Solid Texture Synthesis from 2D Exemplars

Johannes Kopf, University of Konstanz
Chi-Wing Fu, Hong Kong Sc & Tech
Daniel Cohen-Or, Tel Aviv University
Oliver Deussen, University of Konstanz
Dani Lischinski, The Hebrew University
Tien-Tsin Wong, The Chinese University

Solid Textures

Solid Textures

Modeling Natural Materials

No Complex Parameterization

Textured interior
Related Work

3D to 3D synthesis
- Simple extension of 2D→2D algorithms
- 3rd dimension mostly time
- Many, many papers
  - [Szummer and Picard 1996]
  - [Schedl et al. 2000]
  - [Wei and Lewy 2000]
  - [Bar-Joseph et al. 2001]
  - [Soatto et al. 2001]
  - [Kwatra et al. 2003]

Parametric approach
[Heeger and Bergen 1995]

Non-parametric approach
[Wei 2002; 2003]

Stereology
[Jagnow et al. 2004]
Our Technique

Hybrid Approach

- Non-parametric: texture optimization
  - [Kwatra et al. 2005, Wexler et al. 2007]
  - Enforces local neighborhoods
- Parametric: histogram matching
  - [Heeger and Bergen 1995]
  - Enforces global statistics

Solid Texture Optimization

- Two phases:
  - Optimization
  - Search

Optimization Phase

\[ E = \sum_{i} \sum_{j} \left\| s_{ij} - e_{ij} \right\|^p \]

- Iteratively re-weighted least squares (IRLS)
  - [Kwatra et al. 2005]
Optimization Phase

\[ E = \sum_{i} \sum_{k \in \{x,y,z\}} a_{x,i} \| e_{x,i} - e_{y,i} \|^2 \]

Search

- Nearest neighbor in high-dimensional space (standard problem)
- Speed-ups
  - PCA projection (6X-20X)
  - ANN (approximate nearest neighbor) (10X-100X)
  - Sparsity (4X)

Histogram Matching

- Exemplar
- Synthesis
- Average

Histogram Matching

- Exemplar
- Synthesis
- Without Histogram Matching
- With Histogram Matching
Histogram Matching

Results

Implementation Details

- Three level multi-resolution
- Fixed 8x8 neighborhood size
- Synthesis time:
  - $128^3$ volume: 10 – 90 minutes
  - Has to be done only once and for all
  - Preview after 10-20 seconds

Results
Multi-Channel Textures

RGB Specular Shininess Displacement

Finished Wood

[Marschner et al. 2005]

Diffuse Fiber reflectance Fiber axis

Synthesis Control

• Different exemplar for each view

Synthesis Control

• Constrain Colors
Synthesis Control

Limitations

Conclusions

Try it out at home!

- New method for solid texture synthesis
- Optimization + Histogram matching
- Widely applicable
  - Anisotropic textures
  - Large coherent structures
  - Multi-channel textures

- Available Online:
  - Volume files
  - Plugin for Maya
- Coming soon
  - Synth application

http://www.johanneskopf.de/solid
Video

Solid Texture Synthesis from 2D Exemplars
papers_0143

Thank You

Future Research

• Improve quality & speed
• Additional kinds of histograms
  – Heeger & Bergen’s steerable pyramids
• Wang cubes
• More control

Unused Slides

Related Work

• Shell Textures [Chen et al. 2004]

Aura 3D Textures

• Basic Gray Level Aura Matrices (BGLAM)
  [Qin and Yang 2007]
Our Result

Independent Synth

Optimization Phase
• Mean Shift

Comparison with [Wei 2002, 2003]

Comparison with Aura 3D Textures

Comparison with [Jagnow 2004]

Histogram Matching

\[ H_{b,j} = \frac{1}{1+\sum_{i=1}^{n} w_i} \left( \sum_{i=1}^{n} w_i \cdot \left( b_j(c) - \bar{b}_j(c) \right) \right) \]

• \( H_{b,j} \) – j-th histogram of the synth'ed solid
• \( H_{e,j} \) – j-th histogram of the exemplar
• \( b_j(c) \) – bin containing c
Limitations