Texture
How would an edge detector respond?
Mid-level grouping
Shape estimation
Material recognition

http://animals.nationalgeographic.com/
Texture

How does one computationally model texture?
Includes: more regular patterns
Includes: more random patterns
Scale: objects vs. texture

Often the same thing in the world can occur as texture or an object, depending on the scale we are considering.
Psychophysics of texture

Some textures distinguishable with *preattentive* perception without scrutiny, eye movements [Julesz 1975]
Texture representation: example

original image

derivative filter responses, squared

visualization of the assignment to texture “types”
• What filters to put in the bank?
  – Typically we want a combination of scales and orientations, different types of patterns.
Example application of a filter bank

Filter bank of 8 filters

Input image

8 response images: magnitude of filtered outputs, per filter
Capture joint statistics of filter outputs

“Textons”

Texton Map

Figure 8. Top to bottom: the histograms of labels for the materials: "Rough Plastic", "Plaster-a", "Pebbles", and "Terrycloth" respectively. These histograms are used as the material representation for the task of texture recognition. The histograms are very different from each other, thus allowing good discrimination.

7. Texture Recognition

In this section, we will demonstrate algorithms and results on texture recognition.

7.1. 3D Texture Recognition from Multiple Viewpoint/Lighting Images

We first investigate 3D texture recognition when multiple images of each sample are given. Every time we get a sample of the material, 20 images of different lighting and viewing directions are provided. From these images, a texton labeling is computed. Then the sample is classified to be the material with the smallest
Material recognition using texture descriptors (histograms of textons)

- Terrycloth
- Rough Plastic
- Plaster-b
- Sponge
- Rug-a
- Painted Spheres

Columbia-Utrecht Database (http://www.cs.columbia.edu/CAVE)
Texture synthesis

• Goal: create new samples of a given texture
• Many applications: virtual environments, hole-filling, texturing surfaces
The Challenge

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

Markov Chains

Markov Chain

- a sequence of random variables $x_1, x_2, \ldots, x_n$

- $x_t$: the state of the model at time $t$

\[
\begin{array}{c}
x_1 \rightarrow x_2 \rightarrow x_3 \rightarrow x_4 \rightarrow x_5
\end{array}
\]
Markov Chain Example: Text

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

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<th>X_{t-1}</th>
<th>a</th>
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\[ p(X_t | X_{t-1}) \]
Text synthesis

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

Most basic algorithm

1. Build probability histogram \( p(x_t|x_{t-1}, \ldots, x_{t-(n-1)}) \)
   - find all blocks of \( N \) consecutive words/letters in training documents
   - compute probability of occurrence
2. Given words \( x_1, x_2, \ldots, x_{k-1} \)
   - compute \( x_k \) by sampling from \( p(x_t|x_{t-1}, \ldots, x_{t-(n-1)}) \)

WE NEED TO EAT CAKE

Source: S. Seitz
Text synthesis

• Results:
  – “As I've commented before, really relating to someone involves standing next to impossible.”
  – "One morning I shot an elephant in my arms and kissed him.”
  – "I spent an interesting evening recently with a grain of salt"

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 $D$:

$$P(X|A, B, C, D)$$

Source: S. Seitz
Texture Synthesis [Efros & Leung, ICCV 99]

Can apply 2D version of text synthesis
Before, we inserted the next word based on existing nearby words…

Now we want to insert **pixel intensities** based on existing nearby pixel values.

Sample of the texture ("corpus")

Distribution of a value of a pixel is conditioned on its neighbors alone.
Synthesizing One Pixel

- What is $P(x | \text{neighborhood of pixels around } x)$?
- 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

SAMPLE

Alyosha Efros, ICCV 1999
Neighborhood Window

input

Slide from Alyosha Efros, ICCV 1999
Varying Window Size

Increasing window size

Slide from Alyosha Efros, ICCV 1999
Growing Texture

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

french canvas

rafia weave

Slide from Alyosha Efros, ICCV 1999
Synthesis results

white bread

brick wall

Slide from Alyosha Efros, ICCV 1999
Synthesis results
Failure Cases

Growing garbage

Verbatim copying

Slide from Alyosha Efros, ICCV 1999
Hole Filling

Slide from Alyosha Efros, ICCV 1999
Extrapolation

Slide from Alyosha Efros, ICCV 1999