Preserving Realism in real-time Rendering of Bidirectional Texture Functions

Jan Meseth, Gero Müller, Reinhard Klein

Bonn University
Computer Graphics Group

Motivation

- High-quality rendering in real-time
Motivation

Current real-time applications:
- triangular models
- simple materials
  - Textures
  - Bump Mapping
  - Displacement Mapping

Our approach
- more accurate material representation
- Real-time rendering
Problem Description

Real-world materials:
- complex reflectance behavior (pointwise BRDF)
- mesostructure with highly complicated self-occlusion, interreflection and self-shadowing
- changing perceived normal

Previous Work

BTF representation by Dana

$$BTF(x, \tilde{l}, \tilde{v}) = BTF(x, y, \theta_l, \phi_l, \theta_v, \phi_v)$$
Previous Work

Efficient Rendering of Spatial Bi-directional Reflectance Distribution Functions
McAllister, Lastra, Heidrich, Graphics Hardware 2002

\[
BTF(x, \vec{l}, \vec{v}) \approx \rho_{d,x} + \sum_i \rho_{s,x,i} \cdot L_{x,i}(\vec{l}, \vec{v})
\]

\[
L_i(\vec{l}, \vec{v}) = \begin{pmatrix}
    (v'_x, v'_y, v'_z) & \begin{pmatrix}
        c_{x_i} & 0 & 0 \\
        0 & c_{y_i} & 0 \\
        0 & 0 & c_{z_i}
    \end{pmatrix} & \begin{pmatrix}
        l'_x \\
        l'_y \\
        l'_z
    \end{pmatrix}
\end{pmatrix}^N
\]

Efficient Rendering of Spatial Bi-directional Reflectance Distribution Functions
McAllister, Lastra, Heidrich, Graphics Hardware 2002

- Rendering in real-time
- Good results for simple materials
- View-dependent effects require many lobes
- Insufficient for materials with high depth variation
Previous Work

Efficient Cloth Modeling and Rendering
Daubert, Lensch, Heidrich, Seidel, Rendering Workshop 2001

\[ BTF(\bar{x}, \bar{l}, \bar{v}) \approx T(\bar{x}, \bar{v}) \cdot l_z' \cdot \left( \rho + \sum_i L_{l,\bar{x}}(\bar{l}, \bar{v}) \right) \]

- view-dependent shadowing and masking term
- area foreshortening

view-dependent occlusion factor
- evaluated per color channel
- change of perceived normal restricted
- based on synthesized materials
Previous Work

- Towards Interactive Bump Mapping with Anisotropic Shift-Variant BRDFs
  Kautz, Seidel, Graphics Hardware 2000
- Fast, Arbitrary BRDF Shading for Low-Frequency Lighting Using Spherical Harmonics
  Kautz, Sloan, Snyder, Rendering Workshop 2002

Our Approach

- truly view-dependent
  - perceived normal
  - reflectance properties
- minimize approximation error
- suitable for real-time rendering
Data Analysis

Fitting Lafortune lobes to the entire BTF data for one Texel

Fitting a Reflectance Field to the BTF data for one pixel

Energy plot for one Texel of the Corduroy Data Set

Reflectance Field

- describes intensity of surface point for varying light and fixed view direction
- good approximation by lobe-like model

\[
RF_v(\vec{x}, \vec{l}) \approx \sum_i \left[ \begin{array}{c} a_{v,i}(\vec{x}) \\ b_{v,i}(\vec{x}) \\ c_{v,i}(\vec{x}) \end{array} \right] \cdot \vec{l}^i N_{v,i}(\vec{x})
\]
BTF Rendering

Preprocessing:
1. fit Reflectance Fields $RF_{vi}$ for various view directions $v_i$

Runtime:
1. determine current view direction $v$
2. select closest view directions from $\{v\}$
3. compute color according to $RF_{vi}$
4. interpolate between individual results

Storage requirements:
- stack of floating point textures
- about 400 MB per material

⇒ employ BTF synthesis algorithm
⇒ store indices instead of color values
⇒ reduces storage to about 25 MB per material
Textures and Bump-Mapping

Reflectance Field
BTF Rendering

Results

University of Bonn • Computer Graphics Group
Jan Meseth, Gero Müller, Reinhard Klein
Conclusions and Future Work

- in-depth analysis of measured BTF data
- new approach to BTF rendering
  - high-quality
  - real-time
- moderate storage requirements for high-frequency detail materials
- combine with Image Based Lighting

Acknowledgements

Funded by European Union under the project RealReflect (IST-2001-34744)

www.realreflect.org