{d\Phi}{d\omega}$$

- Radiance: the flux density per unit area per unit solid angle

$$L = \frac{d\Phi}{dwdA}$$

Radiometry

ncident and Exitant Radiance functions

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

Li(p,w)!= Lo(p,w)

Radiometric Intergrals

$$E(p,n)=\int_{\Omega}L_i(p,w)\,|\cos q\,|\,dw$$

Scattering equation

Lo(p,w0)=?s 2f(p,w0,wi)Li (p,wi)|cos?i|dwi;

Camera Model

- Projective Camera Models

Project a 3D scene onto a 2D image

Orthographic projection model

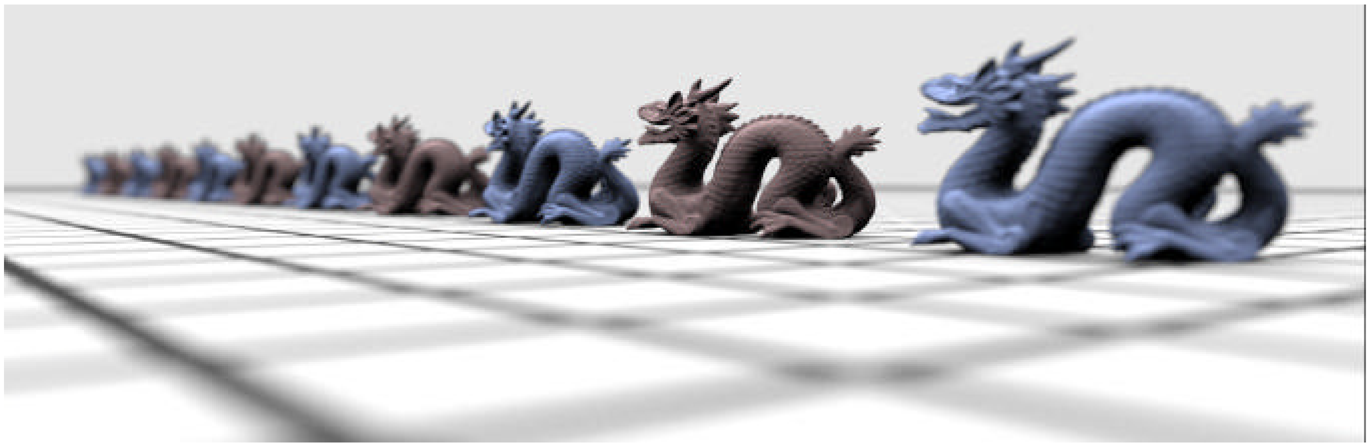
Perspective projection model

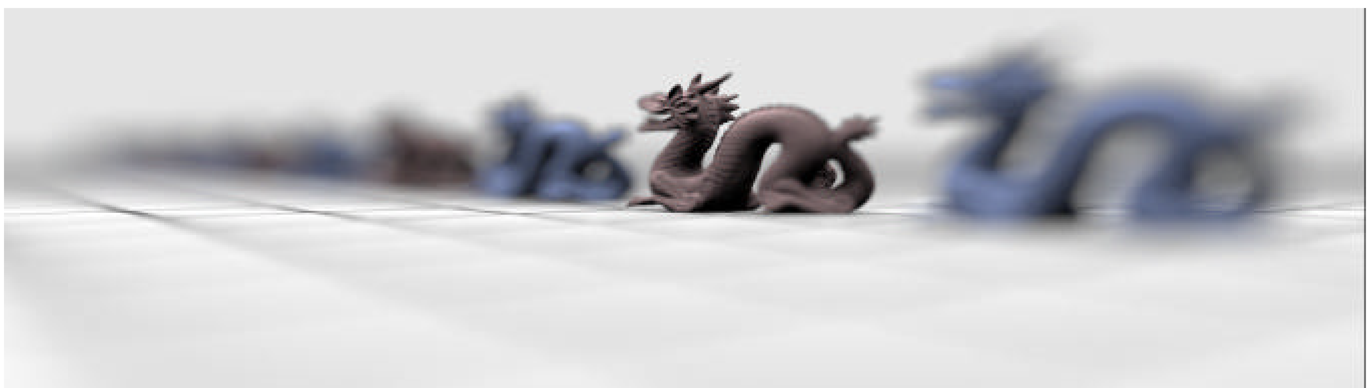
- Depth of field

blurriness in the out-of-focus regions

Cause: aperture has finite area

Cameral





- As the size of the lens aperture increases, more blur

Sampling and Reconstruction

- 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

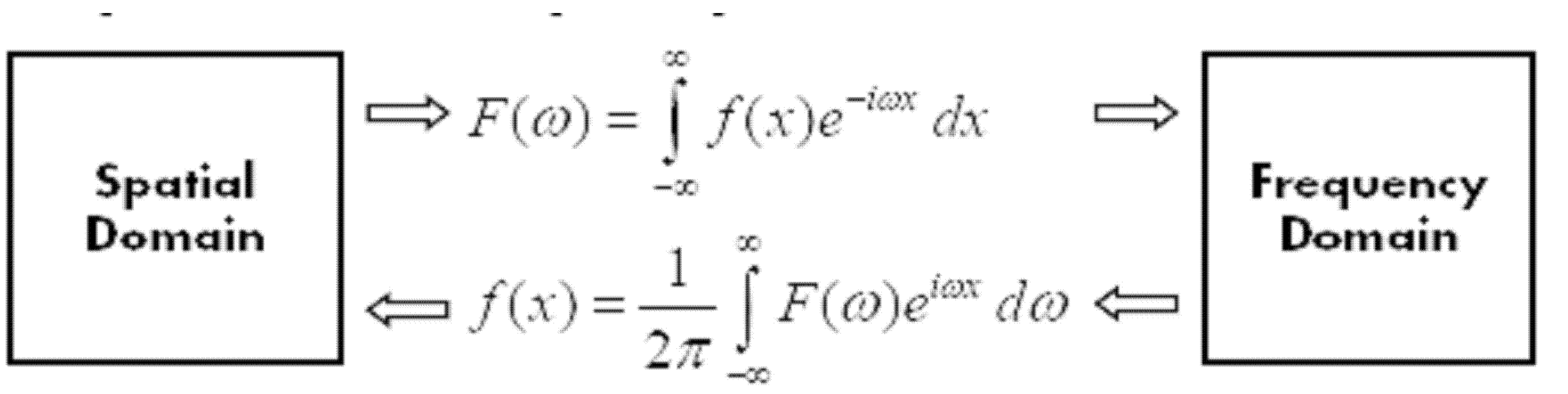
- Fourier Transforms

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

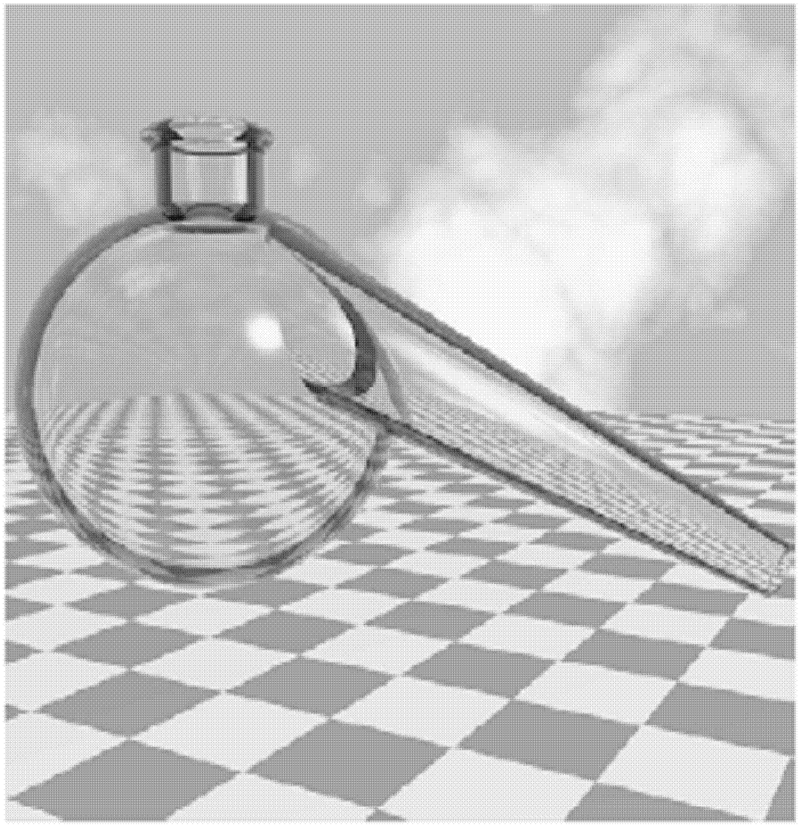


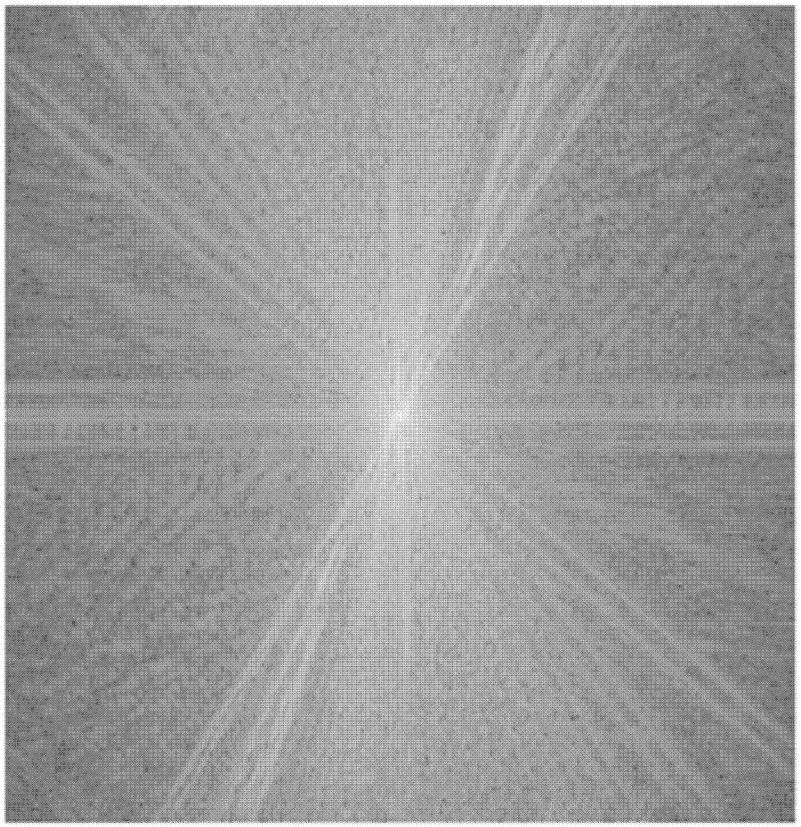
$$F(\omega) = \int_{-\infty}^{\infty} f(x) e^{-i\omega x}\, dx$$

$$f(x) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\omega) e^{i\omega x}\, d\omega$$

- 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

$$III_T(x) = T\sum d(x - iT)$$
$$III_T(x) f(x) = T\sum_i d(x - iT) f(iT)$$

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

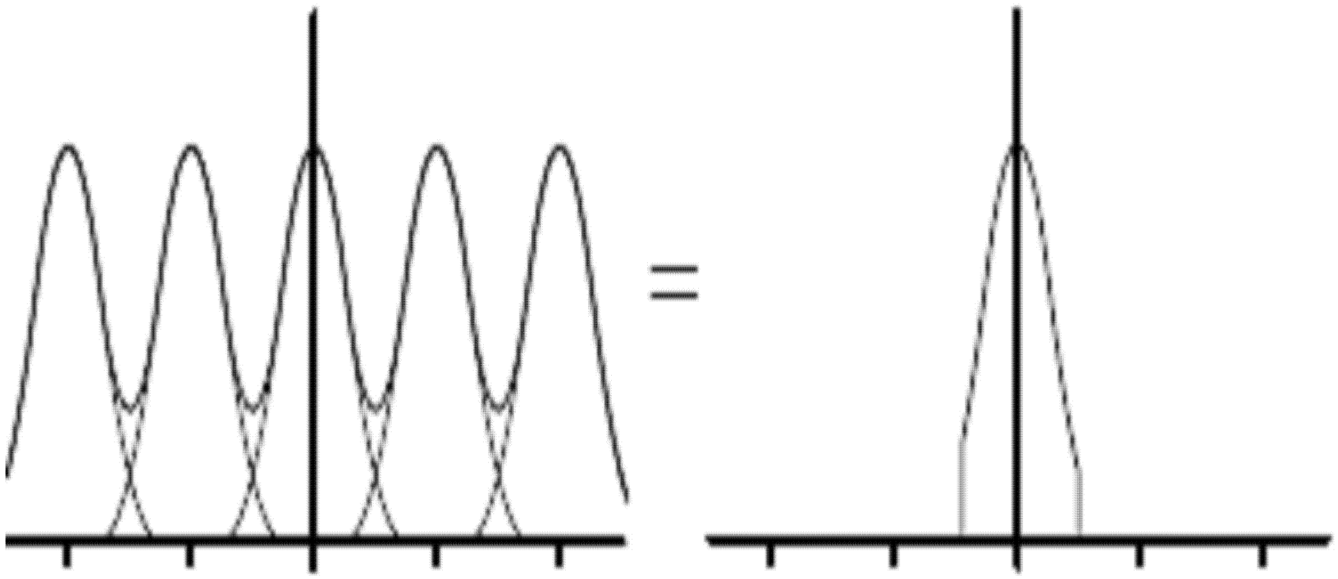
- Ideal reconstruction

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

$$(III_T(x) f(x)) \otimes r(x)$$

Aliasing

- Underasampling :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

- Antialiasing = preventing aliasing
- 1.Analytically prefitler 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

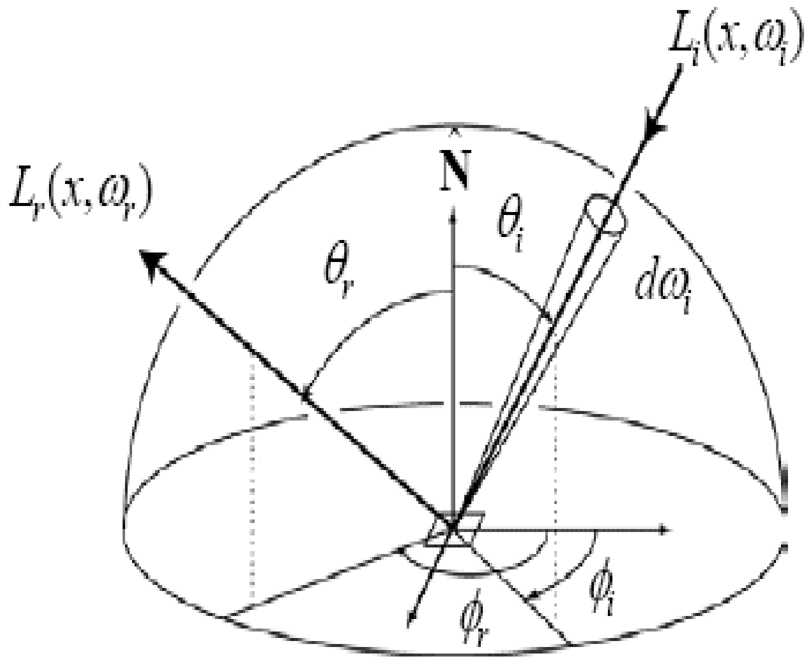
Lambert’s law

Specular

Glossy

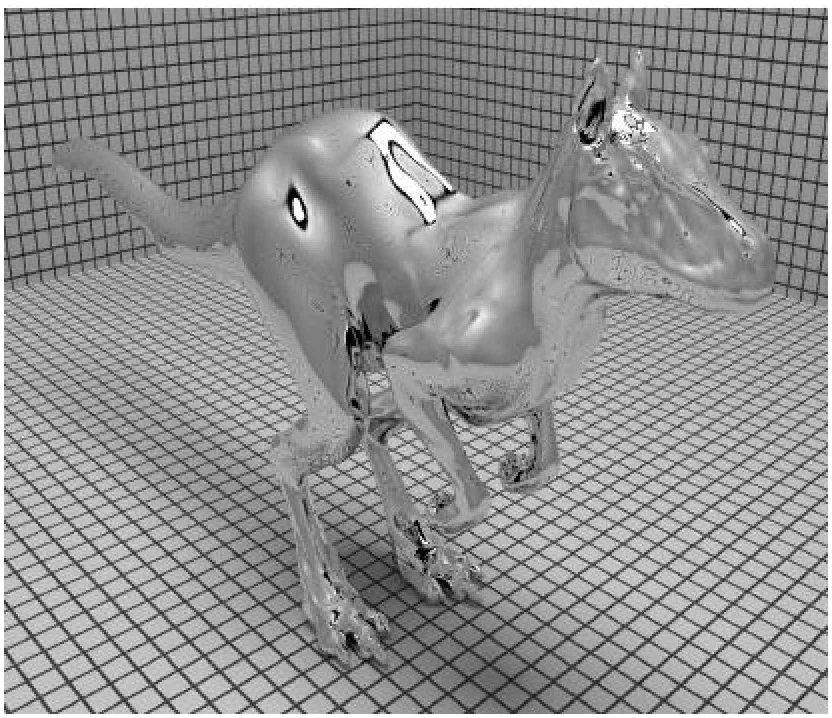
Directional diffuse

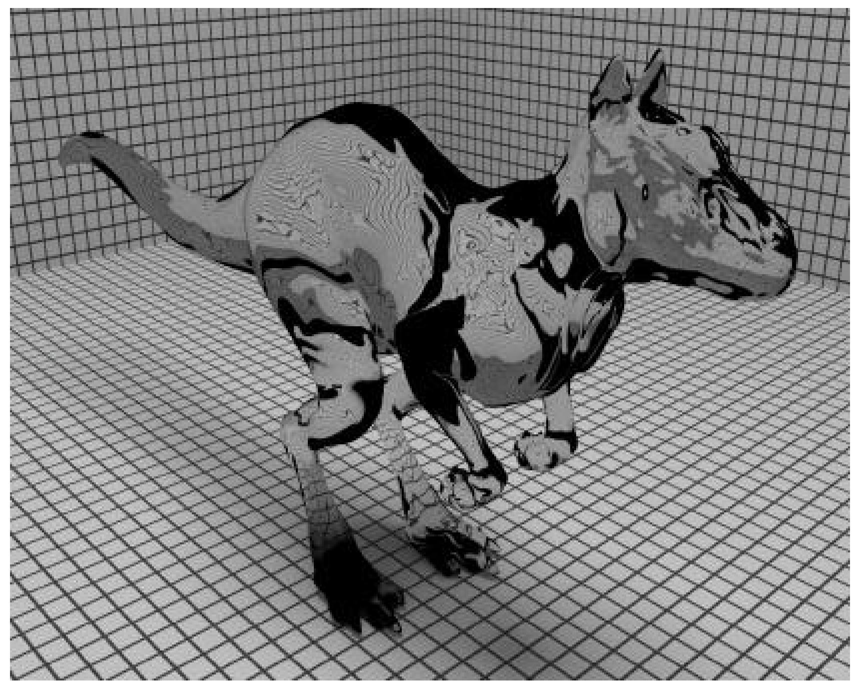
Reflection equation



$$L_r(x,\omega_r) = \int_{H^2} f_r(x,\omega_i \to \omega_r) L_i(x,\omega_i) \cos\theta_i \, d\omega_i$$

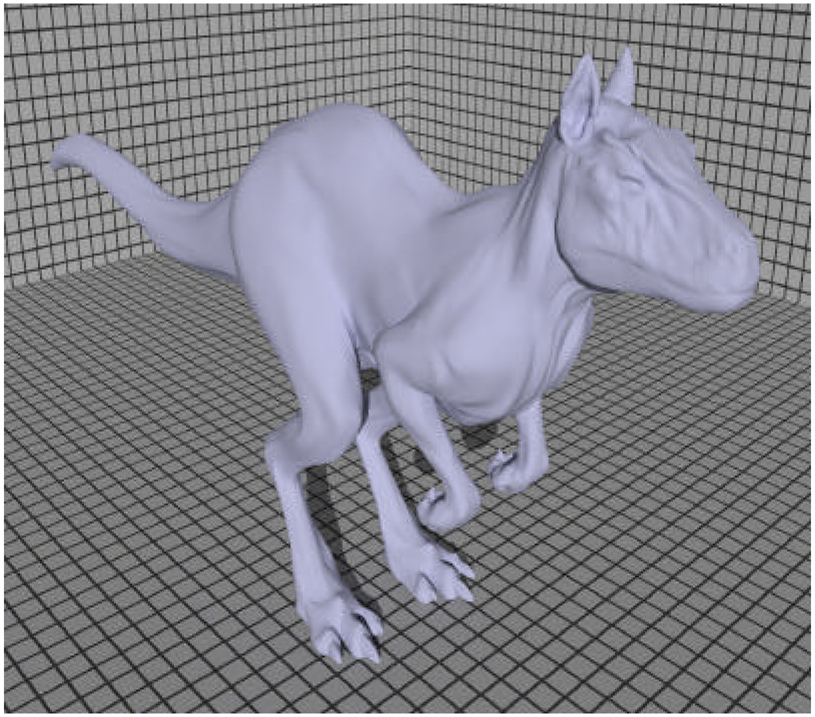
- Reflection and refraction
- Laws
- Lr=kdLicos?;
- $?_{i}\mathrm{sin}?_{i}=?_{t}\mathrm{sin}?_{t}$

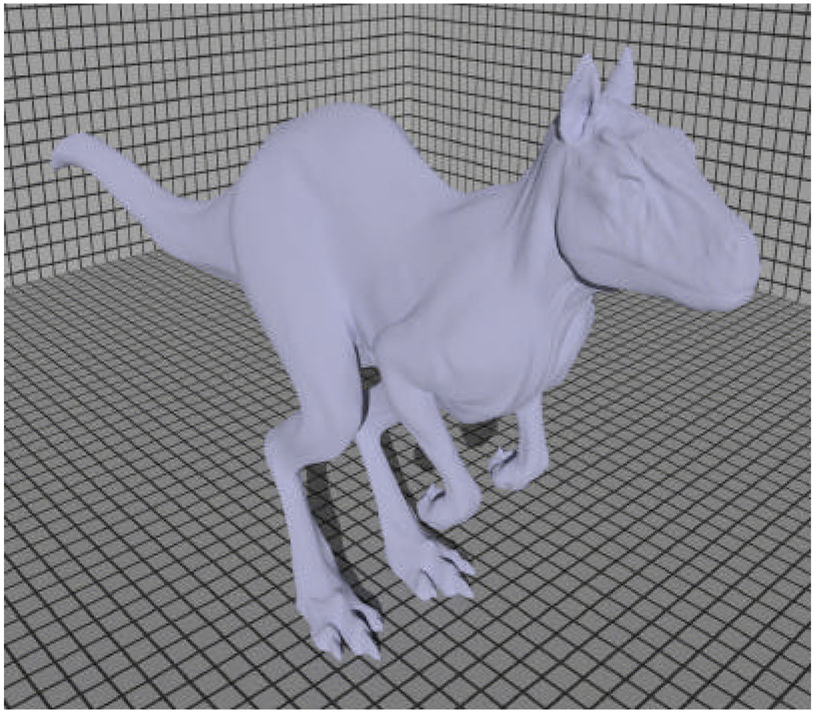




- Microfacet models

Distribution of facets + BRDF from individual microfacets.





Self-shadowing

- shadows on rough surface