Texture Synthesis

Eurythmy, Amkraut & Girard, 1989

Texture Synthesis
Carlton Draught: Big Ad, 2006

Uses Weta Digital's MASSIVE - first significant use in Lord of the Rings movies

Finding Nemo, Fish School, 2009
Last Time?

- Non-Photorealistic Rendering
  - Line Drawing
  - Pen & Ink / Hatching
  - Technical Illustration
  - Painterly Rendering
- Architectural Rendering

Today

- Papers for Today
- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis
- Papers for Friday
Painterly Rendering

Painterly rendering with curved brush strokes of multiple sizes
Hertzmann SIGGRAPH 1998

Example-Based Brushes for Coherent Stylized Renderings
Zheng, Milliez, Gross, and Sumner, NPAR 2017

Figure 1: These 3D paintings are rendered in screen space using our method with calligraphy and watercolor styles. The paint stroke rendering is temporally coherent as the characters and camera are animated.
Figure 3: *Making a drawing*. With the drawing page folded in half, the artist makes a free-hand drawing while referring to the prompt page (left). The completed drawing page (right) contains a free-hand drawing and a registered drawing.
Types of Edges in Line Drawings

- Silhouettes/Contours: where normal is perpendicular to the view direction
- Suggestive Contour: inflection points of the surface normal
- Ridges & Valleys: extremum of curvature
- Apparent Ridges: based on view dependent curvature

Suggestive Contours for Conveying Shape, DeCarlo et al., SIGGRAPH 2003

Today

- Papers for Today
- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis
- Papers for Friday
Texture Tiling

- Specify a texture coordinate \((u,v)\) at each vertex
- Canonical texture coordinates \((0,0) \rightarrow (1,1)\)

```
<table>
<thead>
<tr>
<th>(0,0)</th>
<th>(1,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,0)</td>
<td>(3,0)</td>
</tr>
</tbody>
</table>
```

tiles with visible seams

```
<table>
<thead>
<tr>
<th>(0,0)</th>
<th>(1,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0,0)</td>
<td>(3,0)</td>
</tr>
</tbody>
</table>
```

seamless tiling (repeating)

Texture Synthesis Challenge

input    tiled    synthesis
“Pyramid-Based Texture Analysis/Synthesis”, Heeger & Bergen, SIGGRAPH 1995

• Motivated by human texture perception
• Focused on stochastic textures
  (as opposed to deterministic/periodic textures)

“Pyramid-Based Texture Analysis/Synthesis”, Heeger & Bergen, SIGGRAPH 1995

• Focuses on matching the input histogram at different resolutions (frequencies)
• Failure example: *but is this really a “texture”?*
Today

- Papers for Today
- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis
- Papers for Friday

Markov Random Field

- English words and sentences can be modeled as a Markov Random Field:

  “I spent an interesting evening recently with a grain of salt.”
Template

Alternate Synthesis Order

“Texture Synthesis by Non-parametric Sampling”, Efros & Leung, ICCV 1999
Figure 2. Results: given a sample image (left), the algorithm synthesized four new images with neighborhood windows of width 5, 11, 15, and 23 pixels respectively. Notice how perceptually intuitively the window size corresponds to the degree of randomness in the resulting textures. Input images are: (a) synthetic rings, (b) Brodatz texture D11, (c) brick wall.

Failure Examples

from Efros & Leung  from Wei & Levoy
Questions?

Today

- Papers for Today
- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis
- Papers for Friday
**Constrained Texture Synthesis**

Examples from Efros & Leung
http://graphics.cs.cmu.edu/people/efros/research/EfrosLeung.html

---

**Image Inpainting**

"Image Inpainting", Bertalmío, Sapiro, Caselles & Ballester,
SIGGRAPH 2000
"Fragment-based image completion", Drori, Cohen-Or, Yeshurun, SIGGRAPH 2003

- Coarse to fine completion
- Confidence & traversal order
- Search for best match over different scales, rotations, & resolutions (texture frequency)
- Compositing fragments

"Image Analogies", Hertzmann et al., SIGGRAPH 2001
“Image Quilting for Texture Synthesis and Transfer”, Efros & Freeman, SIGGRAPH 2001

(a) random placement of blocks

(b) neighboring blocks constrained by overlap

(c) minimum error boundary cut
Today

• Papers for Today
• Texture Tiling
• Texture Synthesis Challenge
• Markov Model
• Constrained Texture Synthesis
• Image Completion
• Wang Tiles for Texture Synthesis
• Volumetric Texture Synthesis
• Papers for Friday
Wang Tiles

Align tiles to match edge color to create non-periodic tilings


Wang Tile Texture Synthesis

- As a precomputation, fill the tiles with texture
- Then create infinite amounts of non-periodic texture!

Today

- Papers for Today
- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis
- Papers for Friday

Recovering Sphere Distributions

\[ N_A = \text{Profile density} \]
\[ (\text{number of circles per unit area}) \]

\[ N_V = \text{Particle density} \]
\[ (\text{number of spheres per unit volume}) \]

\[ \bar{H} = \text{Mean caliper particle diameter} \]

The fundamental relationship of stereology:

\[ N_A = \bar{H} N_V \]

Slide from Rob Jagnow
Recovering Sphere Distributions

\[ \begin{bmatrix} N_A \\ K \end{bmatrix} = \begin{bmatrix} \vdots \\ \vdots \end{bmatrix} \]

Profile Statistics

Segment input image to obtain profile densities \( N_A \).

Bin profiles according to their area, \( \sqrt{A/A_{\text{max}}} \)

Slide from Rob Jagnow
Recovering Color

Select mean particle colors from segmented regions in the input image

Input  Mean Colors  Synthetic Volume

Recovering Noise

How can we replicate the noisy appearance of the input?

Input  -  Mean Colors  =  Residual

The noise residual is less structured and responds well to Heeger & Bergen’s method

Synthesized Residual
Putting It All Together

Input

Synthetic volume without noise

Synthetic volume with noise

Slide from Rob Jagnow

Results

Input

Result

Slide from Rob Jagnow
Today

• Papers for Today
• Texture Tiling
• Texture Synthesis Challenge
• Markov Model
• Constrained Texture Synthesis
• Image Completion
• Wang Tiles for Texture Synthesis
• Volumetric Texture Synthesis
• Papers for Friday

“Flocks, Herds, and Schools: A Distributed Behavioral Model”, Craig W. Reynolds, SIGGRAPH 1987
“On Demand Solid Texture Synthesis Using Deep 3D Networks”,
Gutierrez, Rabin, Galerne, and Hurtut, 2019

Figure 8: Illustration of a solid texture whose cross sections cannot comply with the example along three directions. Given a 2D