Shape-Adaptive Subsurface Scattering

“A Learned Shape-Adaptive Subsurface Scattering Model”
by D. Vicini, V. Koltun, W. Jakob, SIGGRAPH 2019

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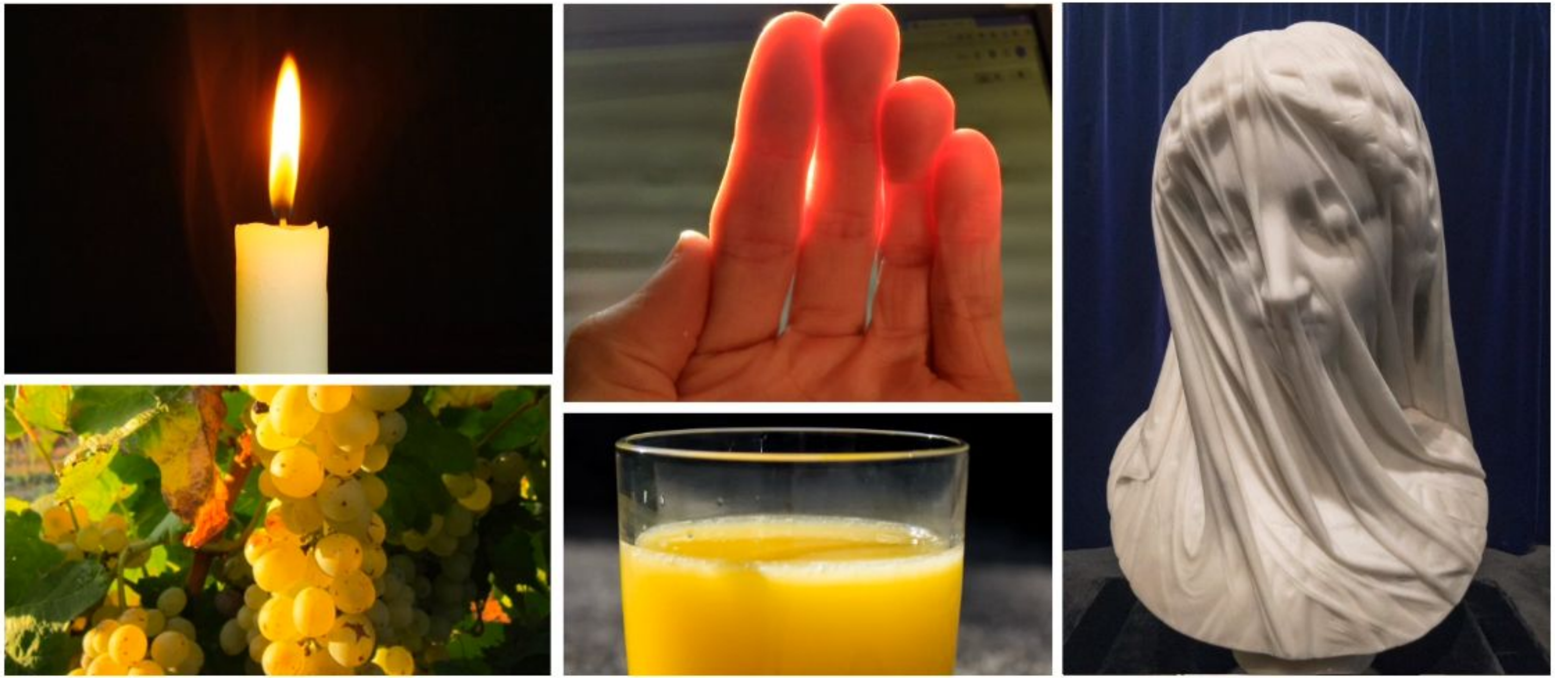
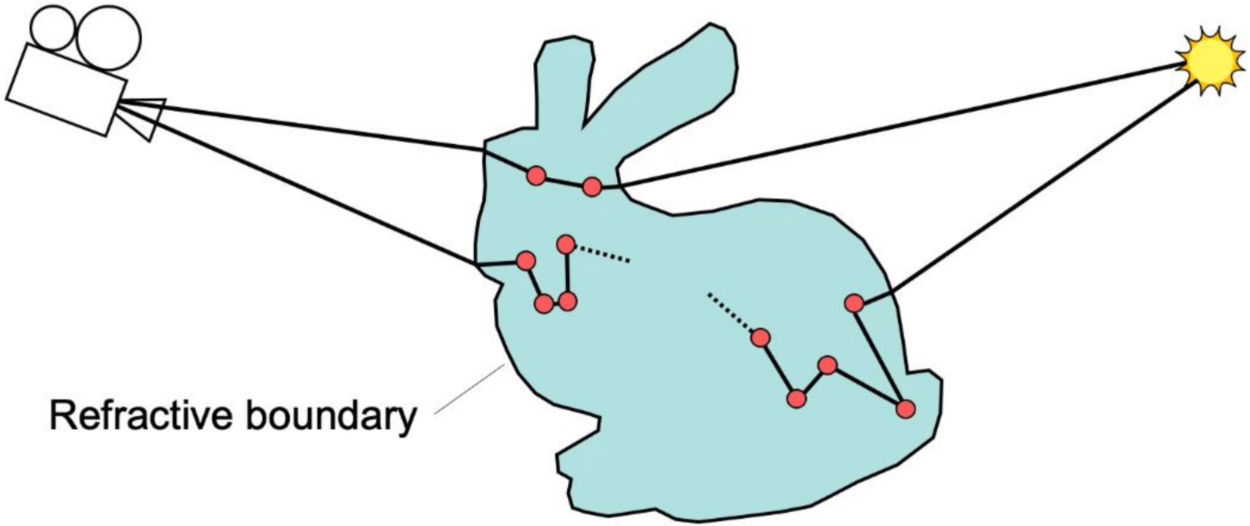
Subsurface Scattering recap



Subsurface Scattering recap

100-1000s of internal scattering events commonly required



Motivation

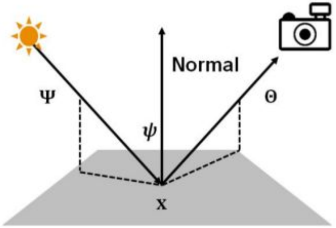
1) **Monte Carlo** sampling of the Radiative Transfer Equation (RTE)
    a) Generally used
    b) **Inefficient** e.g. Highly scattering material; expensive to track long sequence of internal scattering interactions
2) **BSSRDF**(Bidirectional Scattering-Surface Reflectance Distribution Function)
    a) **Efficient**; **directly** encode **surface-to-surface** transport
    b) Severe **assumptions** that are almost always **violated** make **error** in **rendered images** e.g. planar geometry, isotropy, low absorption

=> **A New Shape-Adaptive BSSRDF Model**

Take **Efficiency** of 2) and improve **Accuracy**

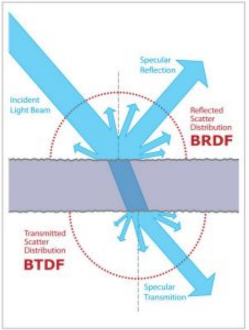
Motivation

Bidirectional Reflectance Distribution Function (BRDF)

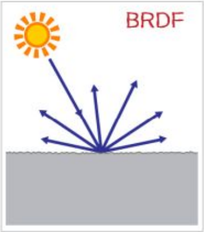


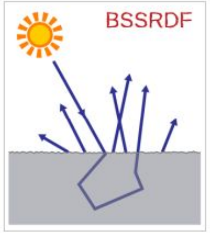
$$f_r(x, \Psi \to \Theta) = \frac{dL(x \to \Theta)}{dE(x \leftarrow \Psi)} = \frac{dL(x \to \Theta)}{L(x \leftarrow \Psi)\cos\psi d\omega_\Psi}$$

- **BSDF (S: Scattering)**
  - **The general form combining BRDF + BTDF (T: Transmittance)**



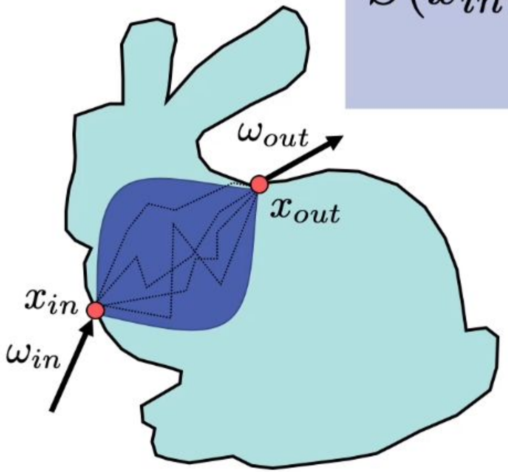
- **BSSRDF (SS: Surface Scattering)**
  - **Handle subsurface scattering**





Motivation

The BSSRDF summarizes internal scattering



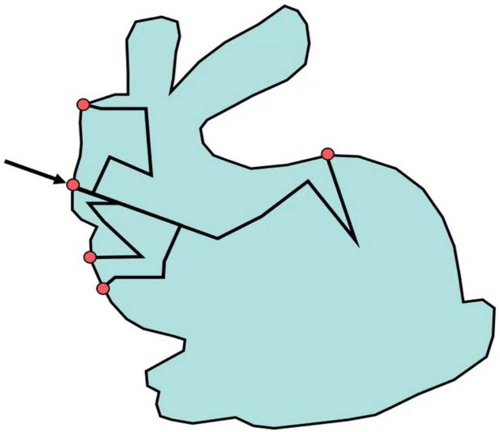
$$S(x_{in}, \omega_{in}, x_{out}, \omega_{out})$$

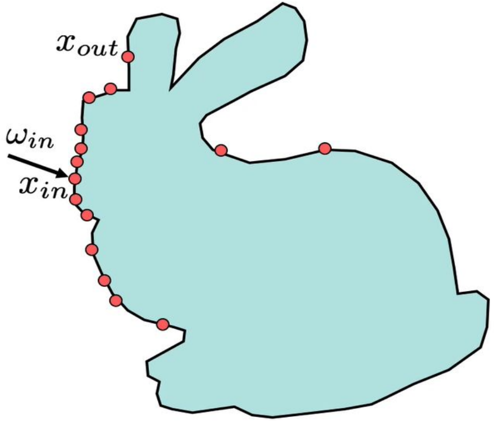
BSSRDF

Paper Introduction

Shape-Adaptive BSSRDF for Efficient Subsurface Scattering

- Treats subsurface scattering as a sampling challenge, focusing on the endpoints of light paths rather than the entire trajectory

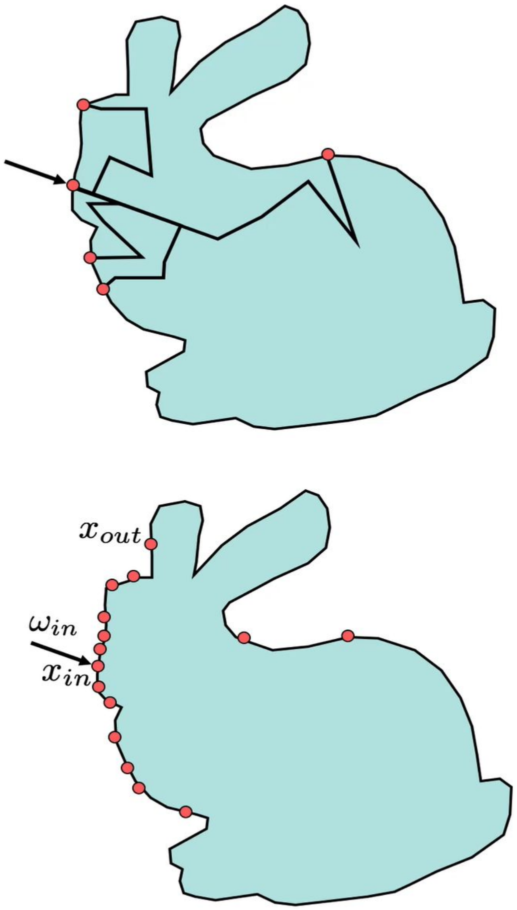




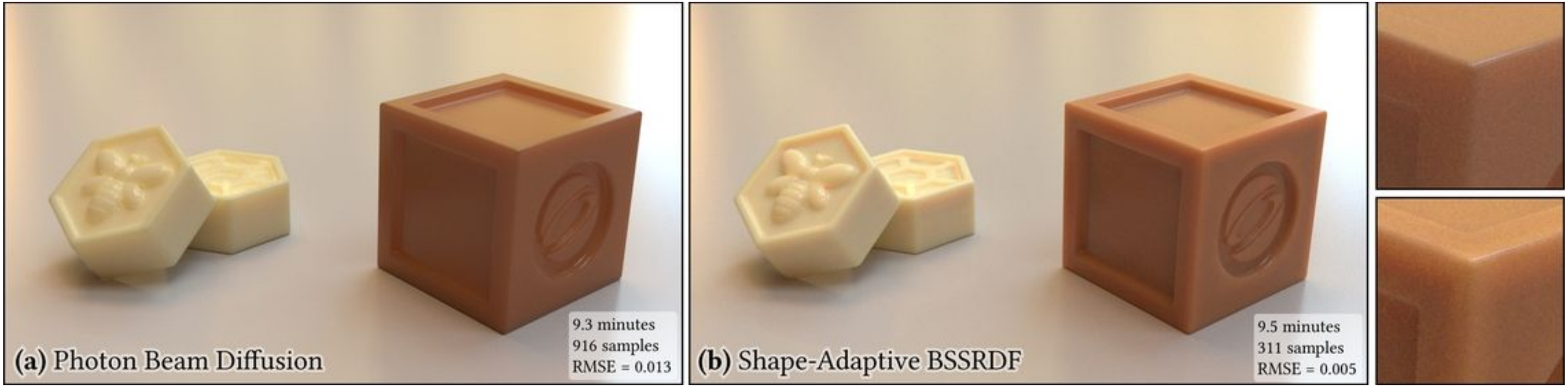
Paper Introduction

Shape-Adaptive BSSRDF for Efficient Subsurface Scattering

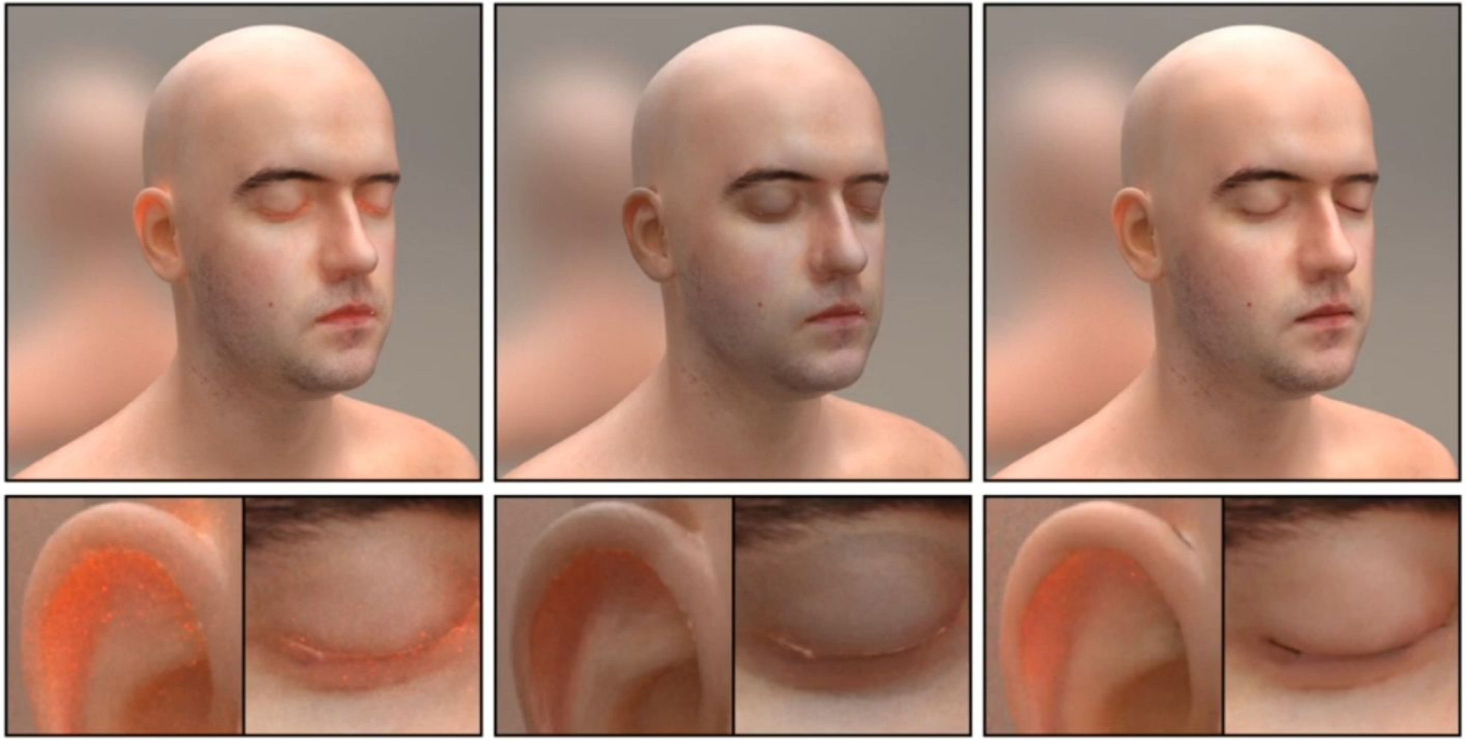
- Treats subsurface scattering as a sampling challenge, focusing on the endpoints of light paths rather than the entire trajectory
- Shape-Adaptive Approach: Adapts to local geometry, with scattering distributions and absorption rates calculated based on the surface's shape characteristics



Paper Results



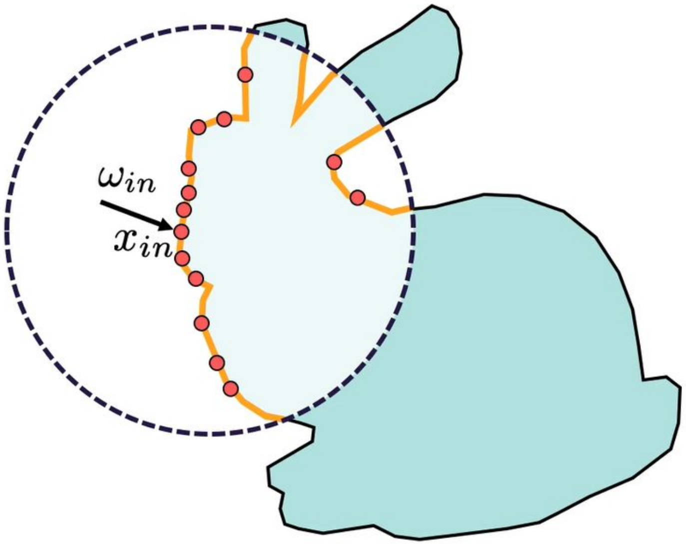
Paper Results



Dipole (variant 1) Dipole (variant 2) Ours

Detailed Explanation

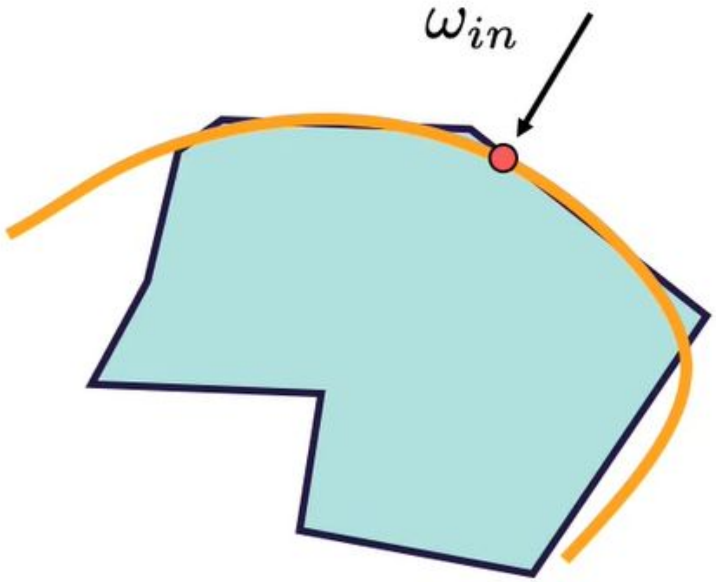
- Scattering distribution and absorption probability depend on **local geometry**
  - scattering is localized phenomenon => shape descriptor only has to summarize the local neighborhood around incident location
  - no need to know about shapes that are far from the incident location



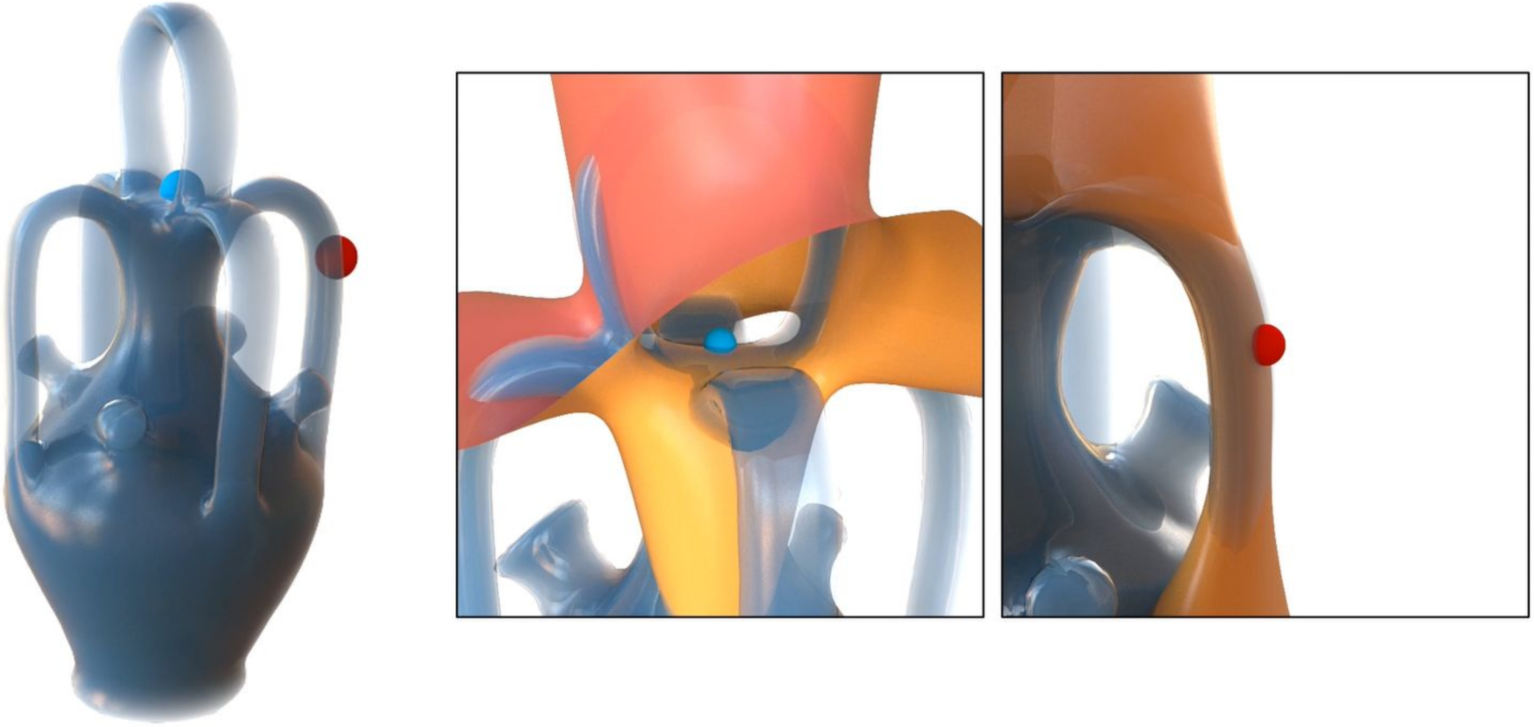
Detailed Explanation

- Scattering distribution and absorption probability depend on **local geometry**
  - scattering is localized phenomenon => shape descriptor only has to summarize the local neighborhood around incident location
  - no need to know about shapes that are far from the incident location
- Represent surface as a **polynomial**
- Polynomial **coefficients** used as shape descriptor

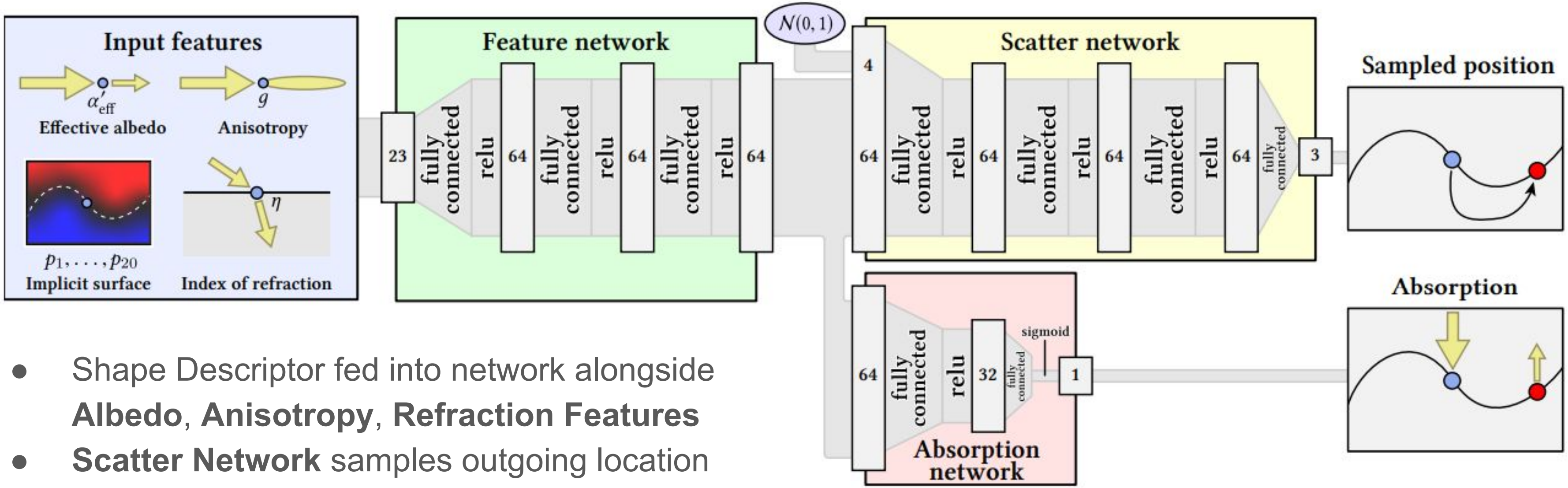
$$P(\mathbf{x}) = c_1 + c_2 x + c_3 y + \ldots c_{20} z^3$$



Detailed Explanation

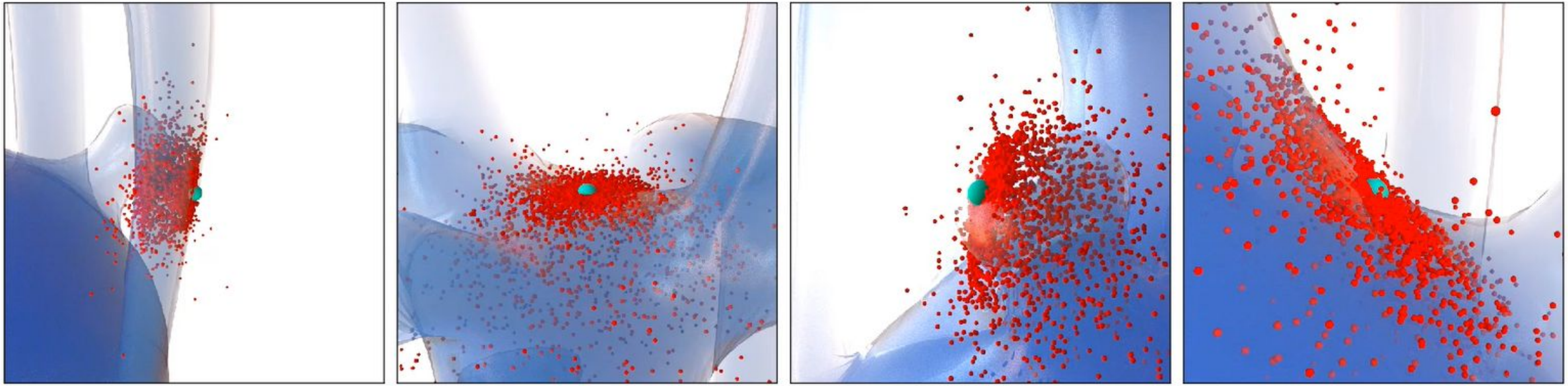


Detailed Explanation

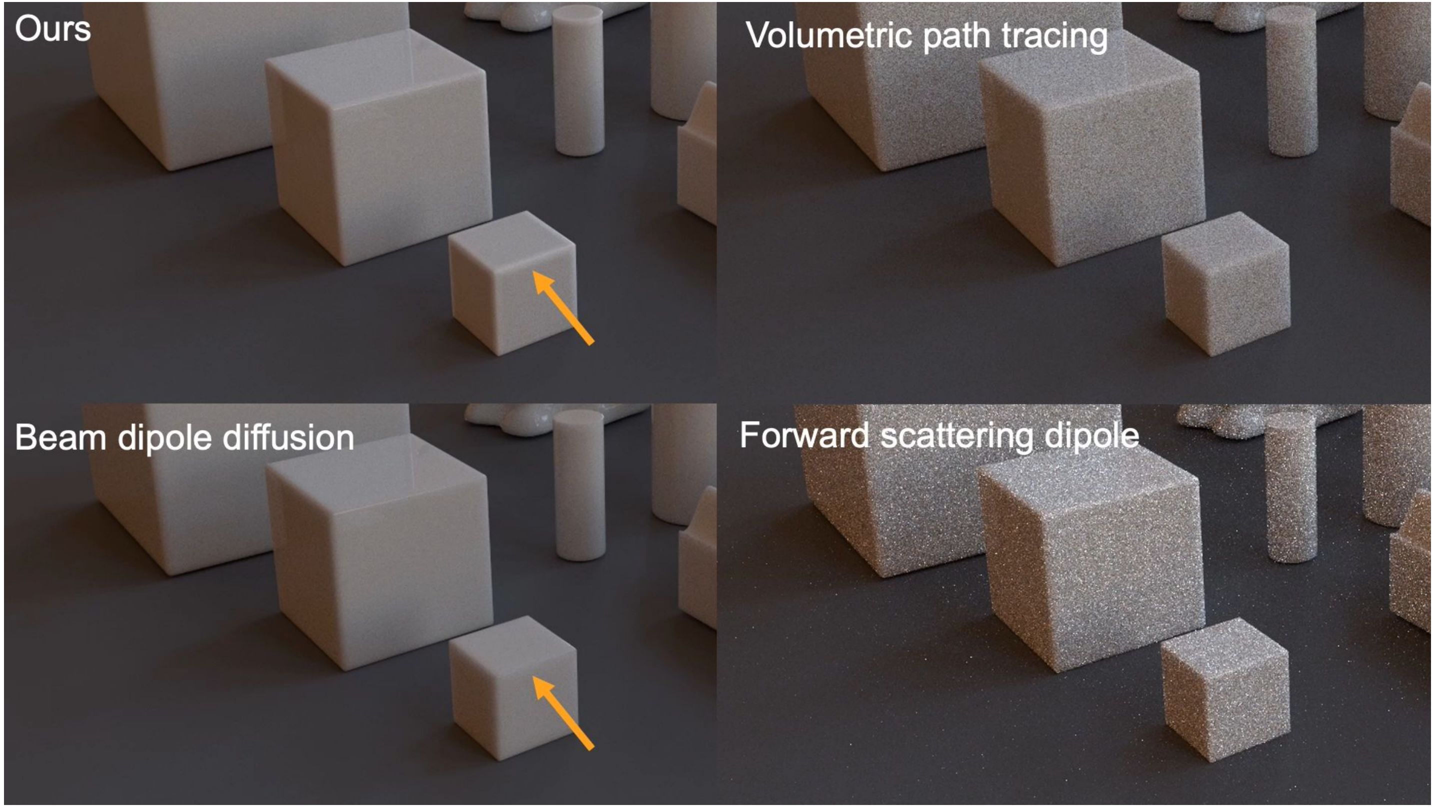


- Shape Descriptor fed into network alongside **Albedo**, **Anisotropy**, **Refraction Features**
- **Scatter Network** samples outgoing location
- **Absorption Network** computes absorption probability

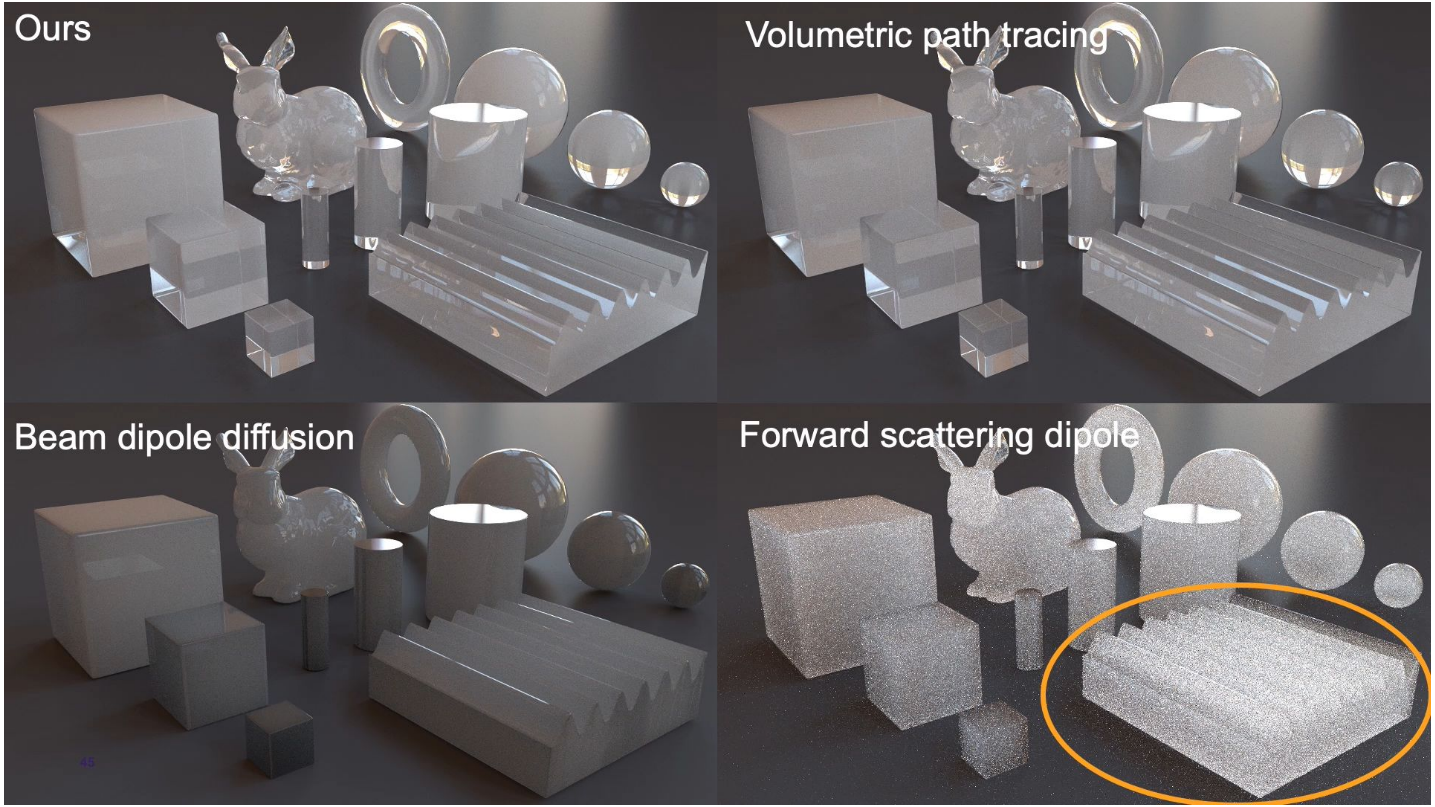
Detailed Explanation



Detailed Explanation



Detailed Explanation



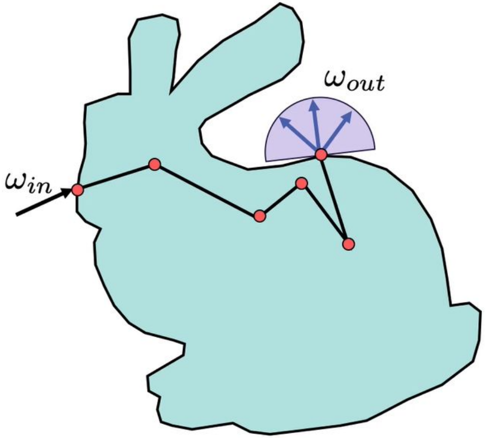
Limitations

Sampling Technique

- High variance with 1024 samples/pixel
- **Greater computational demand** than Monte Carlo reference

Material Interaction

- **Assumes diffuse** material, not accurate for thin anisotropic materials with directional scattering



Improvement Ideas

Sampling Technique

- Batching
- GPU rendering

  -> for better performance

Material Interaction

- Consider other material also (not only diffuse)
- Add direction information to architecture
  - outgoing direction which is not uniform

  -> for more realistic images

Current Progress

- Studying the **paper**
  - This paper is **difficult** and has many backgrounds and formulas
  - Seemed okay at first glance, but…
  - **Hard to find problem**, so we decided to use “**Limitations**” of the paper

- **Setting up**
  - Struggles with **installation**
  - Try to understand and run given **code**

Member Roles

- Janu Kim
  - Focusing on expanding the model to support types of materials beyond diffuse
- Yiwen Mao
  - Focusing on batching techniques and GPU rendering to improve performance
- Tamana Pirzad
  - Leading setting up/installation/running the code
- All
  - Run code
  - Initial implementation modifications
  - Create presentation material

References

- Most pictures and video are from the authors’ paper and video
- Lecture slides from CS482, KAIST