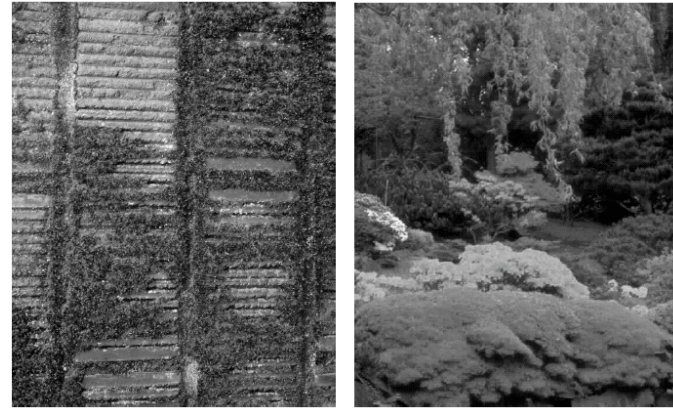


## Texture

- Texture always has a scale (leaf -> bush -> forest)
- Key issue: representing texture
- Texture based matching
  - obvious thing to do, little is known
- Texture segmentation
  - key issue: representing texture
- Texture synthesis
  - useful; also gives some insight into quality of representation
- Shape from texture
  - cover superficially



## Representing textures

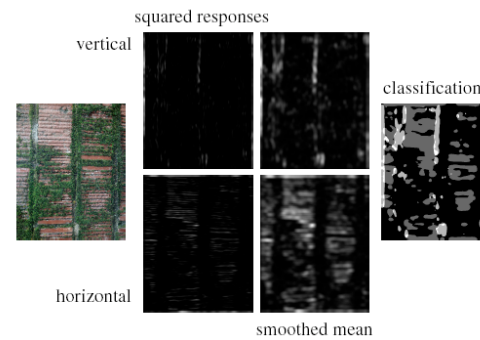
- Textures are made up of quite stylized sub-elements
  - e.g. polka-dots
- Representation:
  - find the sub-elements, and represent their **statistics**
- But what are the sub-elements, and how do we find them?
  - recall normalized correlation
  - find sub-elements by applying filters, looking at the magnitude of the response

## Representing textures

- Begin with collections of responses to a variety of filters
- Generally need a collection of spots and bars at various scales and orientations (for the bars), but it is not so critical how one gets the spots and bars.
- Thus the filter banks are typically chosen based on other (often relatively arbitrary) considerations.

## Representing textures

- Associate texture with **statistics** of the conglomerate of responses over some scale (window size)
- Simplest statistic is mean (square) response for each filter
  - So,  $N$  filters gives a vector of dimension  $N$
- Including standard deviation helps
  - Now,  $N$  filters gives a vector of dimension  $2*N$
- These simple methods ignore spatial correlation
  - Including spatial correlation increases data by a factor of the number of pixels in a window
  - Too many, and too noisy  $\implies$  cluster point data in “textons”
  - Texture in a window is a histogram of texton popularity



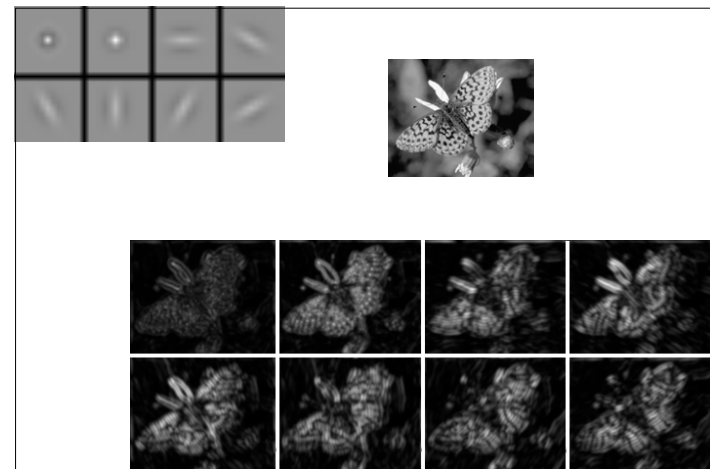
## A typical filter bank

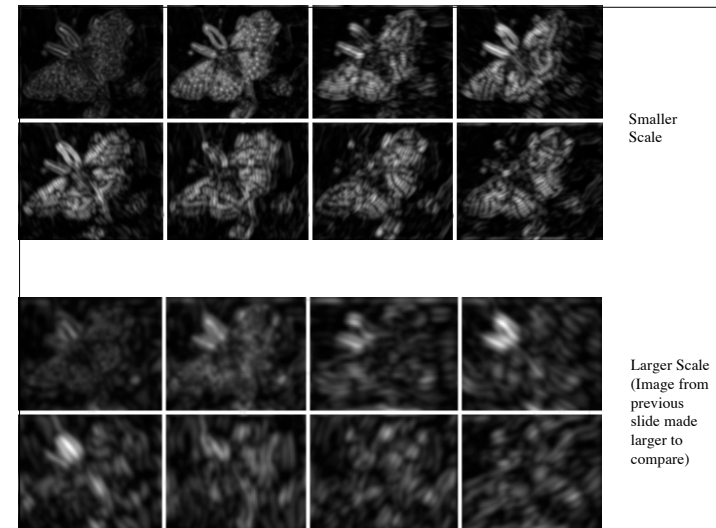
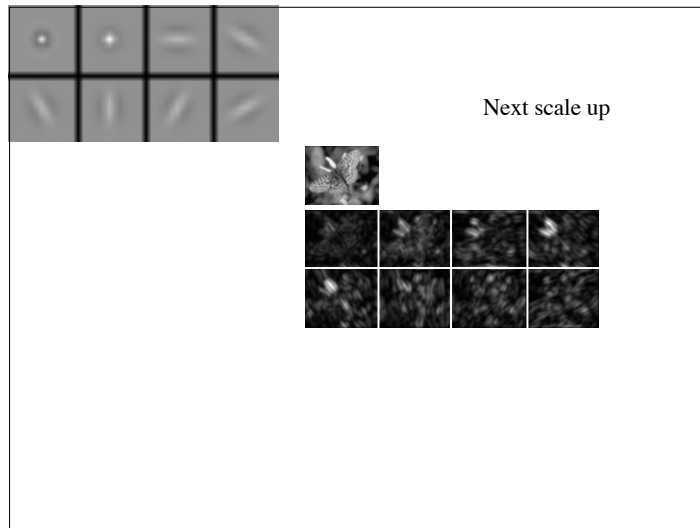


Figure 4. Left: Filter set  $f_i$  consisting of 2 phases (even and odd), 3 scales (spaced by half-octaves), and 6 orientations (equally spaced from 0 to  $\pi$ ). The basic filter is a difference-of-Gaussian quadrature pair with 3 : 1 elongation. Right: 4 scales of center-surround filters. Each filter is  $L_1$ -normalized for scale invariance.

From Malik et al., “Contour and texture analysis for image segmentation”

(We have an implementation for this filter bank, as part of the N-cuts software from Berkeley).





## Final texture representation

- Form an oriented pyramid (or equivalent set of responses to filters at different scales and orientations).
- Square the output
- Take statistics of responses in a window (sets texture scale)
  - simplest is mean of each filter output (are there lots of spots?)
  - next most convenient enhancement is to look at standard deviation of each filter output
  - more complicated schemes are important in practice

## Texture synthesis

Optional

- Use image as a source of probability model
- Grab a section of the image at random for seeding
- Expand from unfilled edges by matching boundary sections to the image, and randomly sampling the unfilled value from the blocks matched
- (For details see pages 206-207 in text)

Optional

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