Solid Texture Synthesis from 2D Exemplars

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Solid Textures

Input: 2D

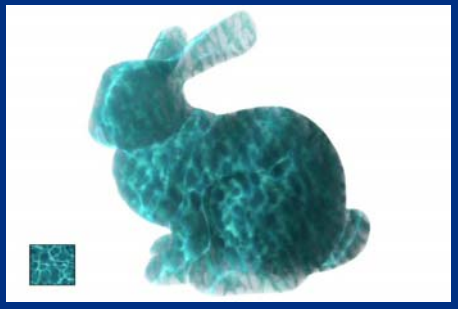
Input: 3D

Solid Textures

Modeling Natural Materials

No Complex Parameterization

Textured interior



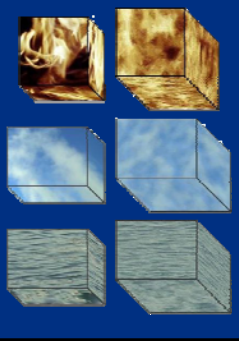
Related Work

Procedural Textures

3D to 3D synthesis

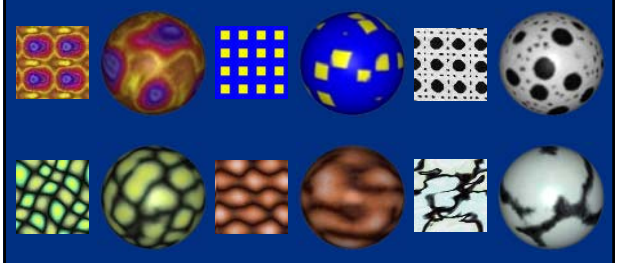
- Simple extension of 2D→2D algorithms
- 3rd dimension mostly time
- Many, many papers

[Szummer and Picard 1996]
[Schödl et al. 2000]
[Wei and Levoy 2000]
[Bar-Joseph et al. 2001]
[Soatto et al. 2001]
[Kwatra et al. 2003]
...

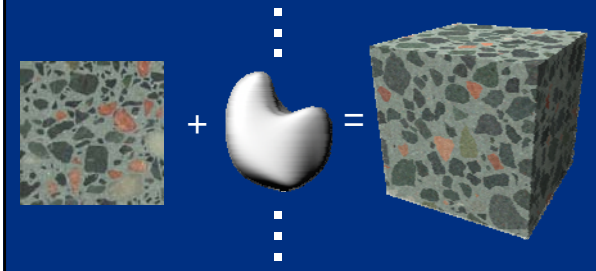


Parametric approach [Heeger and Bergen 1995]

Non-parametric approach [Wei 2002; 2003]



Stereology [Jagnow et al. 2004]

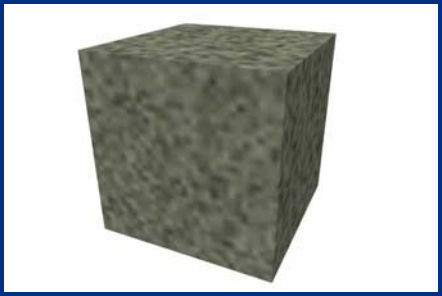


Our Technique

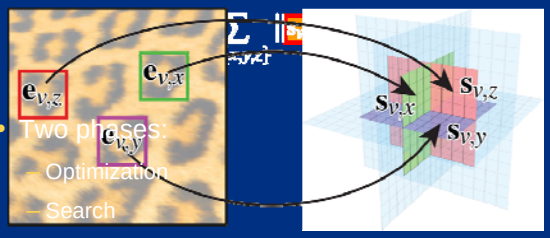
Hybrid Approach

- 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

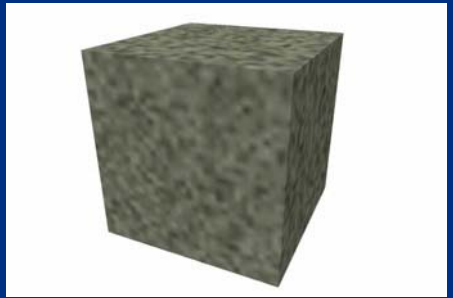


Solid Texture Optimization



- Two phases:
  - Optimization
  - Search

Solid Texture Optimization



Optimization Phase

$$E = \sum_{v} \sum_{i \in \{x,y,z\}} \left\| \mathbf{s}_{v,i} - \mathbf{e}_{v,i} \right\|^{r}$$

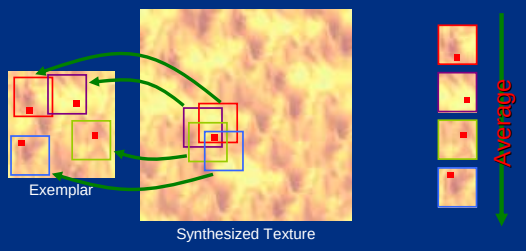
- Iteratively re-weighted least squares (IRLS)
  - [Kwatra et al. 2005]

$$\left\| \mathbf{s}_{v,i} - \mathbf{e}_{v,i} \right\|^{r}$$

Optimization Phase

$$E = \sum_{v} \sum_{i \in \{x,y,z\}} \omega_{v,i} \left\| s_{v,i} - e_{v,i} \right\|^2$$

Optimization Phase

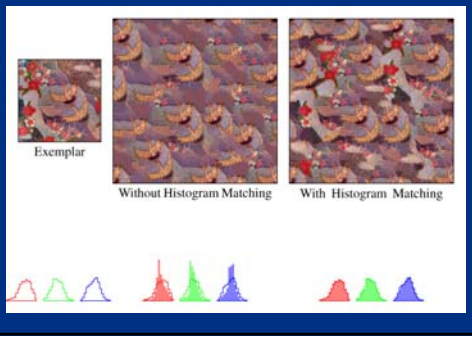


Search

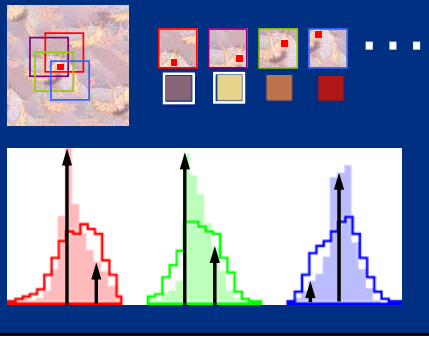
- Nearest neighbor in high-dimensional space (standard problem)
- Speed-ups
  - PCA projection (6X-20X)
  - ANN (approximate nearest neighbor) (10X-100X)
  - Sparsity (4X)

Histogram Matching

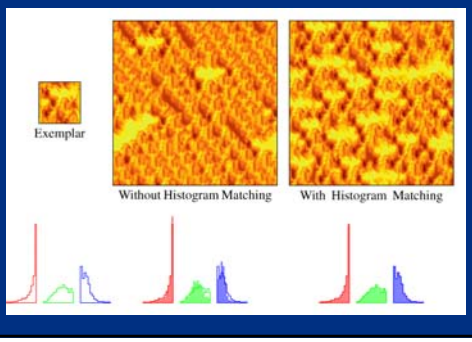
Histogram Matching



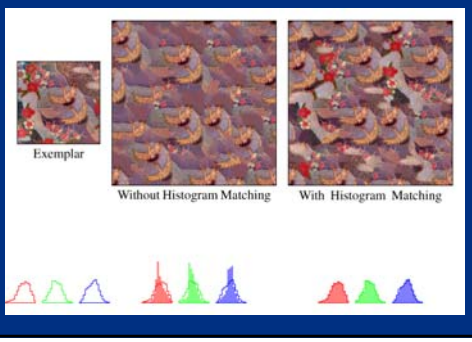
Histogram Matching



Histogram Matching



Histogram Matching



Results

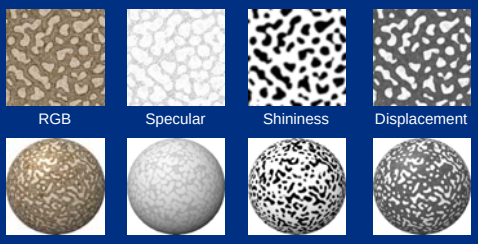
Implementation Details

- 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

Results

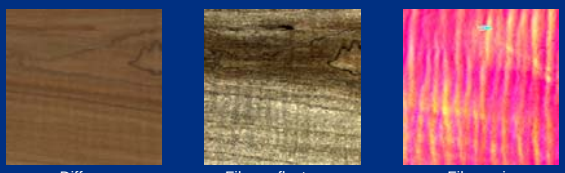
Multi-Channel Textures



Multi-Channel Textures

Finished Wood

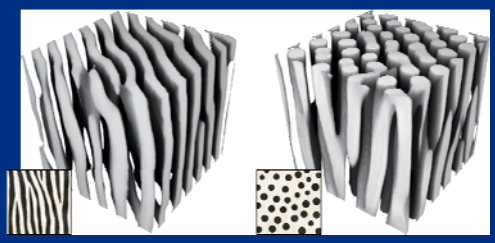
[Marschner et al. 2005]



Finished Wood

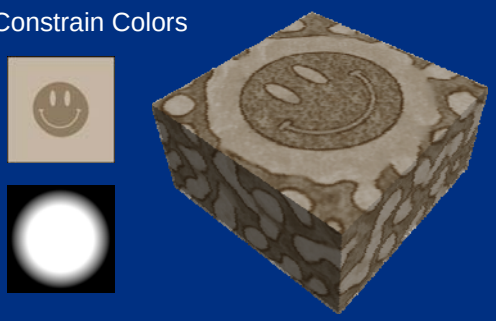
Synthesis Control

- Different exemplar for each view

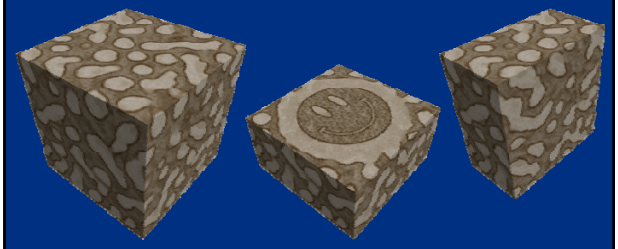


Synthesis Control

- Constrain Colors



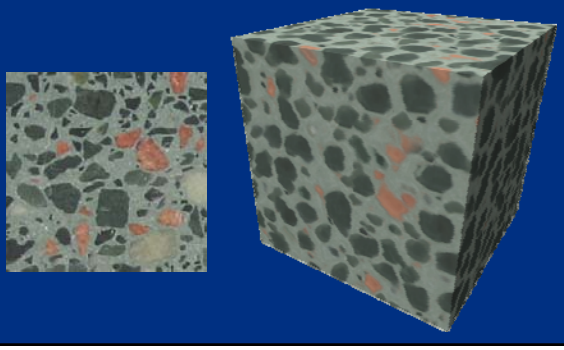
Synthesis Control



Synthesis Control

Limitations

Limitations



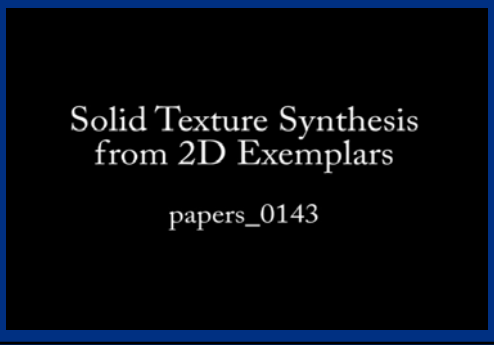
Conclusions

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

Try it out at home!

- http://www.johanneskopf.de/solid
- Available Online:
  - Volume files
  - Plugin for Maya
- Coming soon
  - Synth application

Video



Thank You

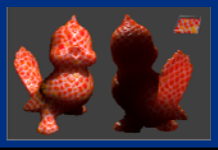
Unused Slides

Future Research

- Improve quality & speed
- Additional kinds of histograms
  - Heeger & Bergen's steerable pyramids
- Wang cubes
- More control

Related Work

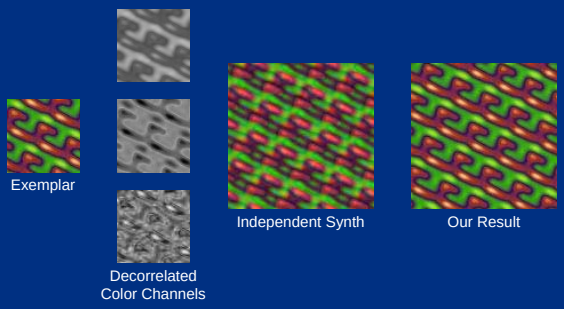
- Shell Textures [Chen et al. 2004]



Aura 3D Textures

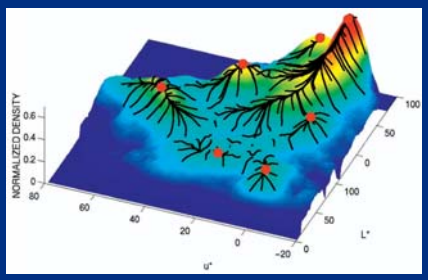
- Basic Gray Level Aura Matrices (BGLAM) [Qin and Yang 2007]

decorrrcrvtfvytvy



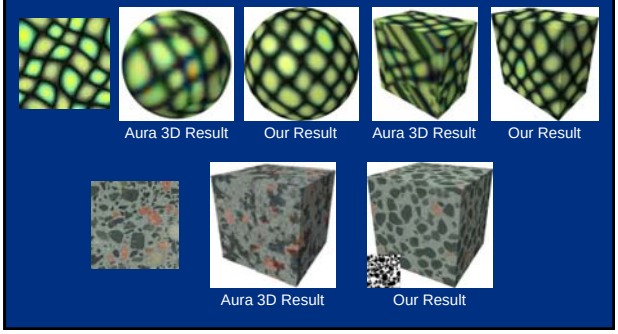
Optimization Phase

- Mean Shift



Comparison with [Wei 2002, 2003]

Comparison with Aura 3D Textures



Comparison with [Jagnow 2004]

Histogram Matching

$$a'_{s,i,p} = \frac{a_{s,i,p}}{1 + \sum_{j=1}^{L} \max\left[0, H_{s,j}(b_j(e_{s,i,p})) - H_{e,j}(b_j(e_{s,i,p}))\right]}$$

- $H_{s,j}$ – j-th histogram of the synth'ed solid
- $H_{e,j}$ – j-th histogram of the exemplar
- $b_j(c)$ – bin containing c

Limitations