Texture Synthesis



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15-463: Computational Photography Alexei Efros, CMU, Fall 2006

Texture

- Texture depicts spatially repeating patterns
- Many natural phenomena are textures



radishes



rocks



yogurt

Texture Synthesis

- Goal of Texture Synthesis: create new samples of a given texture
- Many applications: virtual environments, holefilling, texturing surfaces







The Challenge

• Need to model the whole spectrum: from repeated to stochastic texture



Efros & Leung Algorithm



• Assuming Markov property, compute P(**p**|N(**p**))

- Building explicit probability tables infeasible
- Instead, we search the input image for all similar neighborhoods that's our pdf for p
- To sample from this pdf, just pick one match at random

Some Details

- Growing is in "onion skin" order
 - Within each "layer", pixels with most neighbors are synthesized first
 - If no close match can be found, the pixel is not synthesized until the end
- Using Gaussian-weighted SSD is very important
 - to make sure the new pixel agrees with its closest neighbors
 - Approximates reduction to a smaller neighborhood window if data is too sparse

Neighborhood Window



Varying Window Size











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Increasing window size

Synthesis Results

french canvas





rafia weave



More Results

white bread





brick wall



Homage to Shannon

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Hole Filling







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Extrapolation











Summary

- The Efros & Leung algorithm
 - Very simple
 - Surprisingly good results
 - Synthesis is easier than analysis!
 - ...but very slow

Image Quilting [Efros & Freeman]



Synthesizing a block

- <u>Observation</u>: neighbor pixels are highly correlated
 <u>Idea</u>: unit of synthesis = block
 - Exactly the same but now we want P(B|N(B))
 - Much faster: synthesize all pixels in a block at once
 - Not the same as multi-scale!

Input texture





block

B1 B2

Random placement of blocks Neighboring blocks constrained by overlap

Minimal error boundary cut







Minimal error boundary

overlapping blocks







vertical boundary





min. error boundary

overlap error

Our Philosophy

- The "Corrupt Professor's Algorithm":
 - Plagiarize as much of the source image as you can
 - Then try to cover up the evidence
- Rationale:
 - Texture blocks are by definition correct samples of texture so problem only connecting them together







Failures (Chernobyl Harvest)

Wei & Levoy

Our algorithm

input image

Portilla & Simoncelli

Xu, Guo & Shum

Wei & Levoy

Our algorithm

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input image

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Portilla & Simoncelli

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Wei & Levoy

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Xu, Guo & Shum

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Our algorithm

Political Texture Synthesis!

Bush campaign digitally altered TV ad

President Bush's campaign acknowledged Thursday that it had digitally altered a photo that appeared in a national cable television commercial. In the photo, a handful of soldiers were multiplied many times.

MS Digital Image Pro (DEMO)

• In what order should we fill the pixels?

Fill Order

In what order should we fill the pixels?

 choose pixels that have more neighbors filled

 Criminisi, Perez, choose pixels that are continuations of g," Proc. CVPR, 2003.

Exemplar-based Inpainting demo

http://research.microsoft.com/vision/cambridge/i3l/patchworks.htm

Application: Texture Transfer

• Try to explain one object with bits and pieces of another object:

Texture Transfer

Constraint

Texture sample

Texture Transfer

• Take the texture from one image and "paint" it onto another object

Same as texture synthesis, except an additional constraint:

- 1. Consistency of texture
- 2. Similarity to the image being "explained"

Image Analogies

Aaron Hertzmann^{1,2} Chuck Jacobs² Nuria Oliver² Brian Curless³ David Salesin^{2,3}

¹New York University ²Microsoft Research ³University of Washington

Image Analogies

A'

B

Β'

Blur Filter

Unfiltered source (A)

Filtered source (A')

Unfiltered target (B)

Filtered target (B')

Edge Filter

Unfiltered source (A)

Filtered source (A')

Unfiltered target (B)

Filtered target (B')

Artistic Filters

B

Β'

Colorization

Unfiltered source (A)

Unfiltered target (B)

Filtered source (A')

Filtered target (B')

Texture-by-numbers

Super-resolution

Super-resolution (result!)

B

Β'

Video Matching [Sand & Teller, 2004]