Texture Synthesis

Texture Synthesis

Modeling Texture

What is texture?

How can we model it?

Markov Chains

Markov Chain

- a sequence of random variables \( X_1, X_2, \ldots, X_n \)
- \( X_t \) is the state of the model at time \( t \)

\[
X_1 \rightarrow X_2 \rightarrow X_3 \rightarrow X_4 \rightarrow X_5
\]

- Markov assumption: each state is dependent only on the previous one
  - dependency given by a conditional probability:

\[
p(X_t|X_{t-1})
\]

- The above is actually a first-order Markov chain
- An \( N \)th-order Markov chain:

\[
p(X_t|X_{t-1}, \ldots, X_{t-N})
\]

Today's Reading

Markov Chain Example: Text

"A dog is a man’s best friend. It’s a dog eat dog world out there."

Text synthesis

Create plausible looking poetry, love letters, term papers, etc.

Most basic algorithm

1. Build probability histogram
   - find all blocks of N consecutive words/letters in training documents
   - compute probability of occurrence $p(x_i|x_{i-1}, \ldots, x_{i-(N-1)})$.

2. Given words $x_1, x_2, \ldots, x_k$:
   - compute $X_k$ by sampling from $p(x_i|x_{i-1}, \ldots, x_{i-(N-1)})$.

Example on board...

[Scientific American, June 1989, Dewdney]

“I Spent an Interesting Evening Recently with a Grain of Salt”
- Mark V. Shaney
  (computer-generated contributor to UseNet News group called net.singles)

Output of 2nd order word-level Markov Chain after training on 90,000 word philosophical essay:

“Perhaps only the allegory of simulation is unendurable—more cruel than Artaud’s Theatre of Cruelty, which was the first to practice deterrence, abstraction, disconnection, deterritorialisation, etc.; and if it were our own past. We are witnessing the end of the negative form. But nothing separates one pole from the very swing of voting “rights” to electoral...”

Modeling Texture

What is texture?

- An image obeying some statistical properties
- Similar structures repeated over and over again
- Often has some degree of randomness
Markov Random Field

A Markov random field (MRF)
- generalization of Markov chains to two or more dimensions.

First-order MRF:
- probability that pixel $X$ takes a certain value given the values of neighbors $A$, $B$, $C$, and $D$:
  $$ P(X|A, B, C, D) $$
- Higher order MRF’s have larger neighborhoods

Texture Synthesis [Efros & Leung, ICCV 99]
Can apply 2D version of text synthesis

Synthesizing One Pixel
- What is $f(x)$/neighborhood of pixels around $x$?
- Find all the windows in the image that match the neighborhood
  - consider only pixels in the neighborhood that are already filled in
- To synthesize $x$
  - pick one matching window at random
  - assign $x$ to be the center pixel of that window

Really Synthesizing One Pixel
- An exact neighbourhood match might not be present
- So we find the best matches using SSD error and randomly choose between them, preferring better matches with higher probability
Growing Texture

- Starting from the initial image, “grow” the texture one pixel at a time

Window Size Controls Regularity

More Synthesis Results

More Results

- reptile skin
- aluminum wire
Failure Cases

Growing garbage

Verbatim copying

Speed

- Given: image of \( k^2 \) pixels
- Output: image of \( n^2 \) pixels
- how many window comparisons does this algorithm require?

Image-Based Text Synthesis

Block-based texture synthesis

Observation: neighbor pixels are highly correlated

Idea: 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
Texture Transfer

Take the texture from one image and “paint” it onto another object

Same algorithm as before with additional term
- do texture synthesis on image1, create new image (size of image2)
- add term to match intensity of image2
Combining two images
Graph cut setup

Graph cut texture synthesis: Video

Image Analogies (Hertzmann '01)

Artistic Filters
Texture-by-numbers

Other applications of Image Analogies

• Texture synthesis
• Super-resolution
• Texture transfer
• Image colorization
• Simple filters (blur, emboss)
• More details: Hertzmann et al., SIGGRAPH 2001
  • [http://mrl.nyu.edu/projects/image-analogs/](http://mrl.nyu.edu/projects/image-analogs/)

Applications of Texture Modeling

Super-resolution

• [Freeman & Pasztor, 1999](#)
• [Baker & Kanade, 2000](#)

Image/video compression
Texture recognition, segmentation

• [DeBonet](#)

Restoration

• removing scratches, holes, filtering
• [Zhu et al.](#)

Art/entertainment