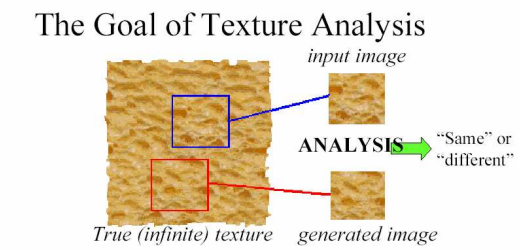
Texture
Reading: Chapter 9 (skip 9.4)

- **Key issue**: How do we represent texture?
- **Topics:**
  - Texture segmentation
  - Texture-based matching
  - Texture synthesis
    - Can be based on simpler representations than analysis
  - Shape from texture (we will skip)

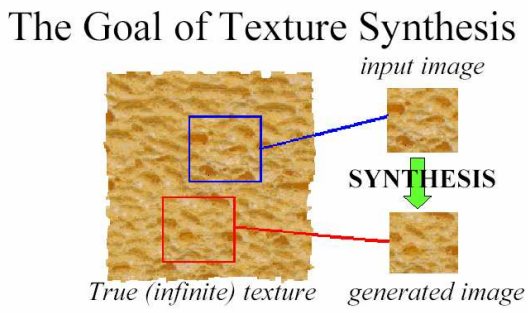
Objectives: 1) Discrimination/Analysis



Compare textures and decide if they're made of the same "stuff".

Slide credit: Freeman

2) Synthesis



Slide credit: Freeman

Representing textures

Observation: textures are made up of subelements, repeated over a region with similar statistical properties

Texture representation:

- find the subelements, and represent their statistics
- What filters can find the subelements?
  - Human vision suggests spots and oriented filters at a variety of different scales
- What statistics?
  - Mean of each filter response over region
  - Other statistics can also be useful

Human texture perception

Bergen and Adelson, Nature 1988

Learn size-tuned filter responses.

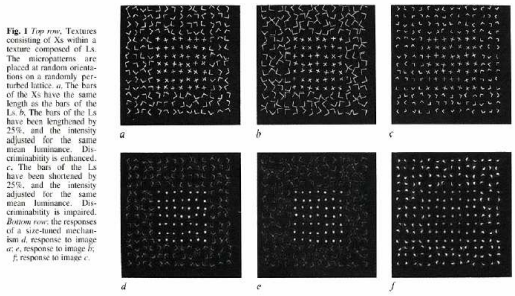
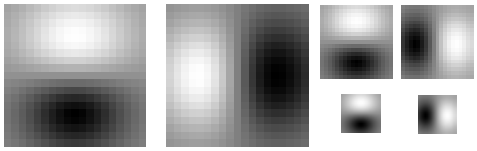
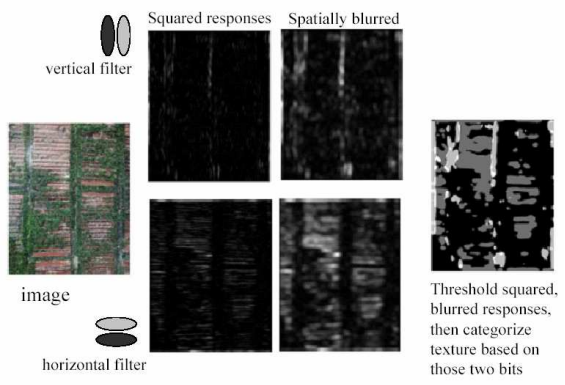


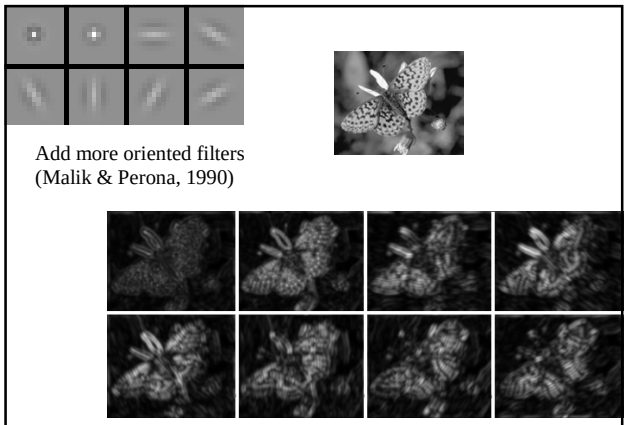
Fig. 1 *Top row*, Textures consisting of Xs within a texture composed of Ls. The micropatterns are placed at random orientations on a randomly perturbed lattice. *a*, The bars of the Xs have the same length as the bars of the Ls. *b*, The bars of the Ls have been lengthened by 25%, and the intensity adjusted for the same mean luminance. Discriminability is enhanced. *c*, The bars of the Ls have been shortened by 25%, and the intensity adjusted for the same mean luminance. Discriminability is impaired. *Bottom row*, the responses of a size-tuned mechanism *d*, response to image *a*; *e*, response to image *b*; *f*, response to image *c*.

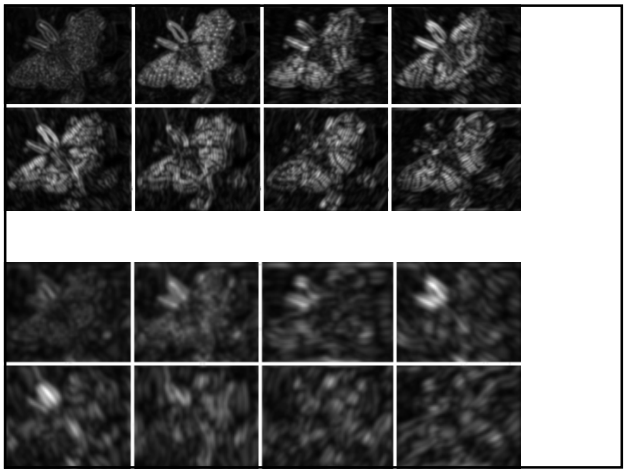
Derivative of Gaussian Filters

Measure the image gradient and its direction at different scales (use a pyramid).

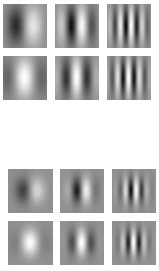








Alternative: Gabor filters



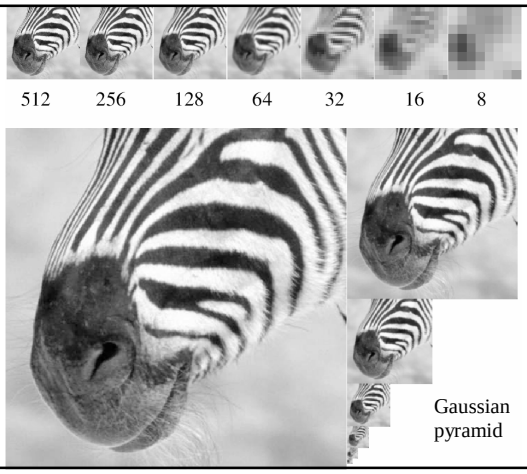
Gabor filters: Product of a Gaussian with sine or cosine

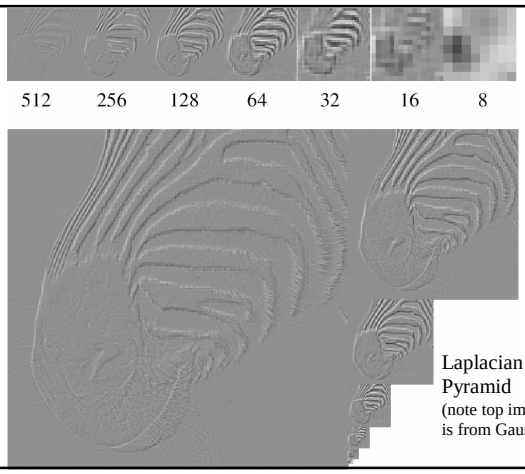
Top row shows anti-symmetric (or odd) filters, bottom row the symmetric (or even) filters.

No obvious advantage to any one type of oriented filters.

The Laplacian Pyramid

- **Building a Laplacian pyramid:**
  - Create a Gaussian pyramid
  - Take the difference between one Gaussian pyramid level and the next (before subsampling)
- **Properties**
  - Also known as the difference-of-Gaussian function, which is a close approximation to the Laplacian
  - It is a band pass filter - each level represents a different band of spatial frequencies
- **Reconstructing the original image:**
  - Reconstruct the Gaussian pyramid starting at top layer

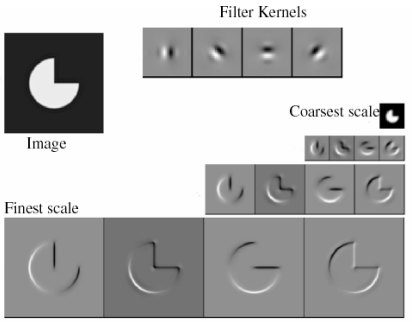




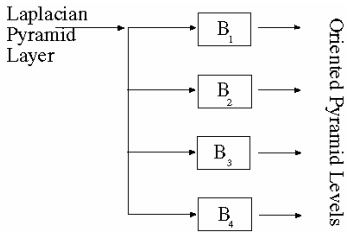
Laplacian Pyramid
(note top image is from Gaussian)

Oriented pyramids

- Laplacian pyramid is orientation independent
- Apply an oriented filter to determine orientations at each layer
  - This represents image information at a particular scale and orientation.
  - We will not study details in this course.



Reprinted from "Shiftable MultiScale Transforms," by Simoncelli et al., IEEE Transactions on Information Theory, 1992, copyright 1992, IEEE

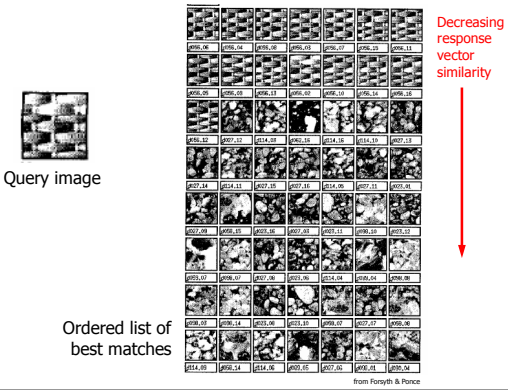


Creating oriented pyramid

Final texture representation

- Form a Laplacian and oriented pyramid (or equivalent set of responses to filters at different scales and orientations).
- Square the output (makes values positive)
- Average responses over a neighborhood by blurring with a Gaussian
- Take statistics of responses
  - Mean of each filter output
  - Possibly standard deviation of each filter output

Application: Texture-based Image Matching

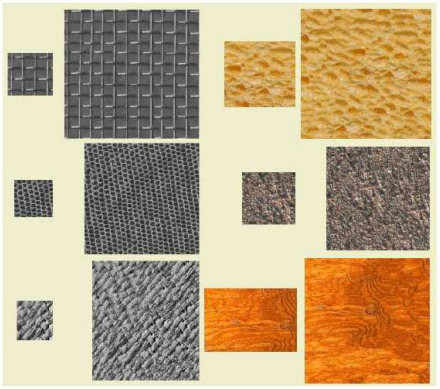


The texture synthesis problem

Generate new examples of a texture.

- **Original approach:** Use the same representation for analysis and synthesis
  - This can produce good results for random textures, but fails to account for some regularities
- **Recent approach:** Use an image of the texture as the source of a probability model
  - This draws samples directly from the actual texture, so can account for more types of structure
  - Very simple to implement
  - However, depends on choosing a correct distance parameter

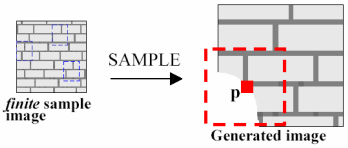
Efros and Leung



This is like copying, but not just repetition

Photo

Efros and Leung method

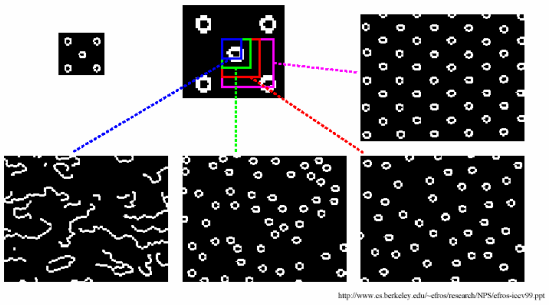


- For each new pixel **p** (select **p** on boundary of texture):
  - Match a window around **p** to sample texture, and select several closest matches
    - Matching minimizes sum of squared differences of each pixel in the window (Gaussian weighted)
    - Give zero weight to empty pixels in the window
  - Select one of the closest matches at random and use its center value for **p**

Initial conditions for growing texture

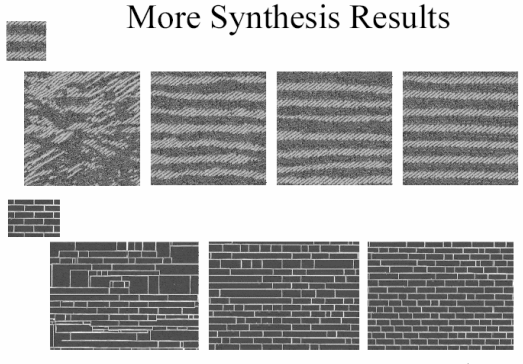
- If no initial conditions are specified, just pick a patch from the texture at random
- To fill in an empty region within an existing texture:
  - Grow away from pixels that are on the boundary of the existing texture

Window size parameter

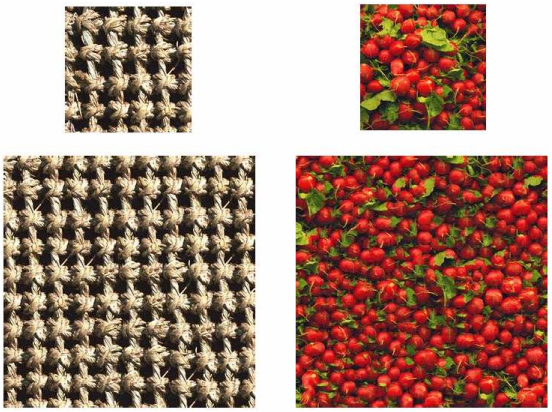


http://www.cs.berkeley.edu/~efros/research/NPS/efros-iccv99.ppt

More Synthesis Results



http://www.cs.berkeley.edu/~efros/research/NPS/efros-iccv99.ppt



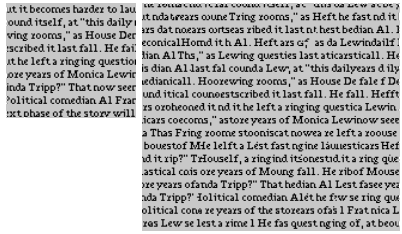
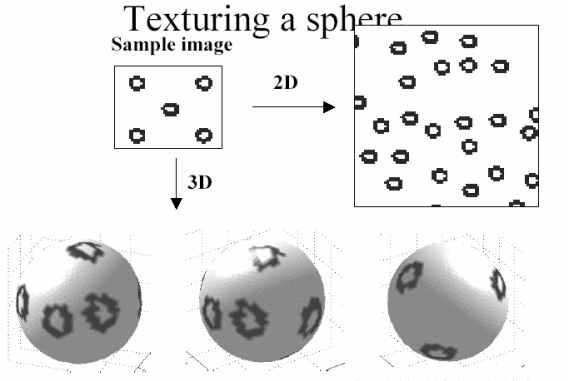


Figure from Texture Synthesis by Non-parametric Sampling, A. Efros and T.K. Leung, Proc. Int. Conf. Computer Vision, 1999 copyright 1999, IEEE

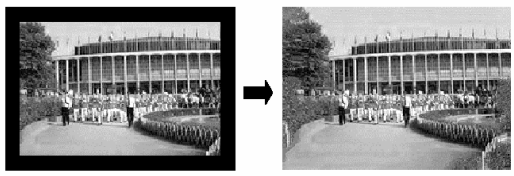
Failures

Texturing a sphere



http://www.cs.berkeley.edu/~efros/research/NPS/efros-iccv99.ppt

Image Extrapolation



45

http://www.cs.berkeley.edu/~efros/research/NPS/efros-iccv99.ppt

Further issues in texture synthesis

- How to improve efficiency
  - Use fast nearest-neighbor search
- How to select region size automatically
- How to edit textures to modify them in natural ways