Lecture 15
Texture Representation
ECEN 5283 Computer Vision

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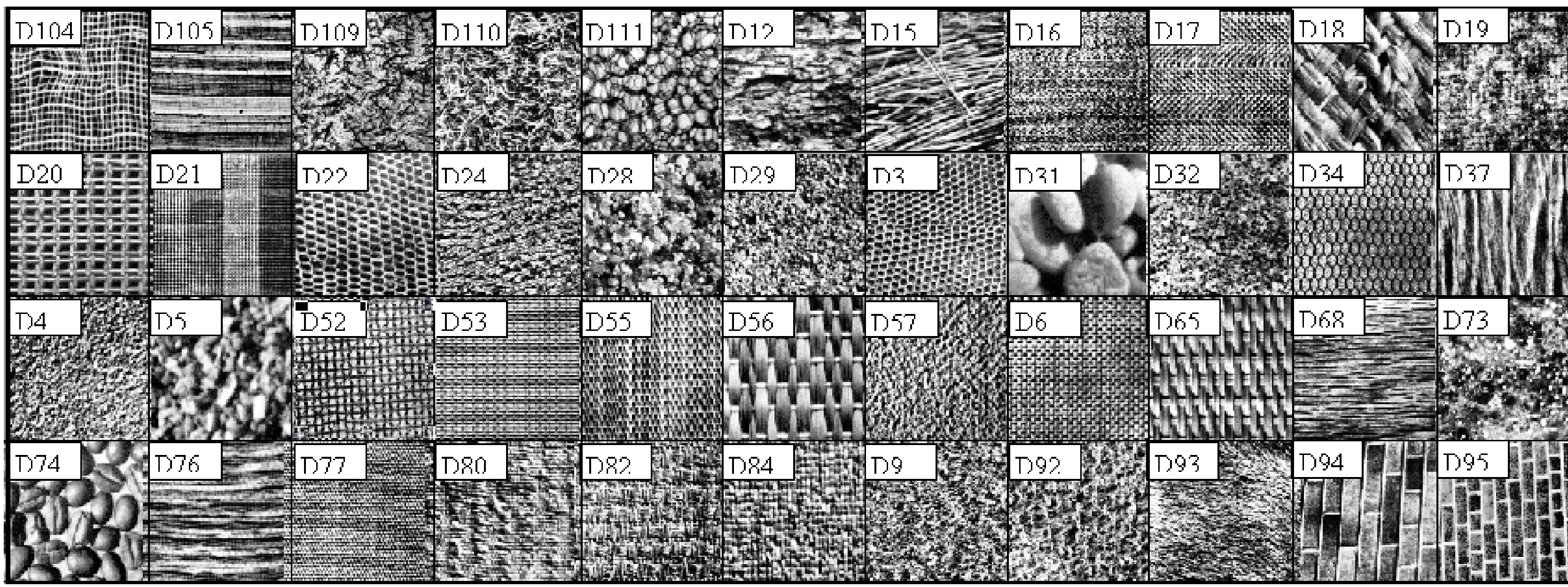
Goals

- To represent textures by a filter bank.
- To discuss two issues of texture representation by filters: statistics and scales

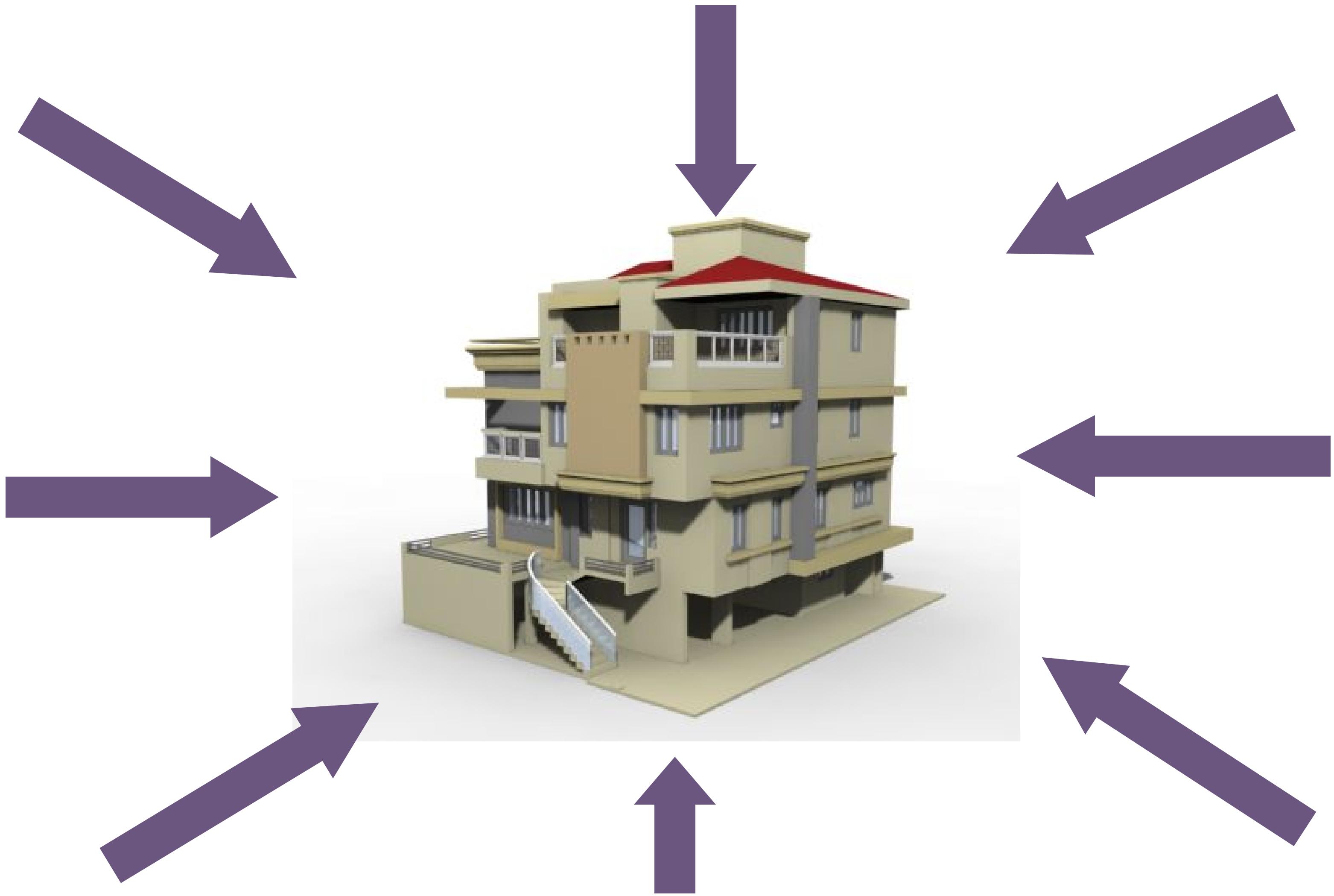
Introduction to Texture

- Texture is a phenomenon that is widespread, easy to recognize and hard to define.
  - Deterministic textures
  - Statistical textures
  - Mixed textures



http://www.ux.uis.no/~tranden/brodatz.html

How to understand a complex object?



Filter Banks for Texture Representation

- How to represent image textures more precisely?
  - Convolving an image with a linear filter yields a representation of the image on a different basis, making the local structure of the image clear.
  - There is a strong response when the image pattern in a neighborhood looks similar to the filter kernel, and a weak response when it doesn't.

- This suggests representing image textures in terms of the responses of a collection of filters.
  - The collection of different filters would consist of a series of patterns (such as spots, bars).
  - While this representation is heavily redundant, it exposes structures in a way that has proven helpful.

Spots and Bars by Weighted Sums of Gaussians

- By analogy with the human visual cortex, it is usual to use some ***spot filters*** and a collection of oriented ***bar filters*** at different *orientations*, *scales*, and *phases*.

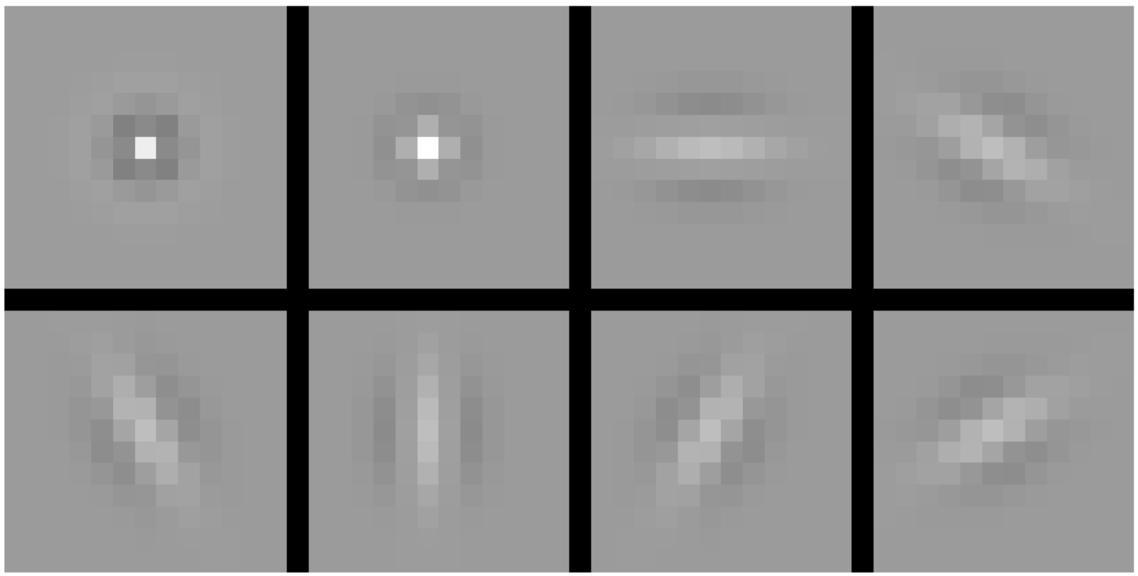


Figure 11.3. A set of eight filters used for expanding images into a series of responses. These filters are shown at a fixed scale, with zero represented by a mid-grey level, lighter values being positive and darker values being negative. They represent two distinct spots, and six bars; the set of filters is that used by [Malik and Perona, 1990].

These filters can be approximated by a set of Gaussian functions with different means and variances.

Spots and Bars by Weighted Sums of Gaussians (Cont'd)

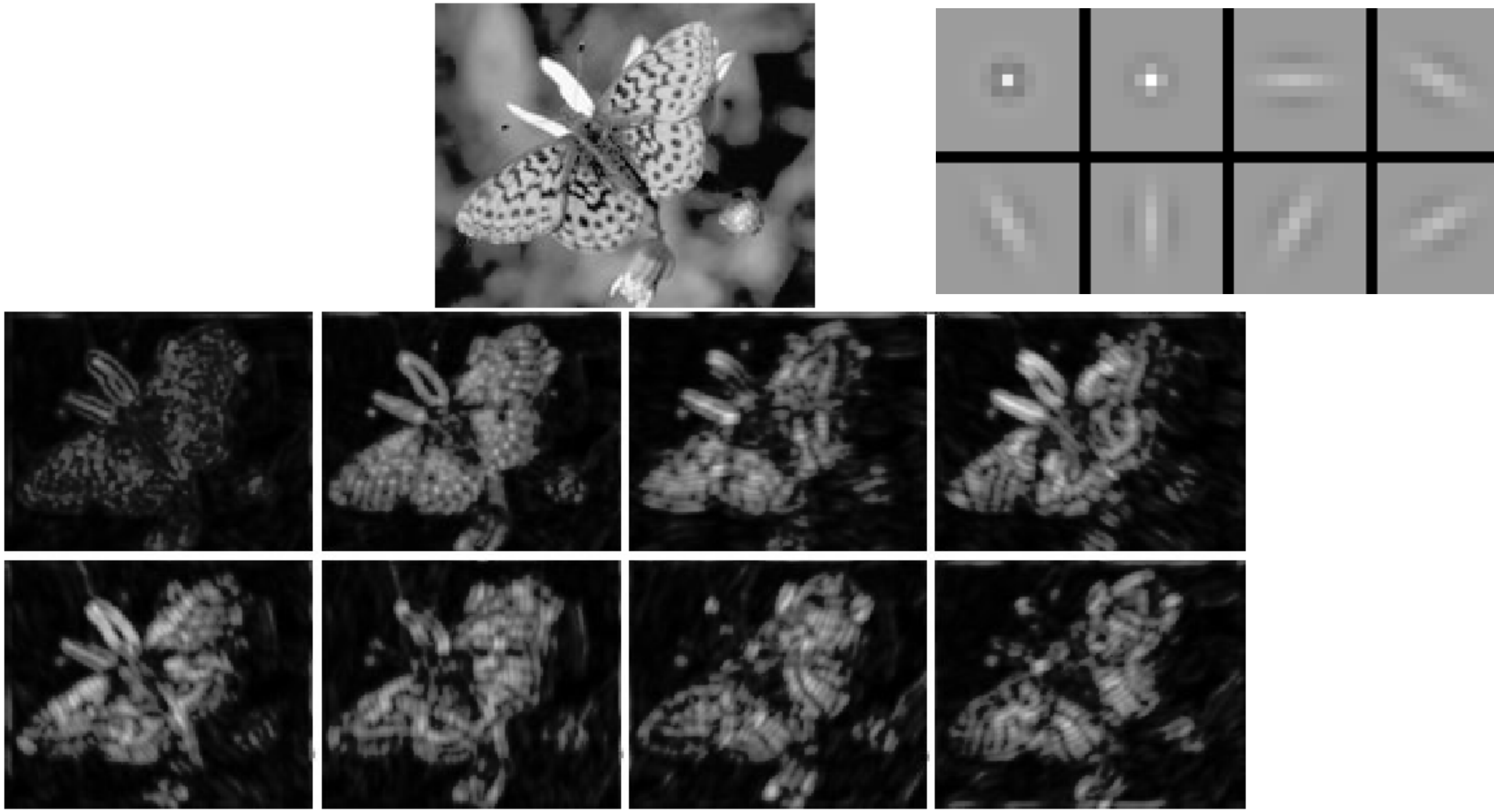
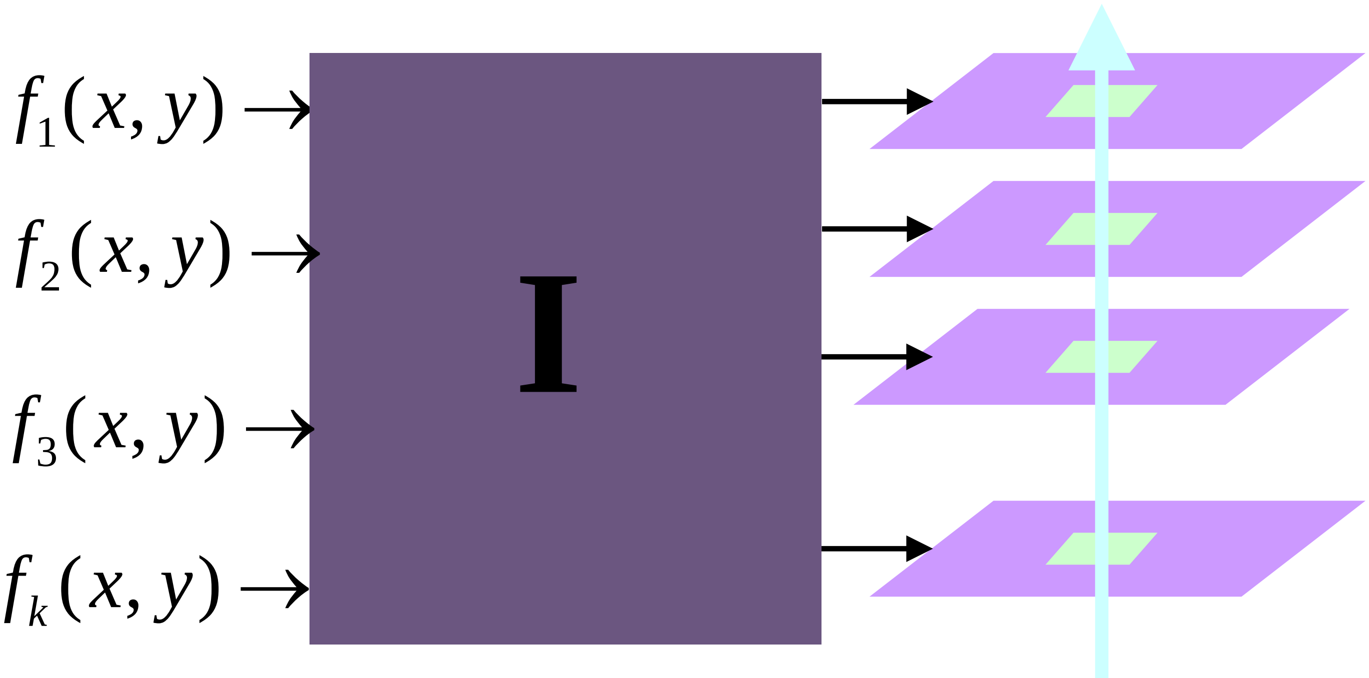


Figure 11.4. At the top, an image of a butterfly at a fine scale, and below, the result of applying each of the filters of figure 11.3 to that image. The results are shown as absolute values of the output, lighter pixels representing stronger responses, and the images are laid out corresponding to the filter position in the top row.

Two Issues for Texture Representation: (1) Statistics

- How to characterize the filter output?
  - A typical representation involves a set of statistics (e.g., mean and variance) of filter outputs for in a window.

$$\mu = \int x p(x) dx : \text{mean} \qquad \delta^2 = \int (x-\mu)^2 p(x) dx : \text{variance}$$

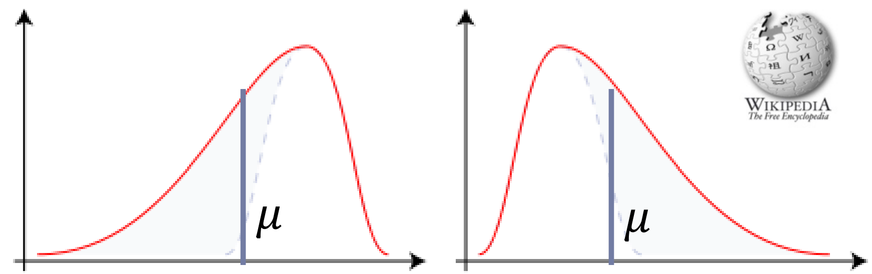


$$\begin{pmatrix} (m_1 & \delta_1^2)^T \\ (m_2 & \delta_2^2)^T \\ (m_3 & \delta_3^2)^T \\ & \cdots\cdots \\ (m_k & \delta_k^2)^T \end{pmatrix}$$

High-order Statistics

- **Skewness** (3^{rd} order central moment) is a measure of the *asymmetry* of the probability distribution of a variable.

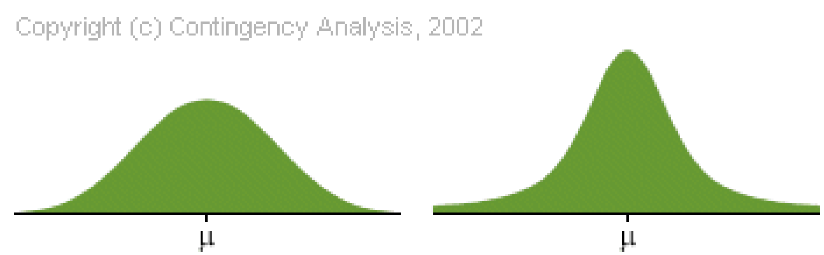
$$\gamma_1 = \int \left(\frac{x-\mu}{\delta} \right)^3 p(x)dx$$



Negative Skew   Positive Skew

- **Kurtosis** (4^{th} order central moment) is the degree of peakedness or flatness of the probability distribution of variable.

$$\gamma_2 = \int \left(\frac{x-\mu}{\delta} \right)^4 p(x)dx$$

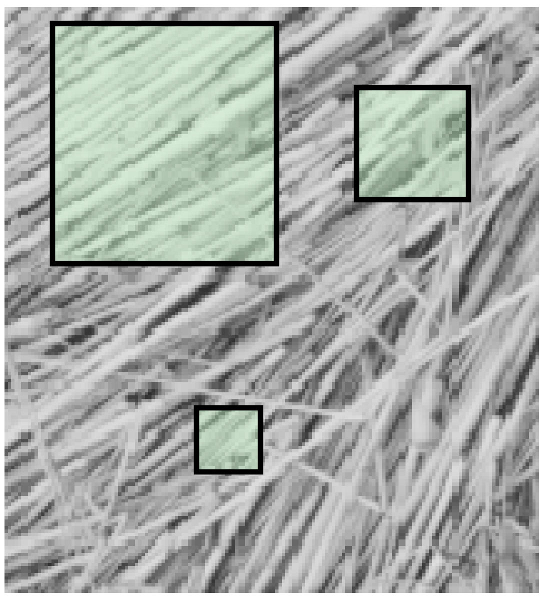


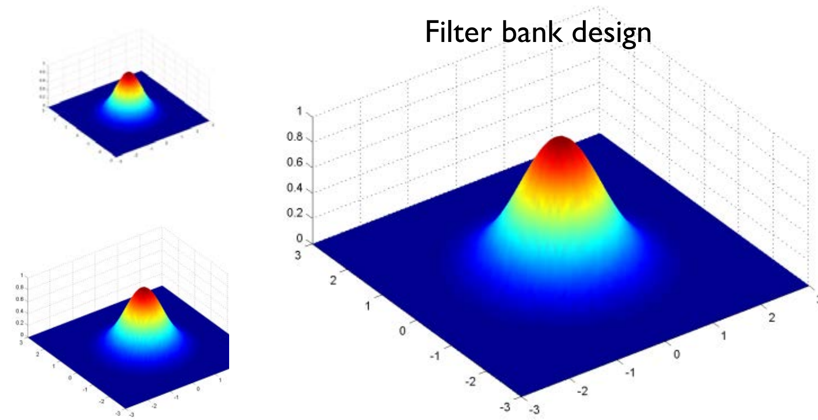
Small kurtosis   large kurtosis

Two issues for Texture Representation: (2) Scales

- Two scales are involved for texture representation:
  - Filter scales are related to the texture structure.
  - Texture scales determine the window size of for computing statistics.

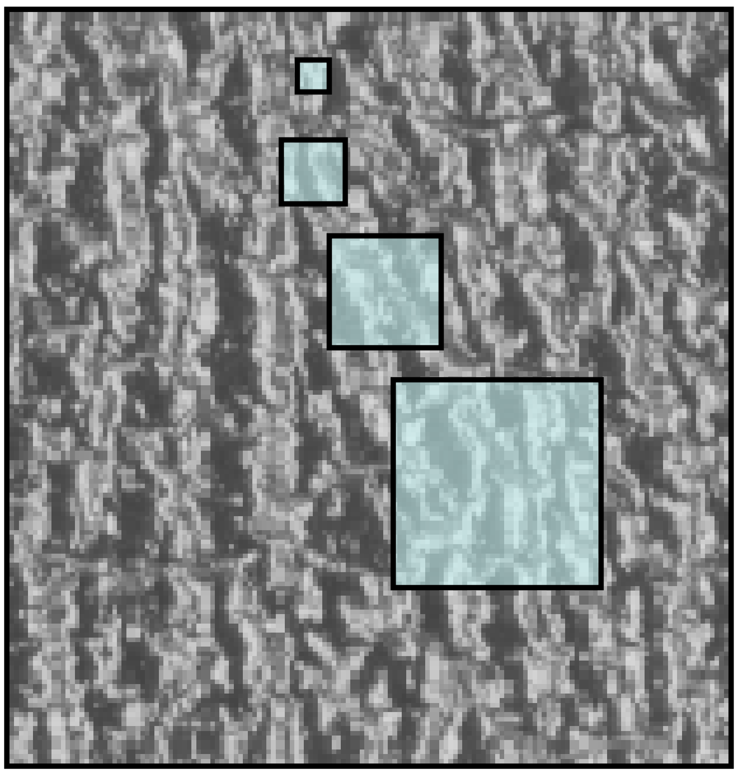
Polarity Analysis



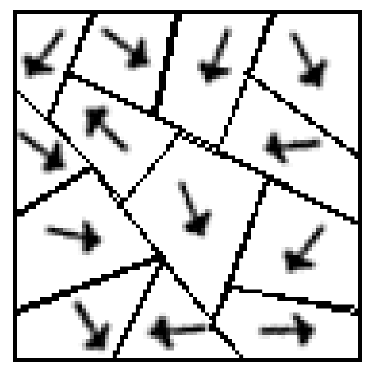


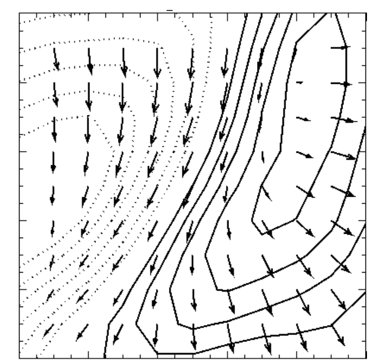
Choice of Texture Scale

- There are two facts about selecting scales for texture analysis:
  - Small windows offer good spatial resolution while large ones good robustness.
  - Different textures may have different optimal scales.



Polarity analysis

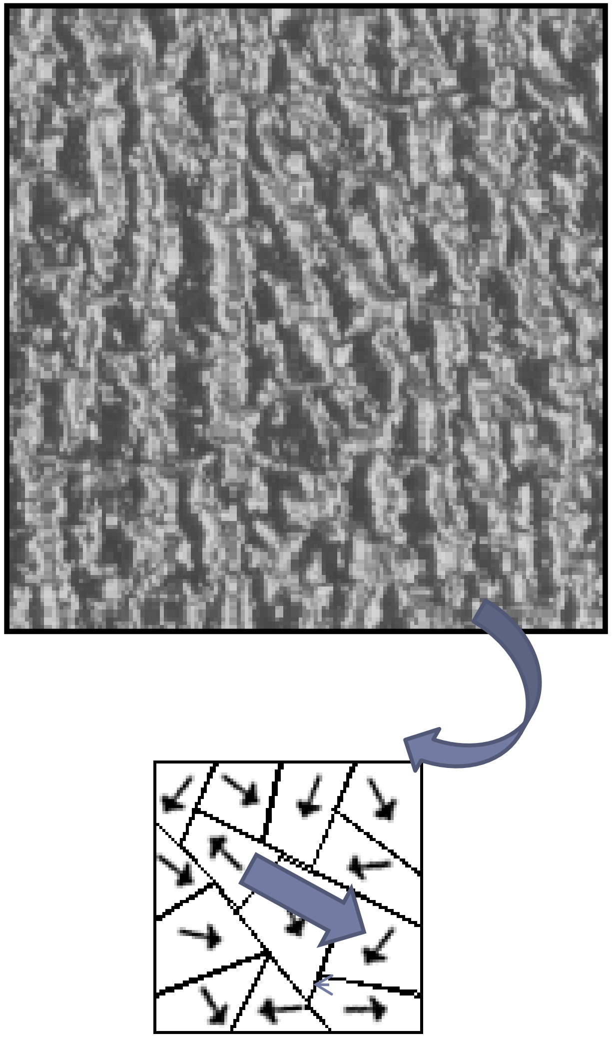


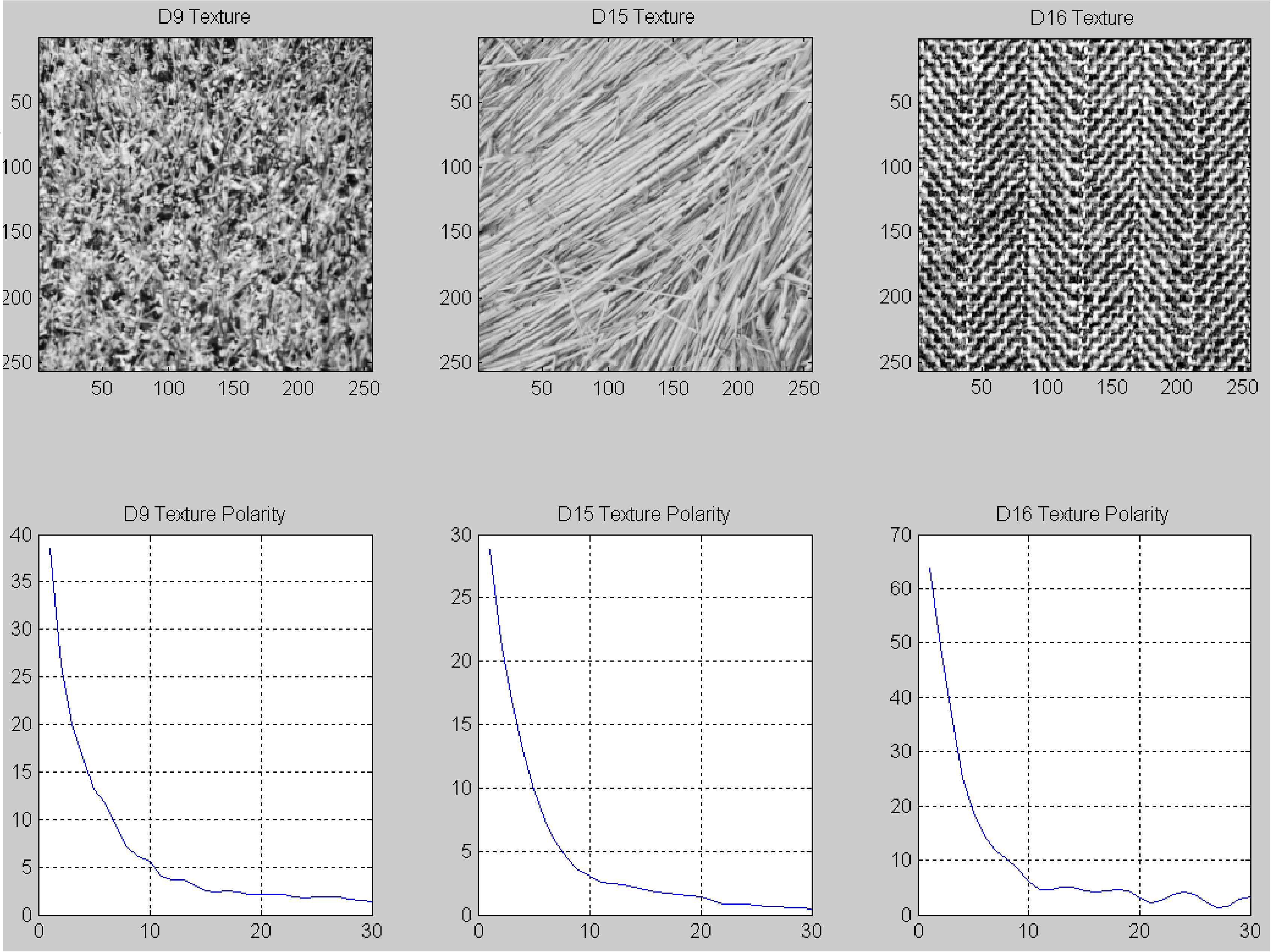


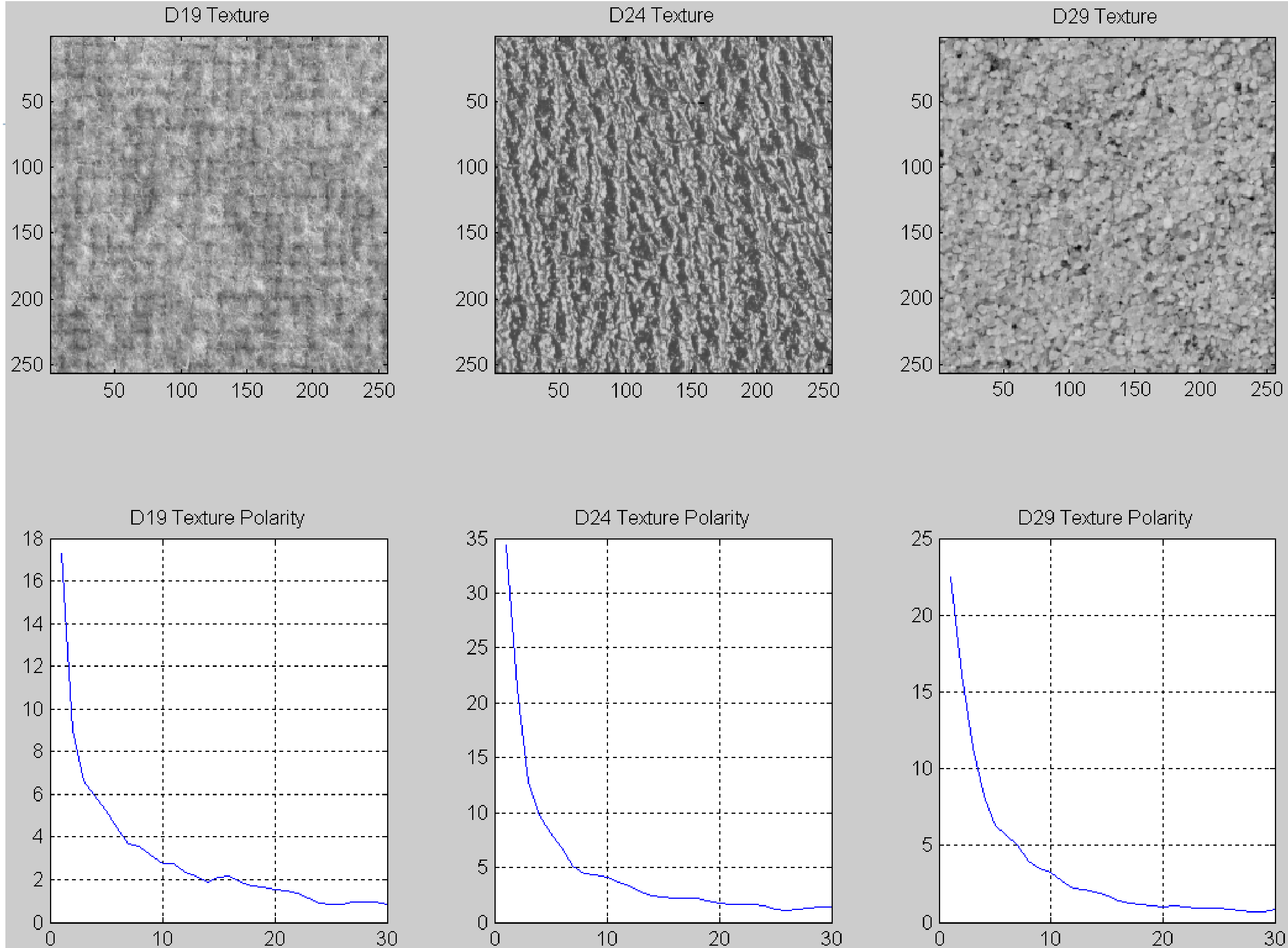
Which one is more polarized?

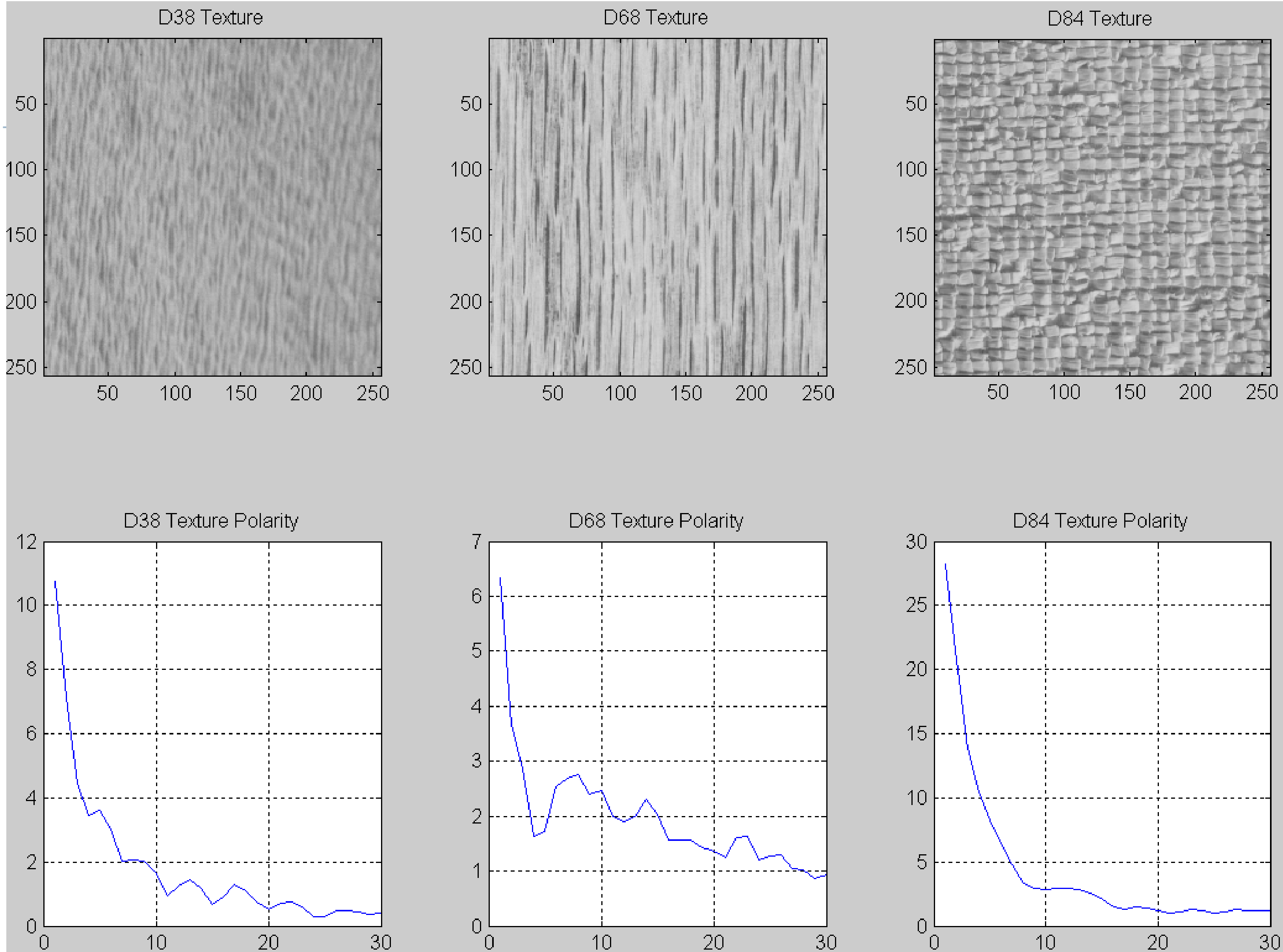
Scale Determination via Polarity

- Step 1: We first determine the *dominant orientation* in a window.
- Step 2: For each gradient vector, we form the *dot product* between the gradient vector and the dominant orientation.
- Step 3: We then form a smoothed average of the *positive dot products* and a smoothed average of the magnitude of the negative dot product, and take the difference of the two.
- Step 4: This polarity measures *the extent to which gradient points along the dominant orientations vs. ones against the dominant orientations*.
- Step 5: We measure polarity for a range of window sizes, and then start at the finest scale and look at increasingly large windows until the polarity has not changed when the scale changed.




D9 Texture
D15 Texture
D16 Texture
D9 Texture Polarity
D15 Texture Polarity
D16 Texture Polarity


D19 Texture
D24 Texture
D29 Texture
50
100
150
200
250
D19 Texture Polarity
D24 Texture Polarity
D29 Texture Polarity
0
10
20
30


D38 Texture
D68 Texture
D84 Texture
D38 Texture Polarity
D68 Texture Polarity
D84 Texture Polarity