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Homomorphic Factorization of BRDFs for High-Performance Rendering

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Outline

- Introduction
- Previous Work
- Factorization
- Results
- Conclusions

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Introduction

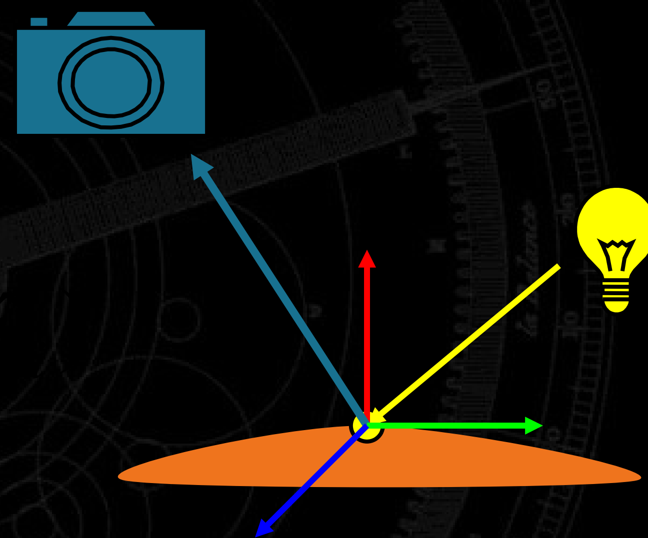
- What is a bidirectional reflectance distribution function (BRDF)?
- Why use BRDFs?

Introduction

- BRDF properties:
  - Helmholtz reciprocity
  - Conservation of energy
- BRDF classes:
  - Isotropic
  - Anisotropic

BRDF

- Functional notation:
- Assume shift-invariant:
- Omit wavelength dependence:



Local Lighting Equation

- Outgoing radiance from point in direction :

- Illumination from N point sources:

Previous Work

- Basis summation
  - Ward, Lafortune, Foo, Torrance, Greenberg
- Environment mapping
  - Kautz, McCool, Vazquez, Heidrich, Seidel
- Factorization
  - Kautz, McCool, Vazquez, Heidrich, Fournier

Previous Work

- Factorization
  - eg. SVD approach (Kautz and McCool)

Factorization

- Approximate *f* using product of positive factors:

- Take logarithm of both sides:

Factorization

- Notice this is just a linear data-fitting problem:

$$f(\hat{\omega}_o, \hat{\omega}_i) \approx$$

Parameterization

- Choose parameterization:
  - Easy to compute parameters
  - Three factors stored in two texture maps
- Take logarithm:

Data Constraints

- Need to find p and q:
  - Set up linear constraints relating samples in f to texels in p and q
  - Use bilinear weighting factors

Smoothness Constraints

- Previous equation can be rewritten as:

[illegible]

Smoothness Constraints

- Add constraints to equate Laplacian with zero:

  - Ensures every texel has a constraint

∀λ controls the smoothness of solution

Iterative Solution

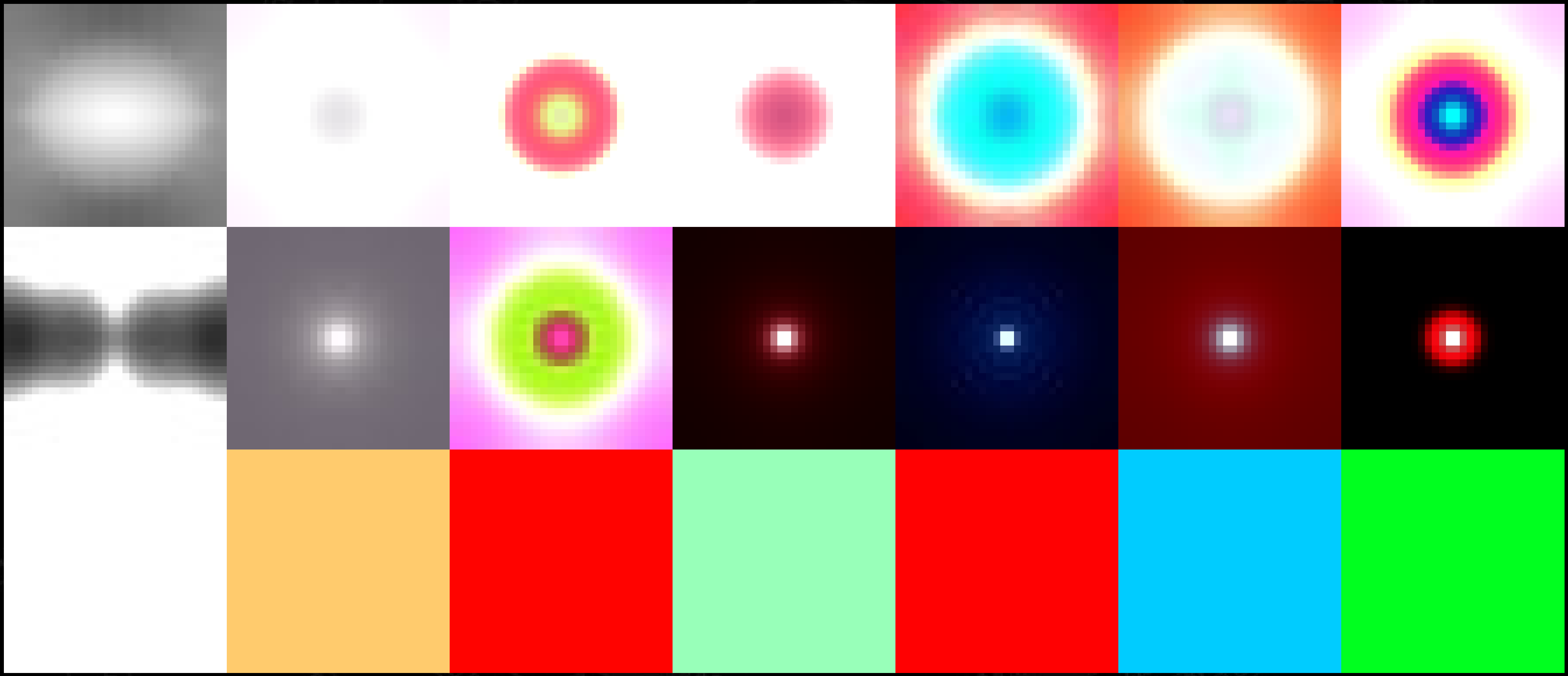
- Solve using quasi-minimal residual (QMR) algorithm in IML++
  - Freund and Nachtigal (1991)
  - Estimate an initial solution by averaging
  - Apply at multiple resolutions
- Divide p and q by their maximums and combine scale factors into a single colour α

Rendering

- Reconstruction equation:

  - N passes on the NVIDIA GeForce 3 using
    - OpenGL 1.2
    - Multitexturing extensions
    - Register combiner extensions
    - Vertex program extensions
    - Compositing

Results



- Top to bottom: p', q' texture maps (32 x 32) and α.
- Left to right: satin (Poulin-Fournier analytic), leather, velvet (CUReT), garnet red, krylon blue, cayman, mystique (Cornell).

Results

- Venus de Milo model with 90752 triangles
- Pentium 4 1.4 GHz, 640 MB, NVIDIA GeForce 3 AGP 4x @ 1280x1024x32bit
- Standard OpenGL Lambertian lighting:
  - 123 fps, 11.2 Mtri/s
- Full illumination:
  - 76 fps, 6.9 Mtri/s

Approximation Error

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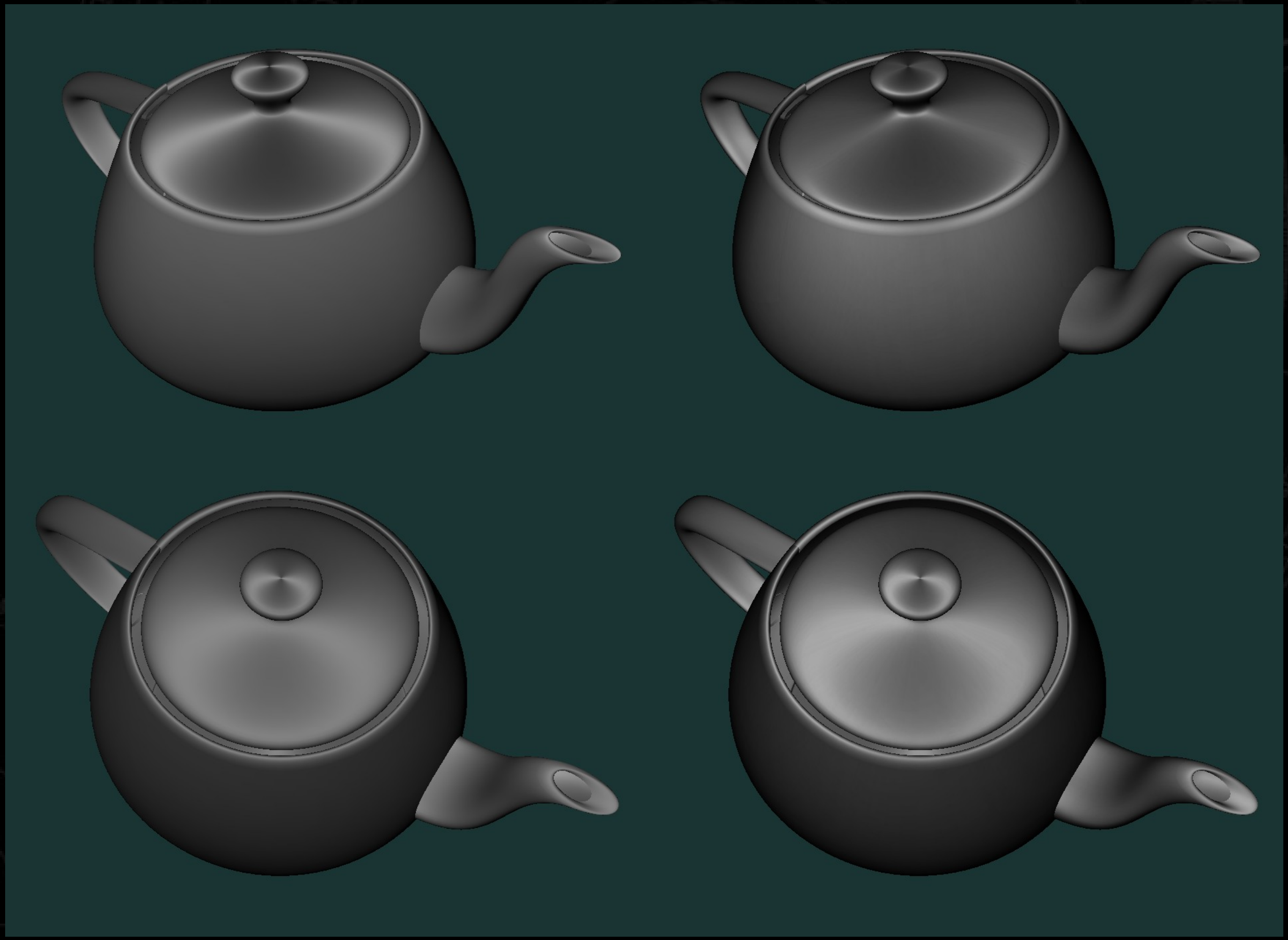
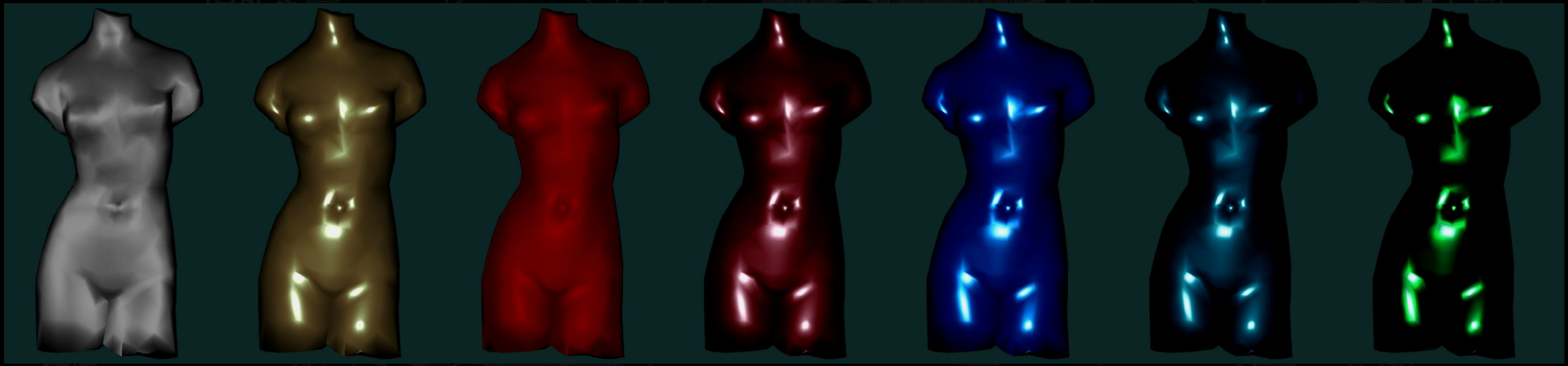


Live Demo



Conclusions

- New BRDF factorization algorithm
  - Achieves reasonable compression ratios
  - Minimizes relative error in approximation
  - Flexible choice of parameterization
  - Results are positive factors
  - Can handle sparse data, reuse texture maps
  - Renders in real-time rates in current hardware

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