Realistic fire rendering

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September 3, 2015

Overview

Outline

Introduction

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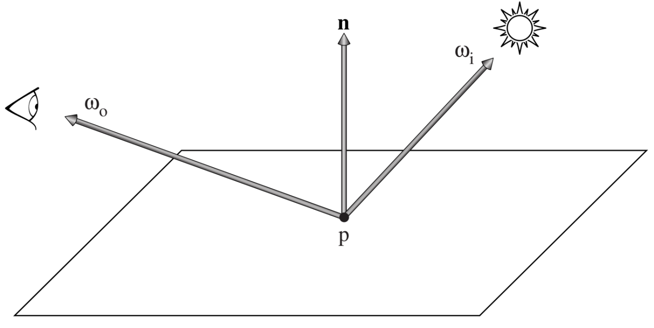


Diagram of light emitted from **p**, image taken from [PH10].

where **p** is the surface point, $\boldsymbol{\omega_i}$ is the incident light direction, $\boldsymbol{\omega_o}$ is the outgoing light direction and n is the surface normal.

The problem

- Render fire realistically
  - Participating media
  - Emission is important
  - Varied fuel types

Real fire with paper as fuel, image courtesy of [JAM*10].

Previous work

- Ray-tracing-based
  - Physically based
  - Accurate
  - Slow
- Raster-based
  - Many artefacts
  - Fast

Previous work: Results

Left, methane fire pool [P06]; right, a dragon emits a flame[H07].

Outline

The model: RTE

$$(\nabla)L_{\mathbf{x}} = -\sigma_a L_{\mathbf{x}} + \sigma_a L_e - \sigma_s L_{\mathbf{x}} + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i,$$

The model: RTE

$$\boxed{(\nabla)L_{\mathbf{x}}} = -\sigma_a L_{\mathbf{x}} + \sigma_a L_e - \sigma_s L_{\mathbf{x}} + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i,$$

Differential of radiance over a segment

The model: RTE

$$(\nabla)L_{\mathbf{x}} = -\boxed{\sigma_a}L_{\mathbf{x}} + \boxed{\sigma_a}L_e - \boxed{\sigma_s}L_{\mathbf{x}} + \boxed{\sigma_s}\int L_{\mathbf{x}}\Phi d\omega_i,$$

Absorption and scattering

The model: RTE

$$(\nabla)L_{\mathbf{x}} = -\sigma_a L_{\mathbf{x}} + \sigma_a \boxed{L_e} - \sigma_s L_{\mathbf{x}} + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i,$$

Emitted light

The model: RTE

$$(\nabla)L_{\mathbf{x}} = -\sigma_a L_{\mathbf{x}} + \sigma_a L_e - \sigma_s L_{\mathbf{x}} + \sigma_s \int L_{\mathbf{x}} \boxed{\Phi} d\omega_i,$$

Scattering function

The model: RTE

$$(\nabla)L_{\mathbf{x}} = -\sigma_a L_{\mathbf{x}} + \sigma_a L_e - \sigma_s L_{\mathbf{x}} + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i,$$

Analytical solution

$$L_{\mathbf{x}} = e^{-\sigma_t \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\Delta\mathbf{x}} + \left(1 - e^{-\sigma_t \|\Delta \mathbf{x}\|}\right) \frac{\sigma_a L_e + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i}{\sigma_t},$$

$$\sigma_t = \sigma_a + \sigma_s.$$

The model: RTE

$$(\nabla)L_{\mathbf{x}} = -\sigma_a L_{\mathbf{x}} + \sigma_a L_e - \sigma_s L_{\mathbf{x}} + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i,$$

Analytical solution

$$L_{\mathbf{x}} = e^{-\sigma_t \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\boxed{\Delta \mathbf{x}}} + \left(1 - e^{-\sigma_t \|\Delta \mathbf{x}\|}\right) \frac{\sigma_a L_e + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i}{\sigma_t},$$

Segment increment

The model: Important quantities

- Scattering function $\Rightarrow \Phi$
- Fuel type $\Rightarrow \sigma_a$, σ_s
  - Burning soot emissions (Propane, Methane, ...)
  - Exotic chemicals (Copper, Lithium, ...)
- Black Body radiation $\Rightarrow L_e$
- Refraction $\Rightarrow \Delta\mathbf{x}$
- Visual Adaptation $\Rightarrow L_{\mathbf{x}}$

Outline

Prior simplifications

$$L_{\mathbf{x}} = e^{-\sigma_t \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\Delta \mathbf{x}} + \left(1 - e^{-\sigma_t \|\Delta \mathbf{x}\|}\right) \frac{\sigma_a L_e + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i}{\sigma_t}$$

Prior simplifications

$$L_{\mathbf{x}} = e^{-\sigma_t \|\Delta\mathbf{x}\|} L_{\mathbf{x}+\Delta\mathbf{x}} + \left(1 - e^{-\sigma_t \|\Delta\mathbf{x}\|}\right) \frac{\sigma_a L_e + \sigma_s \int L_{\mathbf{x}} \Phi d\omega_i}{\sigma_t},$$

$$\sigma_a = 0.$$

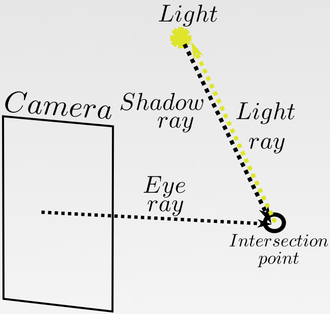
Prior simplifications

$$L_{\mathbf{x}} = e^{-\sigma_t \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\Delta \mathbf{x}} + \left(1 - e^{-\sigma_t \|\Delta \mathbf{x}\|}\right) \frac{\cancel{\sigma_a} L_e + \cancel{\sigma_s \int L_{\mathbf{x}} \Phi d\omega_i}}{\cancel{\sigma_t}}$$

Prior simplifications

$$L_{\mathbf{x}} = e^{-\sigma_a \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\Delta \mathbf{x}} + \left(1 - e^{-\sigma_a \|\Delta \mathbf{x}\|}\right) L_e$$

- MentalRay shader in Maya
  - Ray marching divides the RTE into
    - Light Ray $\rightarrow L_e$
    - Shadow Ray $\rightarrow e^{-\sigma_a \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\Delta\mathbf{x}}$
    - Eye Ray $\rightarrow L_{\mathbf{x}} = e^{-\sigma_a \|\Delta \mathbf{x}\|} L_{\mathbf{x}+\Delta\mathbf{x}} + L_e$
  - Light shader
  - Volume/Shadow shader
  - Utility scripts



Rays diagram for a sample intersection point.

Other details

- OpenVDB → sparse voxel data
- Uintah → fire simulation data
- Nist → atomic spectra
- von Kries transformation → visual adaptation

Outline

Results

Conclusions and Future Work

- Limitations
  - Difficult parametrization
  - Relies on tabulated data
  - Computationally intensive
  - Spherical particles
- Future work
  - Importance sampling

Thank you

Questions?

References

[JAM*10] Jackob W. et al. A radiative transfer framework for rendering materials with anisotropic structure. ACM 2010
[SBD*13] Sadeghi, I. et al. A practical microcylinder appearance model for cloth rendering. ACM 2013
[PH10] Pharr, M. et al. Physically based rendering: From theory to implementation, Morgan Kaufmann, 2010
[MI] Mizutani K. et al. Importance Sampling for Cloth Rendering under Environment Light, Mathematical Progress in Expressive Image Synthesis I, 2014
[WXK] Wang J. et al. Importance Sampling for a Microcylinder Based Cloth Bsdf, SIGGRAPH Talks, 2014