PCBEX: Point-Based Color Bleeding With Volumes Thesis Defense

Christopher James Gibson

California Polytechnic University
CSC Department

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Schedule

Graphics Intro

Rendering is the process of producing 2D images from a 3D scene description

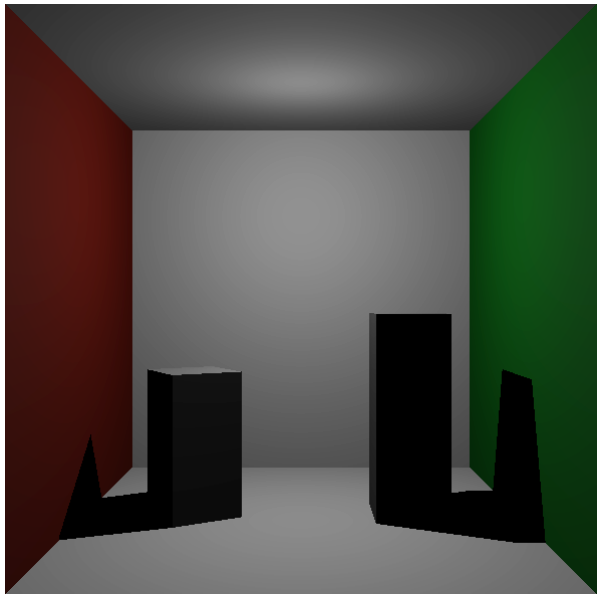
At its core, all of **computer graphics** is the visualization of how light interacts in these scenes

Modelling physically correct light interactions can get extremely computationally expensive

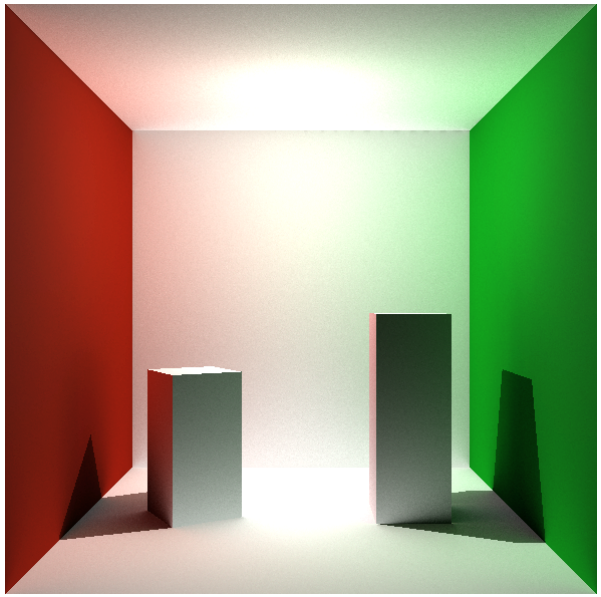
Global Illumination

Global Illumination represents the set of algorithms that estimate complex lighting systems

The results lead to richer, more realistic images



Direct Lighting



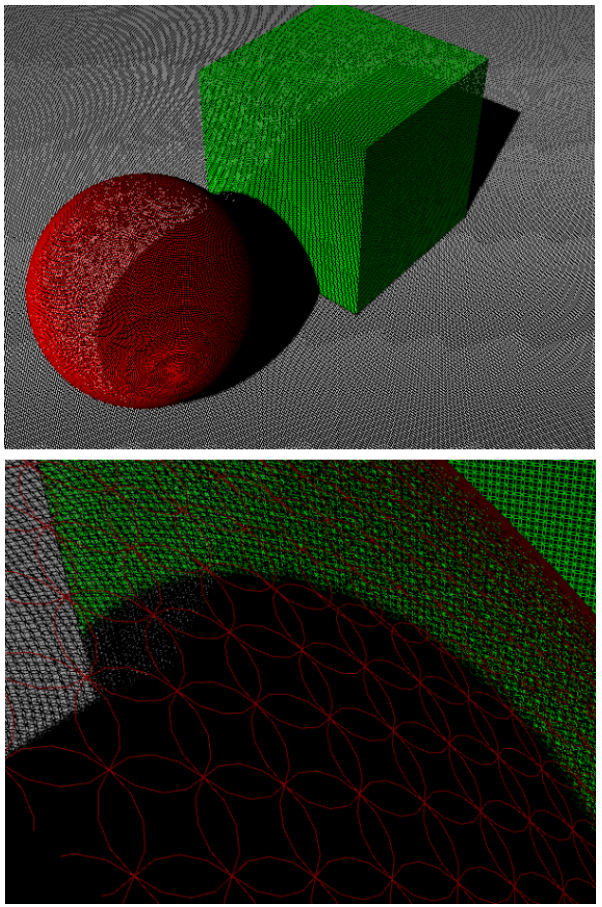
Direct Lighting & Global Illumination

Point-Based Color Bleeding (PCB)

Cheap, accurate global illumination effects using color bleeding

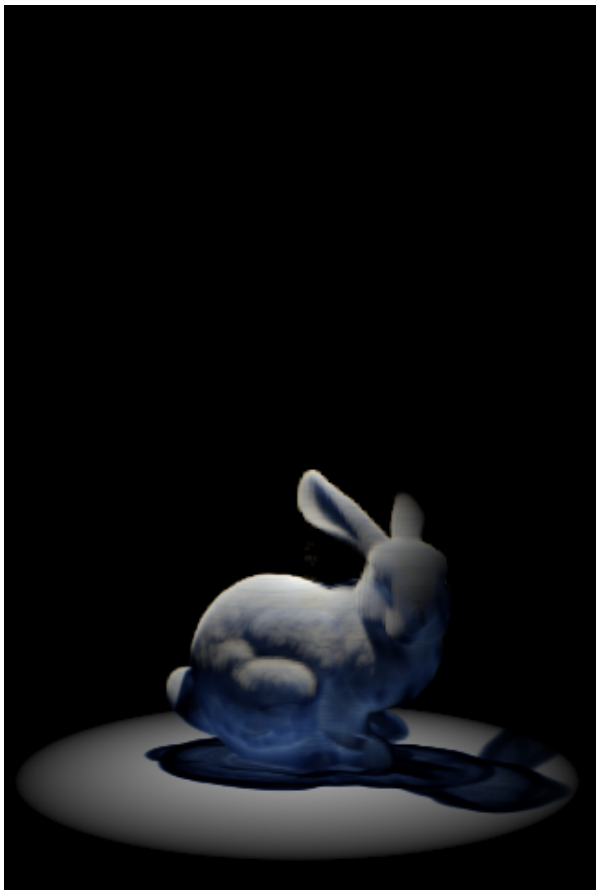
Utilizes direct light point cloud representation of scene's direct lighting

Already used heavily in production due to its performance advantages



Surfels in PCB

Motivation

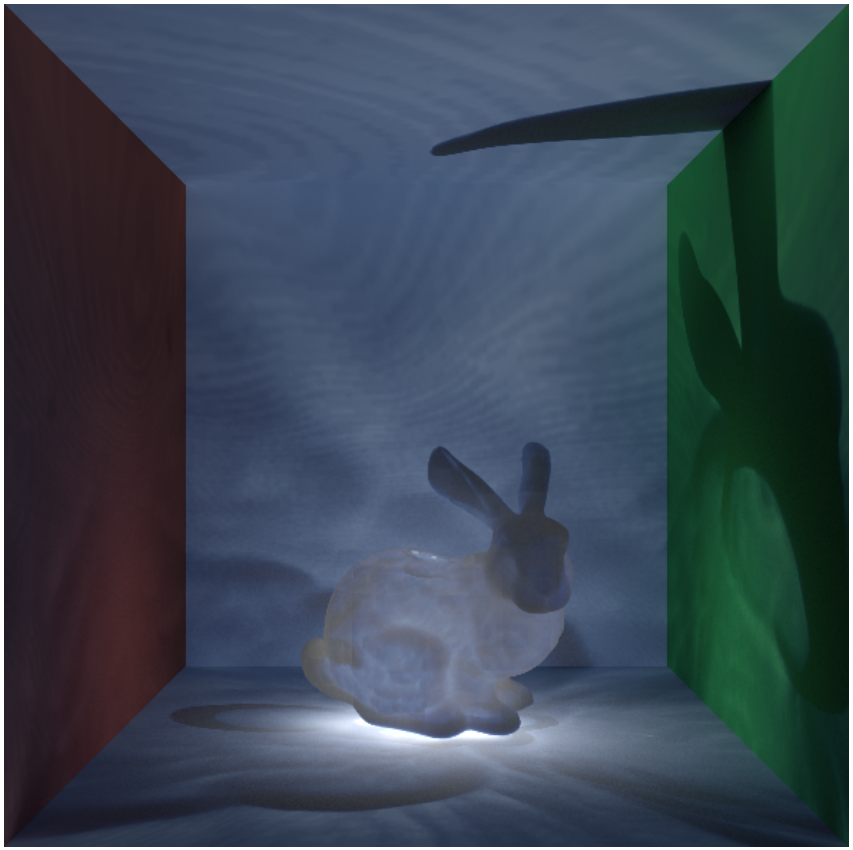


Complex volume lighting algorithms are computationally expensive and complex

Most GA algorithms do not include volume contributions

Goals

- Modify existing PCB in order to include volumetric lighting
- Accurately model scatter, absorption and scatter properties
- Modify volume integration algorithm to add scatter-in effect
- Return comparable results with shorter overall runtimes



Flux and Radiance

Flux is the measure of total light emitted *(Watts)*

Radiance & Radiance Invariance

$$L = \frac{d^2\,\Phi}{dw\;dA^{\perp}} = \frac{d^2\,\Phi}{dw\;dA\cos\theta}$$

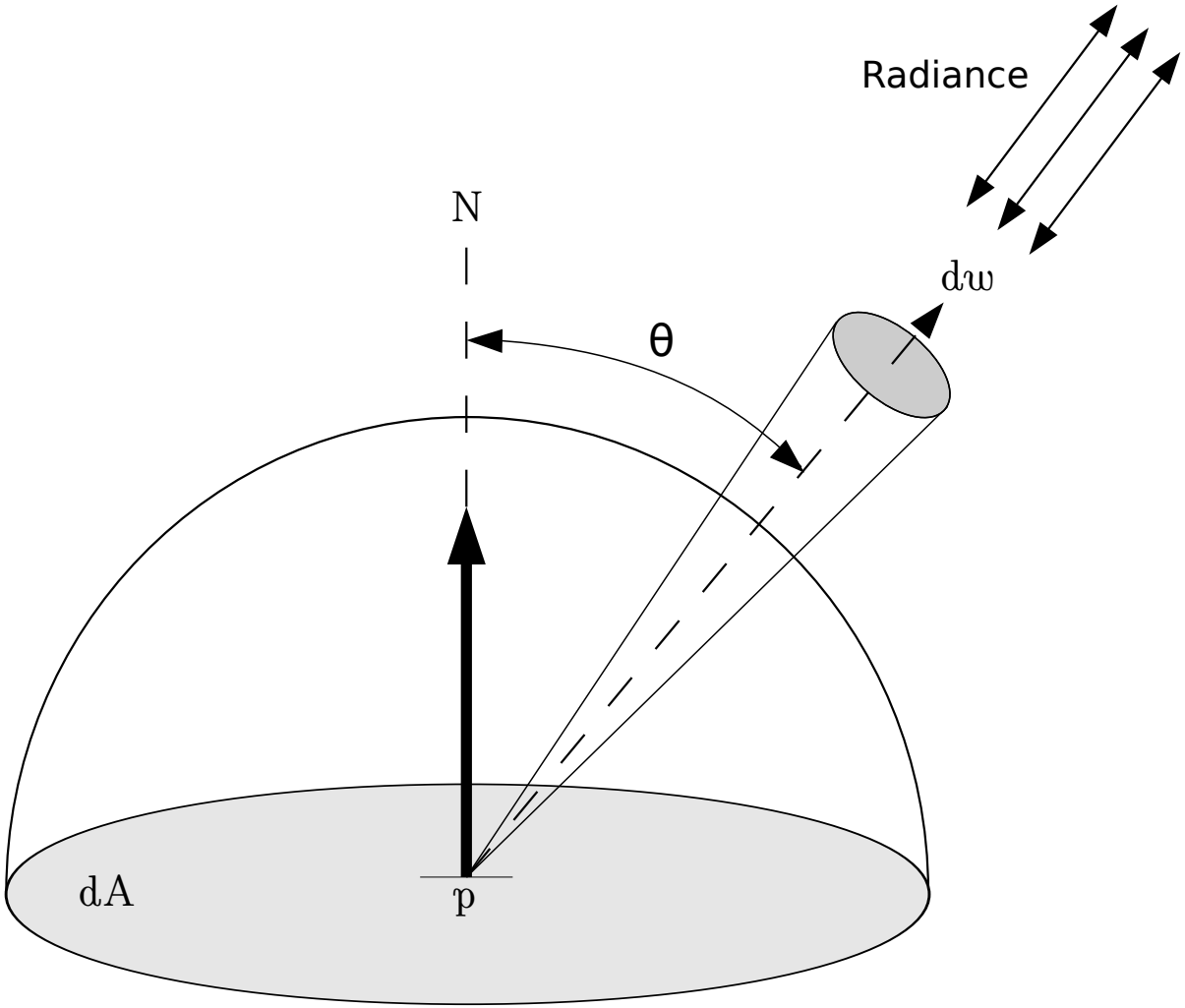
$$L(x \to y) = L(y \to x)$$

Irradiance

$$E = \frac{d\Phi}{dA}$$

$$E = \int L(\mathrm{p} \leftarrow w)\cos\theta dw$$

Irradiance



BRDF and BSRDF

BRDF

Bidirectional **R**eflectance **D**istribution **F**unction

Gives us a formalism for describing the reflection from a surface

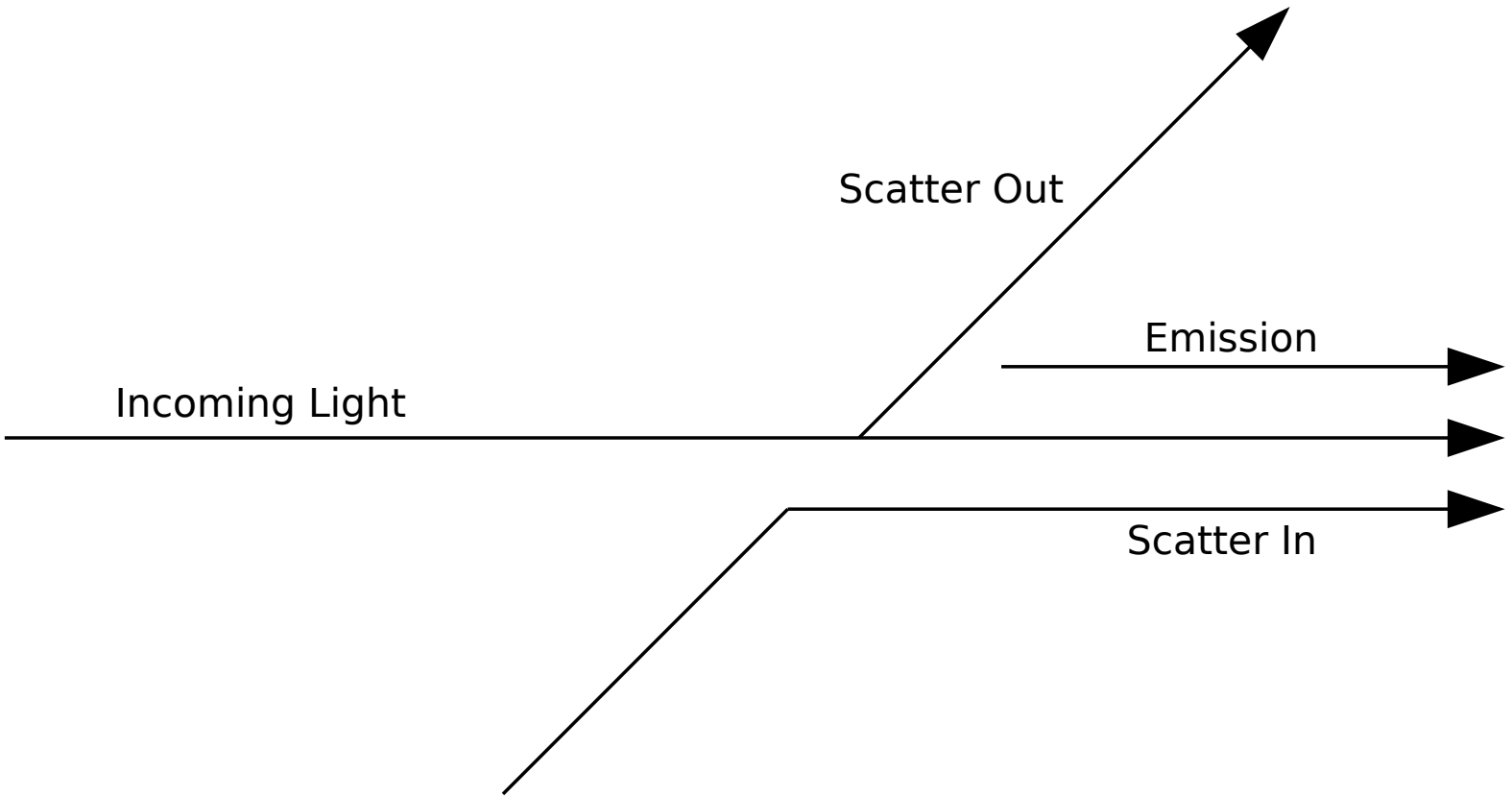
$$dE(\mathsf{p}, w_i) = \int L_i(\mathsf{p} \leftarrow w_i)\cos\theta_i dw_i.$$

BSRDF

Bidirectional **S**cattering-surface **R**eflectance **D**istribution **F**unction

Describes complex behavior of light within surface
(*subsurface scattering*.)

Volume Lighting



Volume Lighting

Absorption

$$e^{-\int_0^d \sigma_a(p+tw,w)dt}$$

Scatter Out

$$dL_o(\mathsf{p},w) = -\sigma_s(\mathsf{p},w)L_i(\mathsf{p},-w)dt$$

Extinction in a volume

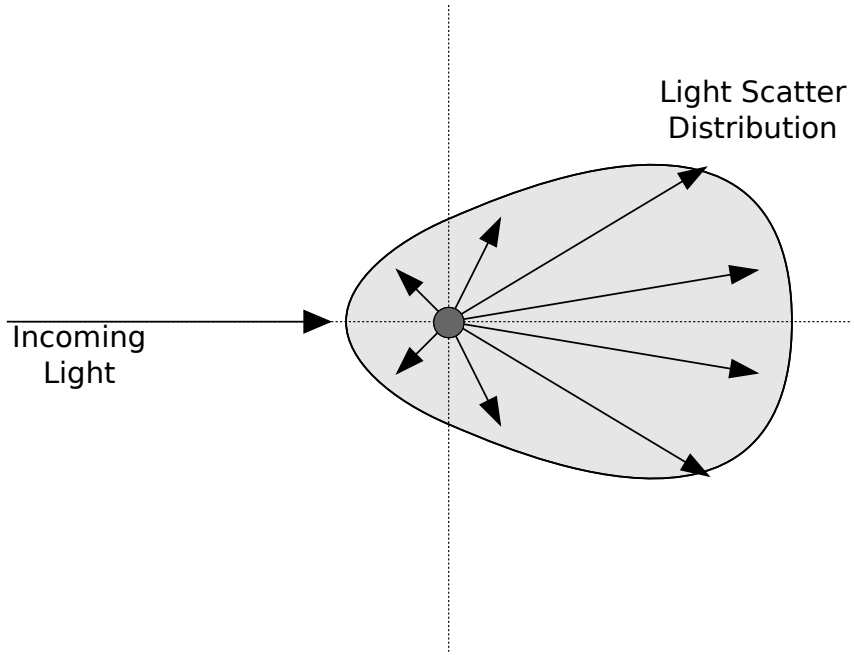
Volume Lighting

Phase Function

Described as $phase(w \rightarrow w')$

Source Normalization

$$\int_{\mathbb{S}^2} phase(w \rightarrow w')\mathrm{d}w' = 1.$$



Phase function distribution

Volume Lighting

Transmittance

$$T_r(\mathsf{p} \rightarrow \mathsf{p}') = e^{-\int_0^d \sigma(p+tw,w)dt}.$$

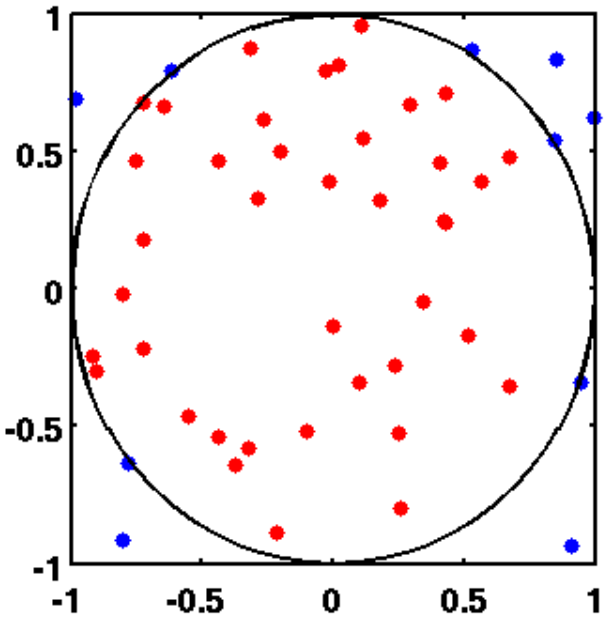
Scatter In

$$S(\mathsf{p}, w) = L_{\mathsf{ve}}(\mathsf{p}, w) + \sigma_{\mathsf{s}}(\mathsf{p}, w) \int_{\mathbb{S}^2} phase(\mathsf{p}, -w' \rightarrow w) L_i(\mathsf{p}, w') \mathsf{d}w'.$$

Monte Carlo Integration

Monte Carlo methods allow estimation of complex systems through use of probability functions and random numbers.

Most useful to us is Monte Carlo Integration.



Randomly sampling a circle

Related Works: Global Illumination

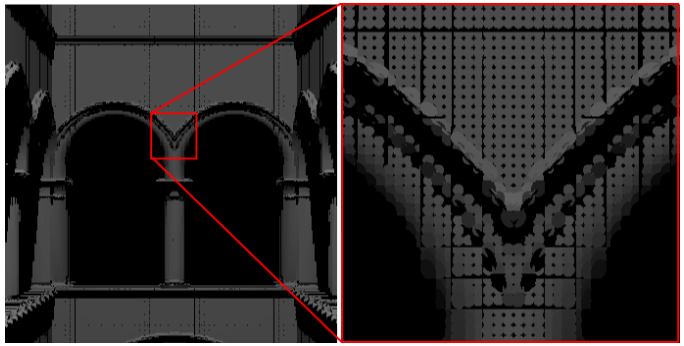
Field of study in computer graphics.
Photon Mapping.
Radiosity.
Monte Carlo Techniques.

Related Works: Point-Based Color Bleeding

Point-Based Approximate Color Bleeding by Per Christensen.

Subset of scene geometry is thoroughly sampled, creating point cloud.

Point cloud is sampled to determin incoming radiance.

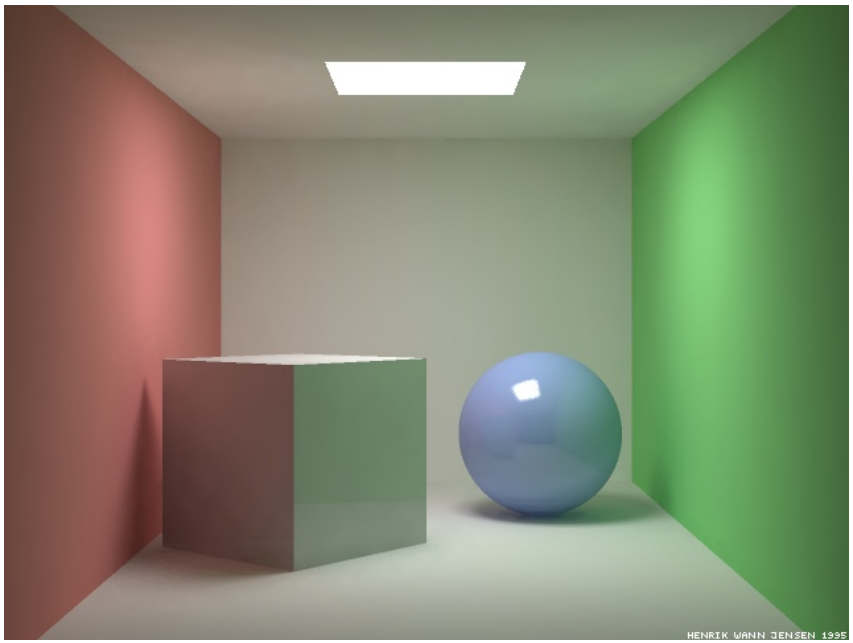


Randomly sampling a circle

Related Works: Photon Mapping

Photons cast from lights interact with the scene. At each hit, a photon can:

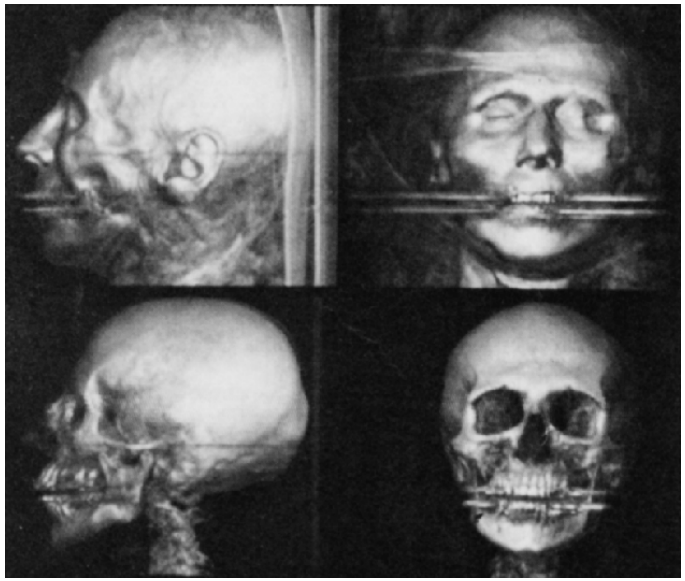
- Bounce
- Pass Through
- Be Absorbed



Related Works: Volume Rendering

Seminal research involved number of approaches...

- Polygonalization of straight voxels *(boxy)*
- Polygonal representation based on isosurfaces
- Opacity/Color arrays *(interpolation across voxels)*

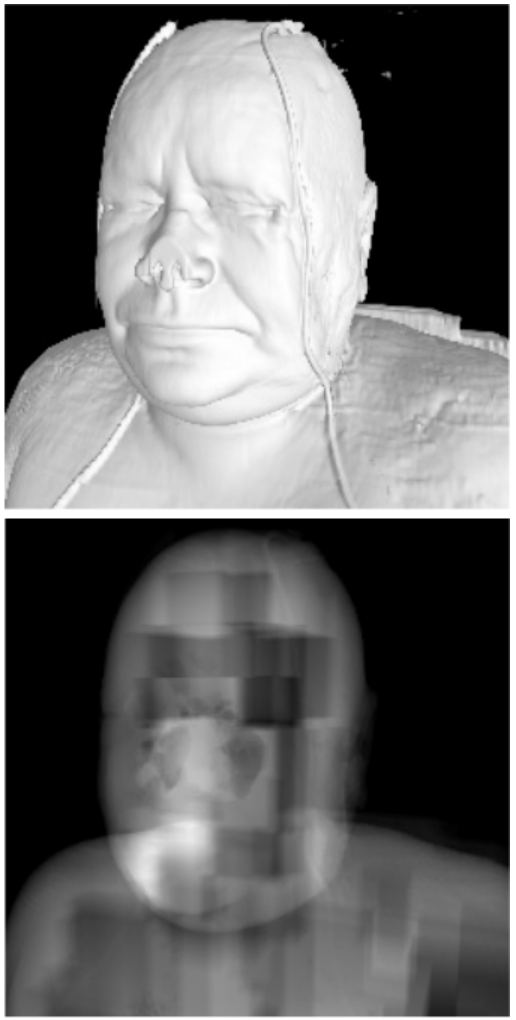


Renders of CT scan data

Related Works: Volume Rendering

Multi-resolution volumes help save on memory and allow for on-demand loading

Occlusion techniques involving volume acceleration structures help avoid extraneous computations



Renders of CT scan data

Point-Based Color Bleeding

1. Sample the scene and generate a point cloud
2. Perform ray tracing on regular geometry
3. Replace ambient estimates with a gather stage using surrounding point cloud

Extension Overview

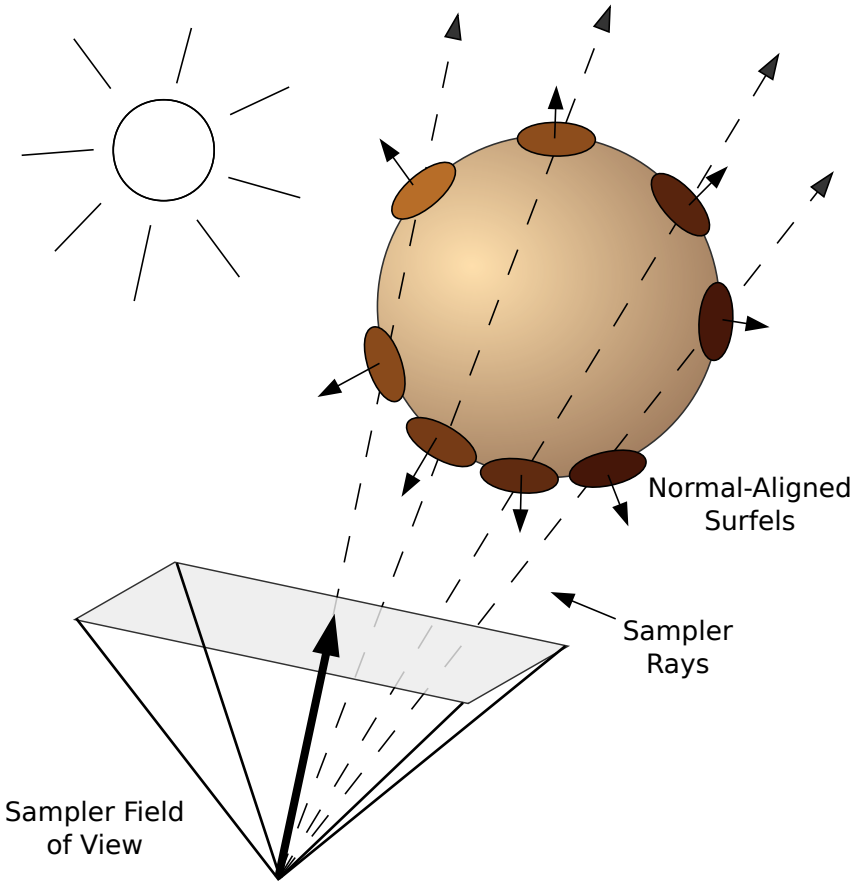
1. Sample the scene and generate a point cloud
2. Sample the participating media and evaluate scatter, absorbtion and direct lighting
3. Cast rays as normal
4. Orient hemispherical samples along the normals of the surfaces intersected
5. Model scatter-out and scatter-in properties during lighting gather stage

Sampling the Scene

Rays are cast and intersections with objects are recorded

Sampling "camera" is behind normal camera with wider field of view

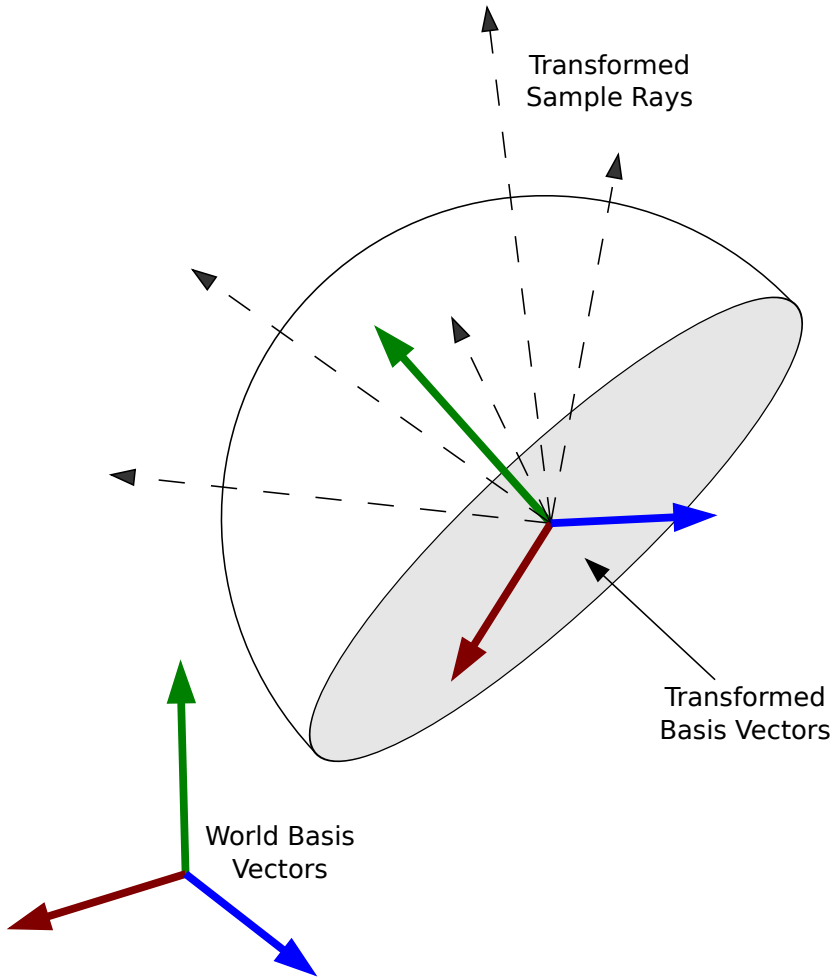
Surfels are oriented at the intersections aligned along the surface normal



Gathering Light

At render time, rays are cast from normal camera

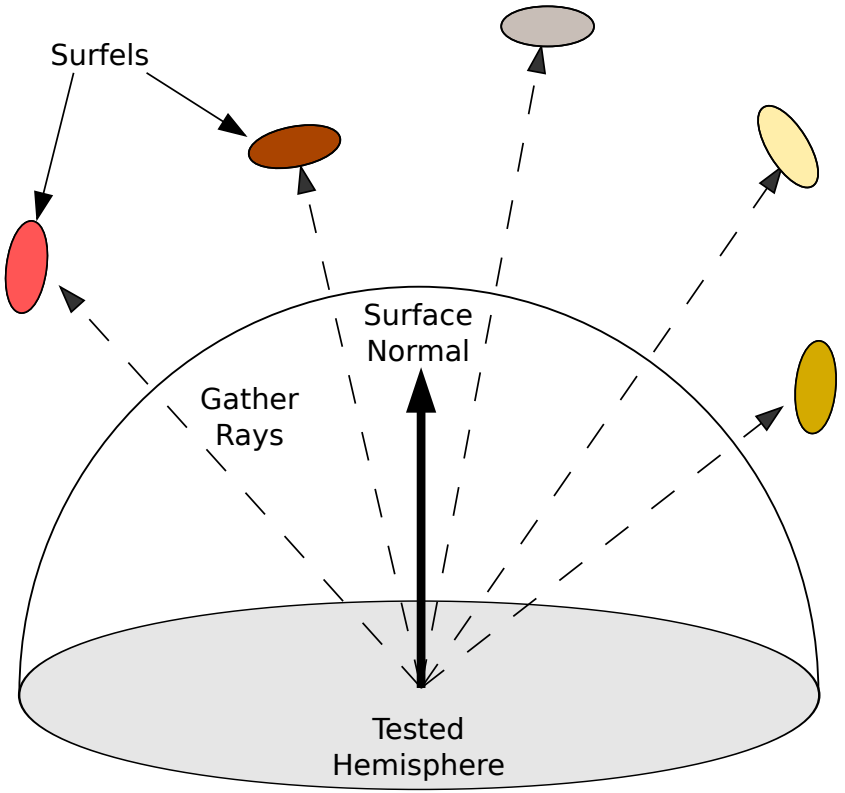
Samples are cast from intersecting surface oriented along its normal



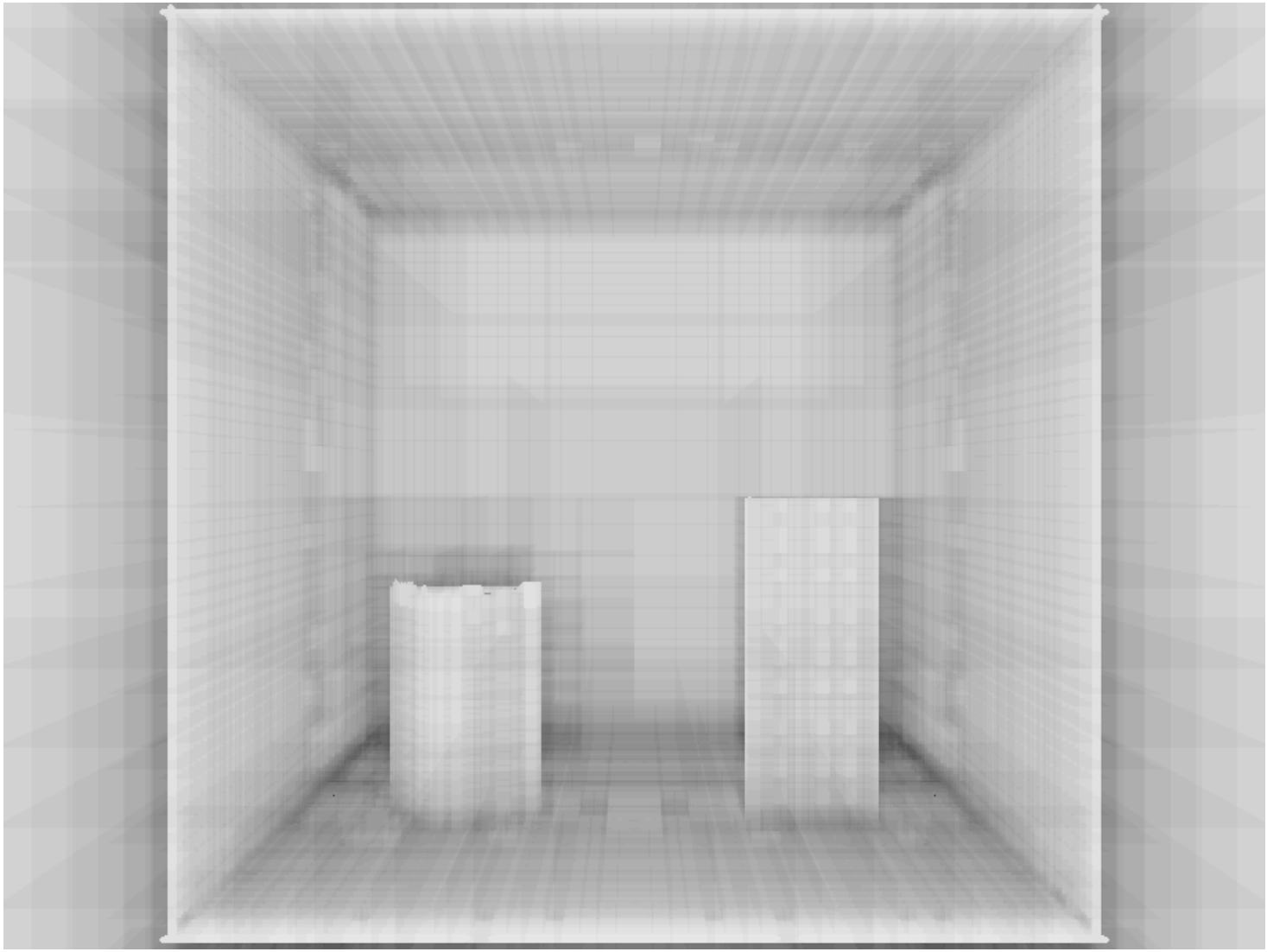
Gathering Light

Samples cast into point cloud "gather" light via intersection

Samples are returned and used to evaluate the integral over the aligned hemisphere



Integrating Volume Data



Results

Scene	Render Time (s)	Image Delta	Memory Overhead
Monte Carlo w/o PCB	3351 sec	NONE	NONE
Traditional PCB	348 sec	11.0%	390 Mb (4.0%)
Extended PCB	397 sec	4.8%	395 Mb (4.1%)

Future Work

1. Multiple bounce
2. Phase functions for volumes
3. Parallelism
4. Optimal Sampling
5. GPU Acceleration

Conclusion

Oh yea!