Directional Dipole Model for Subsurface Scattering

Toshiya Hachisuka

Collaboration with Jeppe Frisvad and Thomas Kjeldsen

The slides are based on the tech. report published in August 2013
For the latest results, please refer to the corresponding paper at TOG
Bidirectional Reflectance Distribution Function
BRDF model
diffuse milk
Bidirectional Surface Scattering
Reflectance Distribution Function
Bidirectional Surface Scattering Reflectance Distribution Function
BSSRDF model
skim milk
BRDF model
diffuse milk
Reference Solution
Existing BSSRDF Model
Our BSSRDF Model
Previous Models
Previous Models

- Dipole [Jensen et al. 2001]
- Multipole [Donner & Jensen 2005]
- Quantized diffusion [d’Eon & Irving 2011]
- Precomputed BSSRDF [Donner et al. 2009] [Yan et al. 2012]
- Photon diffusion [Donner & Jensen 2007] [Habel et al. 2013]
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Dipole
Dipole
Dipole

Approximate solution [Reynolds et al. 1976]
Dipole
Dipole

Virtual

Real
Dipole

Diffuse BRDF

Dipole BSSRDF

[Jensen et al. 2001]
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Multipole
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Quantized Diffusion
Quantized Diffusion
Quantized Diffusion
Quantized Diffusion

Dipole

Quantized Diffusion

[d’Eon & Irving 2011]
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Precomputed BSSRDF
Precomputed BSSRDF
Precomputed BSSRDF
Precomputed BSSRDF
Precomputed BSSRDF

Reference (30 hours)  Dipole (10 min)  Precomputed (30 min)

[Donner et al. 2009]
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Photon Diffusion
Photon Diffusion
Photon Diffusion

[Donner & Jensen 2007]
Photon Beam Diffusion

[Habel et al. 2013]
Photon Diffusion

Dipole

Photon Diffusion

[Donner & Jensen 2007]
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- Ignores incoming light direction
- Requires no precomputation
- Provides fully analytical function
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- Considers incoming light direction
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• Considers incoming light direction
• Requires no precomputation
• Relies on numerical integration
Contributions

- First BSSRDF which...
  - Considers incoming light direction
  - Requires no precomputation
  - Provides fully analytical function
Directional solution
[Menon et al. 2005]
Mirror direction & Offset location
Directional Dipole

Virtual

Real
Two Challenges

- Mirroring sources is unstable
- Singularity at the real source
Two Challenges

- Mirroring sources is unstable
- Singularity at the real source
Unstable Mirroring

Mirroring plane
Modified Mirroring Plane
Modified Mirroring Plane

Modified mirroring plane
Two Challenges

- Mirroring sources is unstable
- Singularity at the real source
Singularity
Singularity
Singularity
Singularity

$O(r^{-3})$
Distance Correction

• Inspired by the correction technique in computational physics [Elliot 86]

\[ r' = \sqrt{r^2 + z^2_0} \]

corrected distance \quad distance \quad correction factor
Results
Simple Test Cases

- Various measured materials
- Comparisons with Monte Carlo simulation
- Highly directional lighting
Simple Test Cases

RMSE

- **standard dipole**
- **better dipole**
- **quantized**
- **our model**

**X-axis:**
- apple
- choc milk
- marble
- potato
- skin1
- soy milk
- grapefruit
- whole milk

**Y-axis:**
- RMSE
- 0.3
- 0.2
- 0.1
- 0.0
- 0.0
Directional Effect

- Incident angle: 30°
Directional Effect

- Incident angle: 45°
Directional Effect

- Incident angle: 60°
Grapefruits Bunny

Dipole

Ours

Quantized

Reference
Image Based Lighting

Quantized  Ours
Image Based Lighting

Quantized  Ours
Image Based Lighting

Quantized  Ours
Failure Case

- Low albedo materials (e.g., Cranberry juice)
Conclusions

• First BSSRDF which...
  • Considers incoming light direction
  • Requires no precomputation
  • Provides fully analytical solution

• Far more accurate than previous models
Thank You

- **First** BSSRDF which...
  - Considers incoming light direction
  - Requires no precomputation
  - Provides fully analytical solution

[http://cs.au.dk/~toshiya/dirpole_tr.pdf](http://cs.au.dk/~toshiya/dirpole_tr.pdf)