Simulation Multiple Scattering in Hair using a Photon Mapping Approach

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Content

Introduction

- Multiple Scattering is
  - *important for accurate rendering (light colored hair)*
  - *difficult to calculate*
- Explicit modeling of strands
- Smooth volumetric representation of the scattered radiance field
- Generalization of Volume Photon Mapping
- 1-2 magnitudes faster than Monte Carlo Path Tracing

Related Work

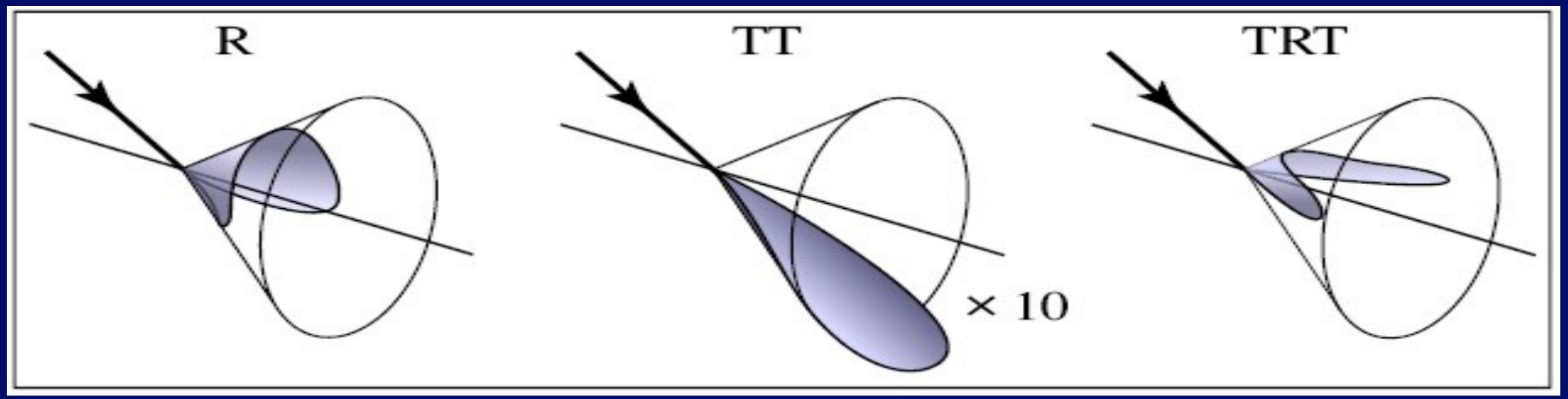
- Previous work focused on
  - *1) Shadowing [Lokovic/Veach 2000]*
  - *2) Direct illumination [Kajiya/Kai 1989]*
    - renders black hair accurately
  - *3) Transmission and internal reflection (single reflection) [Maschner et al. 2003]*
  - *4) Multiple Scattering [Zinke et al. 2003]*
    - Monte Carlo Path Tracing extension for 3

General Idea

- Inspired by rendering participant media
  - *Consider scattered light as continuous distribution*
- Particle Tracing (photons)
- Store photons uniformly along paths
- Use a 6D data structure (position & orientation)
- Reuse illumination information (irradiance cache)
  - *needs little modification -> fibre cache*

Multiple Scattering in Hair

- Light colored fibres scatter in the hemisphere facing away from the lightsource
- Strongly forward scattering
- Scattered light can be definied as a cone of directions
  - *its slope is near the incident direction*



Simulating Multiple Scattering

- Scattering from a one dim. fiber
  - *omit variation in radiance across a fibre*
- Outgoing radiance: $L_o(x,\vec{w}) = \int_{S^2} f_s(\omega_i,\omega_o) L_i(x,\omega_i) \sin(\omega_i,u)\, d\omega_i'$
- Separate the direct illumination from the indirect

$$L_o(x,\vec{w}) = \underbrace{\int_{S^2} f_s(\omega_i,\omega_o) L_i(x,\omega_i) \sin(\omega_i,u)\, d\omega_i'}_{direct} + \underbrace{\int_{S^2} f_s(\omega_i,\omega_o) L_s(x,\omega_i) \sin(\omega_i,u)\, d\omega_i'}_{indirect}$$

- L_d-> random directions towards light sources
- L_i-> random directions (obtained by f_s) and evaluation of 5D photon map

Overview Photon Mapping for hair

Creation of the photon map

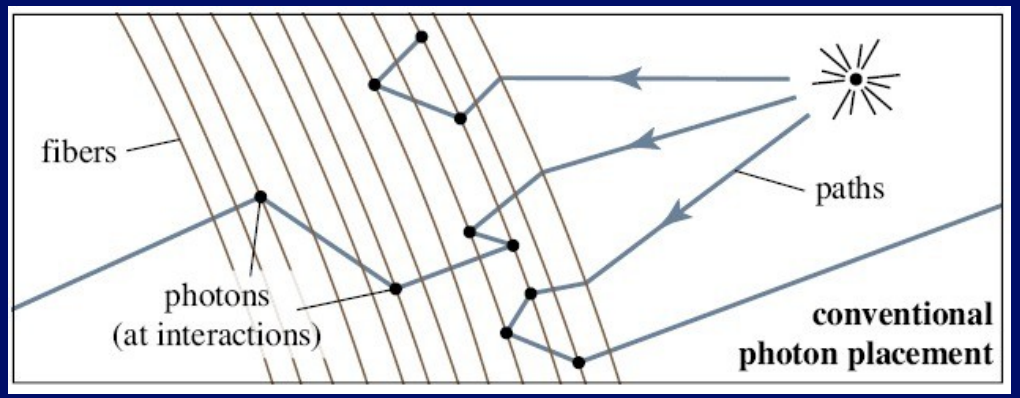
- Emit photons from the light sources
- Trace photons through the scene (multiple scattering)
- Store their positions and directions in a 5D data structure

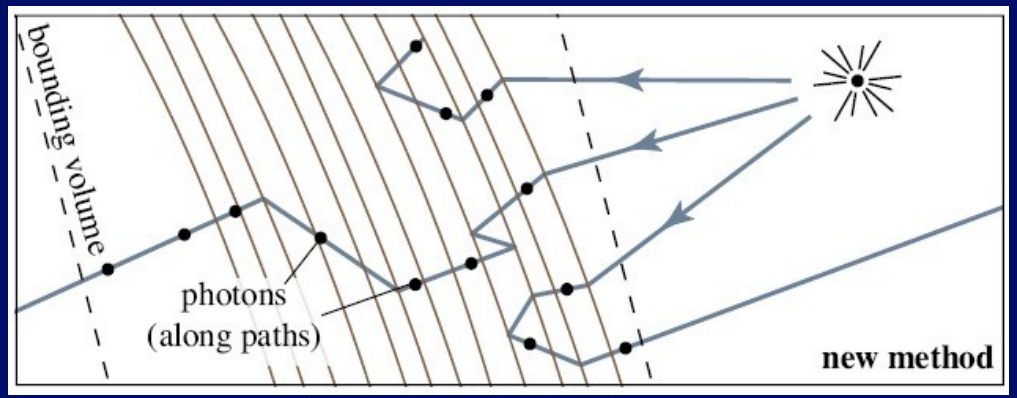
Evaluation of the photon map

- Locate nearby photons (metric needed)
- Density estimation both in position and direction

Depositing photons

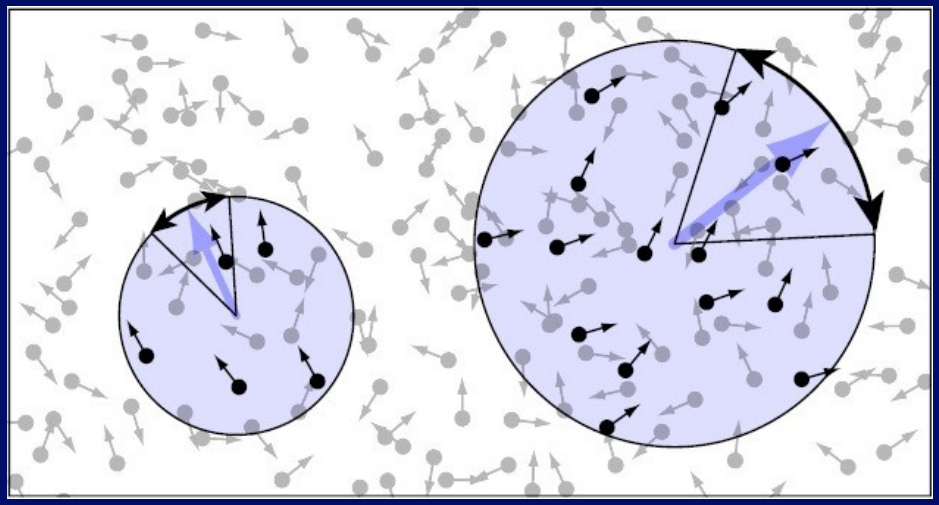
- Photons are generated with a constant propability along a path with unit length
- Russian Roulette used to terminate path -> weights of the photons remain constant
- Deposit photons uniformly along paths





Density estimation (I / II)

- Ordinary 3D photon map is smothing in the spatial dimension
- Problem: 5D map!
- Solution: Density estimation with respect to the position and the direction



Density estimation (II / II)

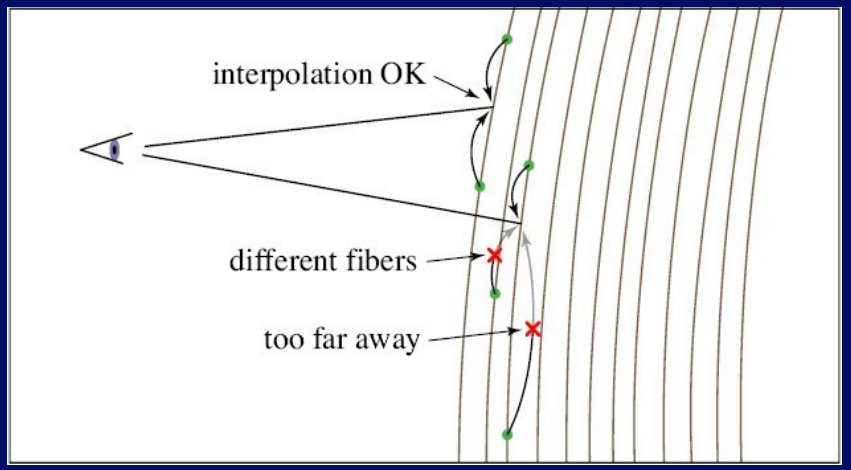
- Metric for position – direction space
  - *Defines a conversion between distances & angles*
- Simple Metric: Maximum of the euclidian metrics in position and direction space:

$$d((p_1,\omega_1),(p_2,\omega_2)) = max(length(p_1-p_2),\sqrt{(w)}\,length(\omega_1-\omega_2))$$

- Define $\sqrt{(w)}$ in position space equal to one unit in direction space (depends on the sceen scale)

Fiber Cache

- Idea of Irradiance Caching
- No assumption of diffuse illumination in hair possible (across fibres)
- Along a fibre the scattered radiance is slightly varying
  - *Cache irradiance along a fibre*



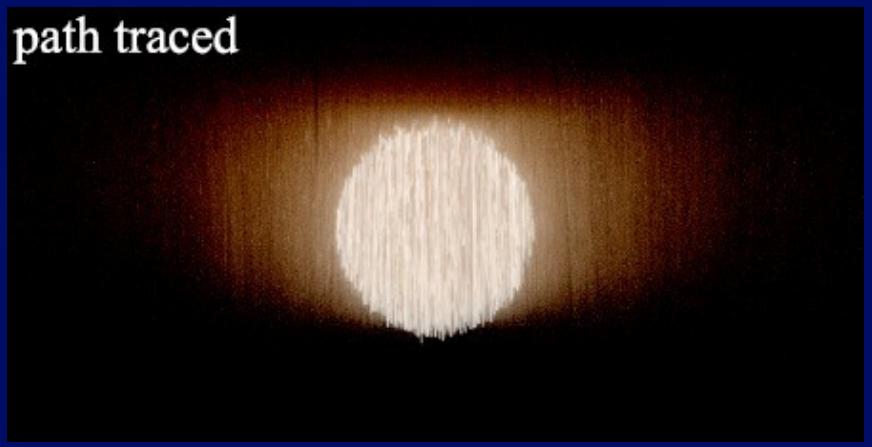
Ponytail (light behind)

Ponytail (light infront)

Blond hair illuminated by a spotlight

new method

path traced



photograph

Summing Up

- Trace n photons, specify the mean distance d between photons
- Paths are generated through the hair using the cylindric model
- Photons are stored randomly in every interval of length d. (Bounding Volume needed)
- Tracing rays from the eye into the scene
  - *Combine direct illumination with the scattered radiance from the hair*

Thanks for listening.
Any questions?