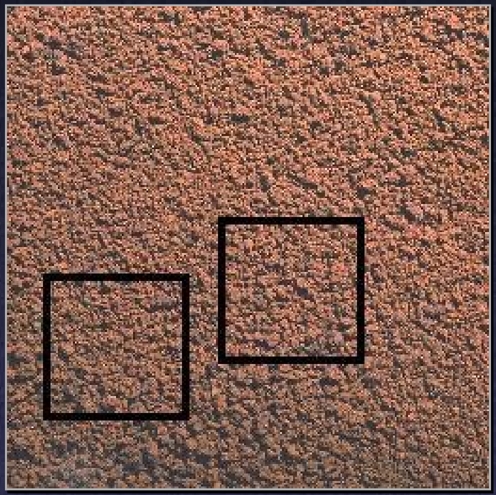
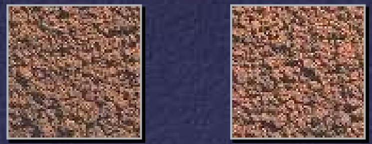
Texture Analysis and Synthesis

Texture

- Texture: pattern that "looks the same" at all locations
- May be structured or random





[Wei & Levoy]

Applications of Textures

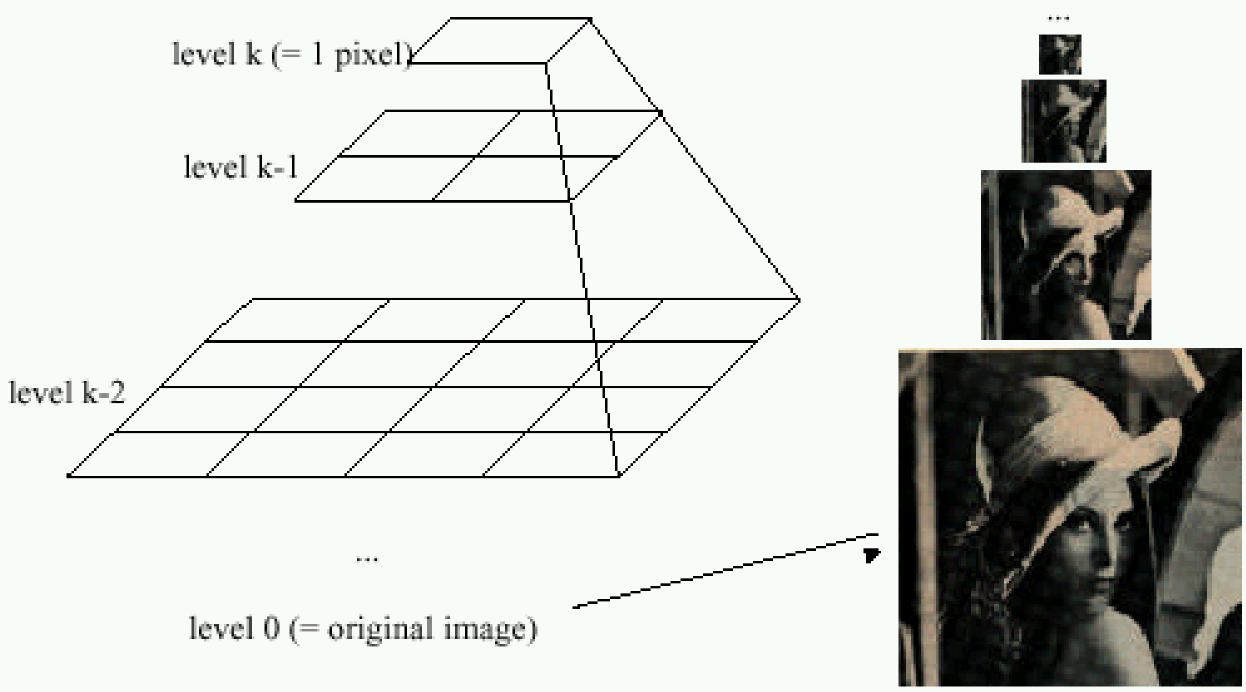
- Texture analysis
  - Detemining statistical properties of textures
  - Segmentation
  - Recognition
  - Shape from texture
- Texture synthesis

Approaches

- Statistics of filter banks
- Textons
- Markov Random Fields

Image Pyramids

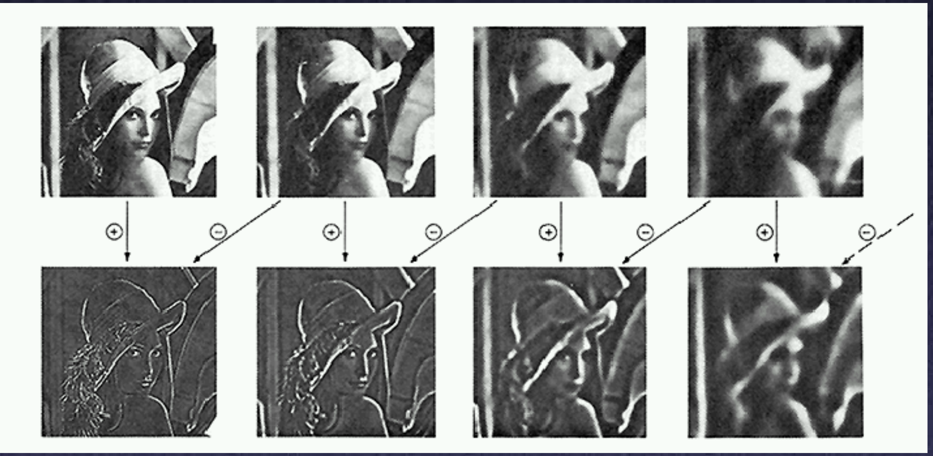
Idea: Represent NxN image as a "pyramid" of $1x1, 2x2, 4x4, \ldots, 2^k x 2^k$ images (assuming $N=2^k$)



Szeliski

Pyramid Creation

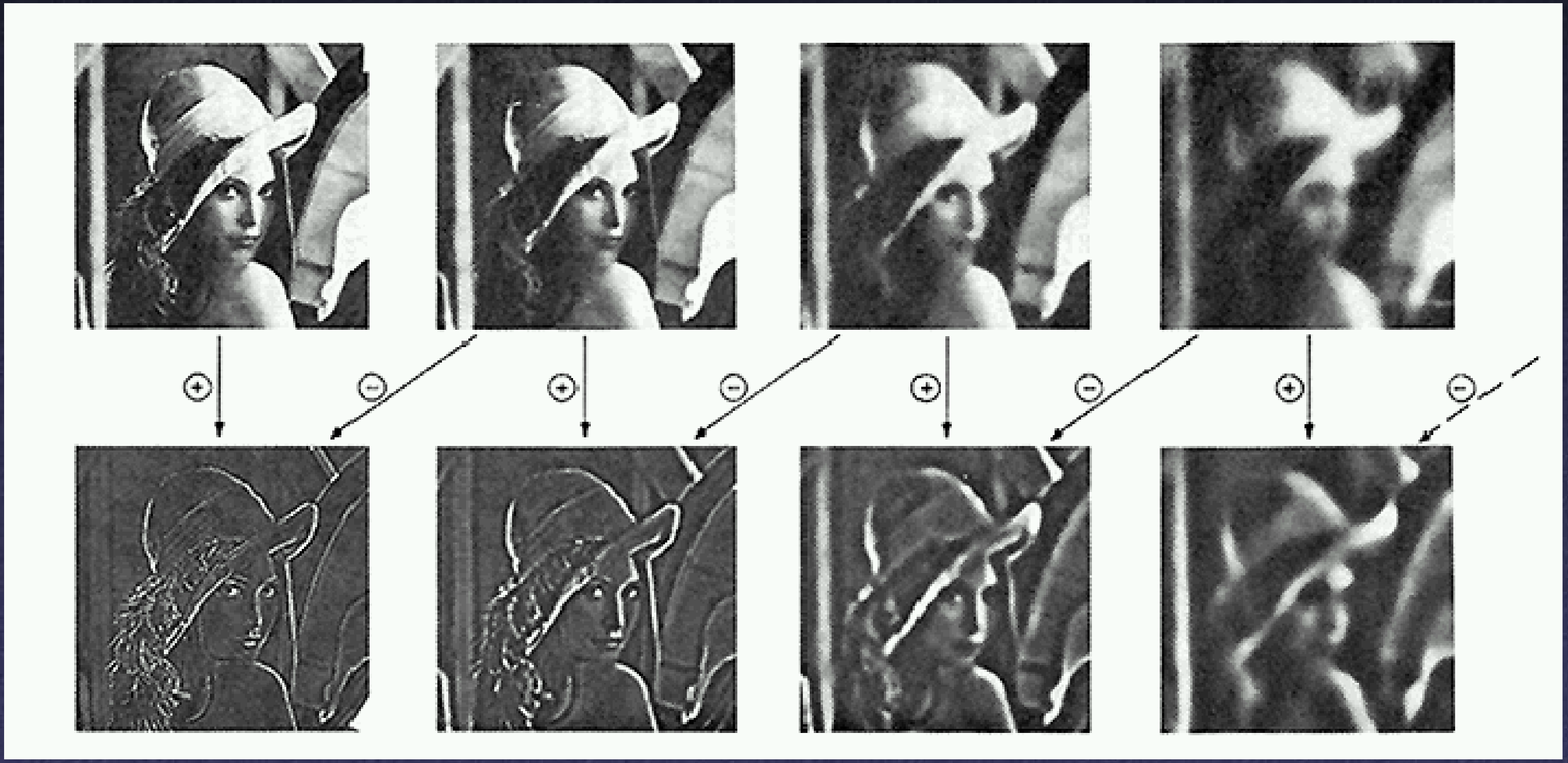
- "Gaussian" Pyramid
- "Laplacian" Pyramid
  - Created from Gaussian pyramid by subtraction $L_i = G_i - \text{expand}(G_{i+1})$



Szeliski

Octaves in the Spatial Domain

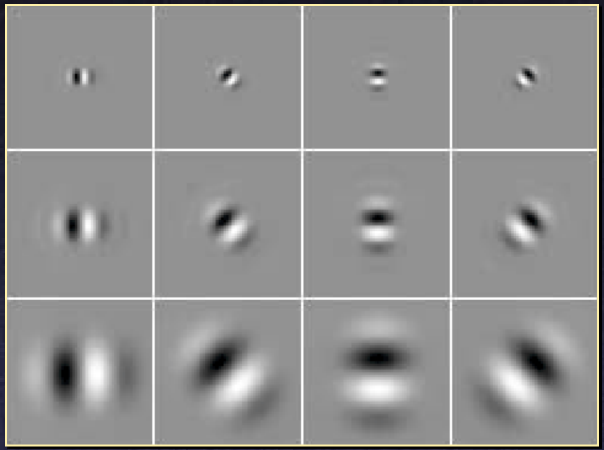
Lowpass Images



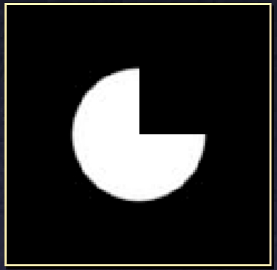
Bandpass Images

Szeliski

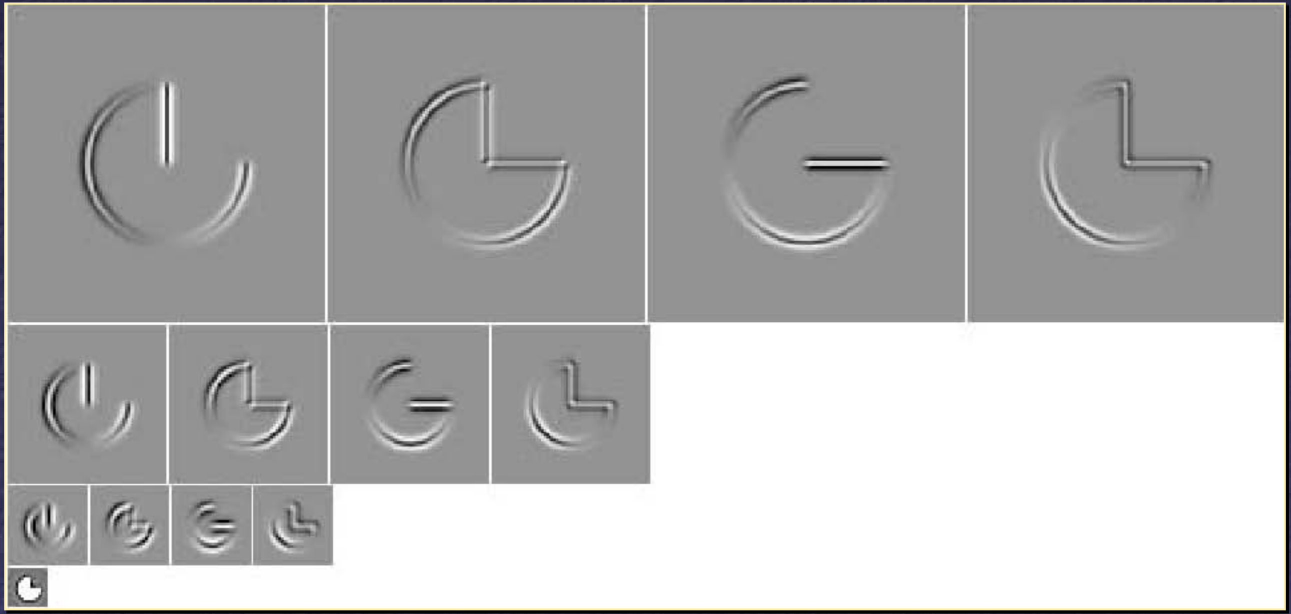
Oriented Filter Banks



Multiresolution
Oriented
Filter Bank



Original
Image



Steerable
Pyramid

Steerable Pyramid Texture Analysis

- Pass image through filter bank
- Compile histogram of intensities output by each filter
- To synthesize new texture:
  - Start with random noise image
  - Adjust histograms to match original image
  - Re-synthesize image from filter outputs

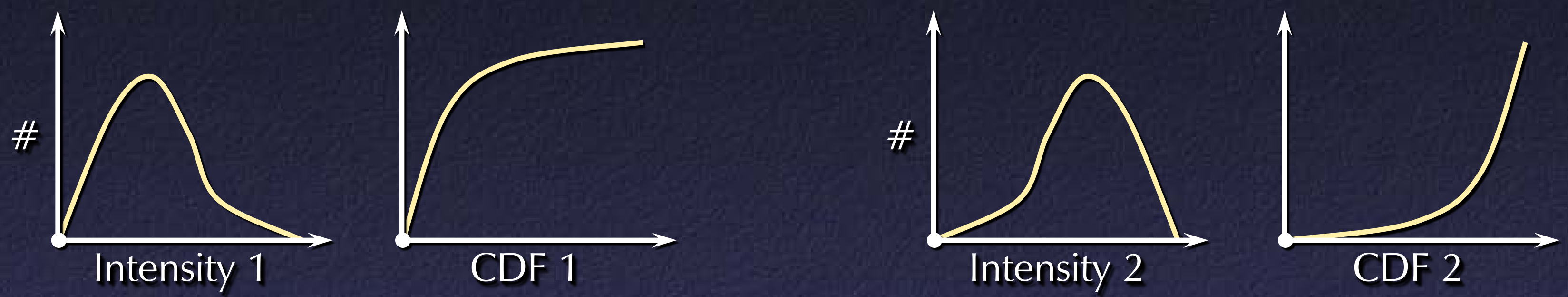
Histogram Equalization

- Given: two histograms of intensity H_1 and H_2

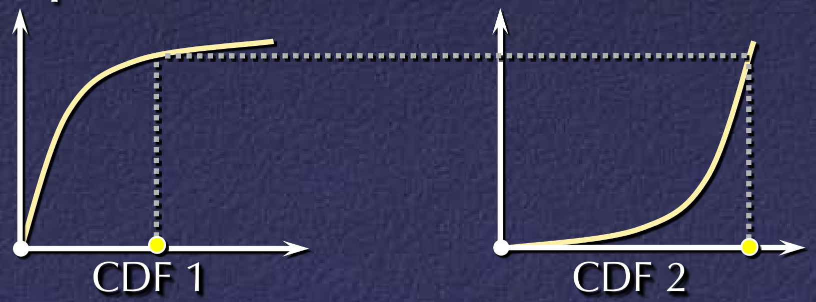
- Goal: function that remaps intensities to make new histogram $H_{1'}$ equal H_2

Histogram Equalization

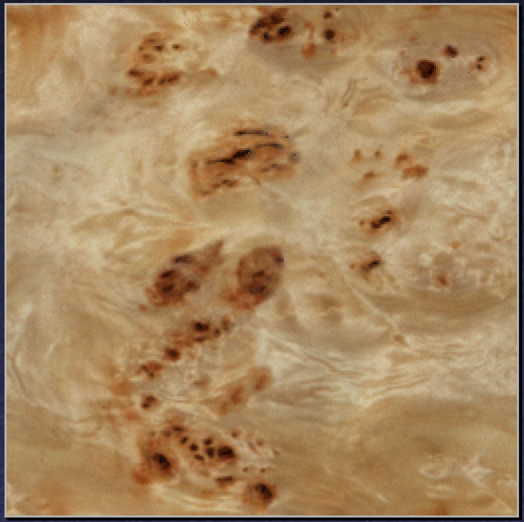
1. Compute CDFs (integrals) of histograms



2. For each intensity, map through CDF 1 then look up inverse in CDF 2



Texture Analysis / Synthesis



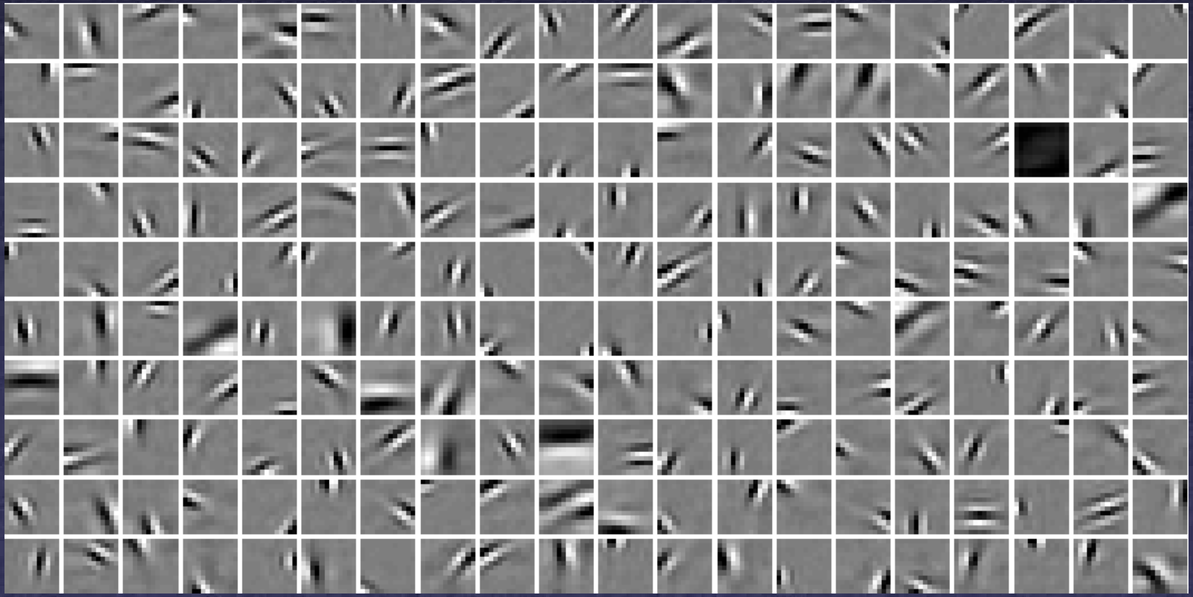
Original
Texture

Synthesized
Texture

Heeger and Bergen

Textons

- Elements ("textons") either identical or come from some statistical distribution
- Can analyze in natural images



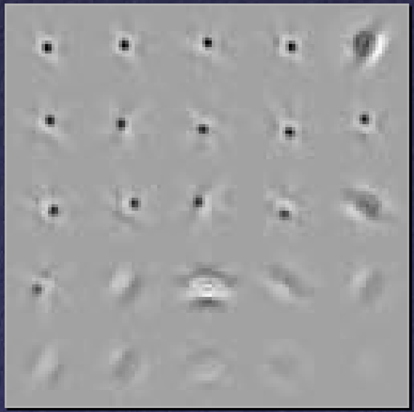
Olhausen & Field

Clustering Textons

- Output of bank of *n* filters can be thought of as vector in *n*-dimensional space
- Can *cluster* these vectors using *k*-means [Malik et al.]
- Result: dictionary of most common textures

Clustering Textons

Image



Clustered Textons

Texton to Pixel Mapping

[Malik et al.]

Using Texture in Segmentation

- Compute histogram of how many times each of the *k* clusters occurs in a neighborhood
- Define similarity of histograms h_i and h_j using χ^2

$$\chi^2 = \frac{1}{2}\sum_k \frac{\left(h_i(k) - h_j(k)\right)^2}{h_i(k) + h_j(k)}$$

- Different histograms $\rightarrow$ separate regions

Texture Segmentation

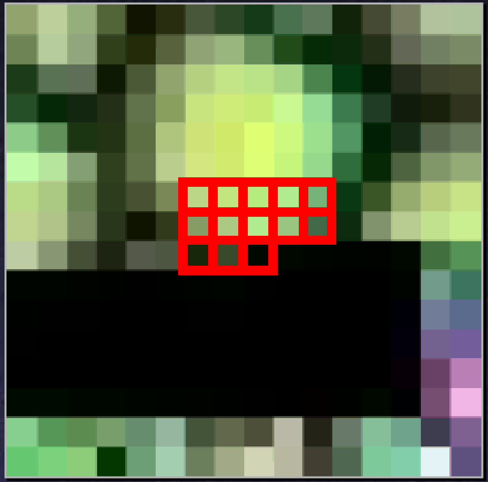
[Malik et al.]

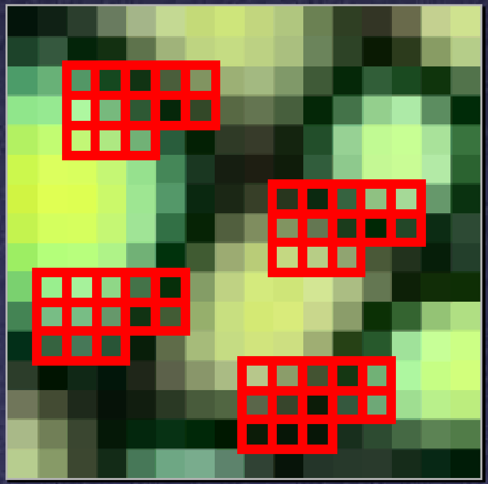
Markov Random Fields

- Different way of thinking about textures
- Premise: probability distribution of a pixel depends on values of neighbors
- Probability the same throughout image
  - Extension of Markov chains

Texture Synthesis Based on MRF

- For each pixel in destination:
  - Take already-synthesized neighbors
  - Find closest match in original texture
  - Copy pixel to destination
- Efros & Leung 1999, speedup by Wei & Levoy 2000
- Extension to copying whole blocks by Efros & Freeman 2001
  - Let's look at their talk…





[Wei & Levoy]