

ECE5554 – Computer Vision

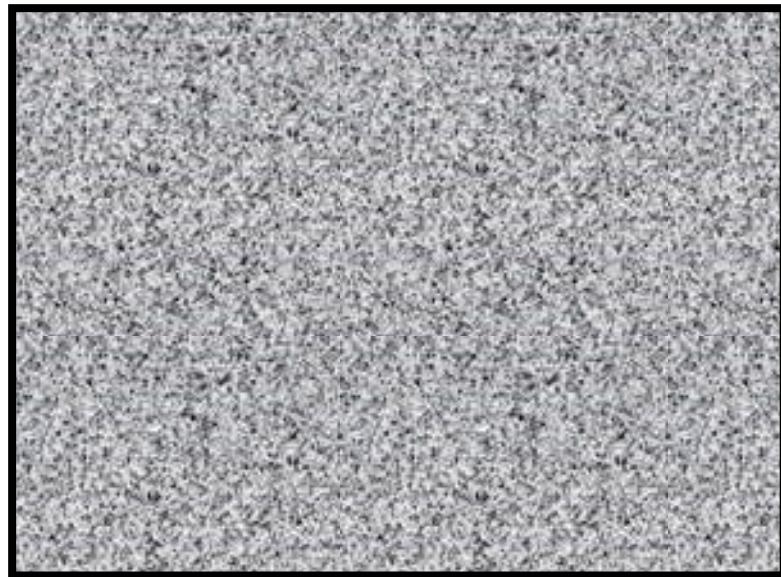
Lecture 5c – Texture

Creed Jones, PhD

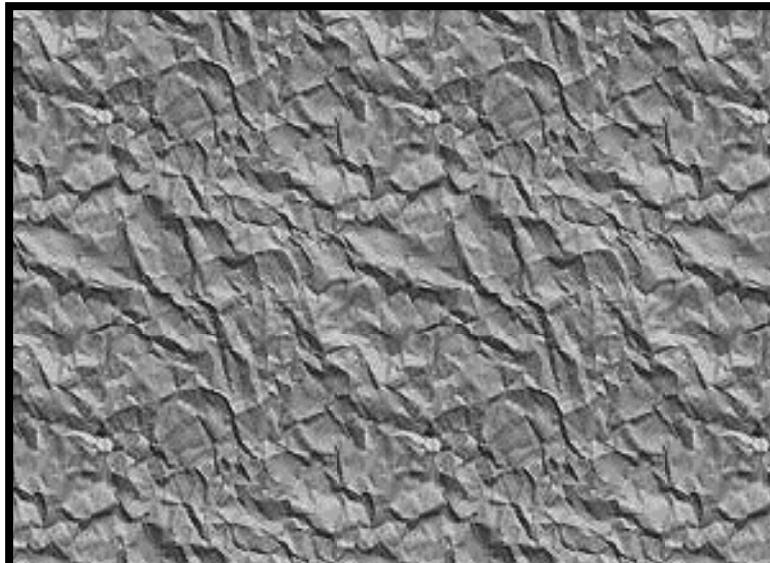
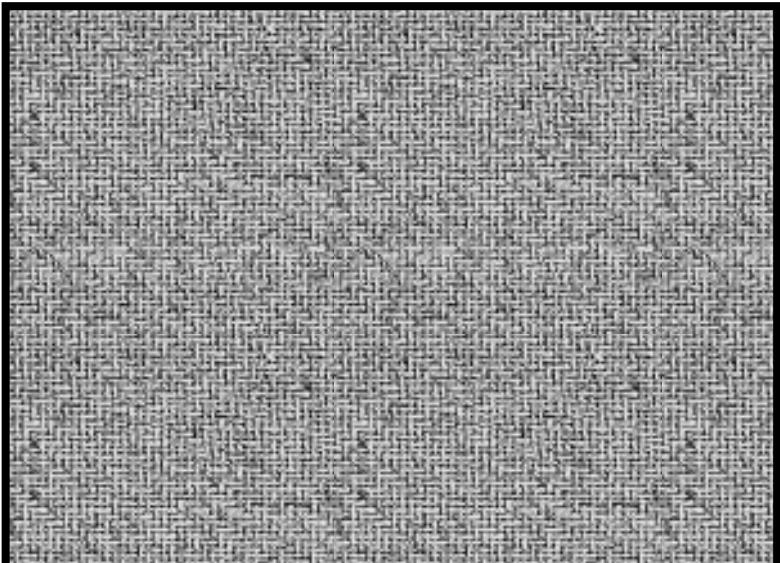
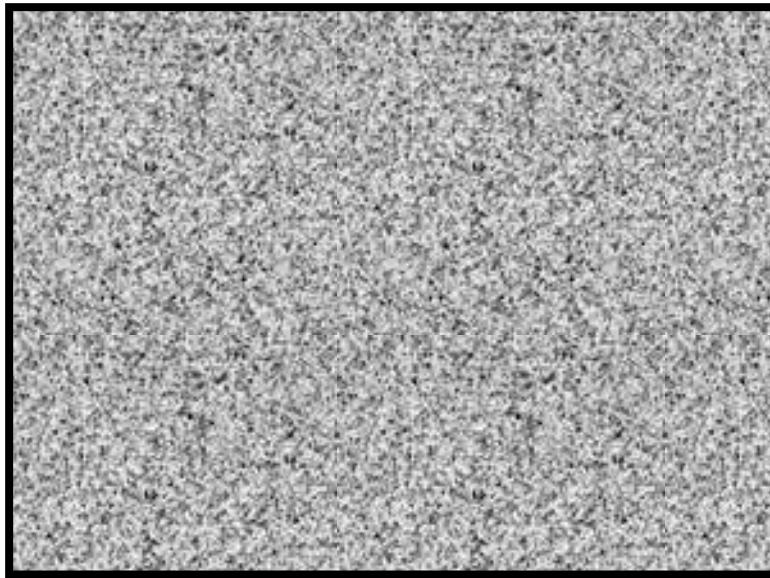
Today's Objectives

- Texture as a visual cue
 - Segmentation
 - Depth
- Texture representation by derivatives
- Filter banks
 - Texture feature vectors
- Texture analysis

Can you identify these materials?

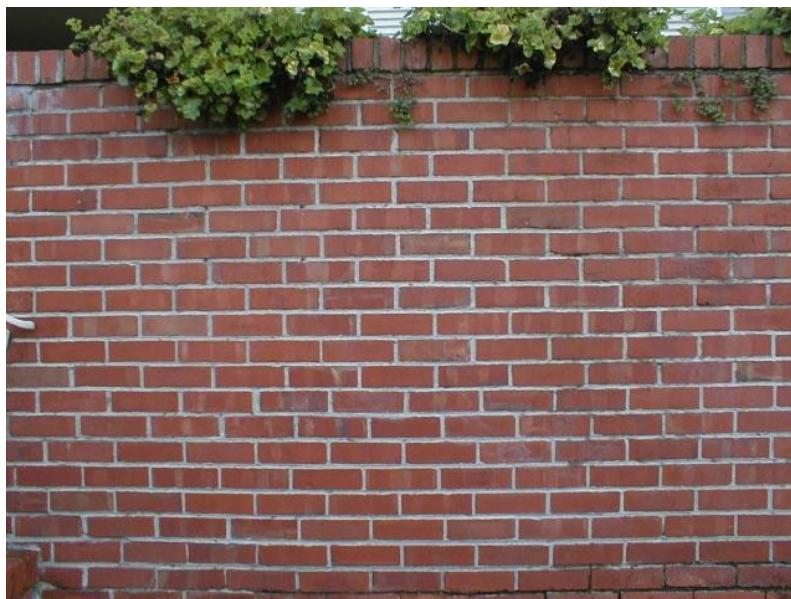


Can you identify these materials, without using color?



What is texture?

- Visual texture is something that everyone understands, but it is difficult to define
- "*Despite its importance and ubiquity in image data, a formal approach or precise definition of texture does not exist.*"
(Haralick, 1979)
- Texture is "*something composed of closely interwoven elements.*"
(Webster's dictionary)
- Texture is "*repeating patterns of local variations in image intensity which are too fine to be distinguished as separate objects at the observed resolution.*"
(Jain, Kasturi, and Schunck, 1995)





<http://animals.nationalgeographic.com/>

Different textures can indicate different objects in the scene

Texture 1



Texture 2



Texture 3



Texture 4



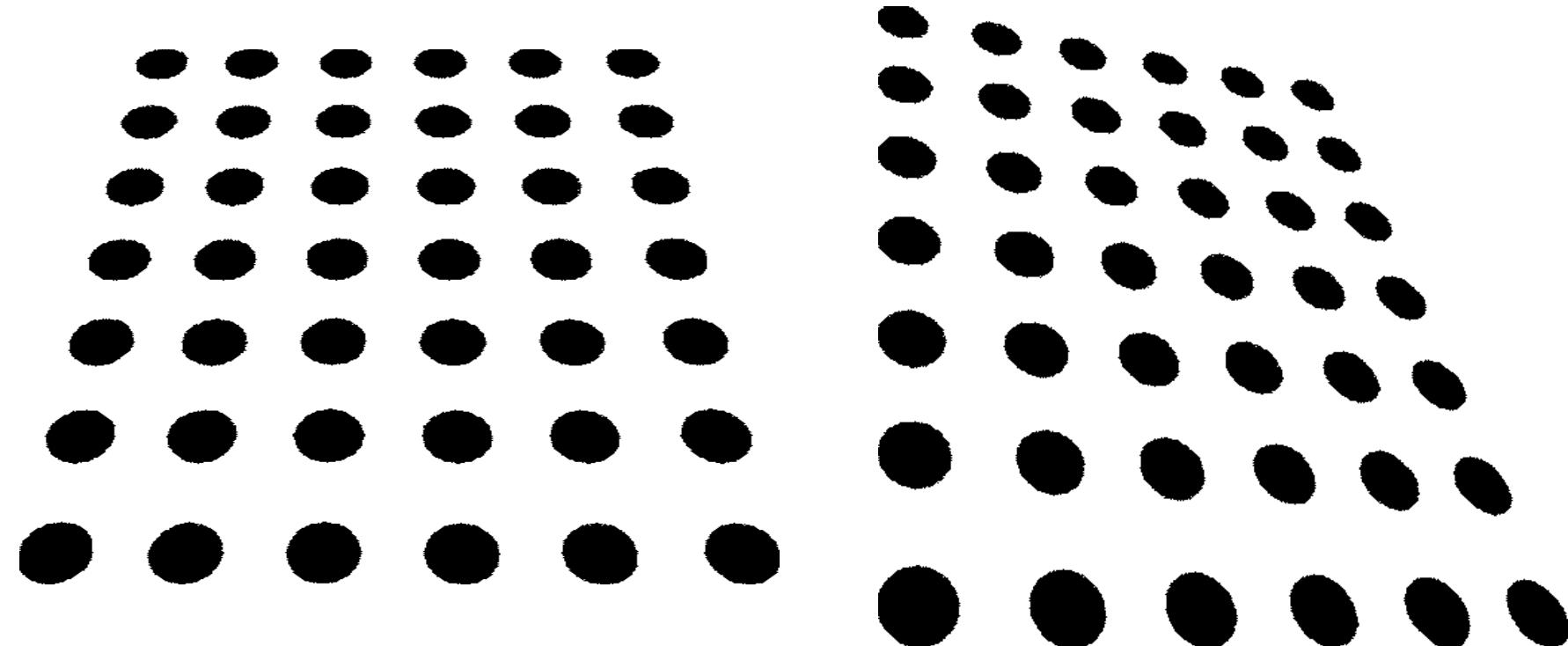
Texture 5



Texture-related tasks

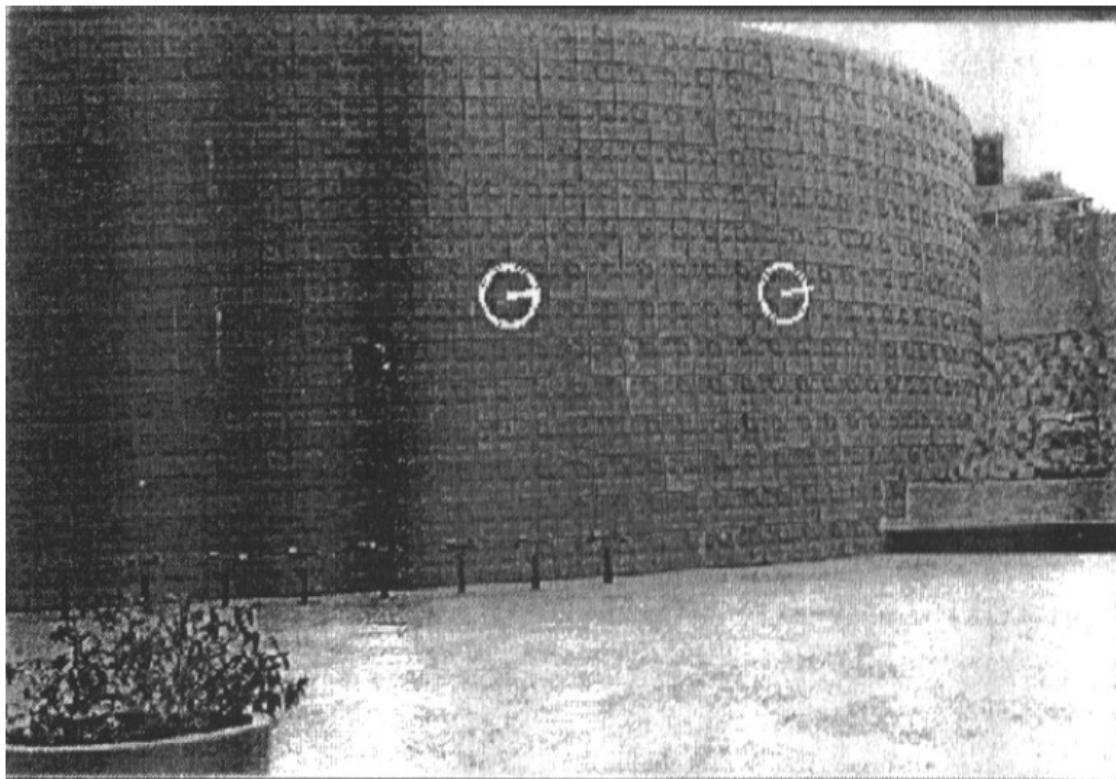
- **Shape from texture**
 - Estimate surface orientation or shape from image texture
- **Segmentation/classification** from texture cues
 - Analyze, represent texture
 - Subdivide an image into regions with consistent texture
 - Search other images for matching texture regions
- **Synthesis**
 - Generate new texture patches/images,
given some examples

Even very simple textures can convey depth information

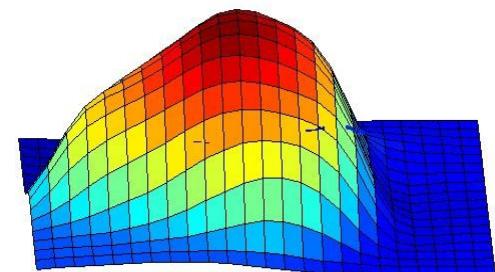
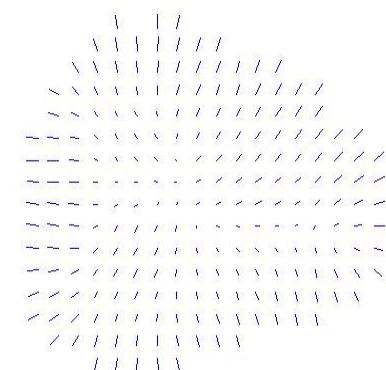


Shape from texture

- Use deformation of texture from point to point to estimate surface shape



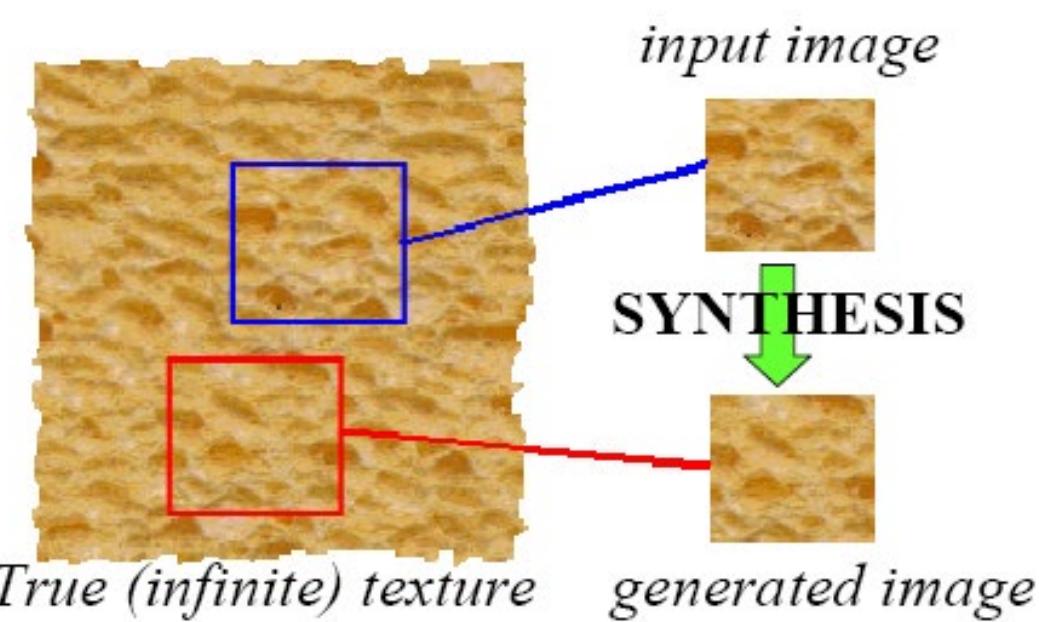
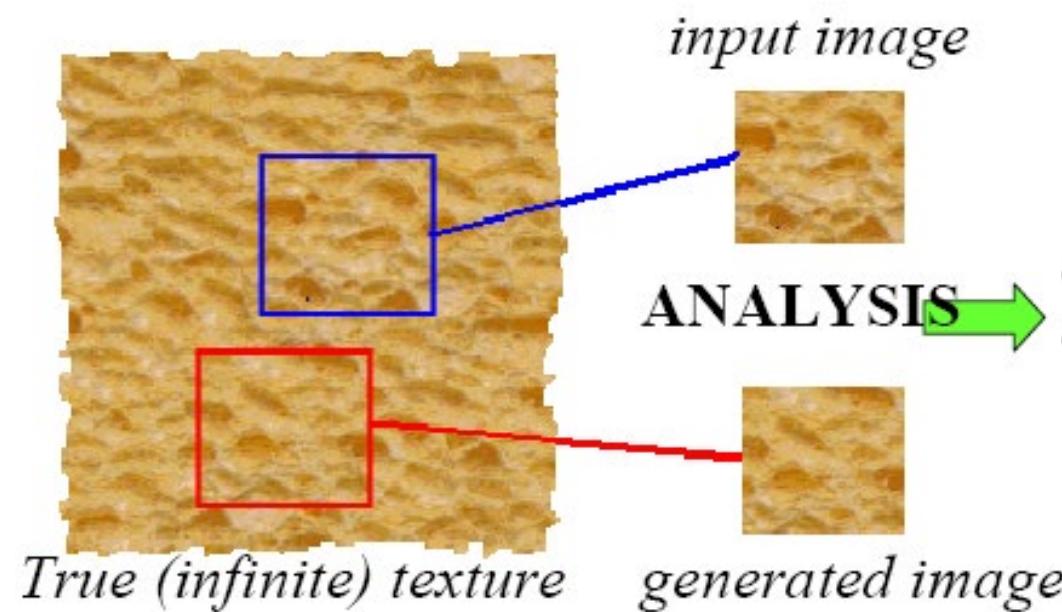
(Credit: A. Loh)



Texture-related tasks

- **Shape from texture**
 - Estimate surface orientation or shape from image texture
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Analysis vs. Synthesis



(Images: Freeman, Efros)

Why analyze texture?

Importance to perception:

- Often indicative of a material's properties
- Can be important appearance cue, especially if shape is similar across objects
- Aim to distinguish between shape, boundaries, and texture

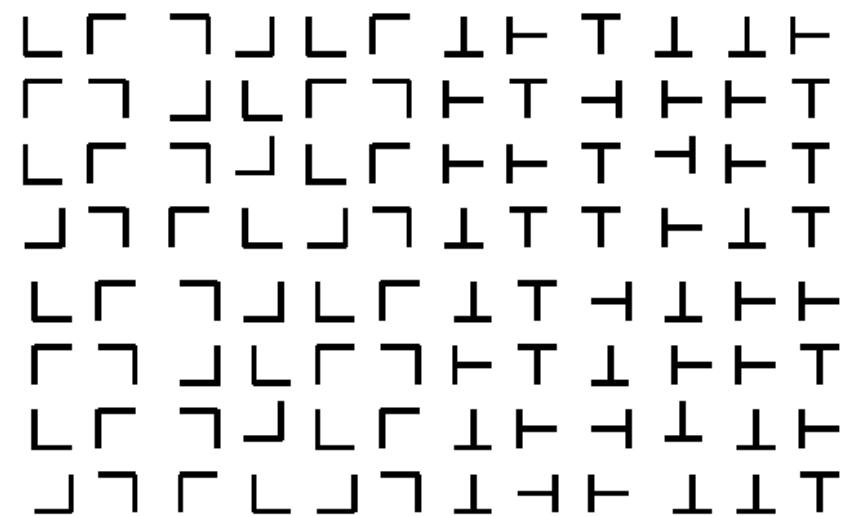
Technically:

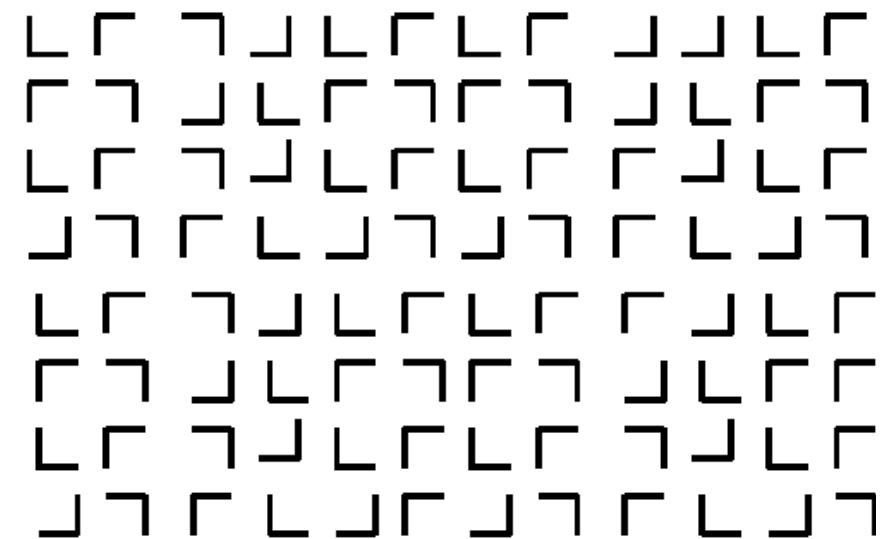
- To represent a texture, we want a feature descriptor that's one step above "building blocks" of filters or intensity edges

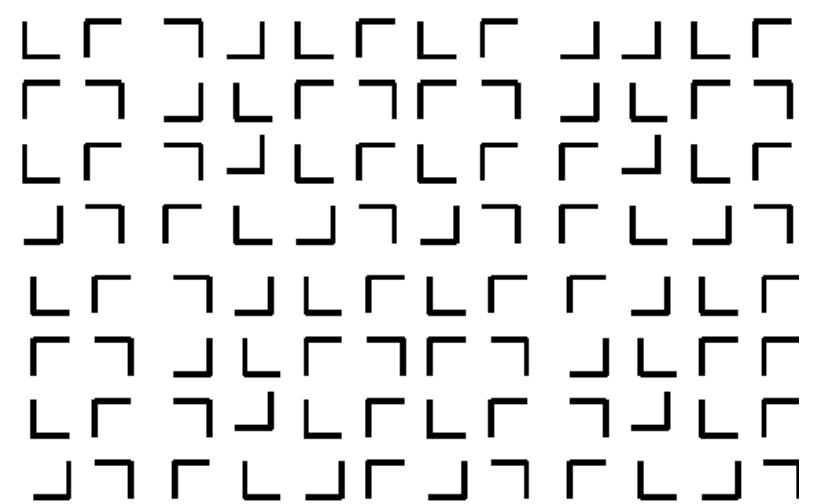
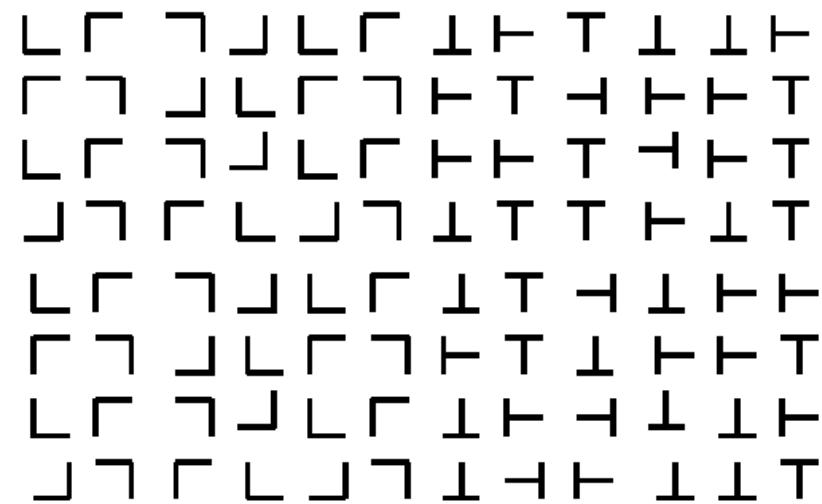
Psychophysics of texture

- Some textures are distinguishable with *preattentive* perception – without scrutiny, eye movements [Julesz, 1975]

In the following slides, are the two sections the same or different?

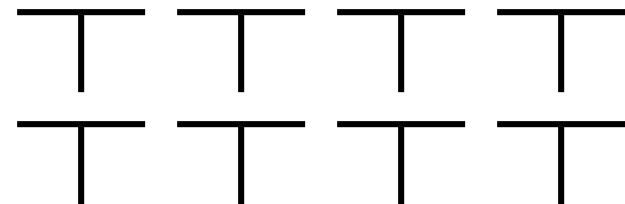
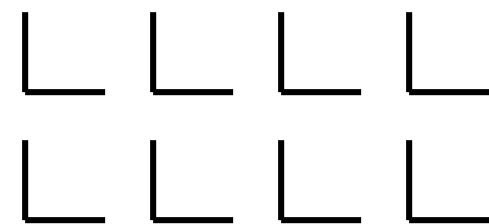






Julesz analyzed texture in terms of statistical relationships between fundamental texture elements, called “textons” or “texels”

- It generally required a human to look at the texture in order to decide what those fundamental units were...



Texture representation

- Textures are made up of repeated local patterns, so:
 - Find the patterns
 - Use filters that look like small shapes of interest (spots, bars, raw patches...)
 - Consider magnitude of response
 - Describe their statistics within each local window
 - Mean, standard deviation
 - Histogram
 - Histogram of “prototypical” feature occurrences

Texture representation: example



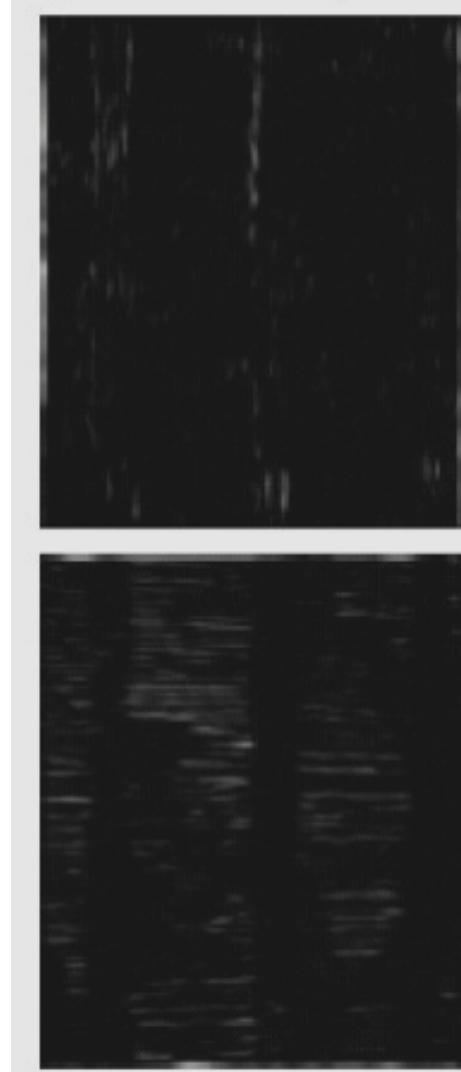
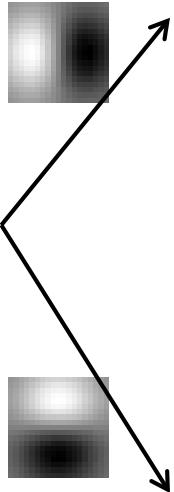
original image

(Credit: Grauman)

Texture representation: example



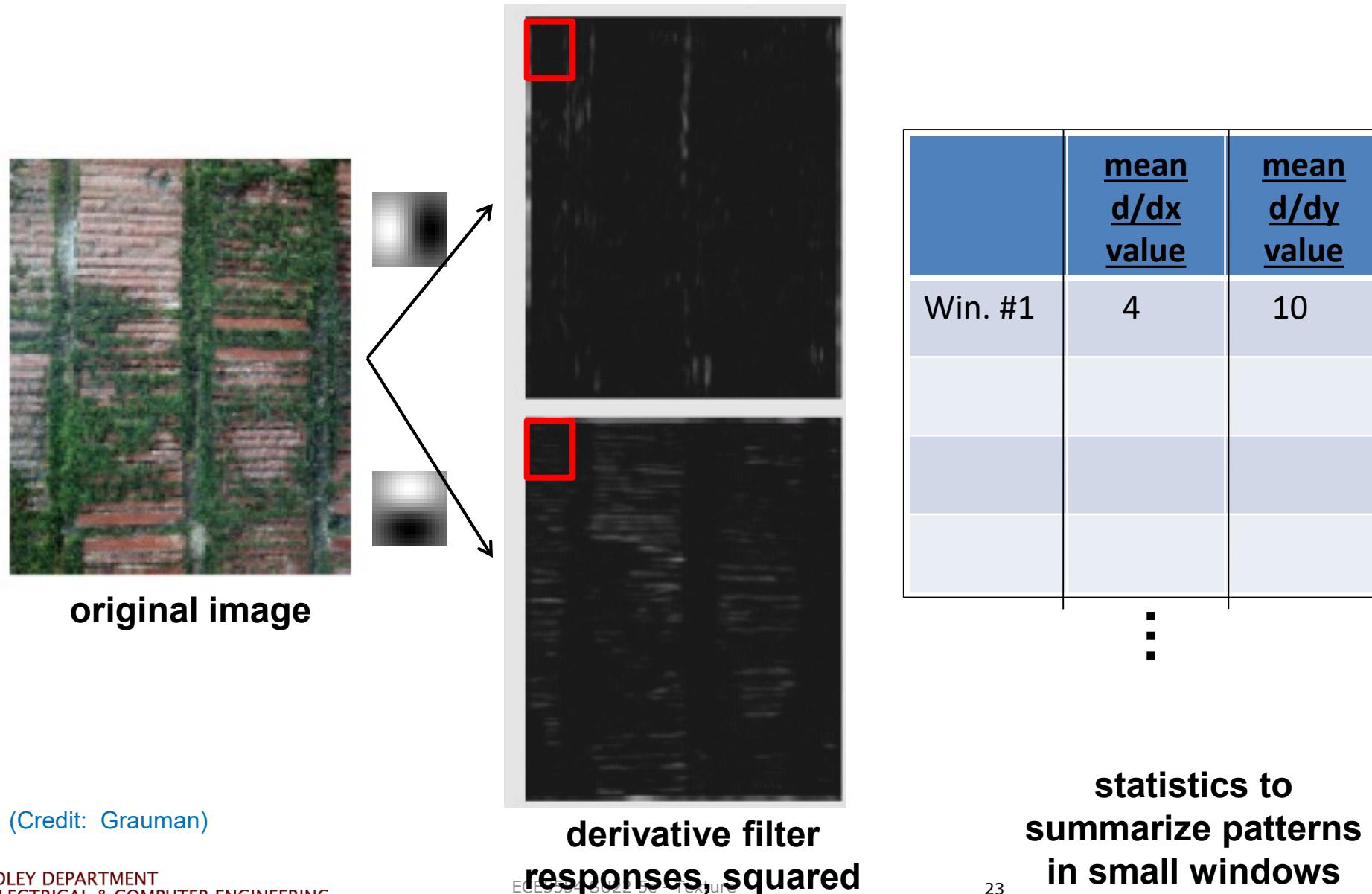
original image



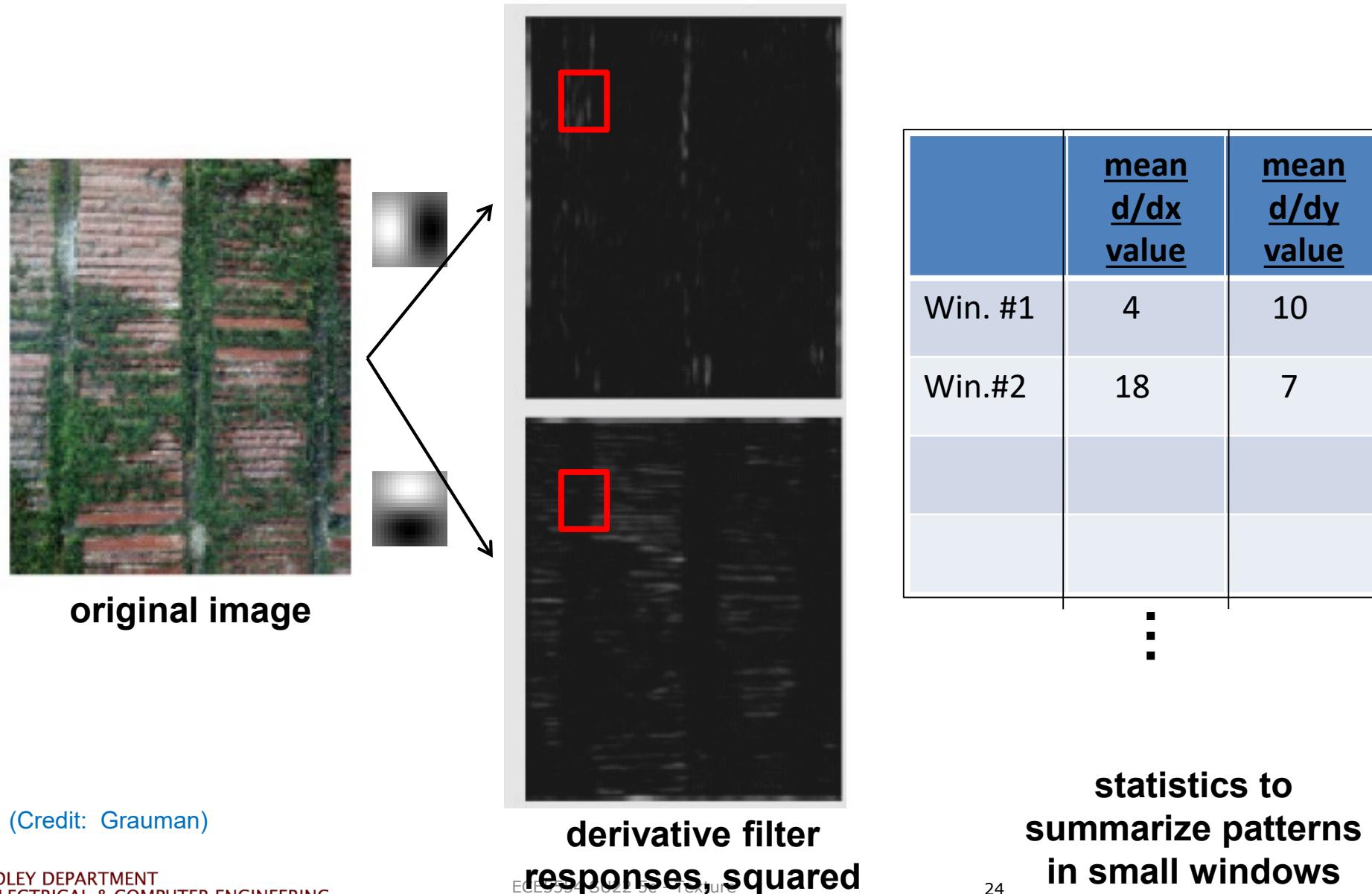
derivative filter
responses, squared

(Credit: Grauman)

Texture representation: example

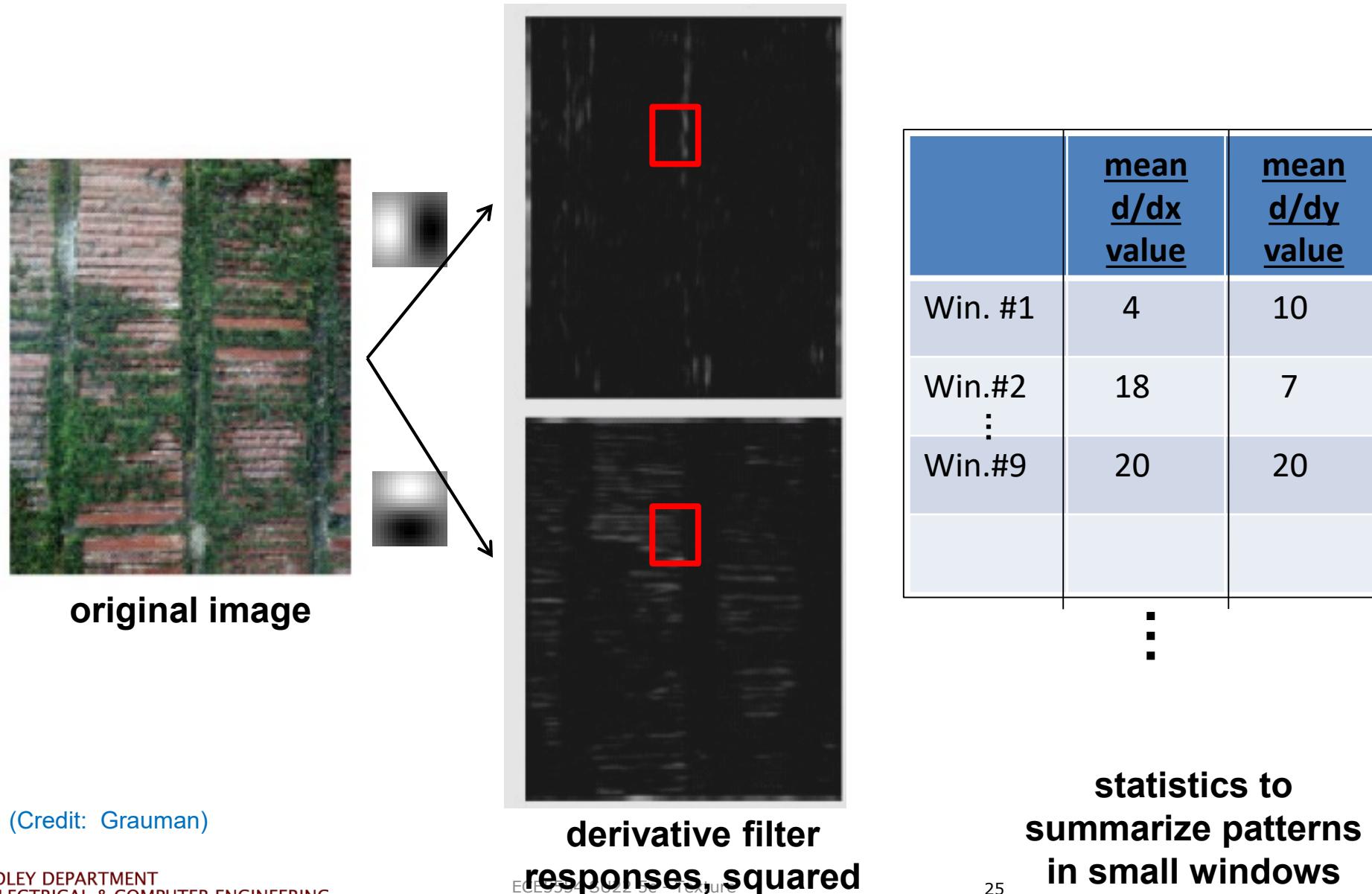


Texture representation: example



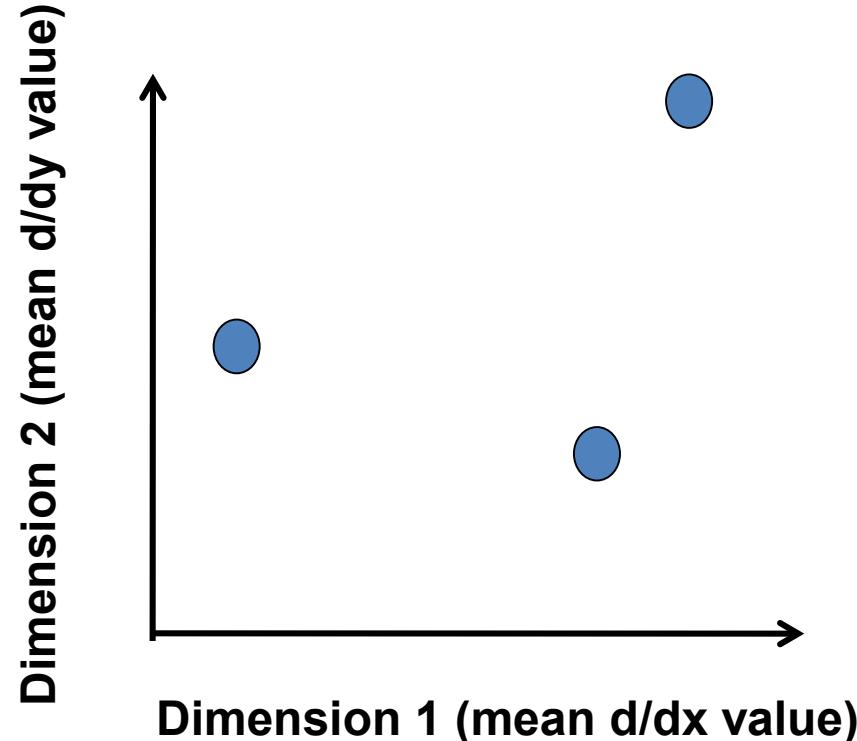
**statistics to
summarize patterns
in small windows**

Texture representation: example



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Texture representation: example

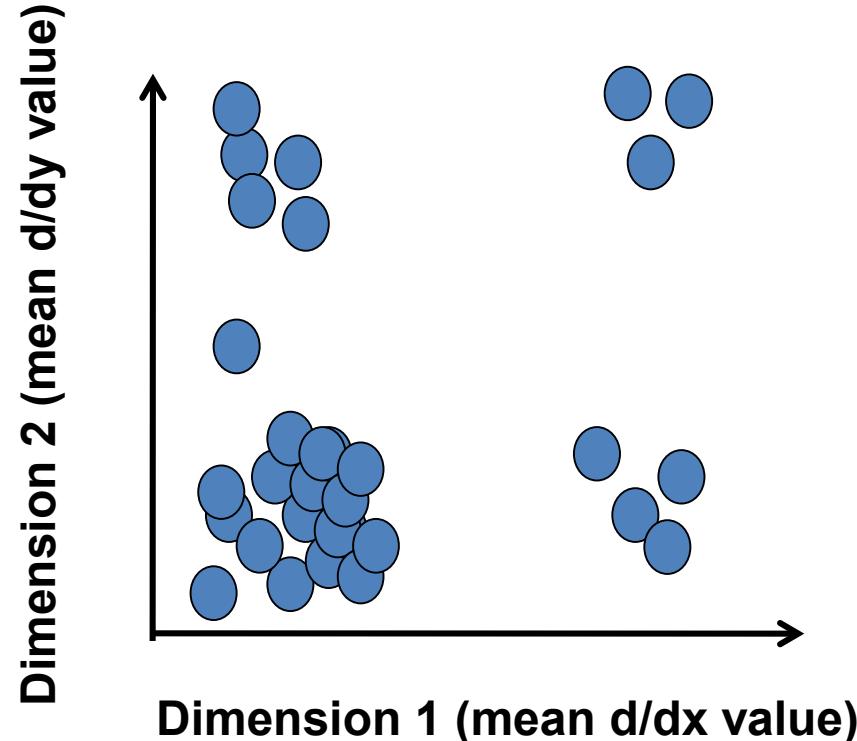


	<u>mean d/dx value</u>	<u>mean d/dy value</u>
Win. #1	4	10
Win.#2	18	7
⋮	⋮	⋮
Win.#9	20	20
⋮	⋮	⋮

(Credit: Grauman)

**statistics to
summarize patterns
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Texture representation: example

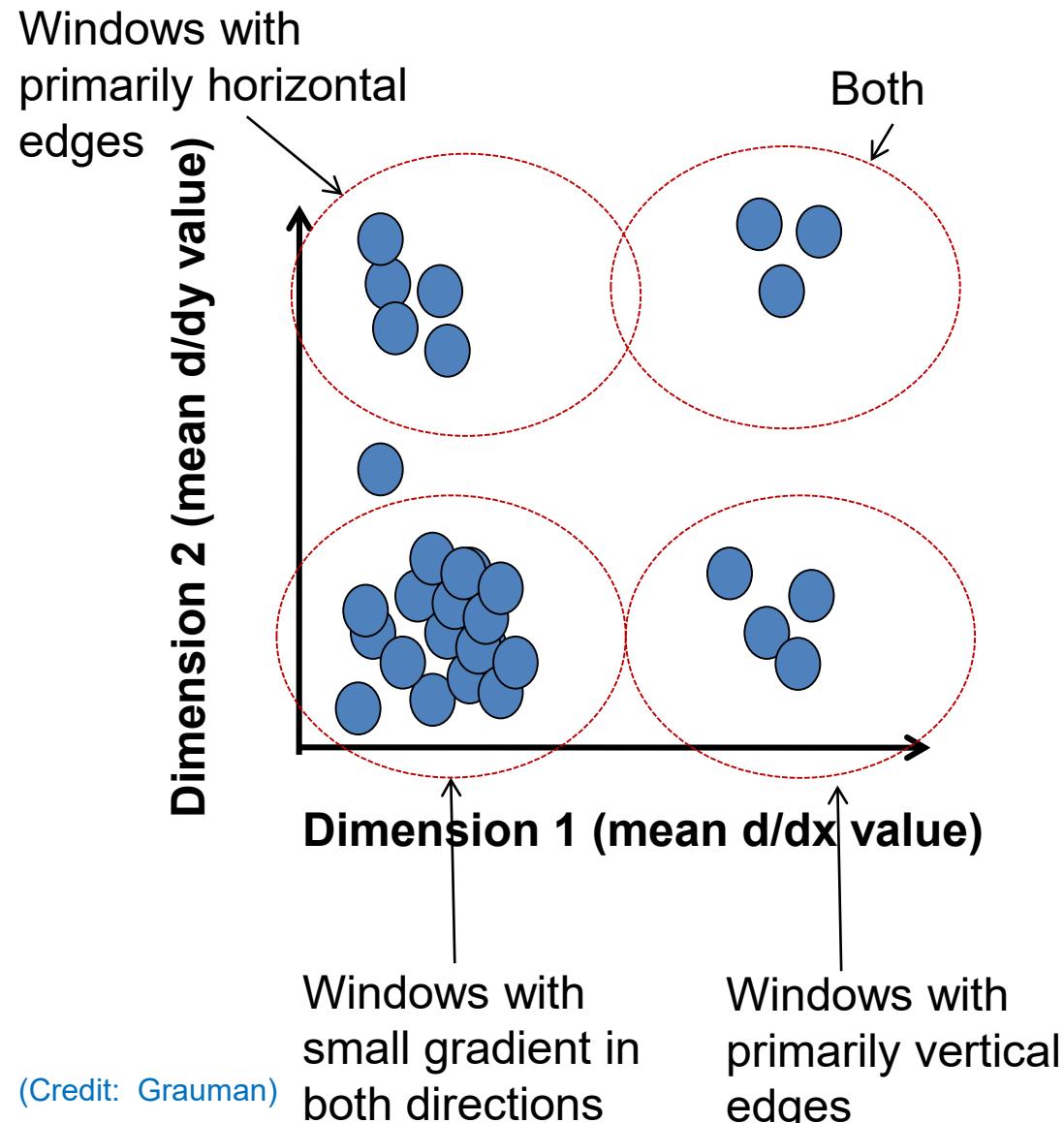


	<u>mean d/dx value</u>	<u>mean d/dy value</u>
Win. #1	4	10
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Texture representation: example



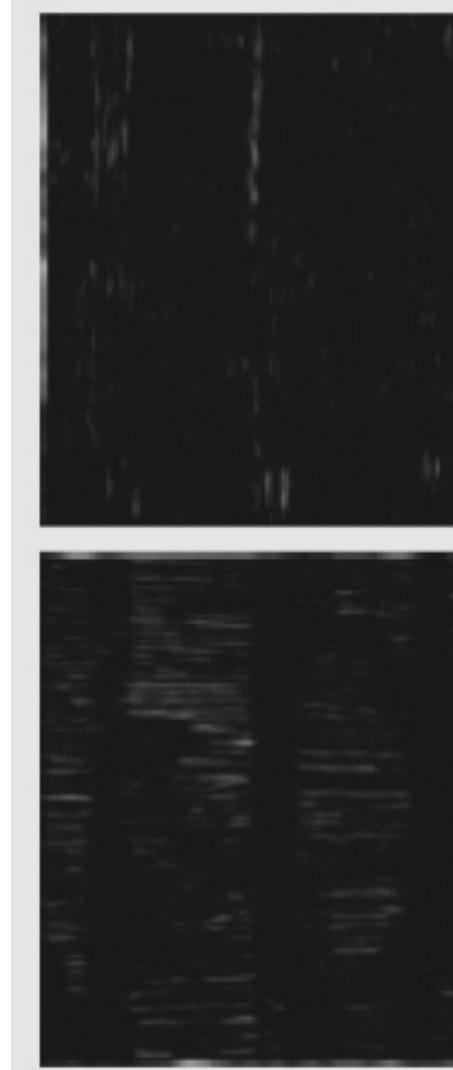
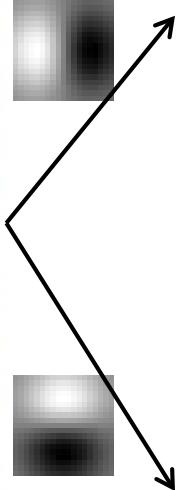
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statistics to summarize patterns in small windows

Texture representation: example



original image

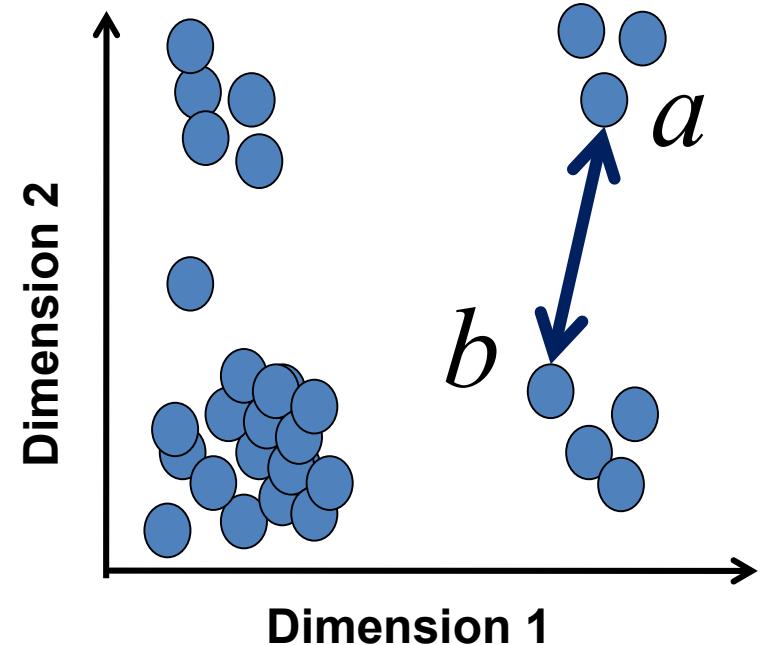


derivative filter
responses, squared

(Credit: Grauman)



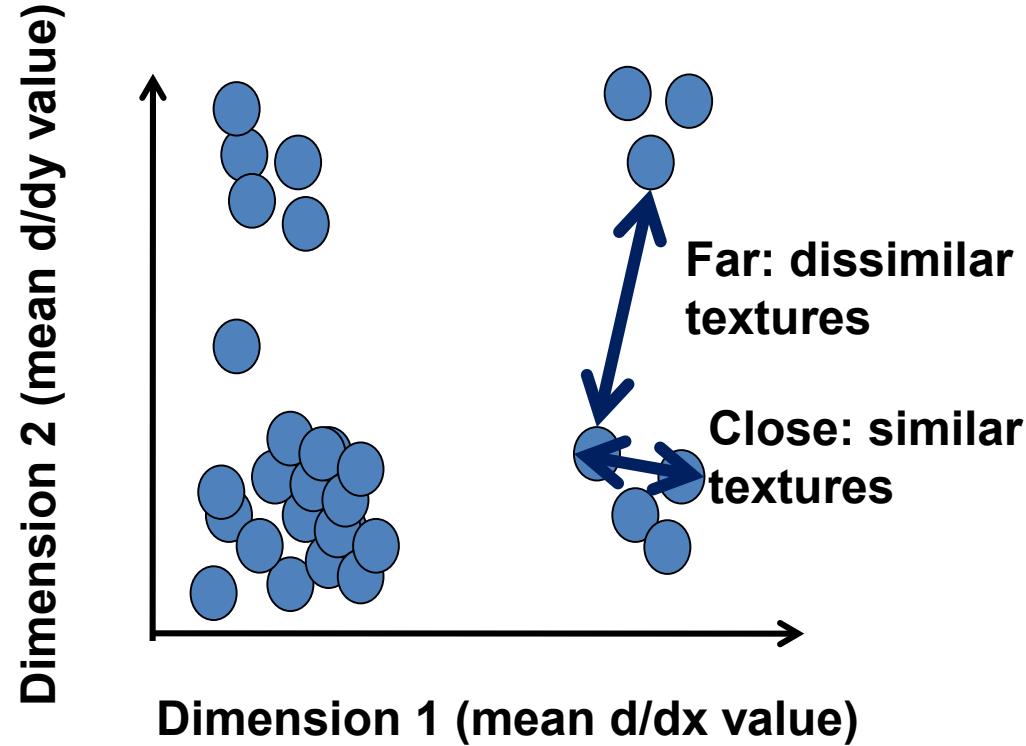
Texture representation: example



$$D(a,b) = \sqrt{(a_1 - b_1)^2 + (a_2 - b_2)^2}$$

(Credit: Grauman)

Texture representation: example



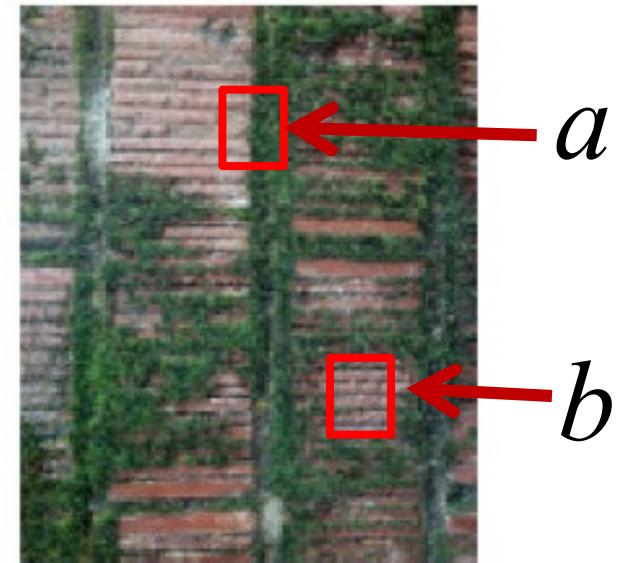
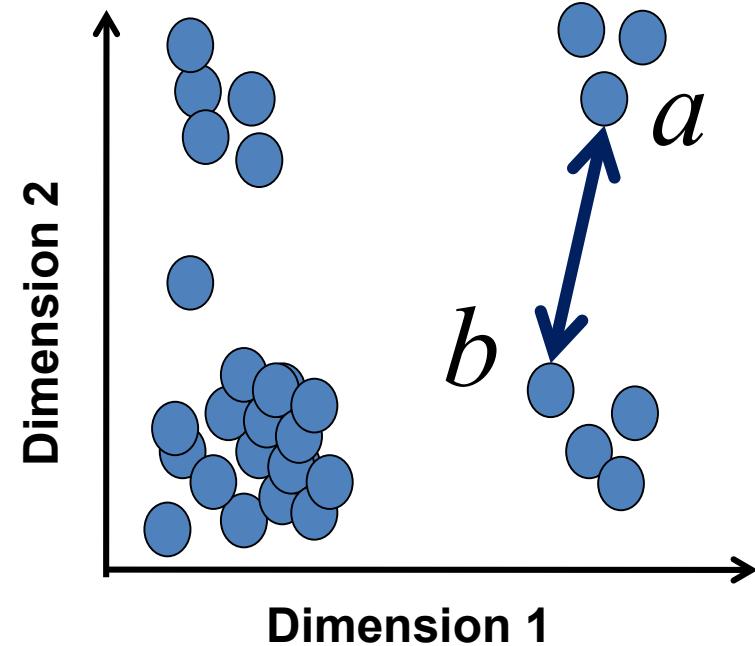
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Win. #1	4	10
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:	:	
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⋮

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**statistics to
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in small windows**

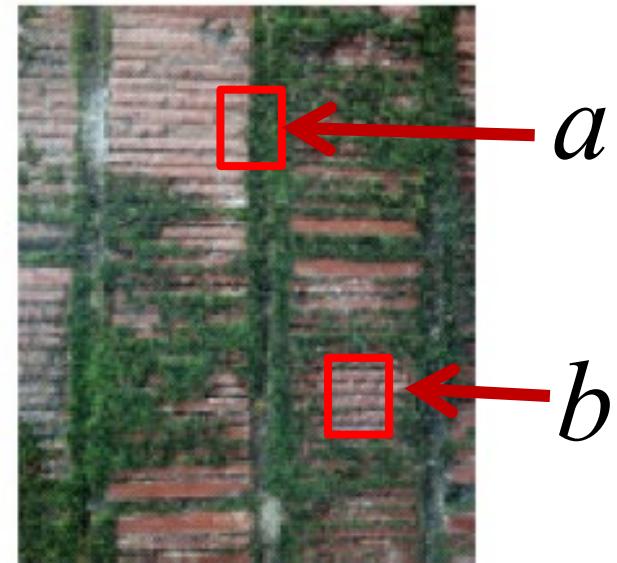
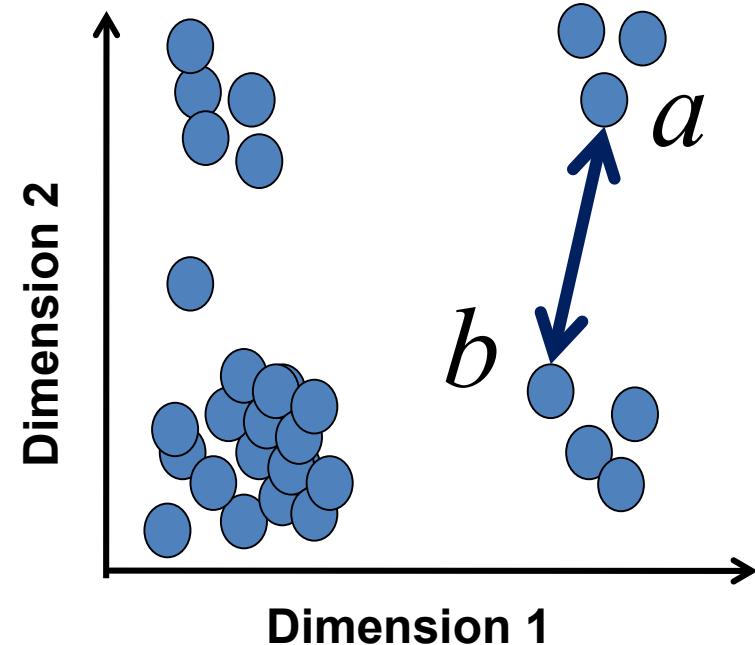
Texture representation: example



Distance is a measure of how dissimilar texture from window a is from texture in window b.

(Credit: Grauman)

Texture representation: example

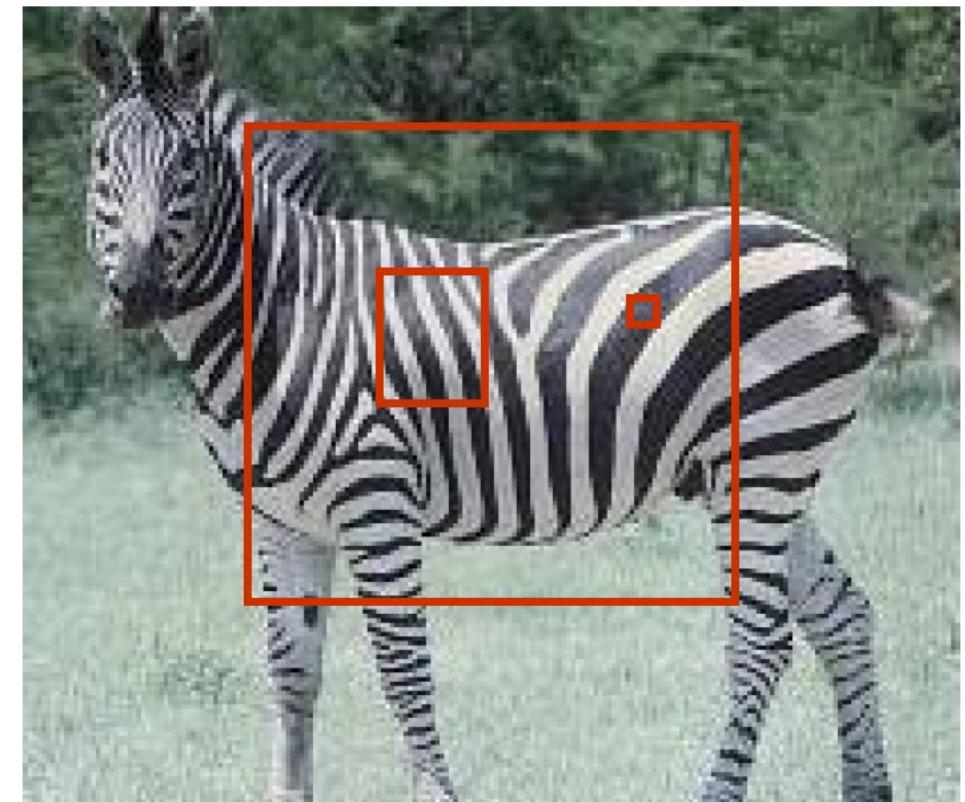


Distance is a measure of how dissimilar texture from window a is from texture in window b.

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Texture representation: window scale

- We're assuming that we know the relevant window size for which we collect these statistics
- It is possible to perform scale selection by looking for window scale where texture description is not changing



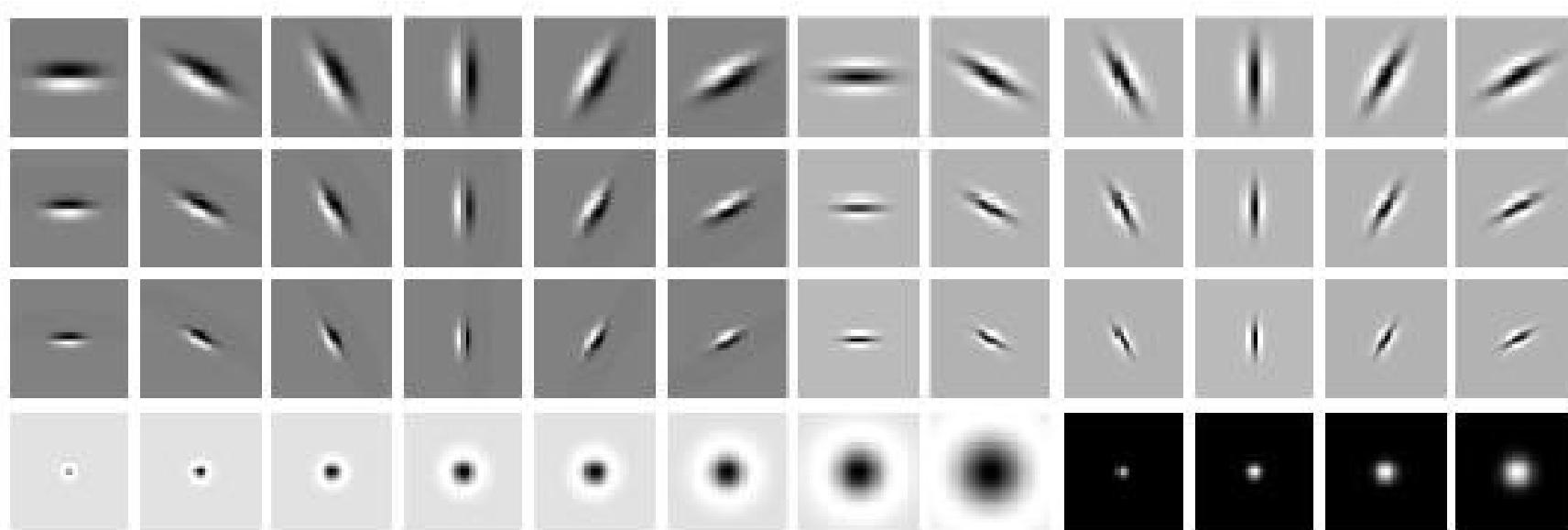
(Credit: Grauman)

Filter banks

- Our previous example used two filters, and resulted in a 2-dimensional feature vector to describe texture in a window
 - x and y derivatives revealed something about local structure
- We can generalize to apply a collection of multiple (d) filters: a “filter bank”
- Then our feature vectors will be d -dimensional

(Credit: Grauman)

Filter banks

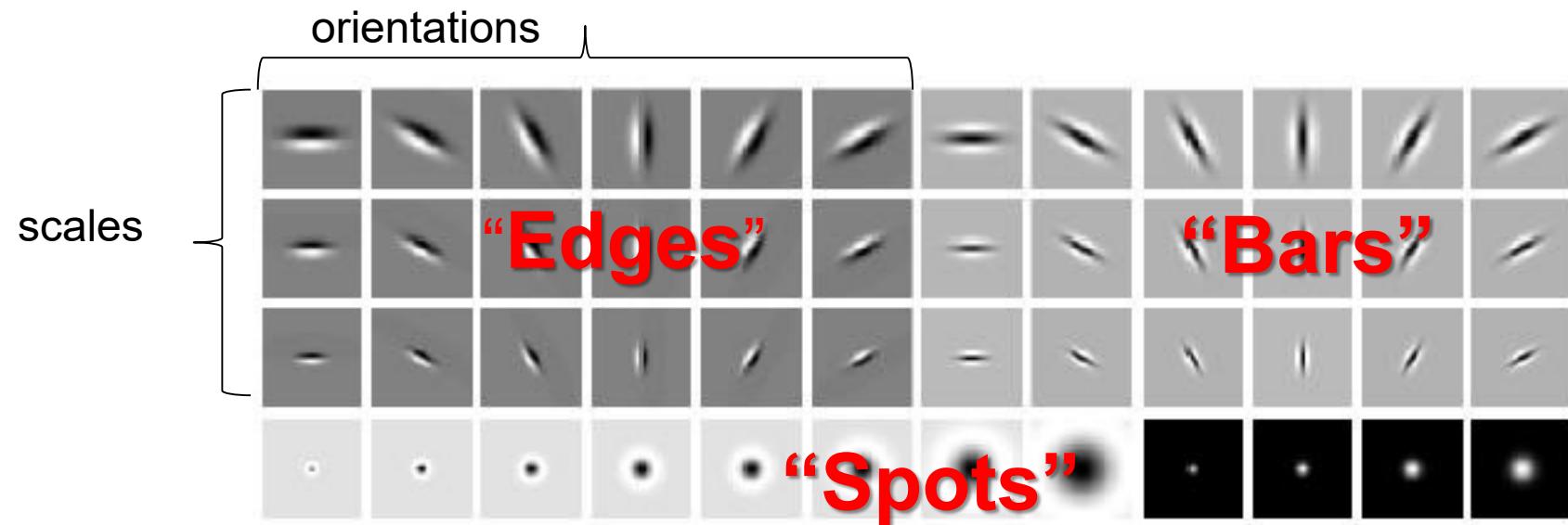


- What filters to put in the bank?
 - Typically we want a combination of scales and orientations, different types of patterns
 - The one above is called the Leung-Malik (LM) filter bank (Leung and Malik, 2001)

opencv code for these filters:

https://github.com/CVDLBOT/LM_filter_bank_python_code

Filter banks



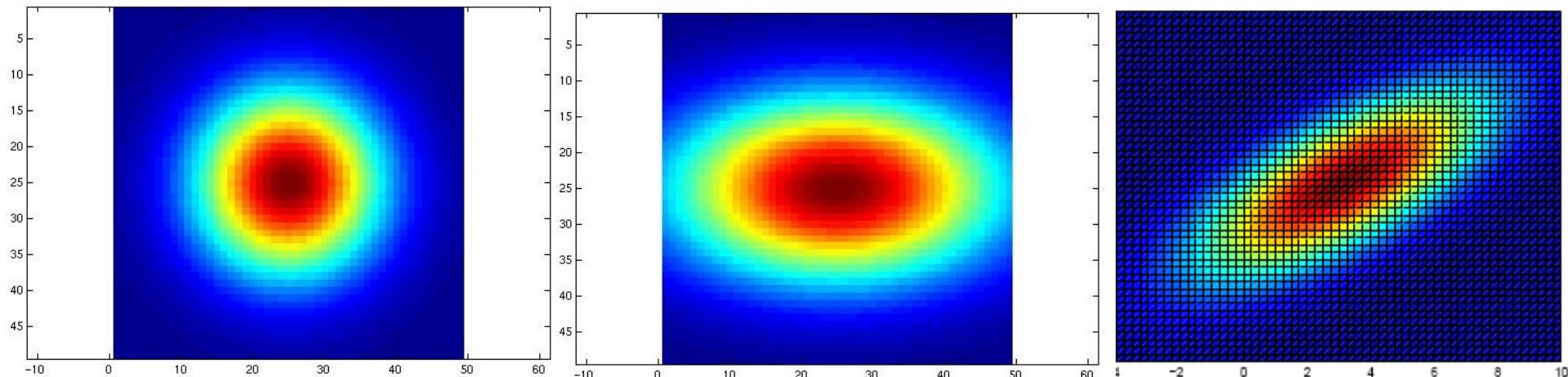
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Multivariate Gaussian

$$p(x; \mu, \Sigma) = \frac{1}{(2\pi)^{n/2} |\Sigma|^{1/2}} \exp \left(-\frac{1}{2} (x - \mu)^T \Sigma^{-1} (x - \mu) \right)$$

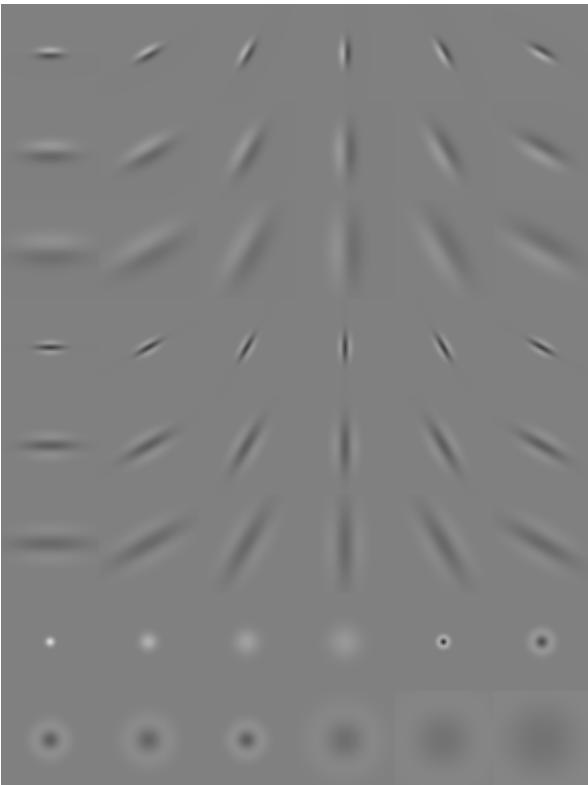


$$\Sigma = \begin{bmatrix} 9 & 0 \\ 0 & 9 \end{bmatrix}$$

$$\Sigma = \begin{bmatrix} 16 & 0 \\ 0 & 9 \end{bmatrix}$$

$$\Sigma = \begin{bmatrix} 10 & 5 \\ 5 & 5 \end{bmatrix}$$

The Leung and
Malik filters will
have high
response to areas
of various
frequency and
orientation



By forming histograms of the responses to these filters in a region of interest, we can characterize different textures

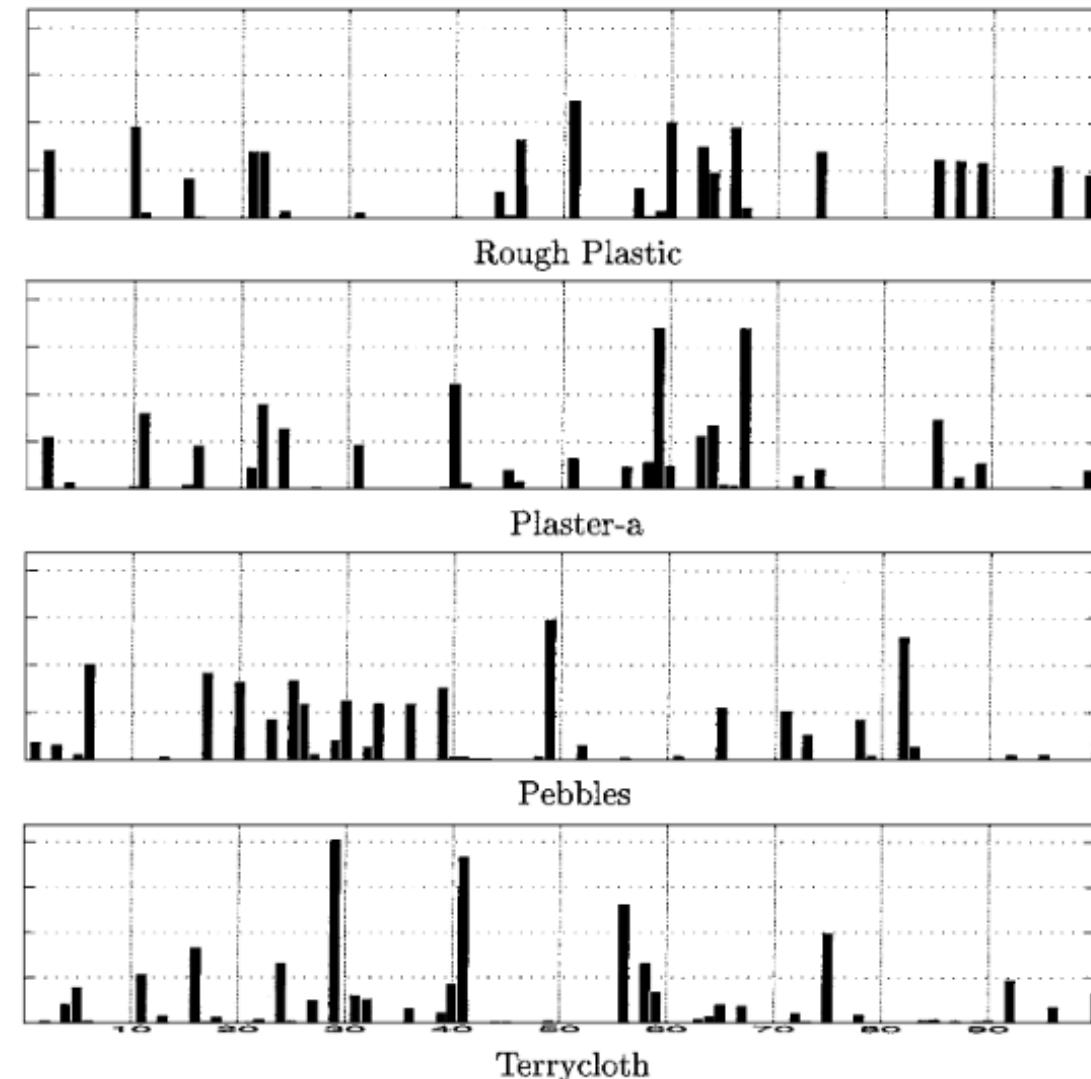
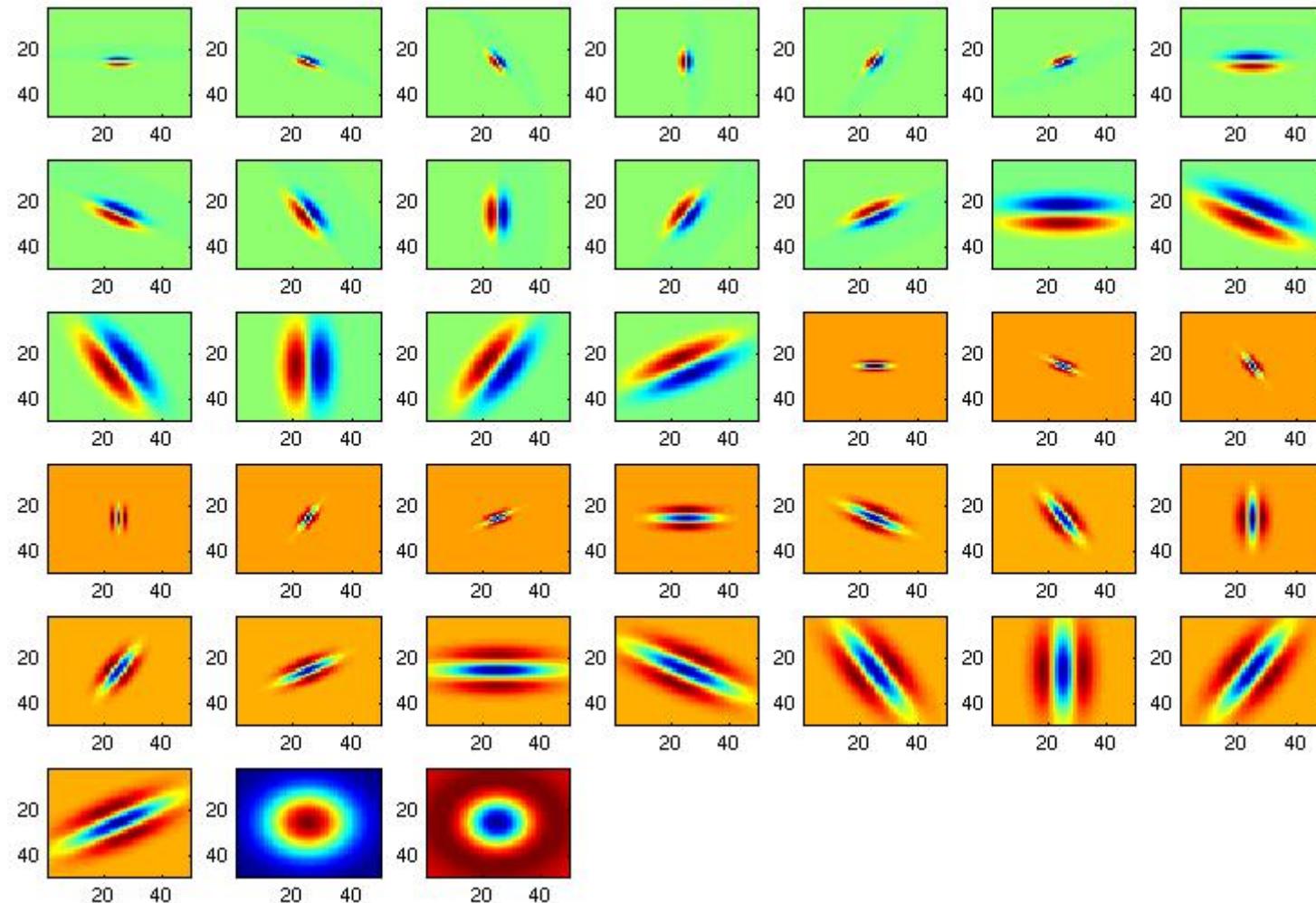


Figure 8. Top to bottom: the histograms of labels for the materials: “Rough Plastic”, “Plaster-a”, “Pebbles,” and “Terrycloth” respectively. These histograms are used as the material representation for the task of texture recognition. The histograms are very different from each other, thus allowing good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

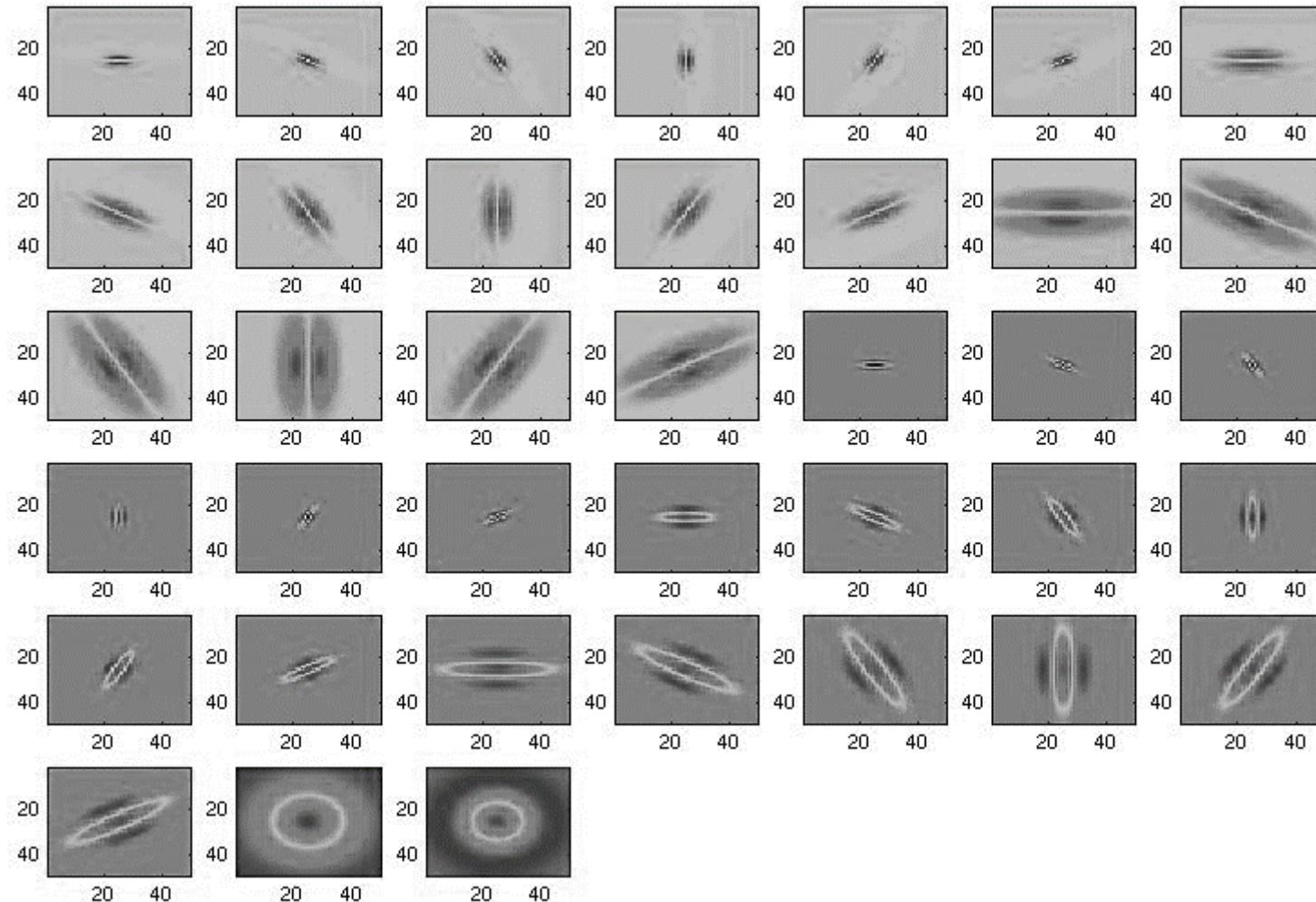
(Credit: Leung and Malik)

Another filter bank; note – the pseudocolor is just to show positive (blue) and negative (red) values



(Credit: Grauman)

Another filter bank; note – the pseudocolor is just to show positive (blue) and negative (red) values



(Credit: Grauman)

Image from <http://www.texasexplorer.com/austincap2.jpg>



Let's apply this filter bank to the entire image to get an idea of the responses to it by various image sections

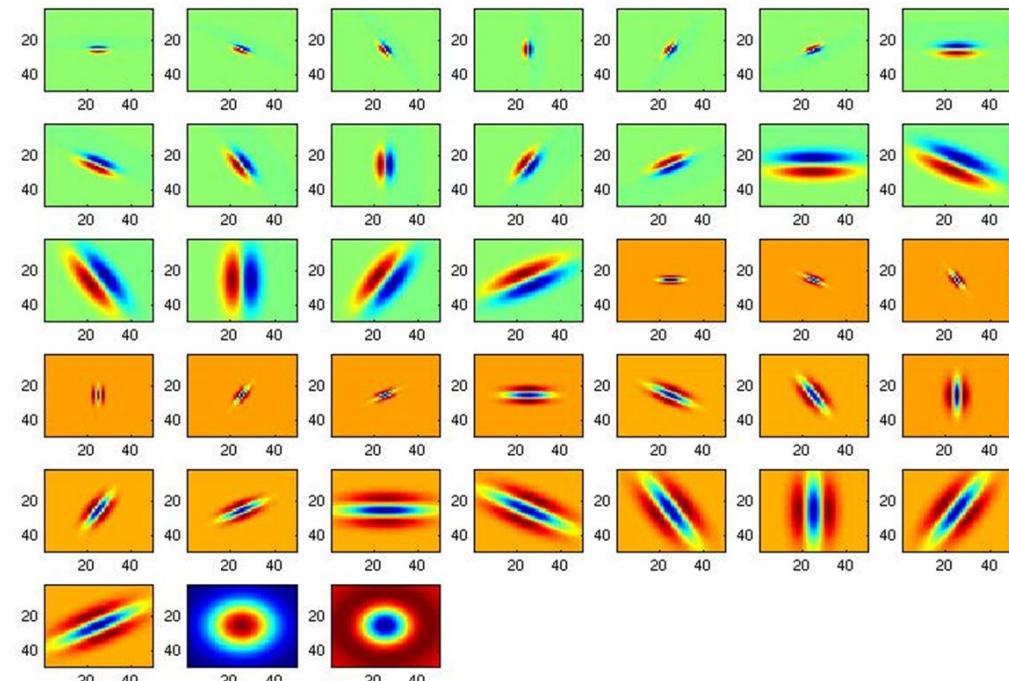
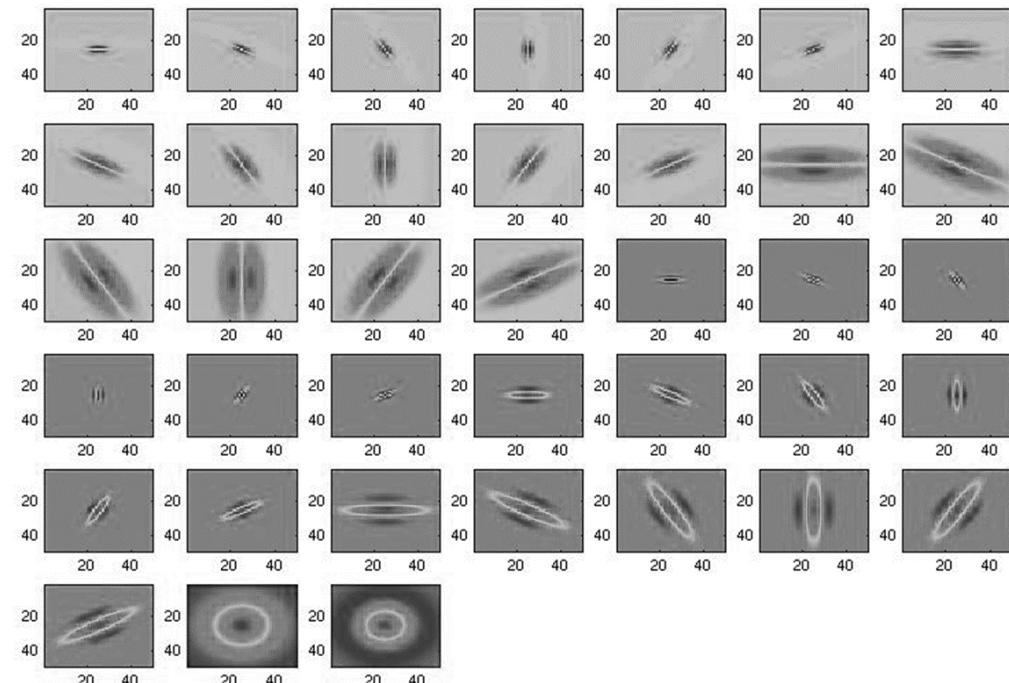
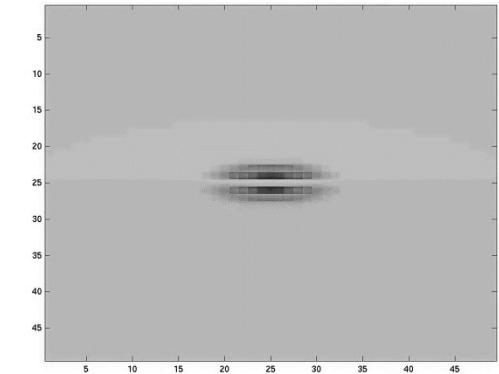
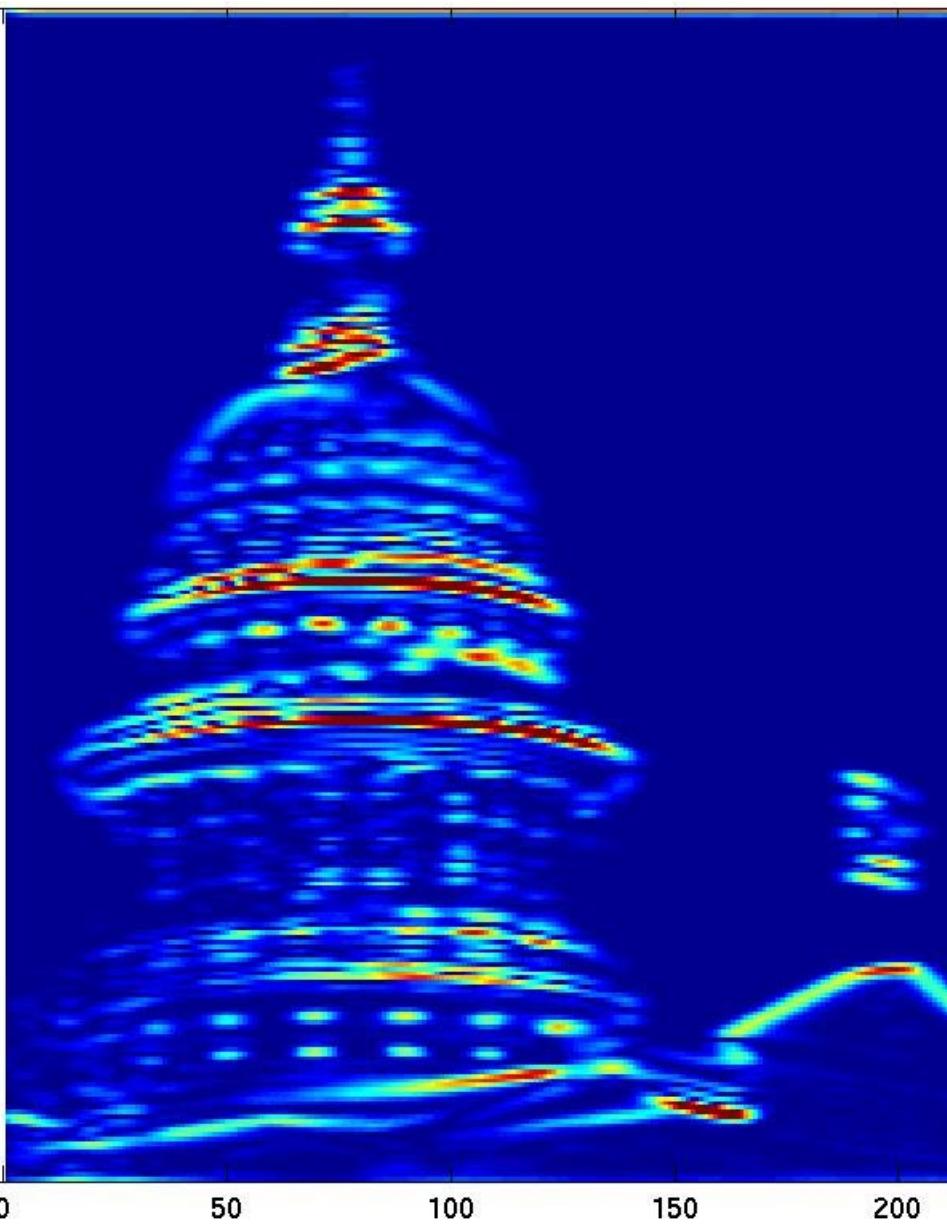


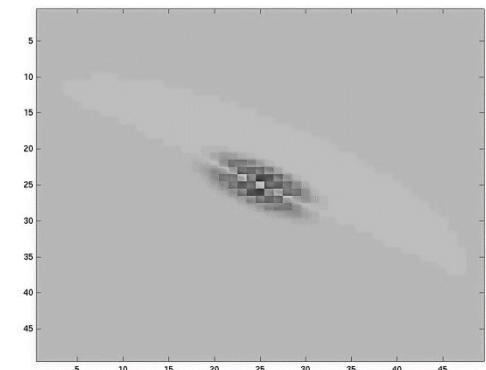
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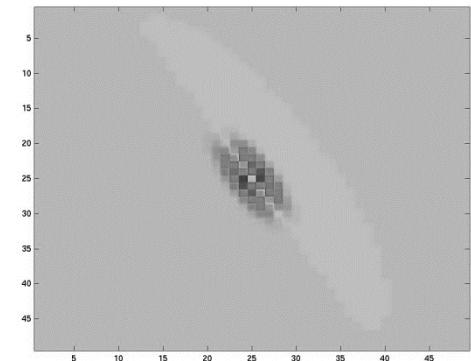






250
-50

0 50 100 150 200 250





250

-50

0

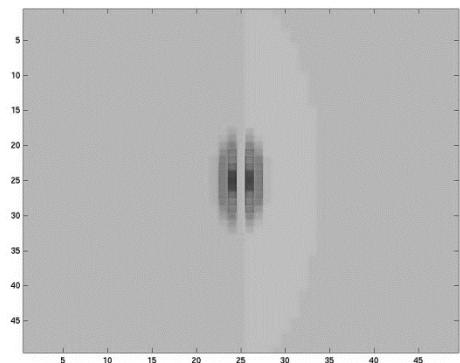
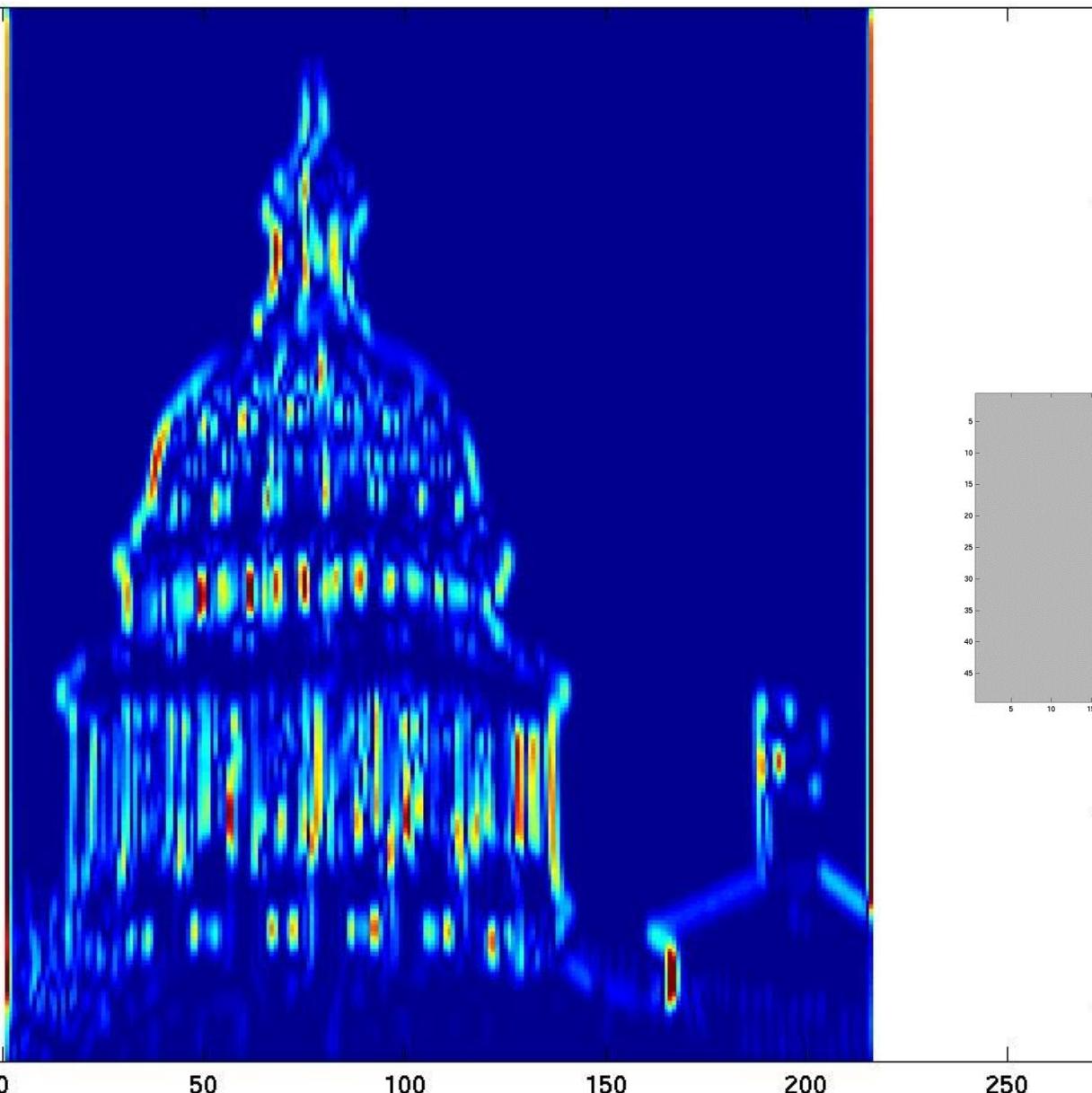
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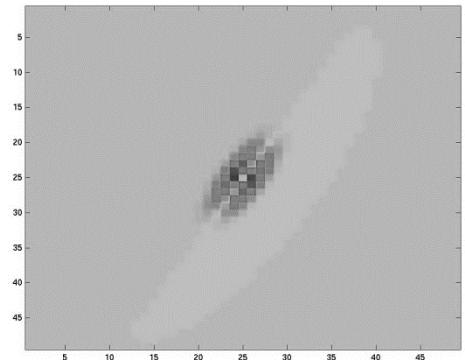
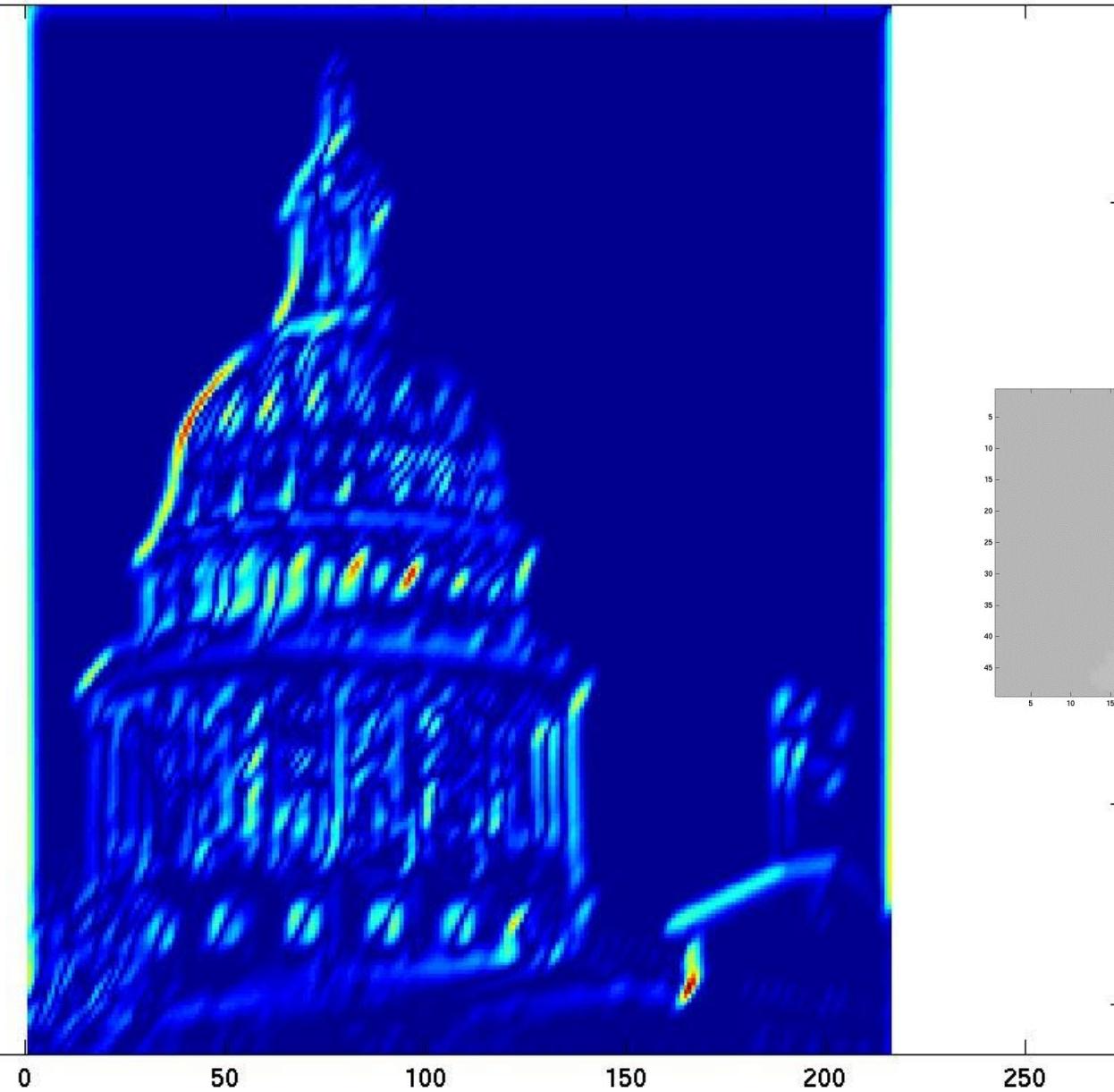
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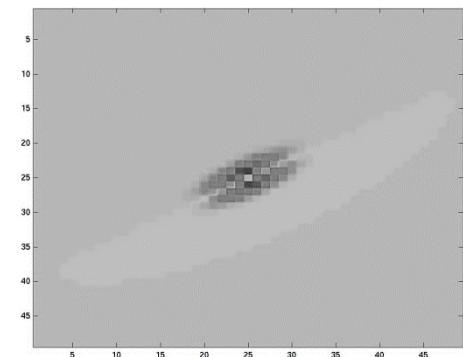
150

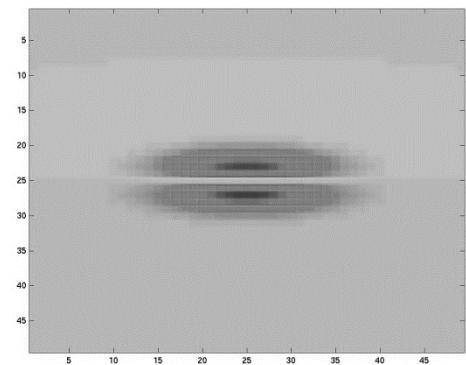
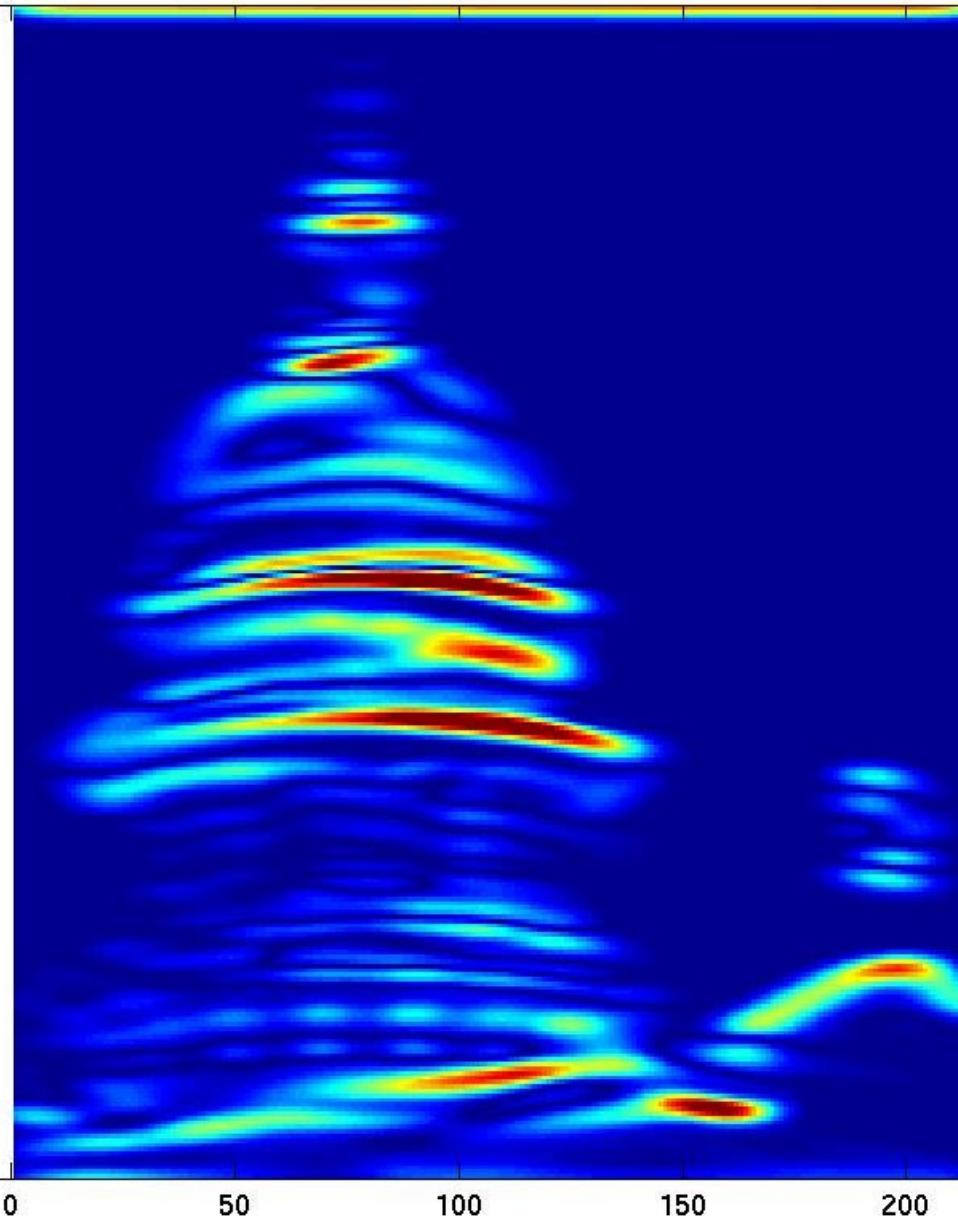
200

250











250

-50

0

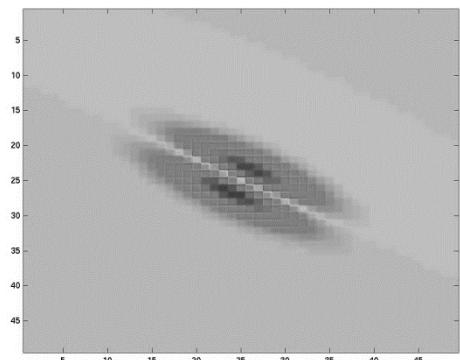
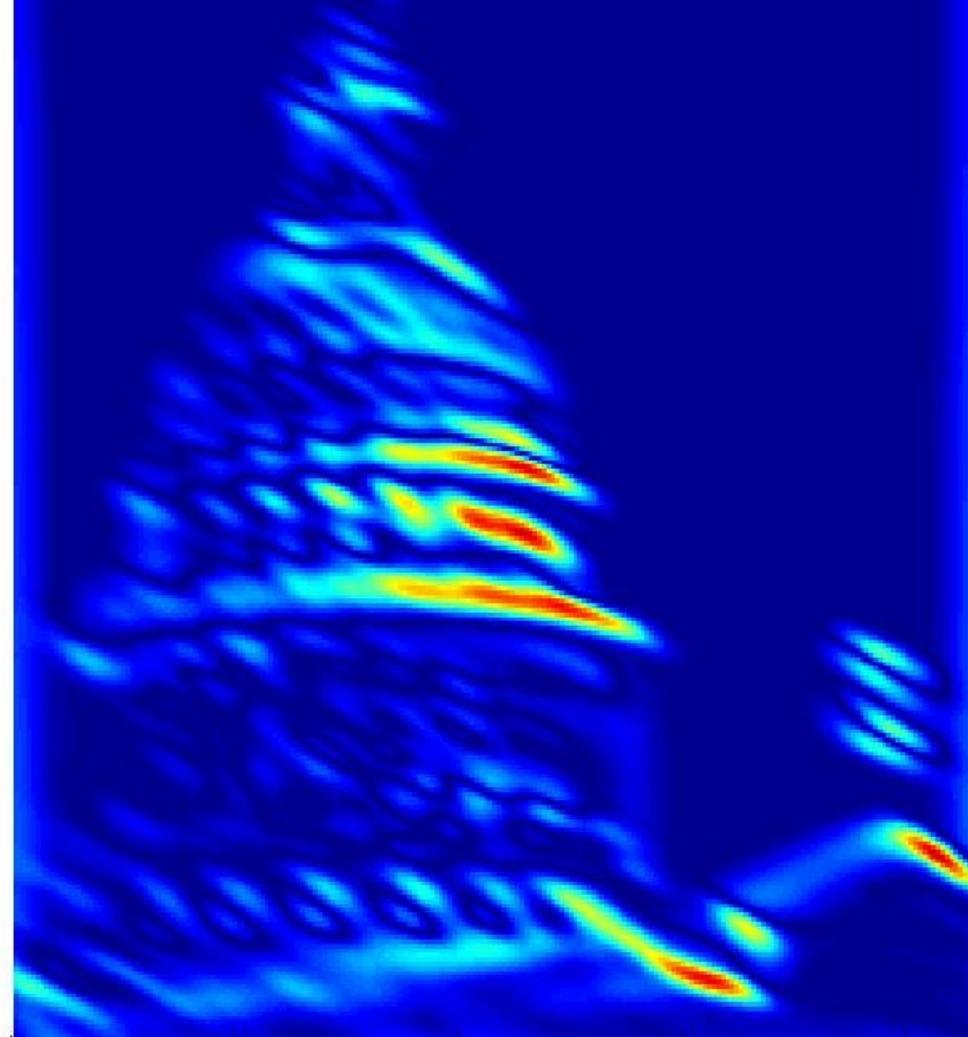
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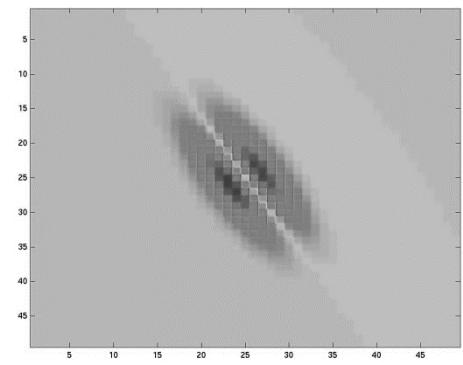
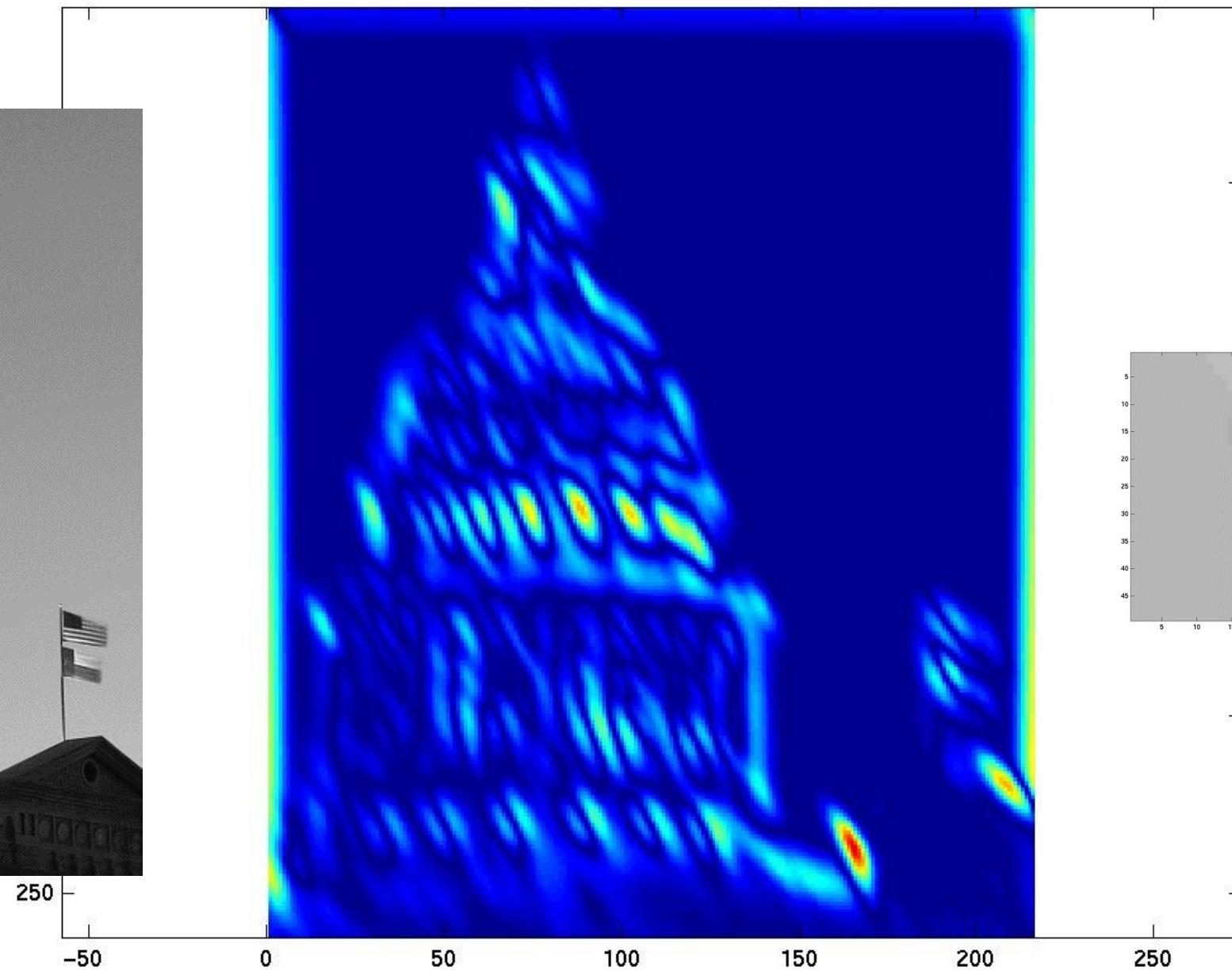
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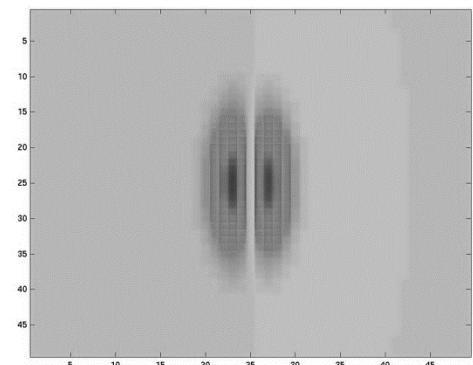
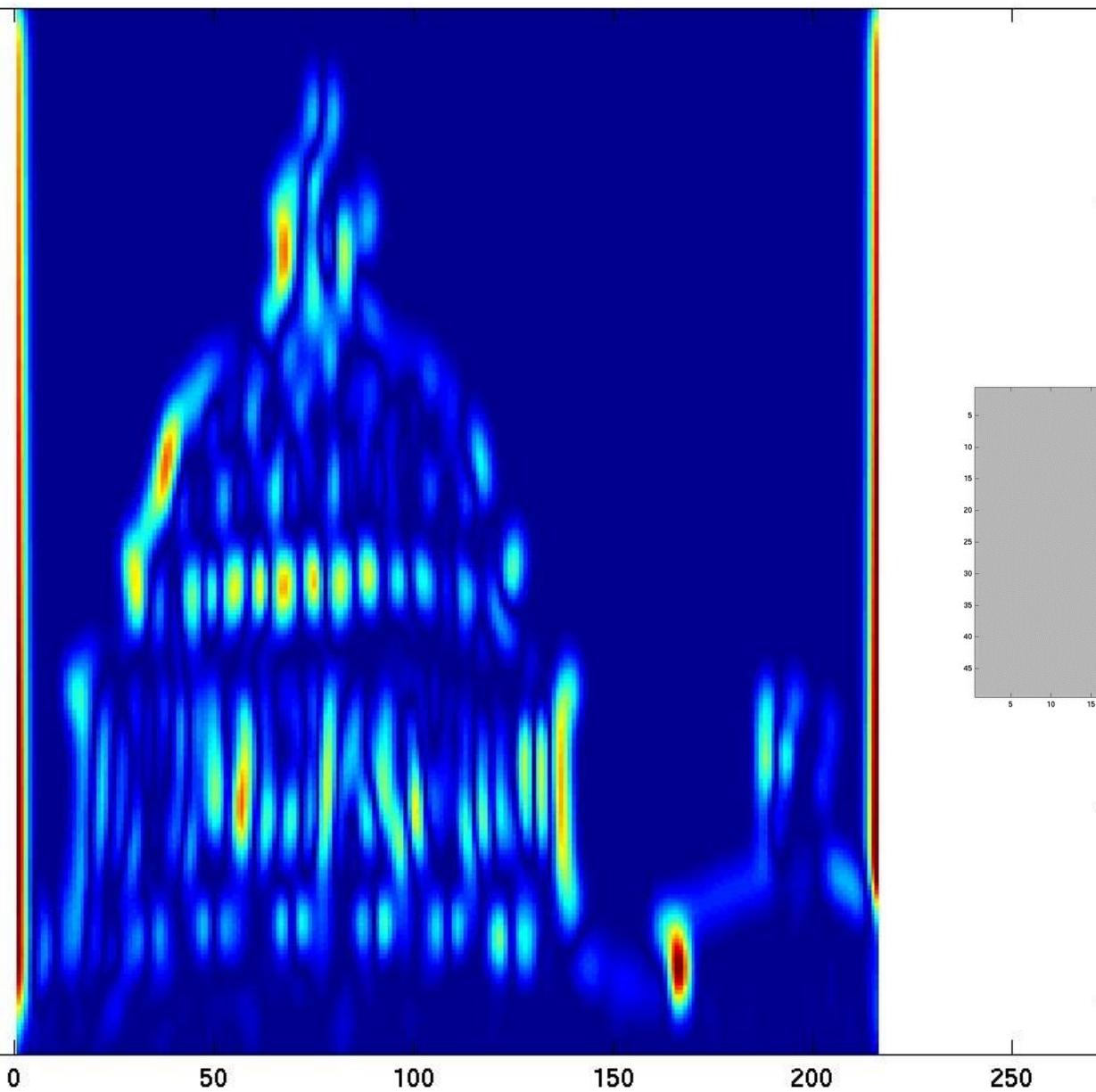
150

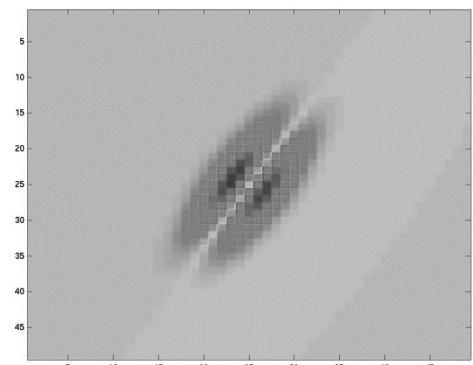
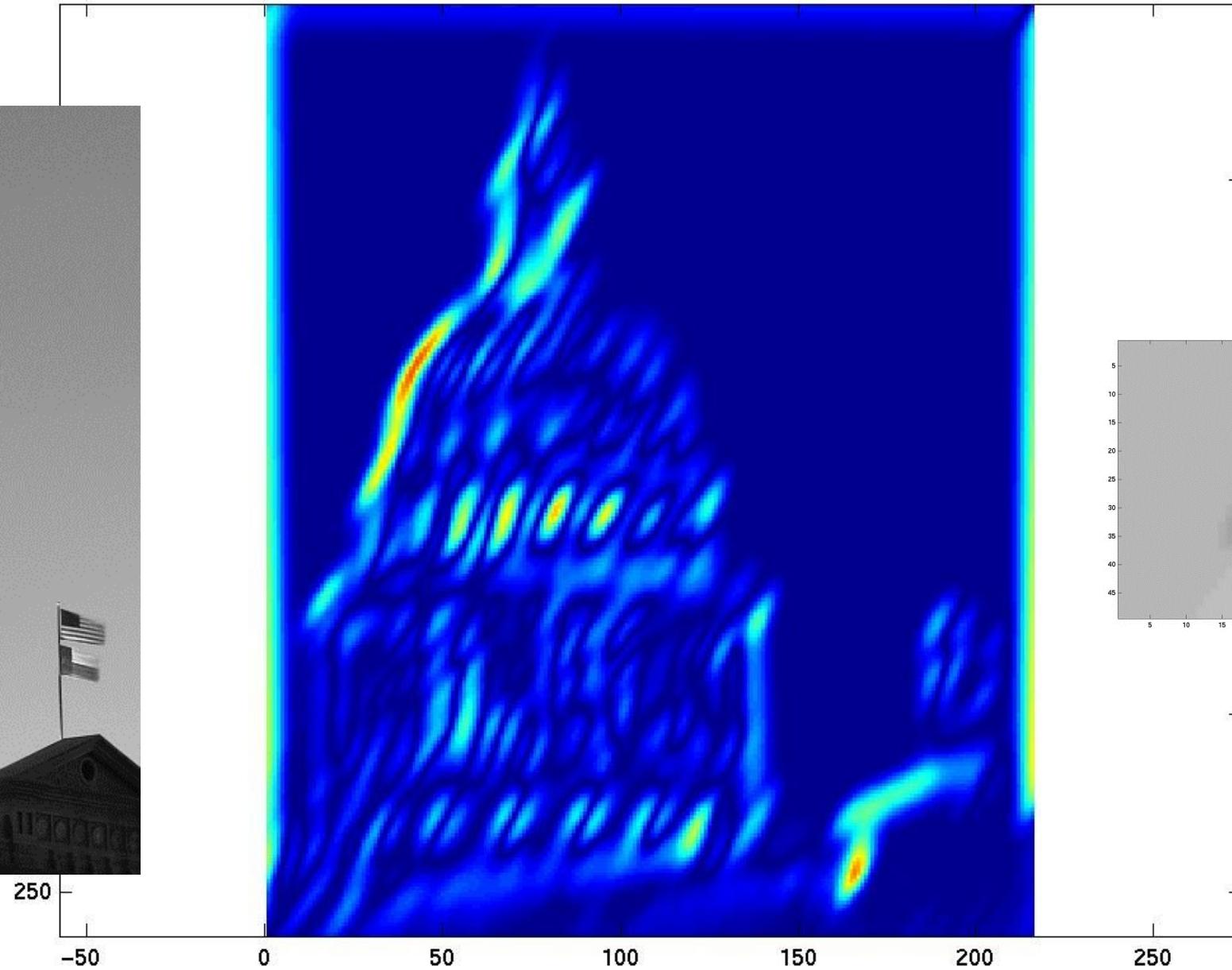
200

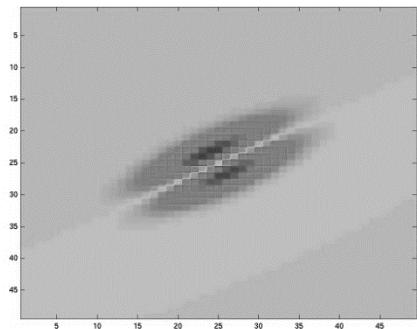
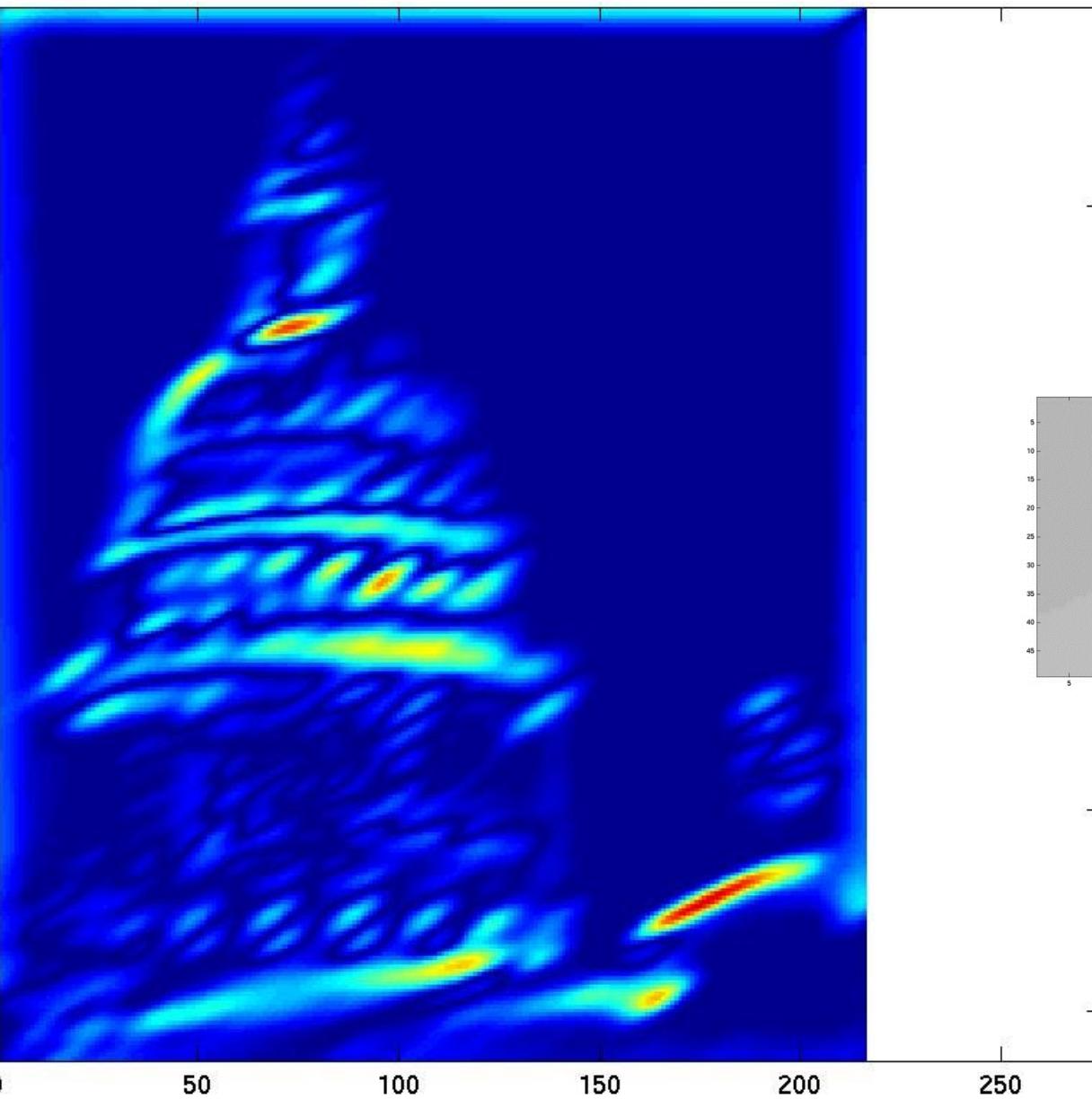
250













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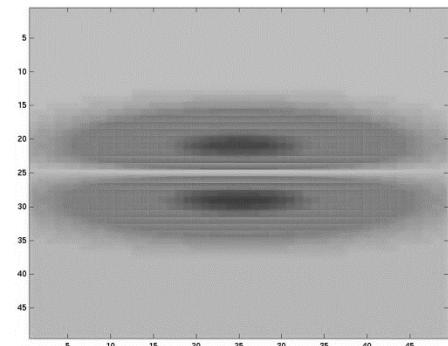
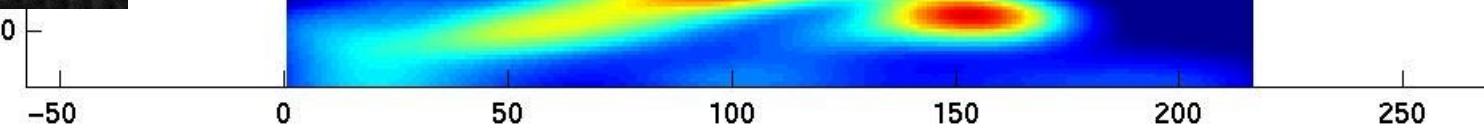
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100

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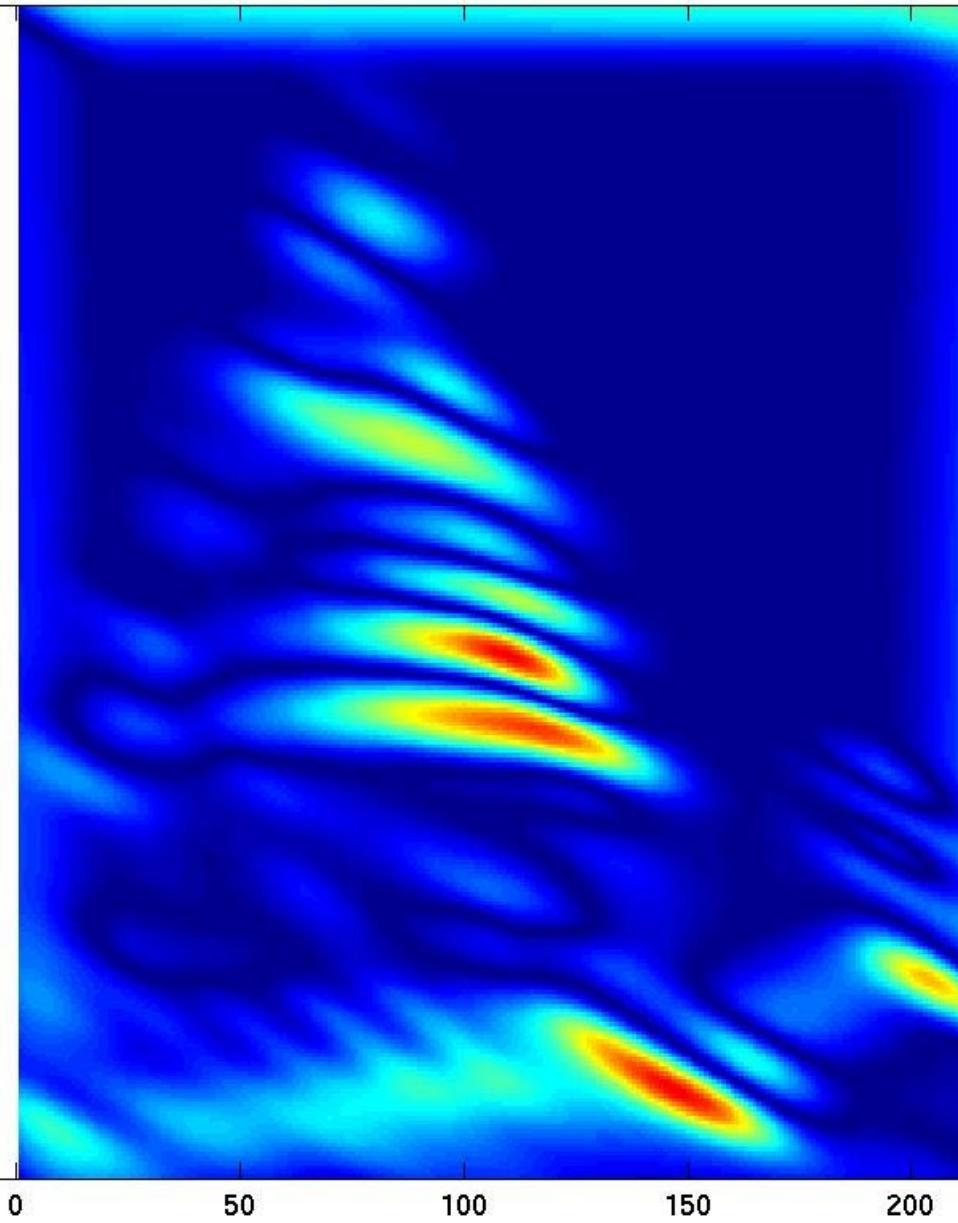
200

250

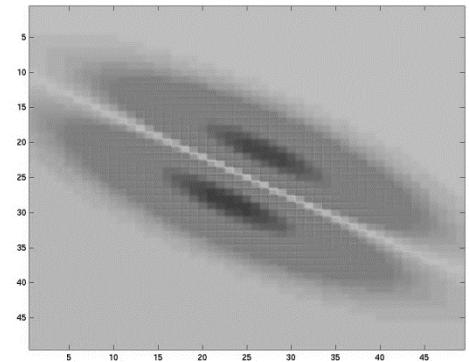




250
-50



0
50
100
150
200
250



5 10 15 20 25 30 35 40 45



250

-50

0

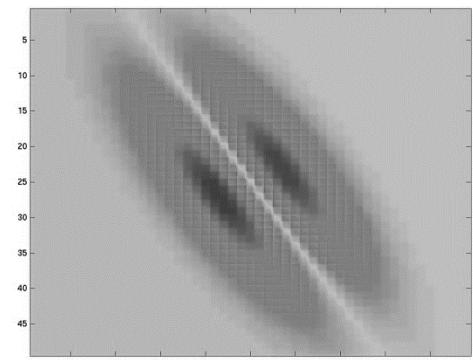
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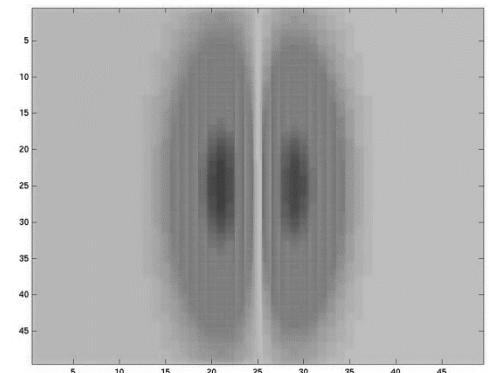
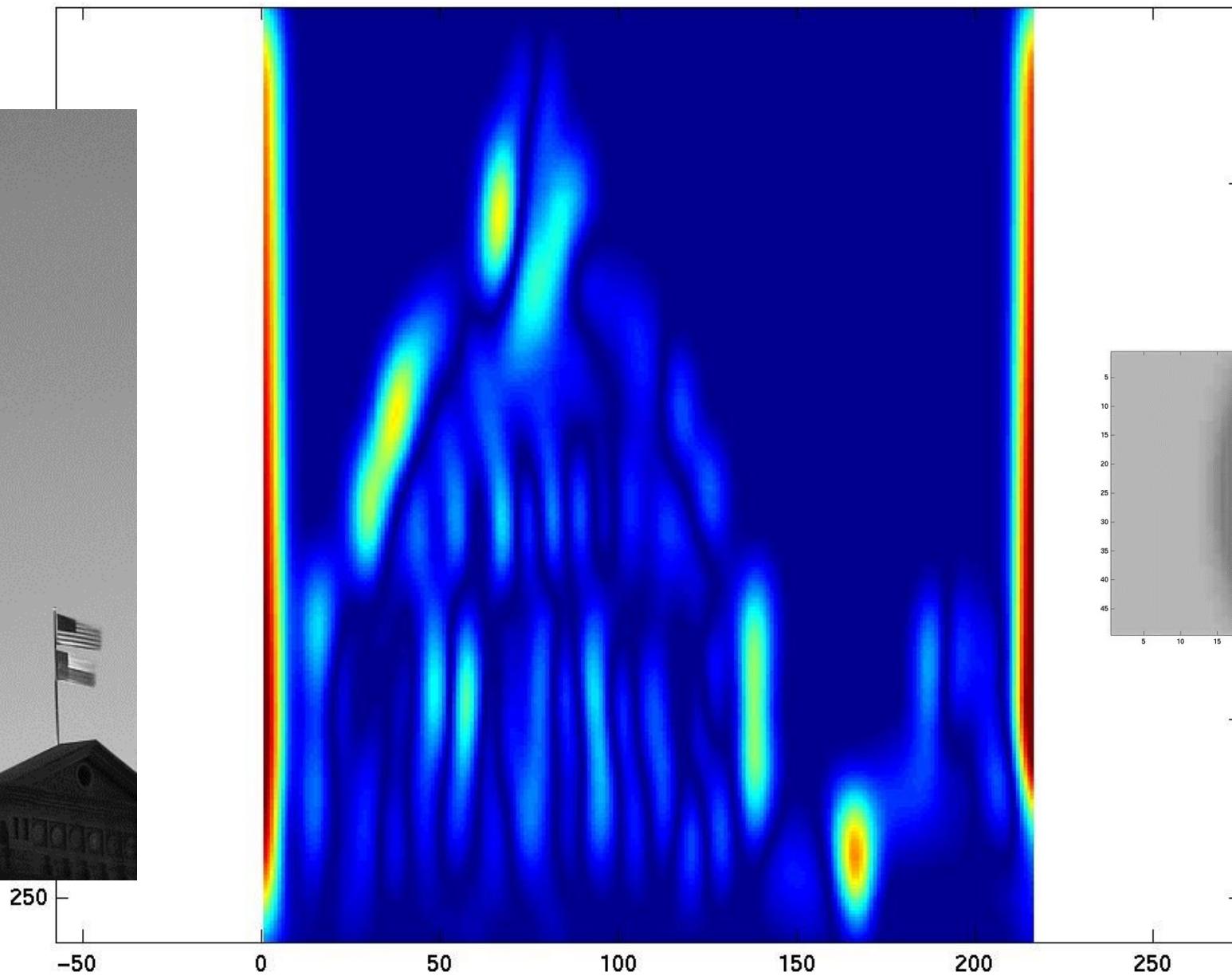
100

150

200

250

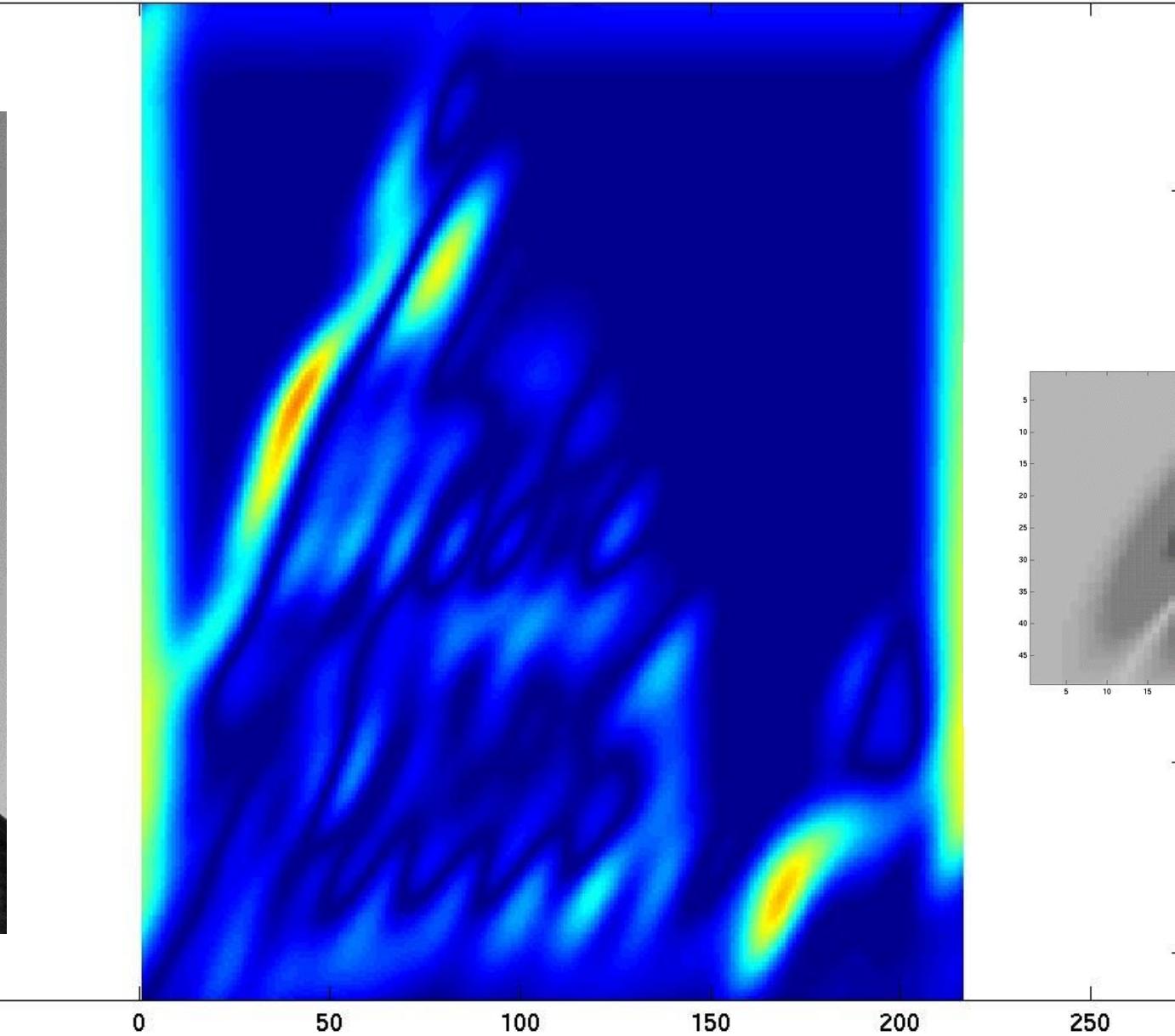






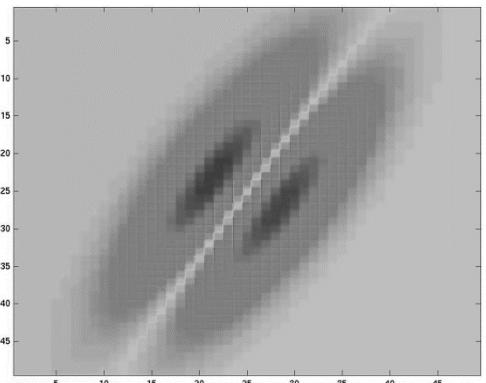
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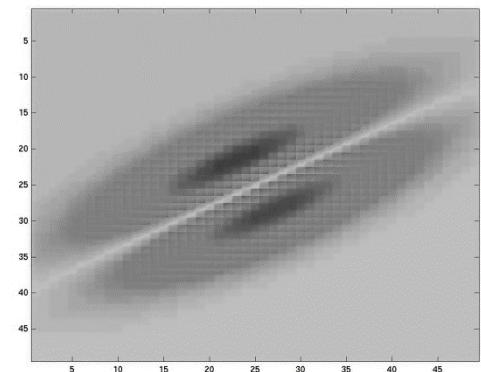
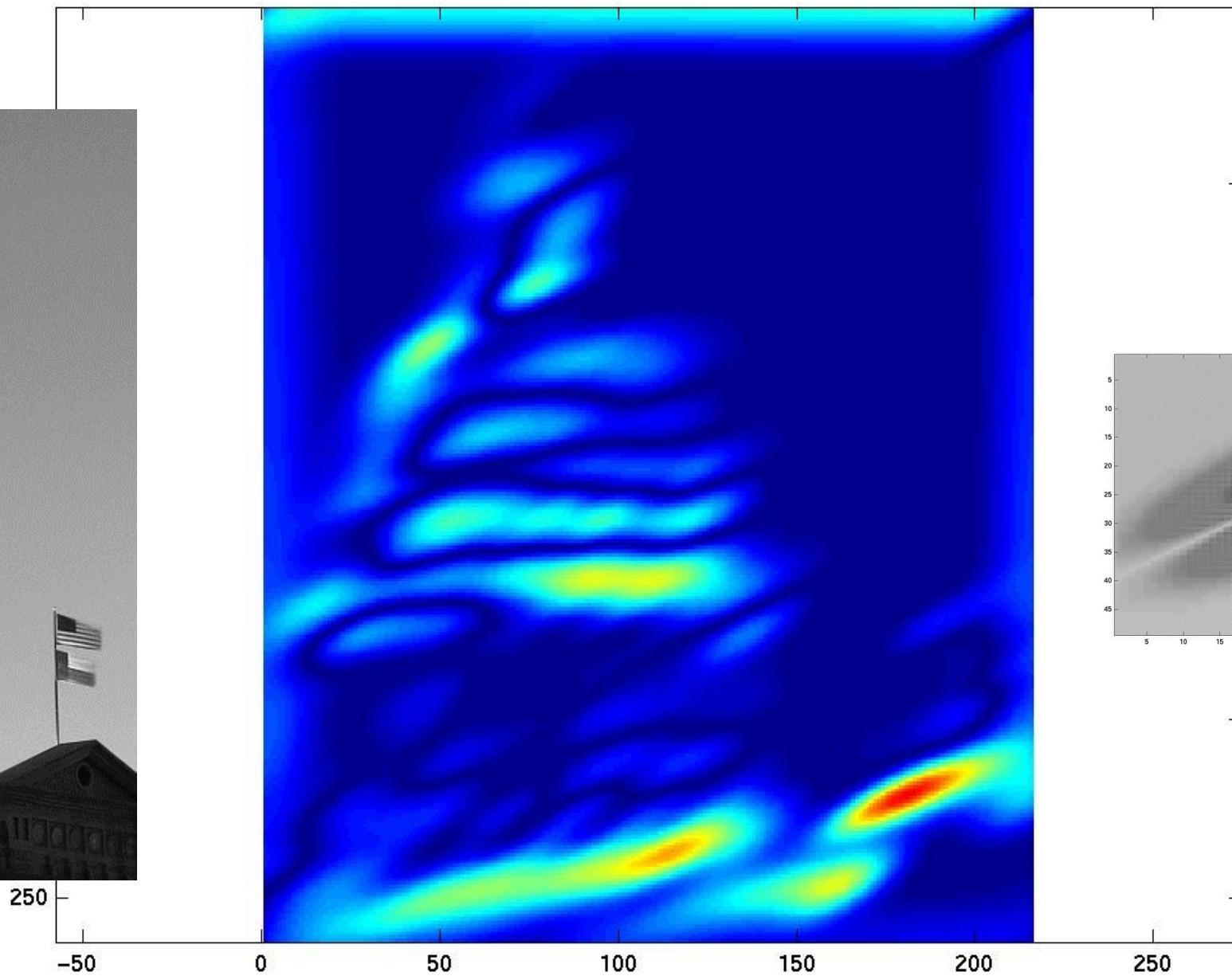
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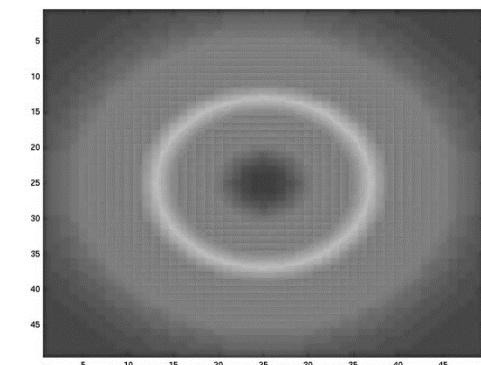
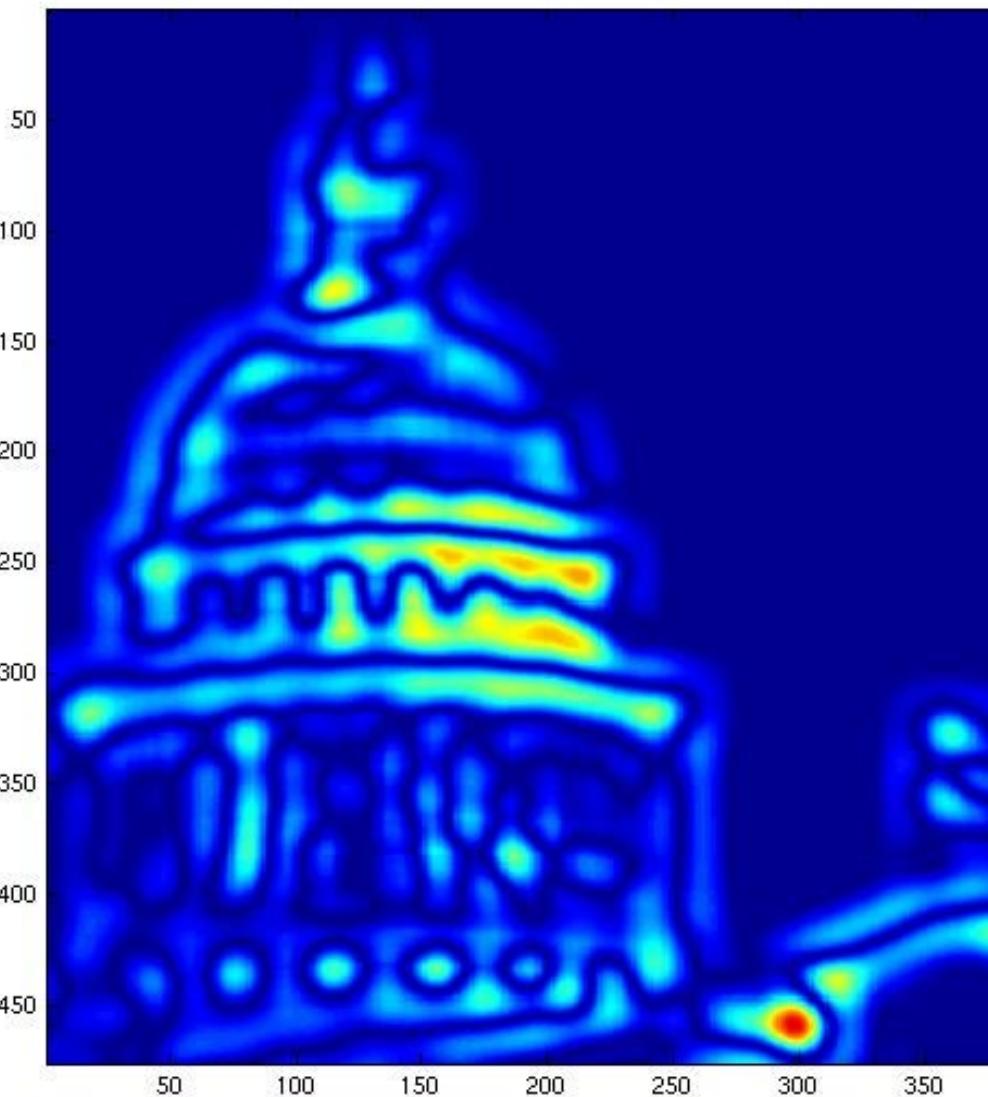


250

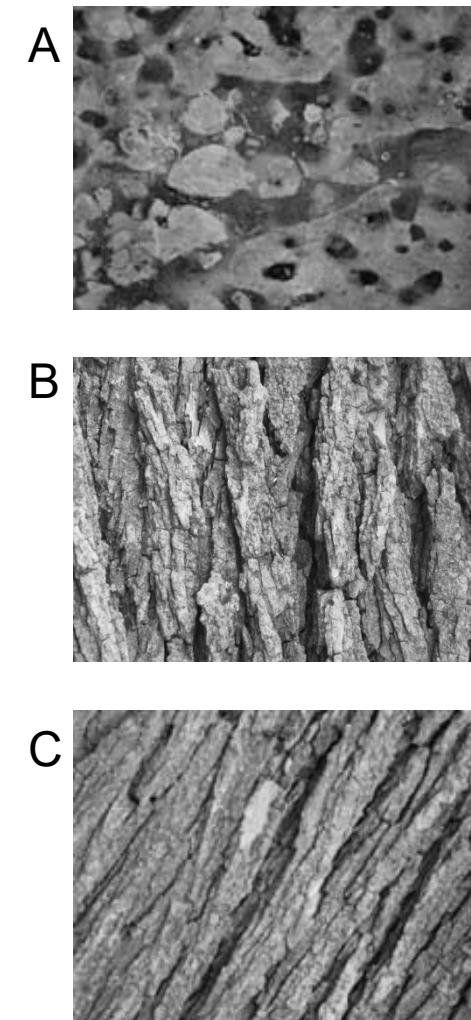
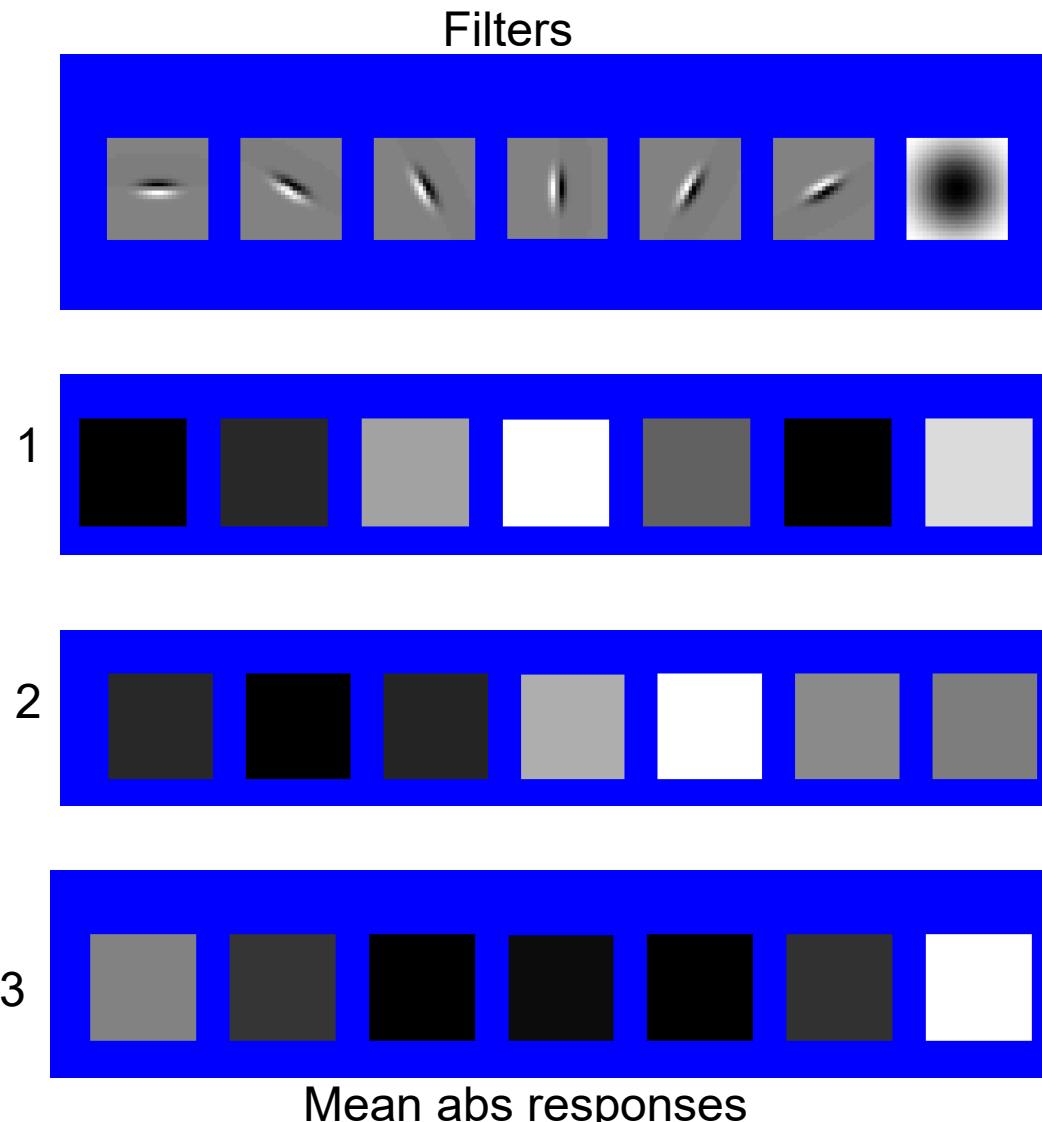
-50



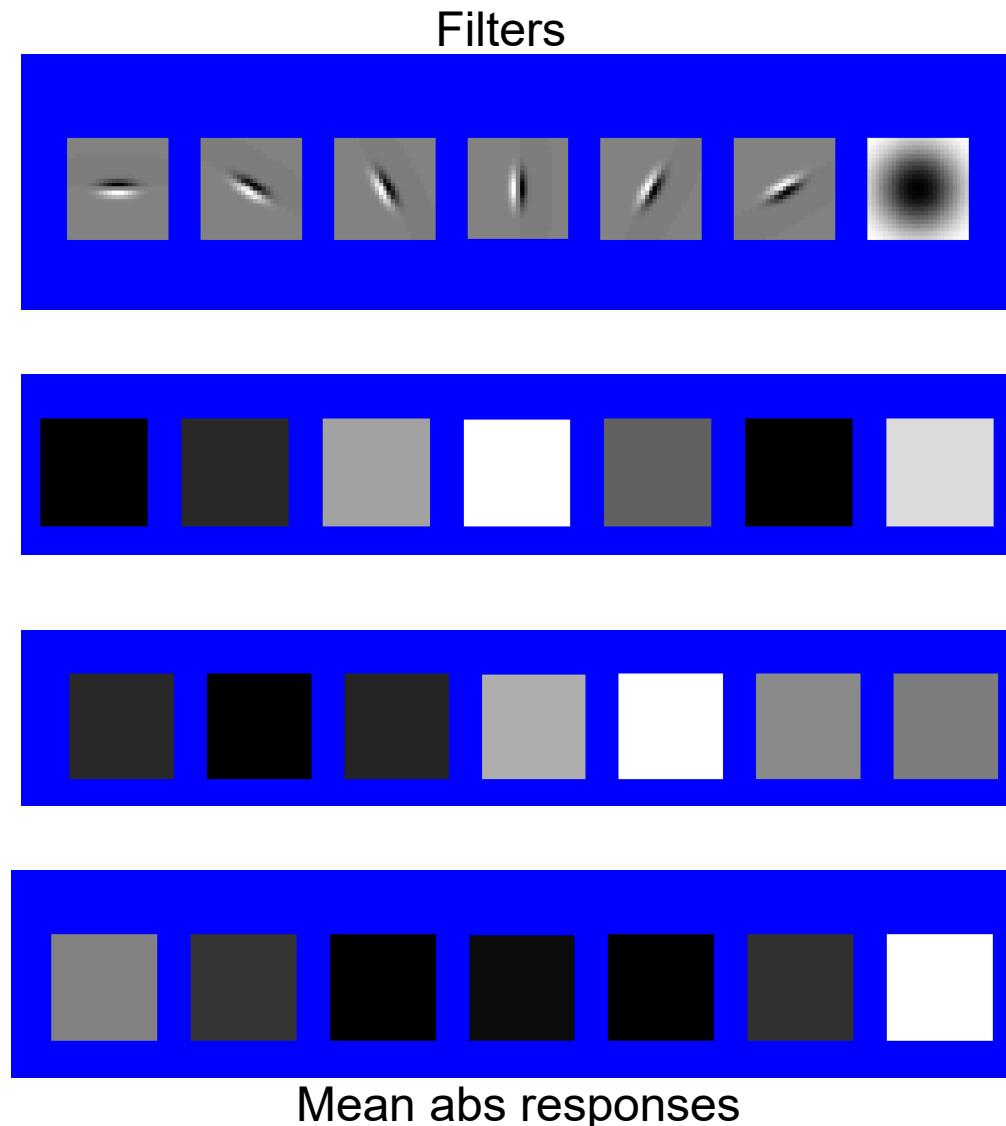
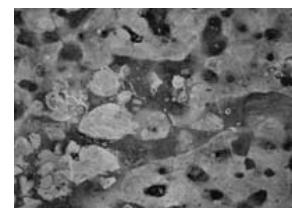


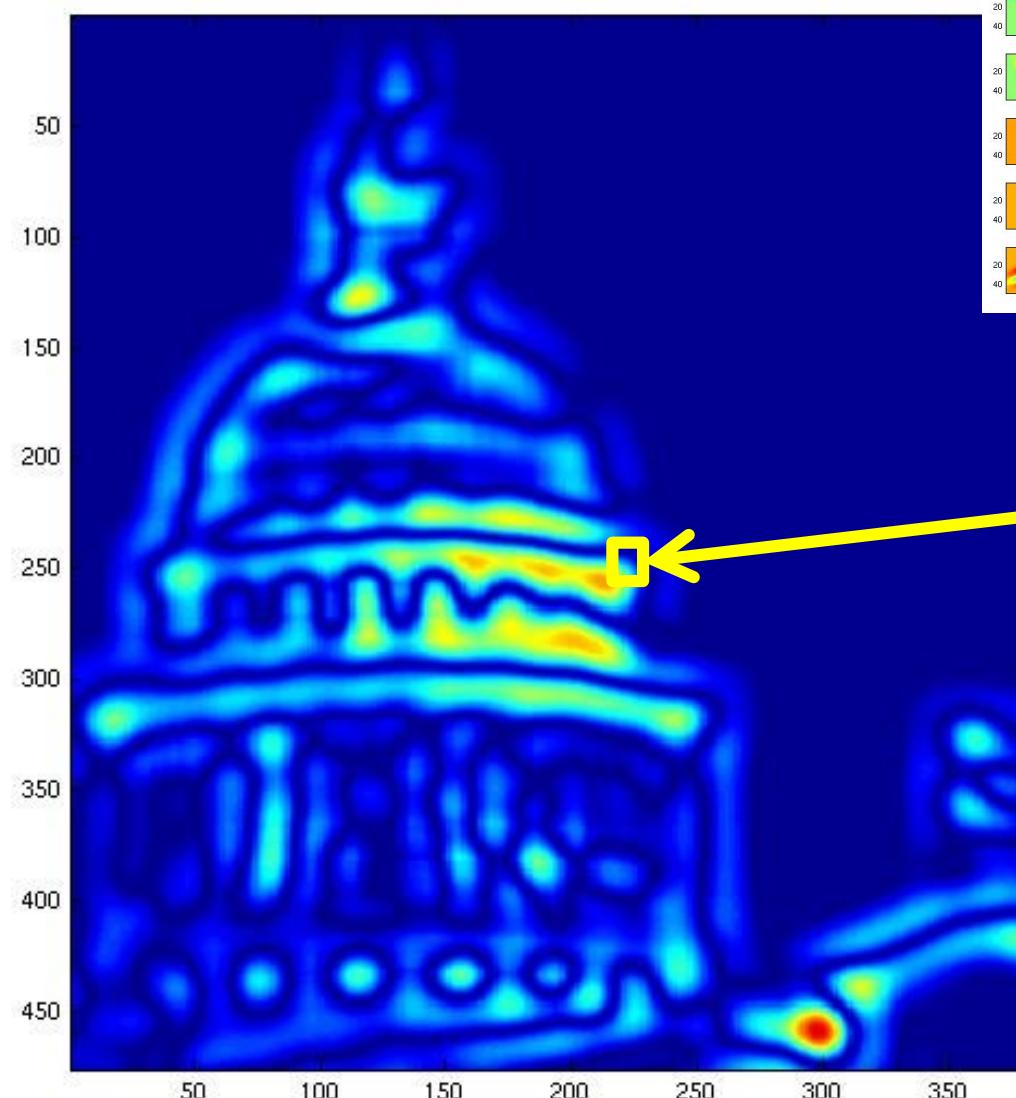


You try: Can you match the texture to the response?

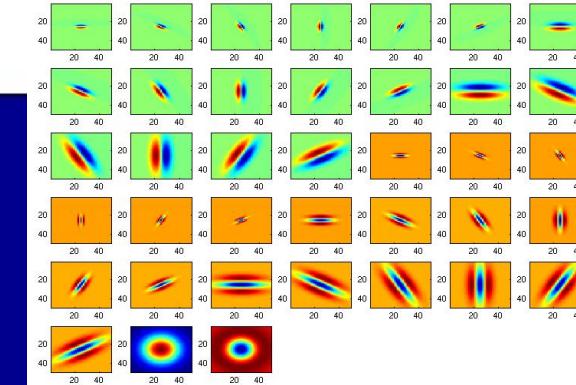


Representing texture by mean abs response





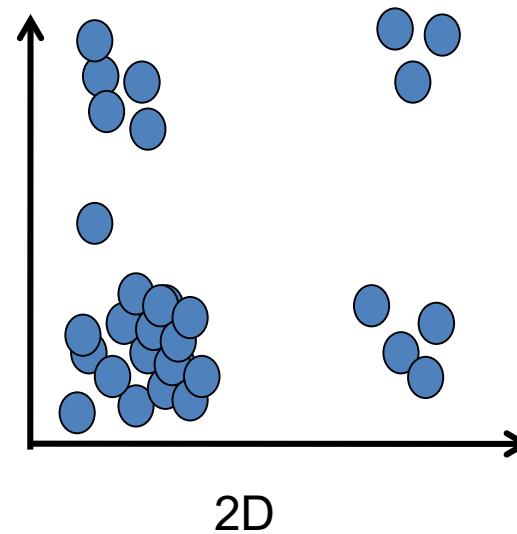
We can form a feature vector from the list of responses at each pixel.



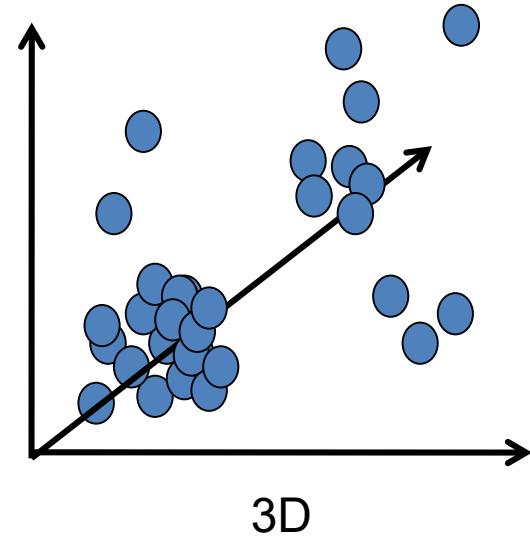
d-dimensional features

$$D(a, b) = \sqrt{\sum_{i=1}^d (a_i - b_i)^2}$$

Euclidean distance (L_2)



(Credit: Grauman)



...

A *texton* is the feature vector composed of the responses to a filter bank at a pixel location; it characterizes the textures in the neighborhood

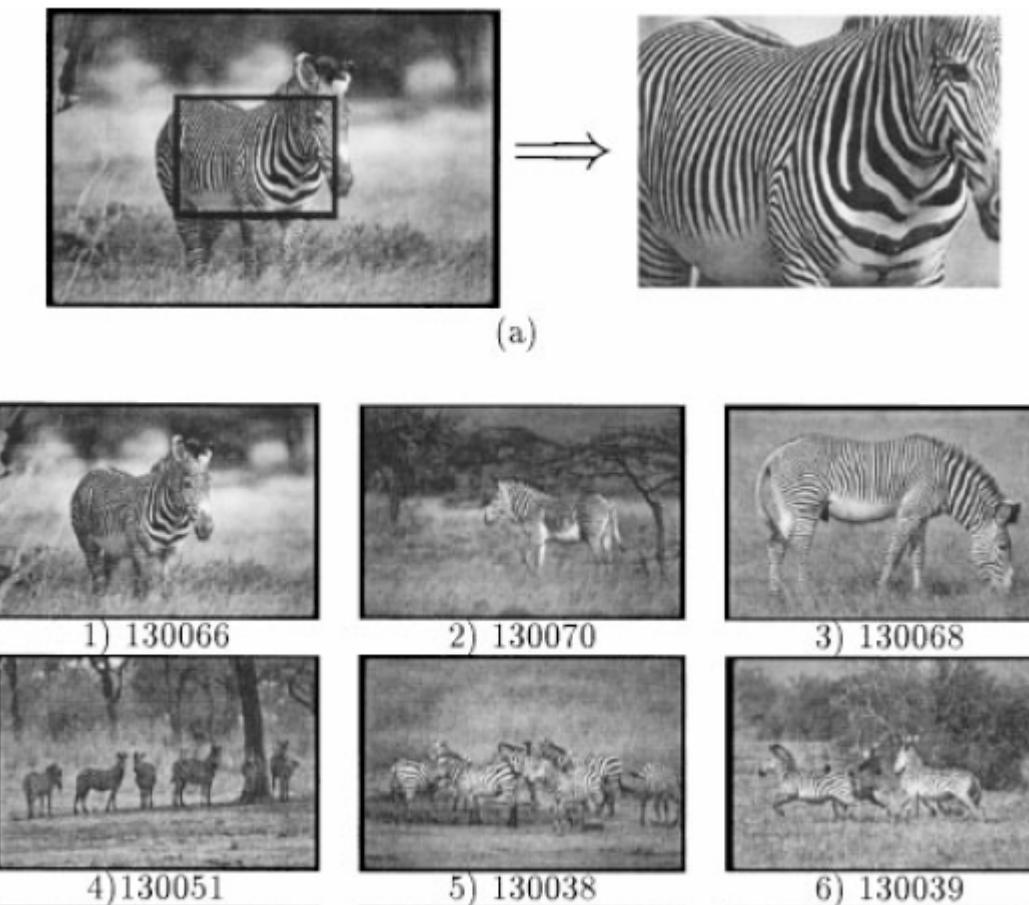
- Though often, a texton is defined at each pixel location in the image, there is much redundancy among neighboring textons
 - texture is a property of a region
- We usually aggregate them into larger units
 - the size of the filters used?
 - let the data tell us?
 - superpixels
 - clustering

EXAMPLE USES OF TEXTURE IN VISION: ANALYSIS

Classifying / recognizing materials



(Credit: Grauman)



Texture features
for image
retrieval from a
database

Rubner, Tomasi, and Guibas. The earth mover's distance as a metric for image retrieval. *International Journal of Computer Vision*, 40(2):99-121, November 2000



Characterizing scene categories by texture

L. W. Renninger and
J. Malik. When is
scene identification
just texture
recognition?
Vision Research 44
(2004) 2301–2311

Segmenting aerial imagery by texture

M.-P. Dubuisson-Jolly, A. Gupta / Image and Vision Computing 18 (2000) 823–832

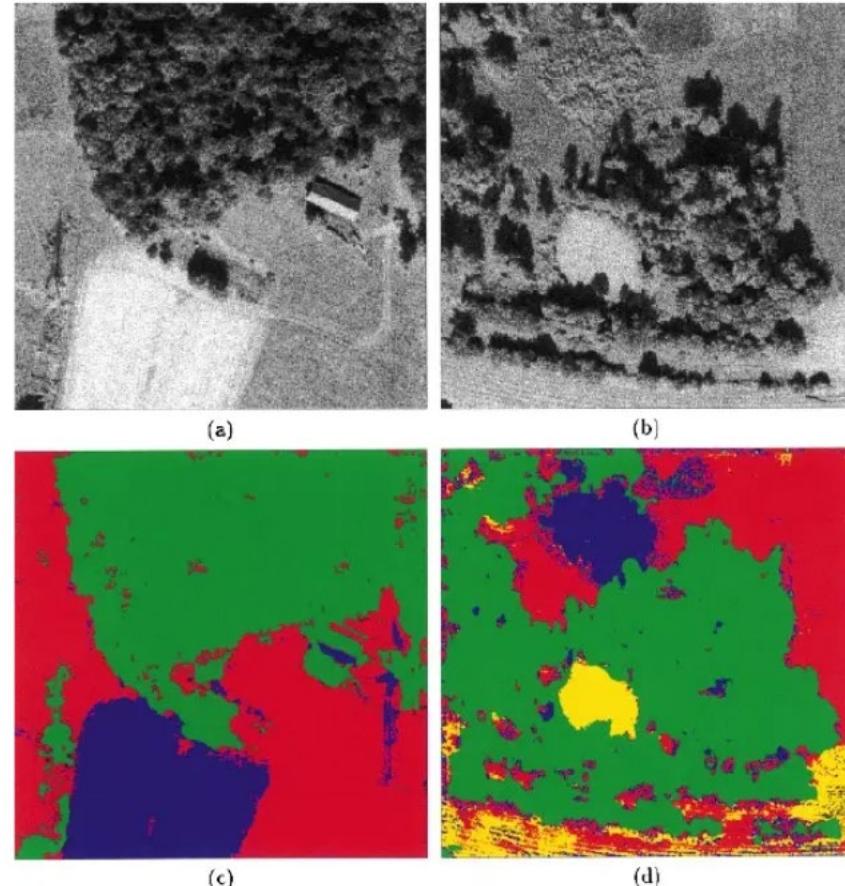


Fig. 7. Gray level images and segmentation results.

What about texture analysis using color information?

- Most of the above analysis methods are used on the intensity plane of the color image
- There are other methods, generally not based on filter banks, suited for application to color images
- See <https://pdfs.semanticscholar.org/4d12/4fe13c880719e70a1595a80cc9b54b745810.pdf> for a summary

Today's Objectives

- Texture as a visual cue
 - Segmentation
 - Depth
- Texture representation by derivatives
- Filter banks
 - Texture feature vectors
- Texture analysis