

# Texture

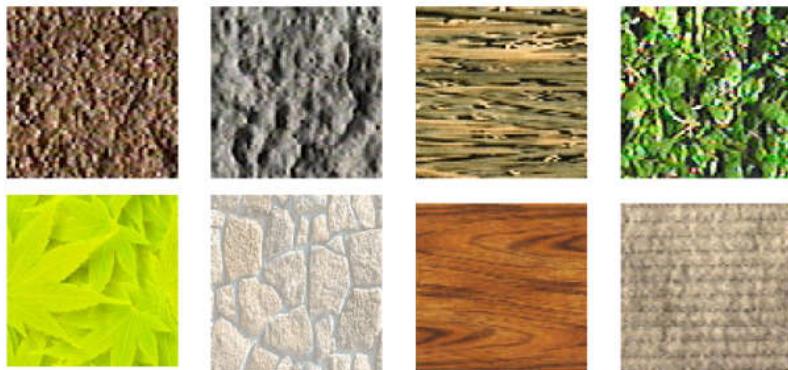
Lu Peng

School of Computer Science,  
Beijing University of Posts and Telecommunications

Machine Vision Technology							
Semantic information				Metric 3D information			
Pixels	Segments	Images	Videos	Camera		Multi-view Geometry	
Convolutions Edges & Fitting Local features Texture	Segmentation Clustering	Recognition Detection	Motion Tracking	Camera Model	Camera Calibration	Epipolar Geometry	SFM
10	4	4	2	2	2	2	2

## Today: Texture

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What defines a texture?

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## Includes: more regular patterns

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Source:Kristen Grauman

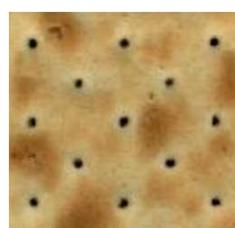
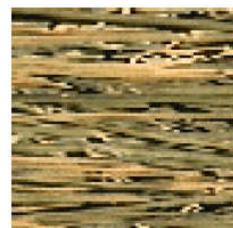
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## **Includes: more random patterns**

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Source:Kristen Grauman

## **Texture-related tasks**

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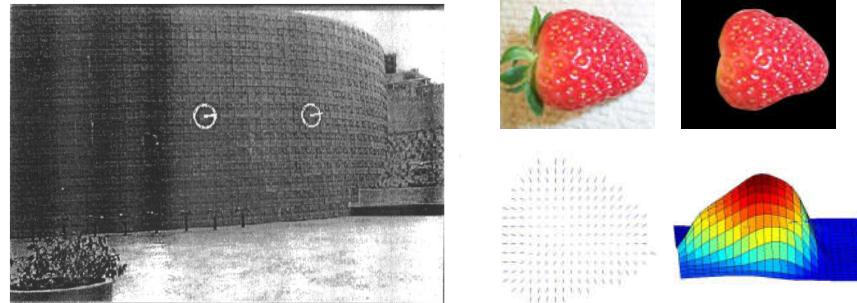
### **Shape from texture**

- Estimate surface orientation or shape from image texture

Source:Kristen Grauman

## Shape from texture

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



Source:Kristen Grauman

2020/4/13 Pics from A. Loh: <http://www.csail.mit.edu/research/projects/cv/>

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## Texture-related tasks

### **Shape from texture**

- Estimate surface orientation or shape from image texture

### **Segmentation/classification** from texture cues

- Analyze, represent texture
- Group image regions with consistent texture

### **Synthesis**

- Generate new texture patches/images given some examples

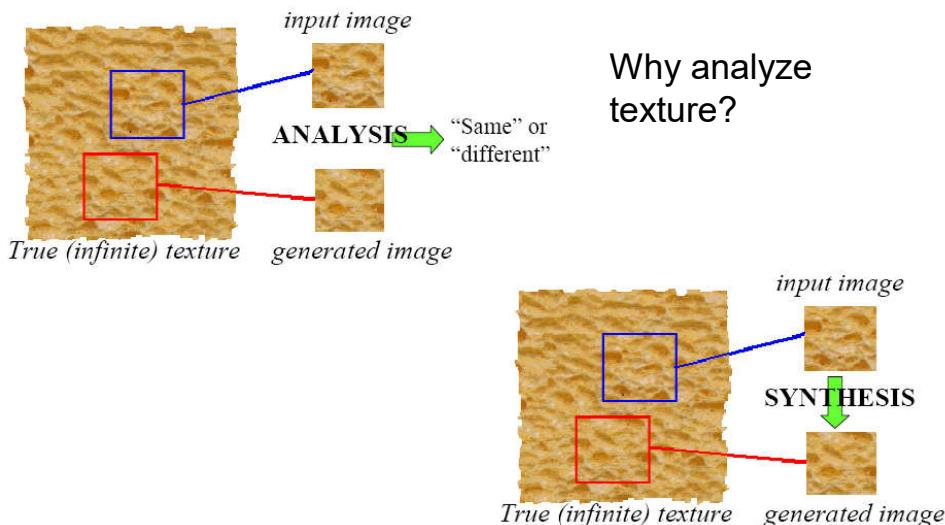
Source:Kristen Grauman

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## Analysis vs. Synthesis



Source: Bill Freeman, A. Efros

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## Texture-related tasks

### **Shape from texture**

- Estimate surface orientation or shape from image texture

### **Segmentation/classification** from texture cues

- Analyze, represent texture
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### **Synthesis**

- Generate new texture patches/images given some examples

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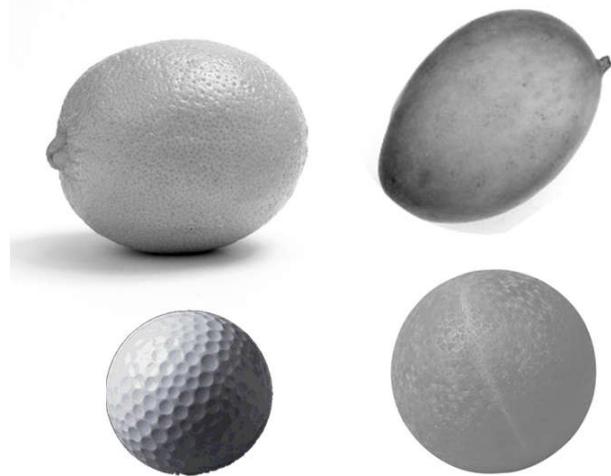


Source:Kristen Grauman

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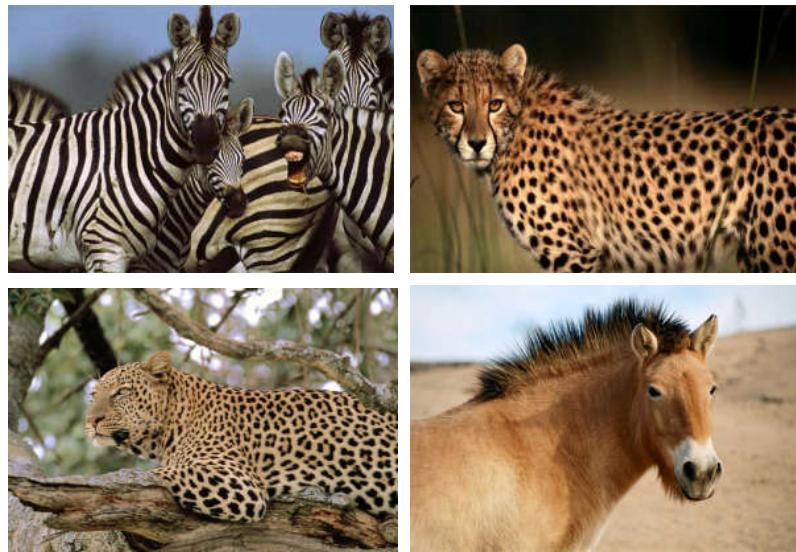


Source:Kristen Grauman

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

Source:Kristen Grauman

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What kind of response  
will we get with an  
edge detector for these  
images?

Images from Malik and Perona, 1990

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...and for this image?

Source: D. Forsyth

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## 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:

- Representation-wise, we want a feature one step above "building blocks" of filters, edges.

Source: Kristen Grauman

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## Texture representation

Textures are made up of repeated local patterns, so:

- Find the patterns
  - Use filters that look like patterns (spots, bars, raw patches...)
  - Consider magnitude of response
- Describe their statistics within each local window
  - Mean, standard deviation
  - Histogram
  - Histogram of “prototypical” feature occurrences

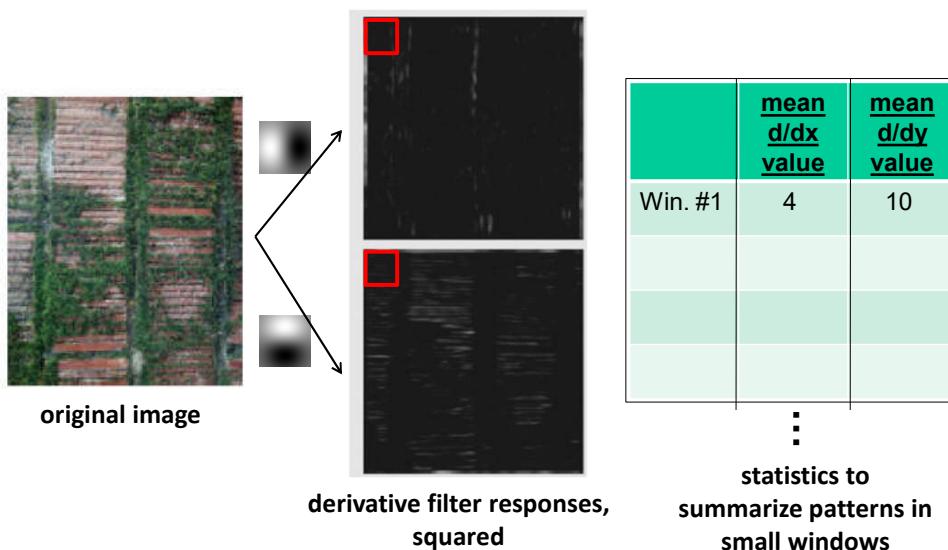
Source:Kristen Grauman

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## Texture representation: example



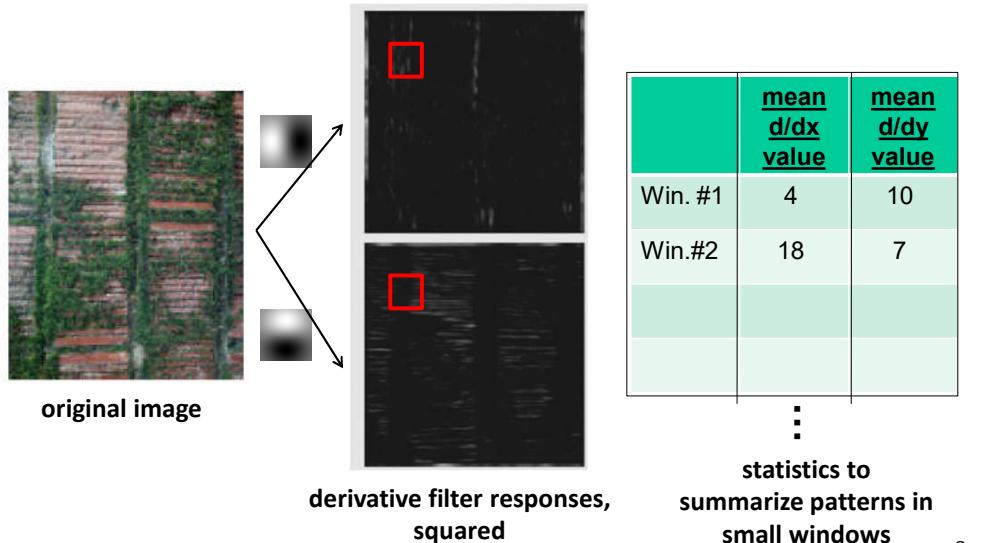
Source:Kristen Grauman

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## Texture representation: example



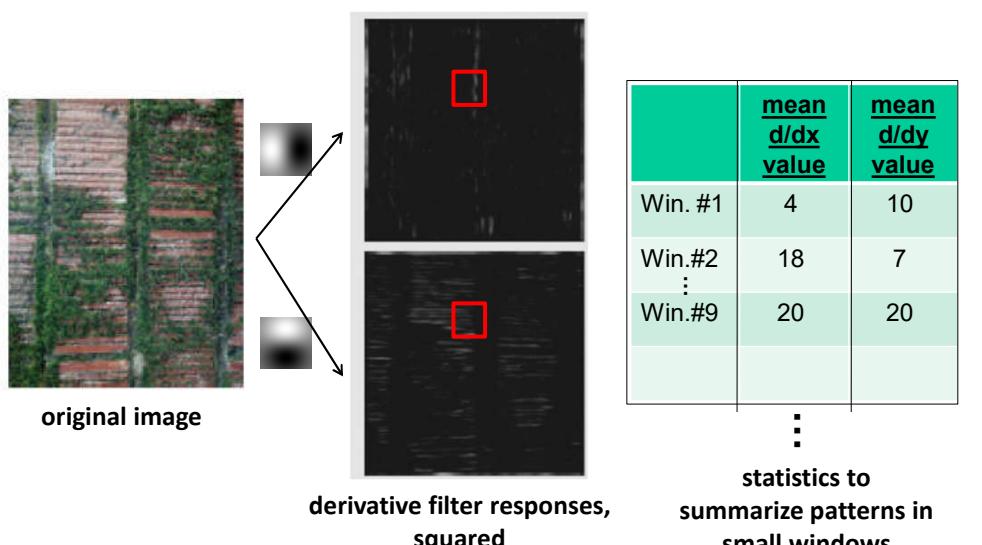
Source:Kristen Grauman

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## Texture representation: example



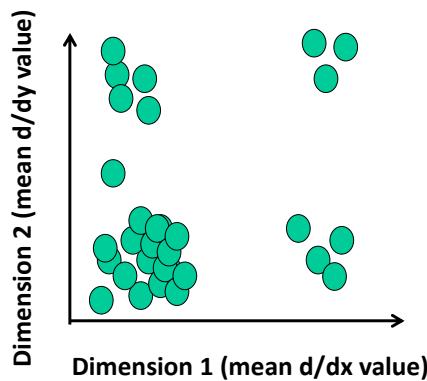
Source:Kristen Grauman

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## Texture representation: example



	mean $d/dx$ value	mean $d/dy$ value
Win. #1	4	10
Win.#2	18	7
:		
Win.#9	20	20

statistics to  
summarize patterns in  
small windows

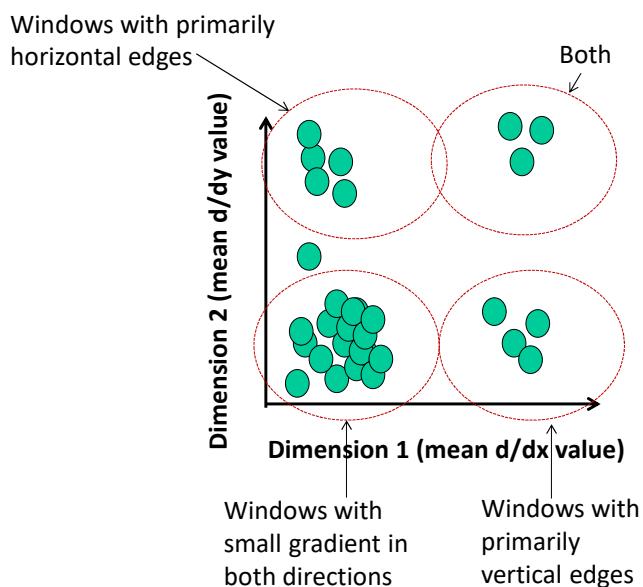
Source:Kristen Grauman

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## Texture representation: example



	mean $d/dx$ value	mean $d/dy$ value
Win. #1	4	10
Win.#2	18	7
:		
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statistics to  
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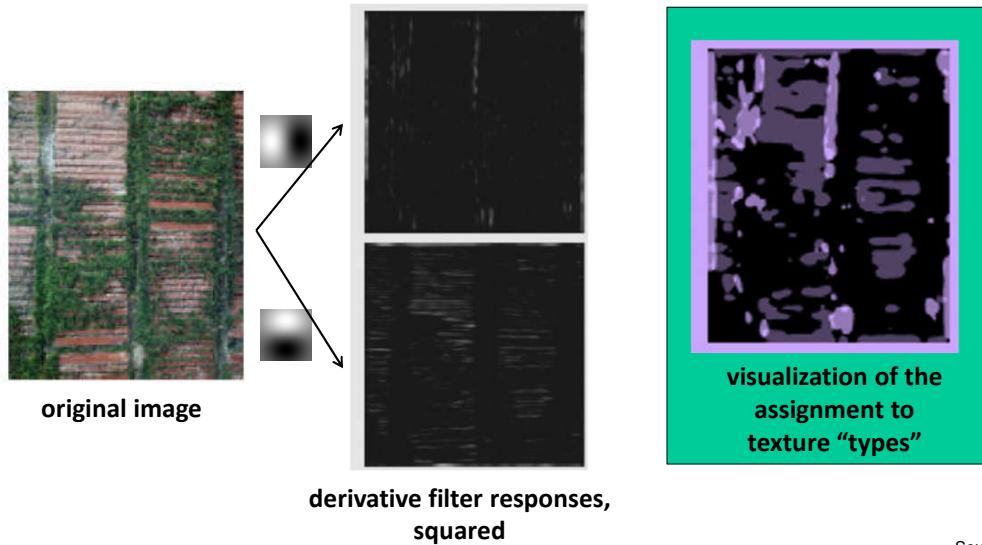
Source:Kristen Grauman

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## Texture representation: example



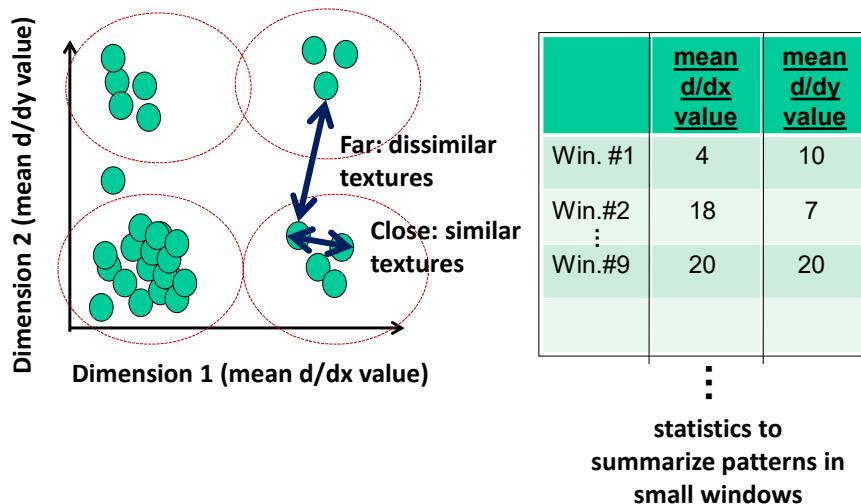
Source:Kristen Grauman

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## Texture representation: example



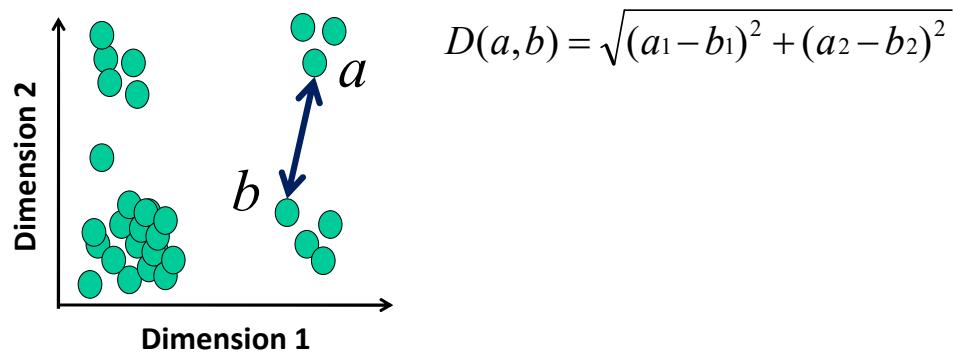
Source:Kristen Grauman

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## Texture representation: example



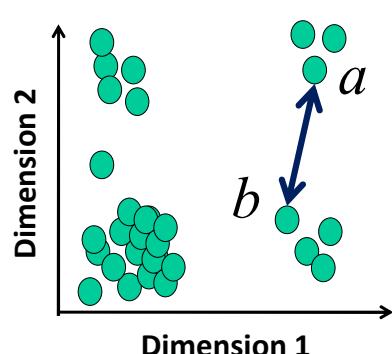
Source:Kristen Grauman

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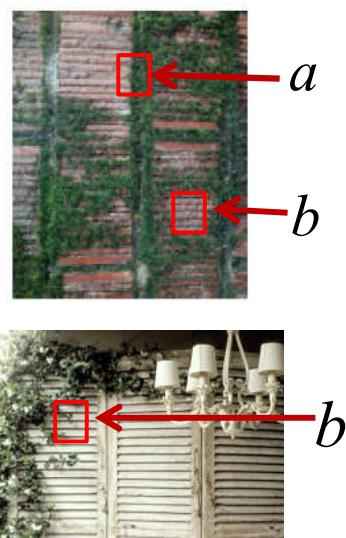
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## Texture representation: example



Distance reveals how dissimilar texture from window a is from texture in window b.



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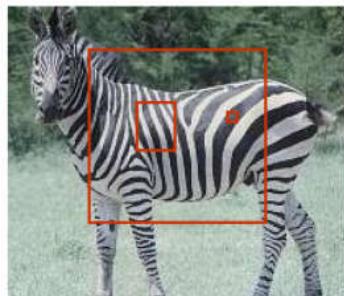
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## Texture representation: window scale

We're assuming we know the relevant window size for which we collect these statistics.



Possible to perform scale selection by looking for window scale where texture description not changing.

Source:Kristen Grauman

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## 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.

- still can think of nearness, farness in feature space

Source:Kristen Grauman

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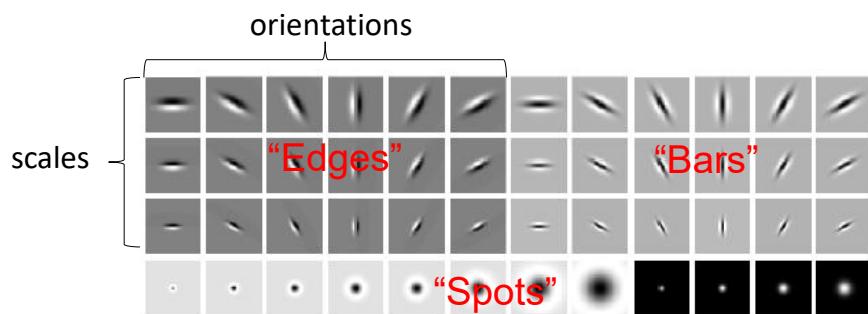
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## Filter banks

What filters to put in the bank?

- Typically we want a combination of scales and orientations, different types of patterns.



Matlab code available for these examples:  
<http://www.robots.ox.ac.uk/~vgg/research/texclass/filters.html>

Source:Kristen Grauman

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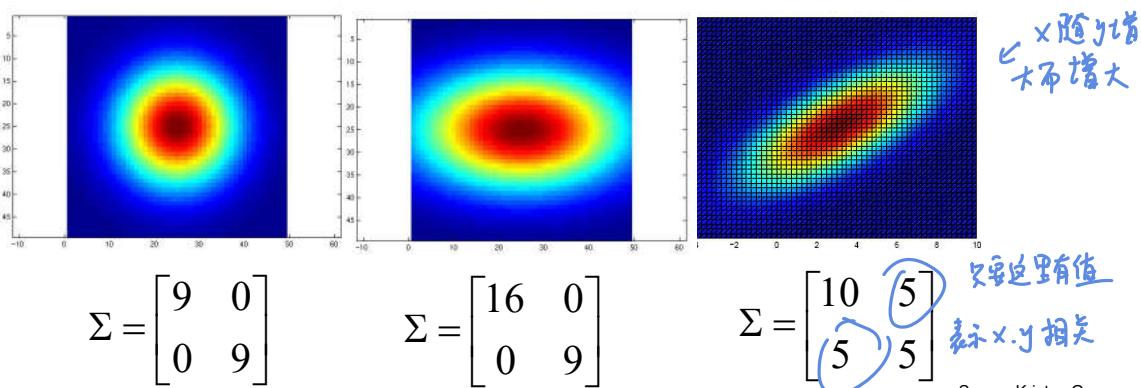
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## Multivariate Gaussian

多维高斯

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



Source:Kristen Grauman

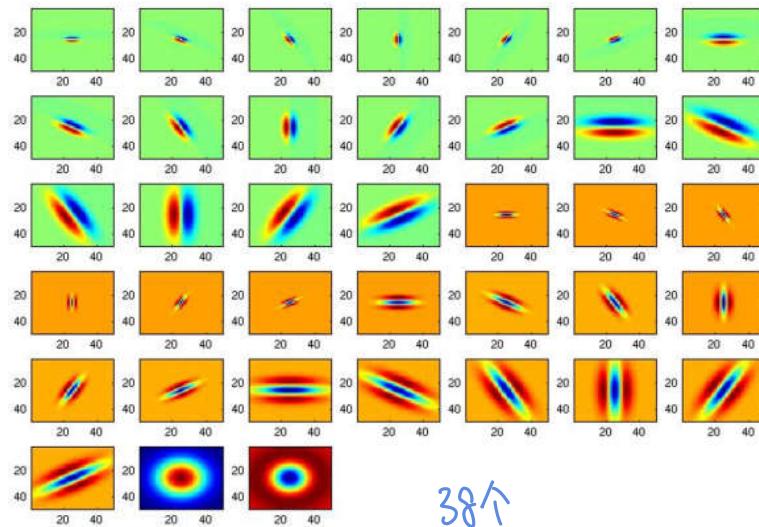
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## Filter bank

反卷积核组



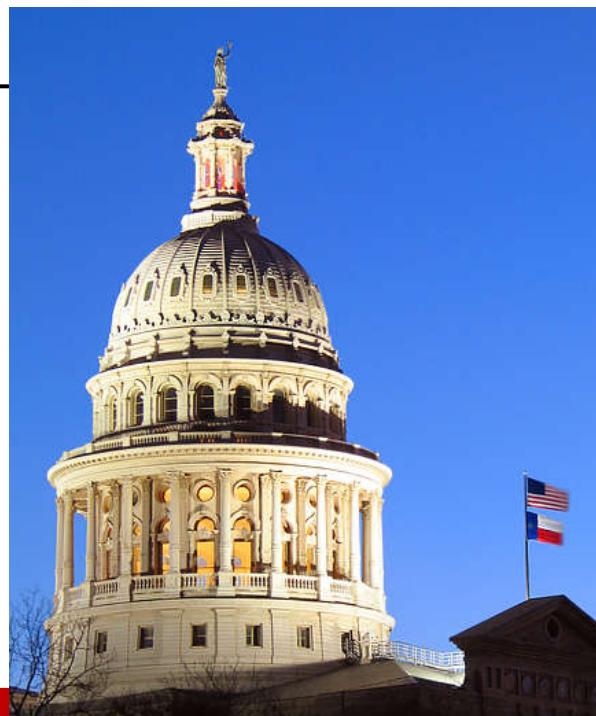
Source:Kristen Grauman

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Image from <http://www.texasexplorer.com/ajustincap2.jpg>



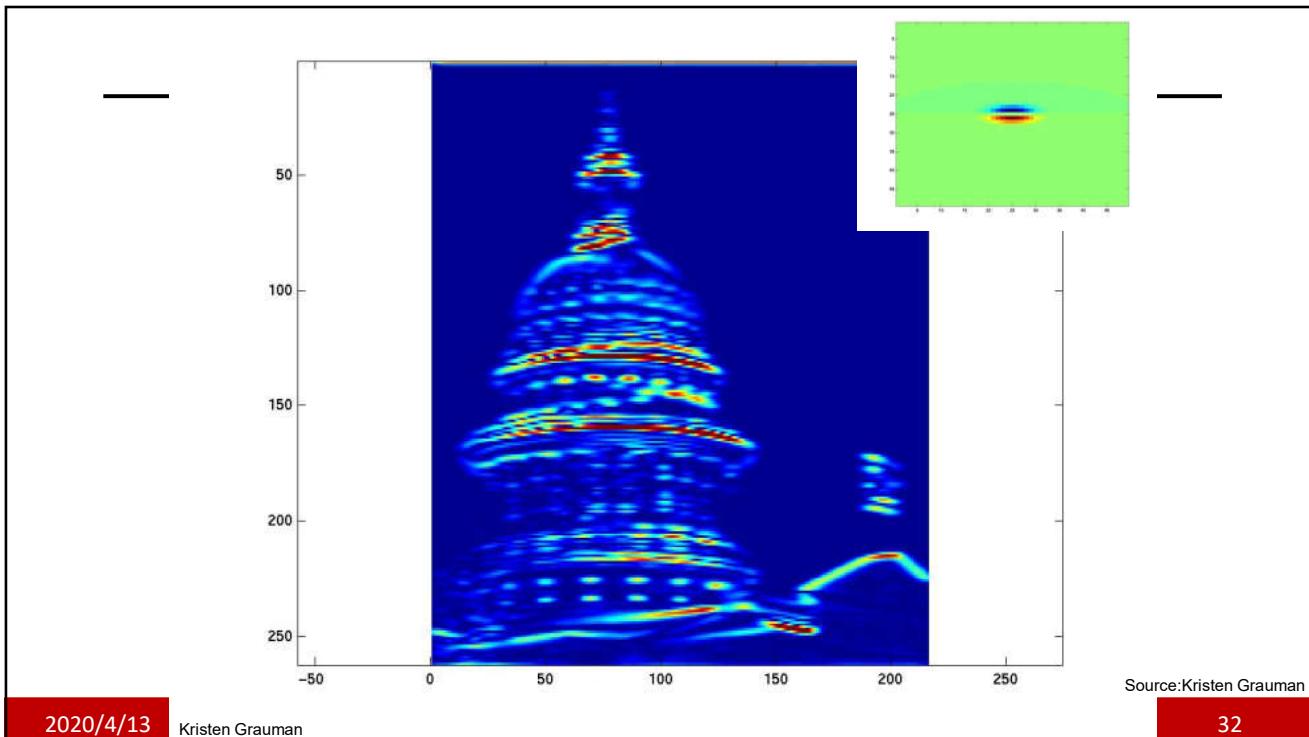
用上面38个filter  
对这张图每个像素进  
进卷积  
↓

每个像素点都  
将产生一个38维向量

Source:Kristen Grauman

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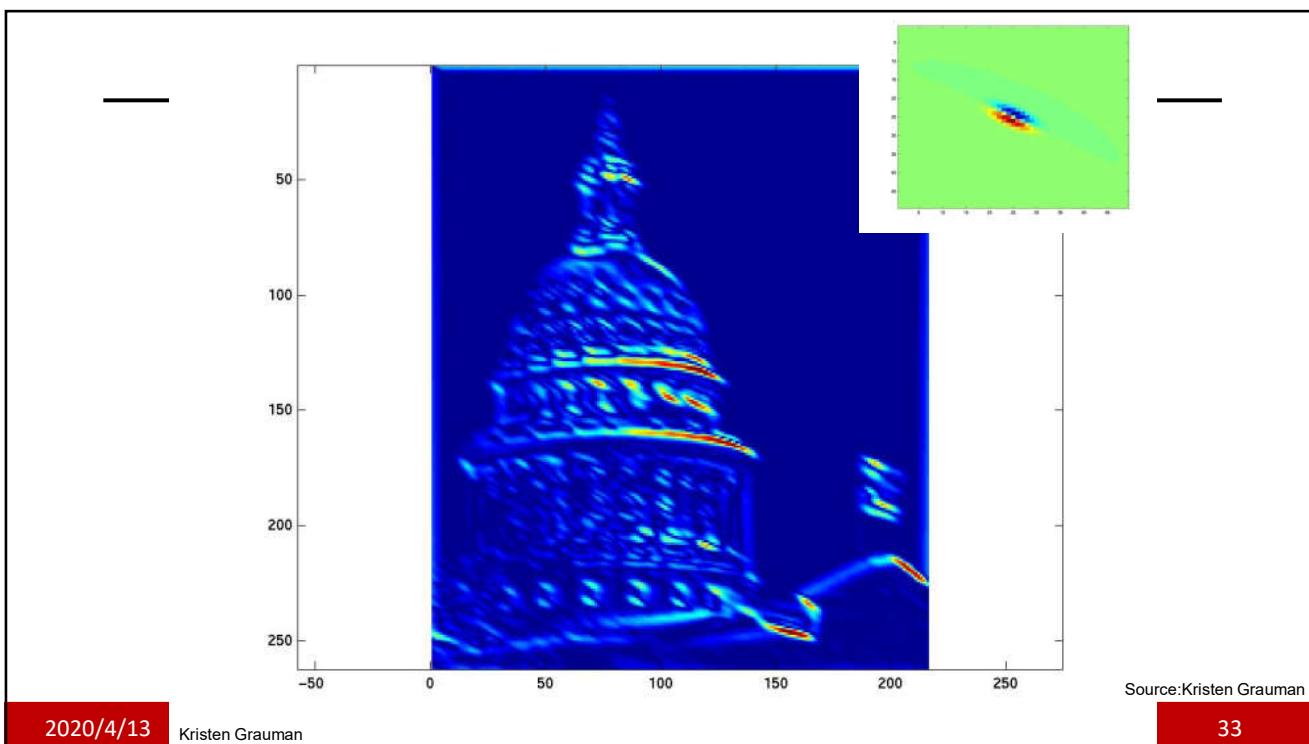
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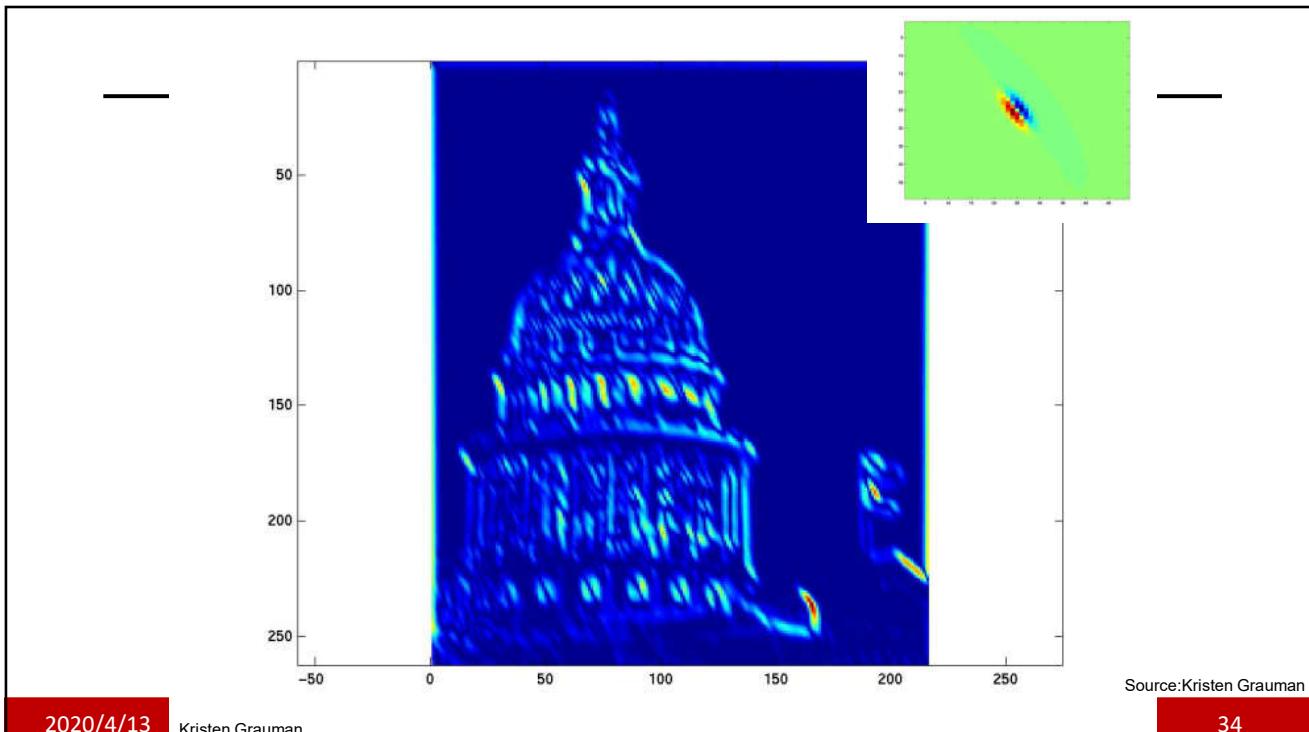
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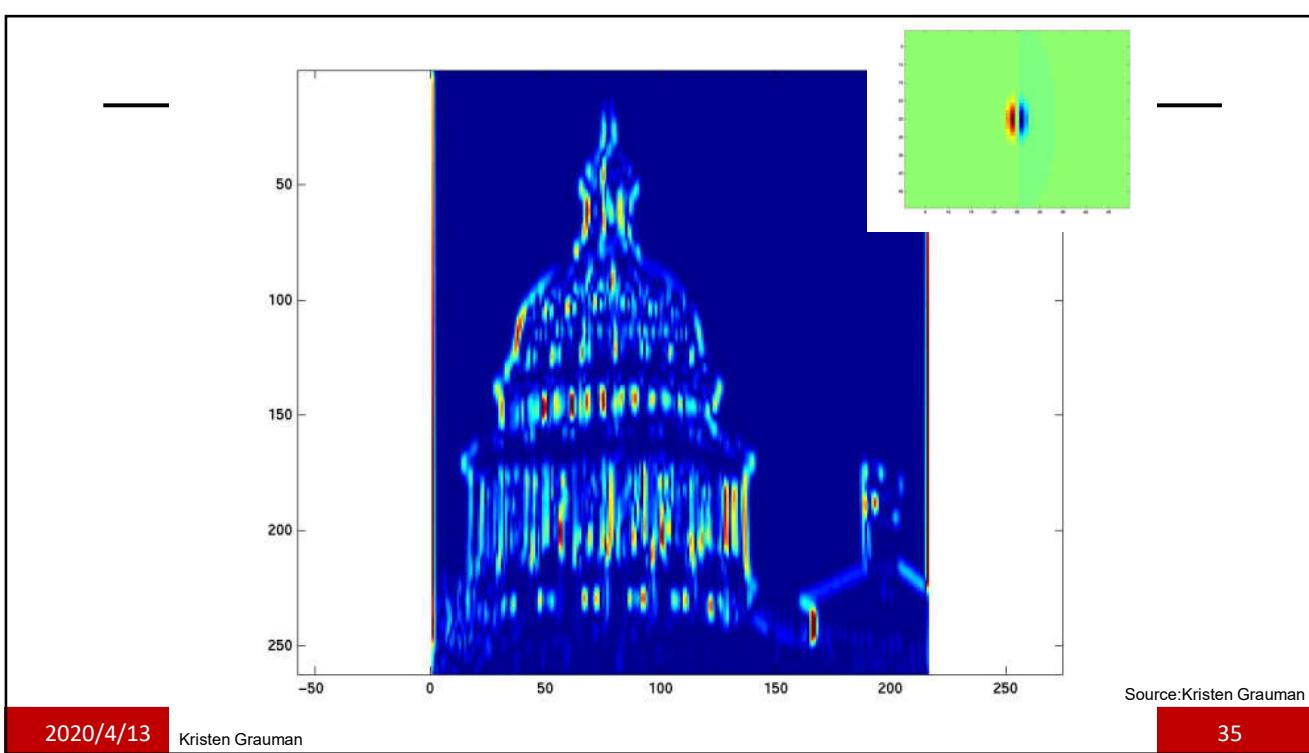
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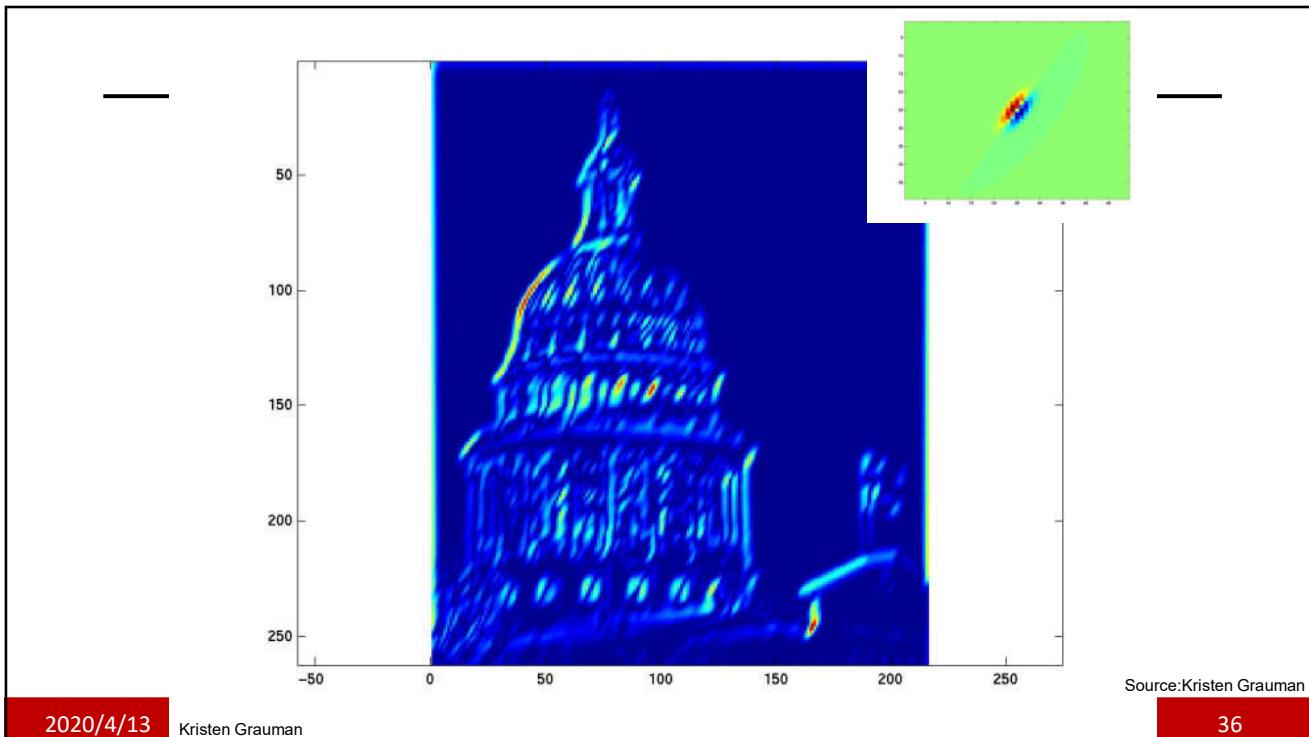
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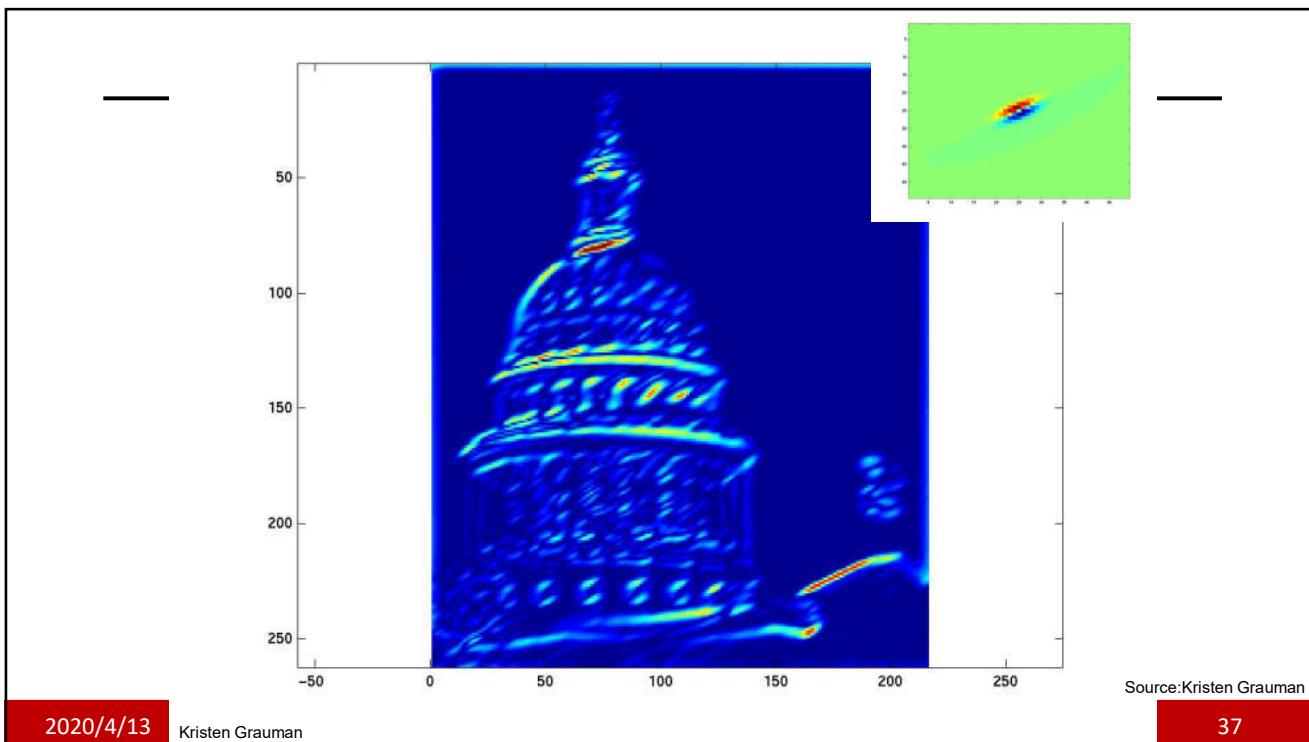
35



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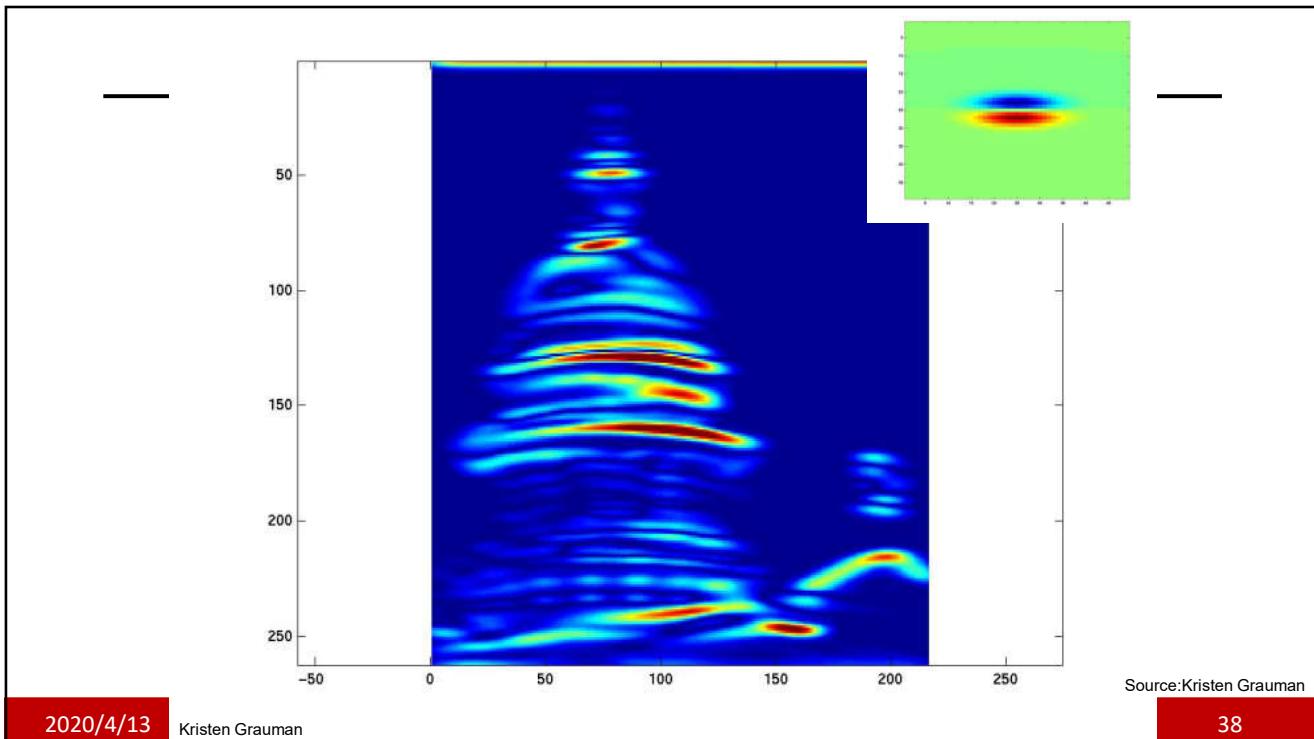
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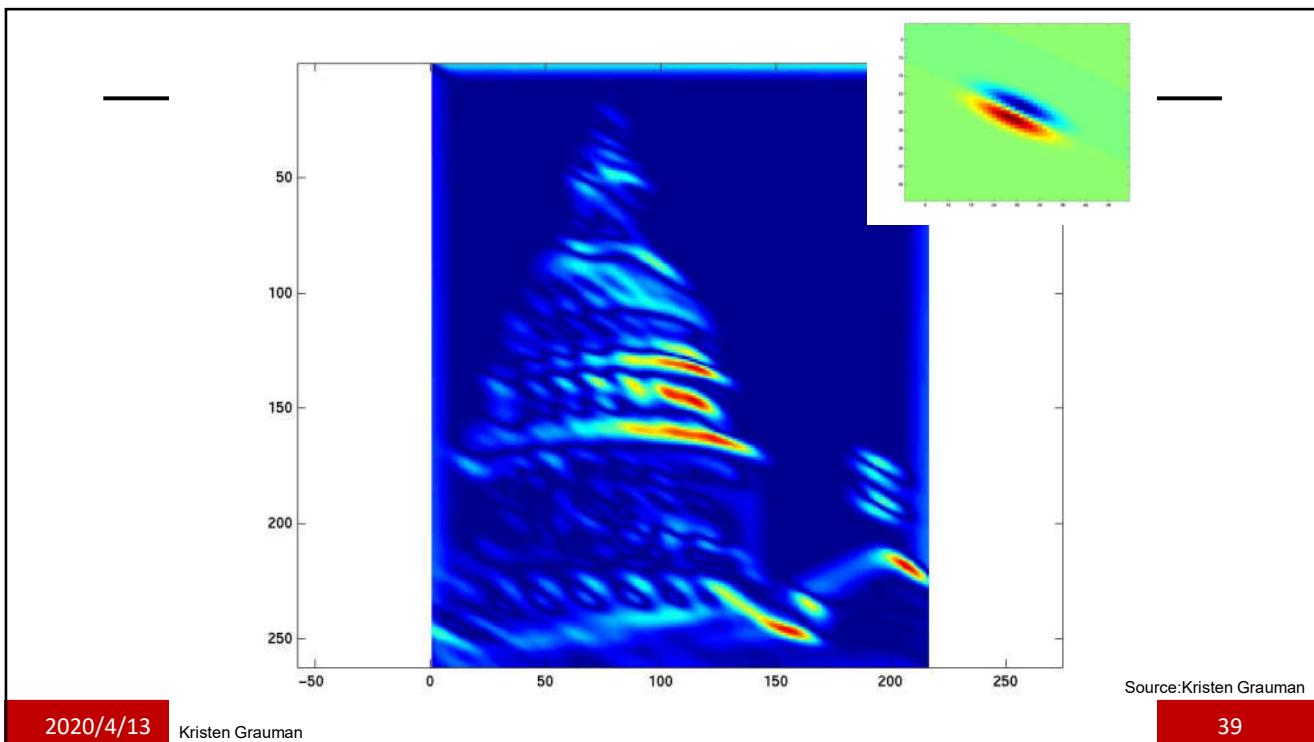
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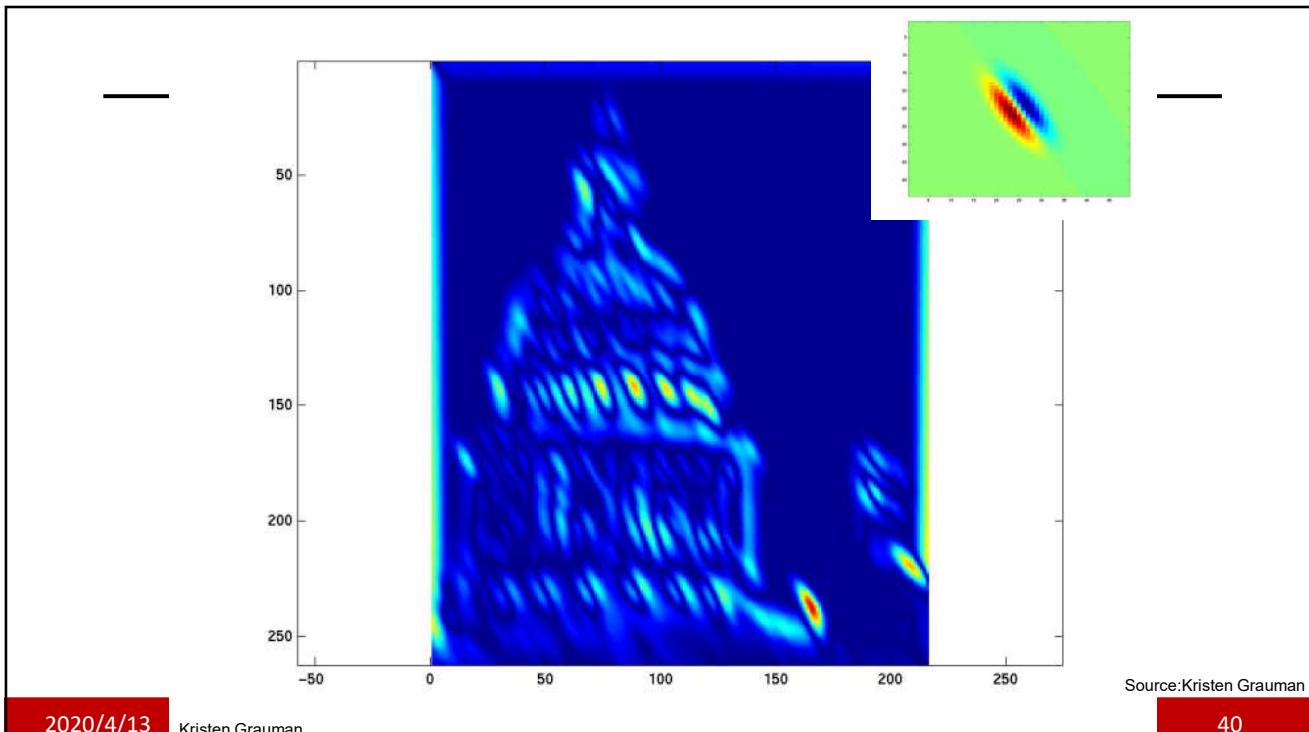
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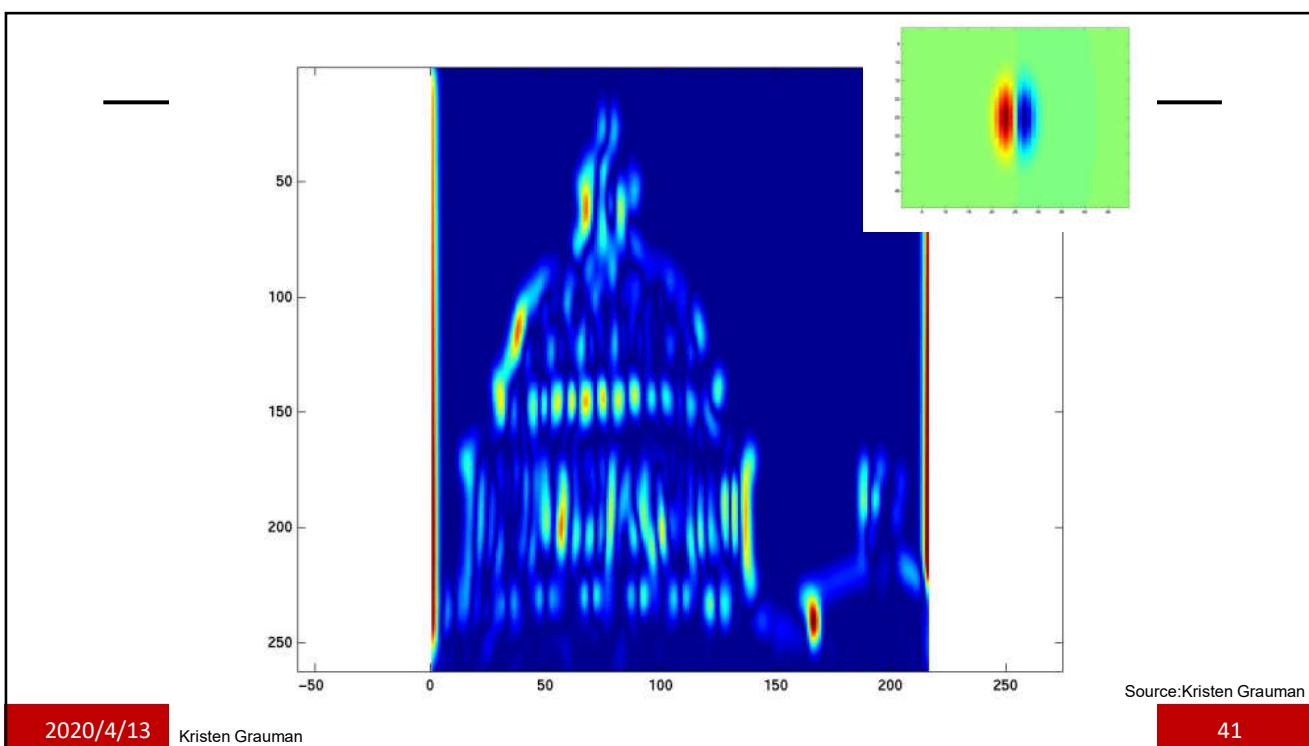
39



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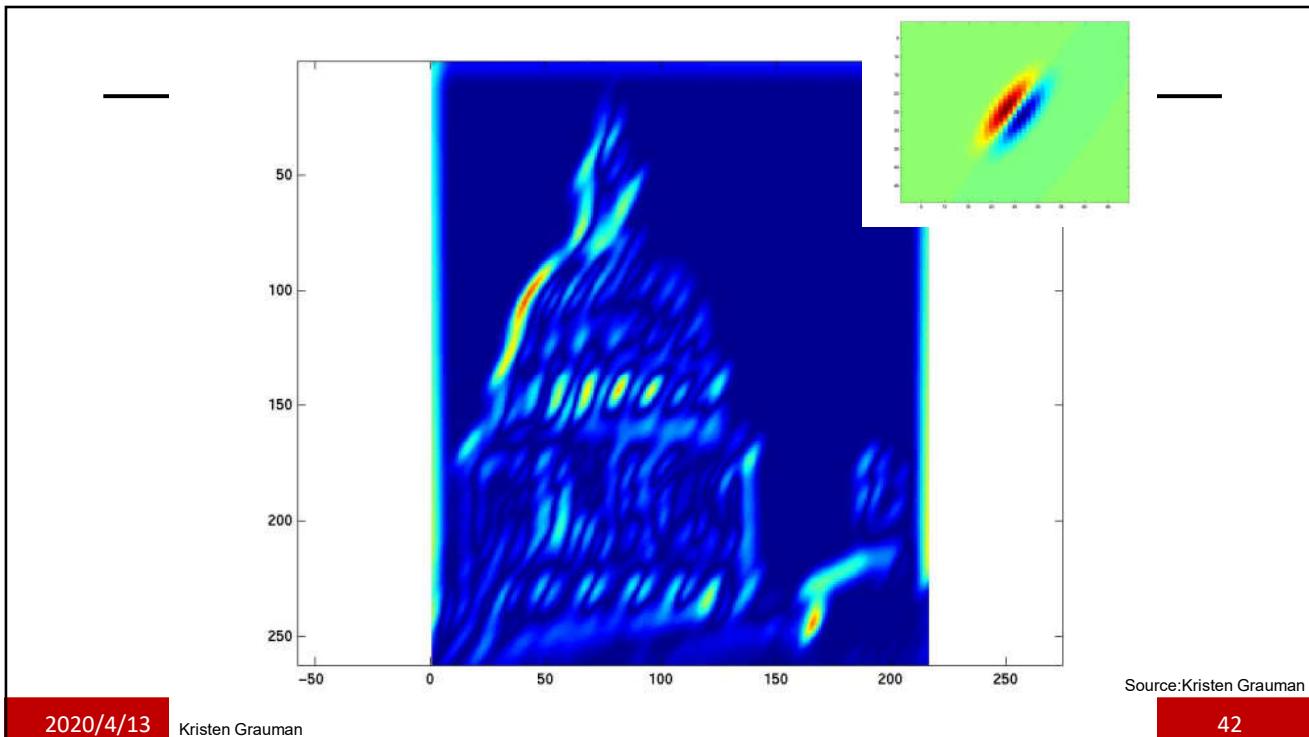
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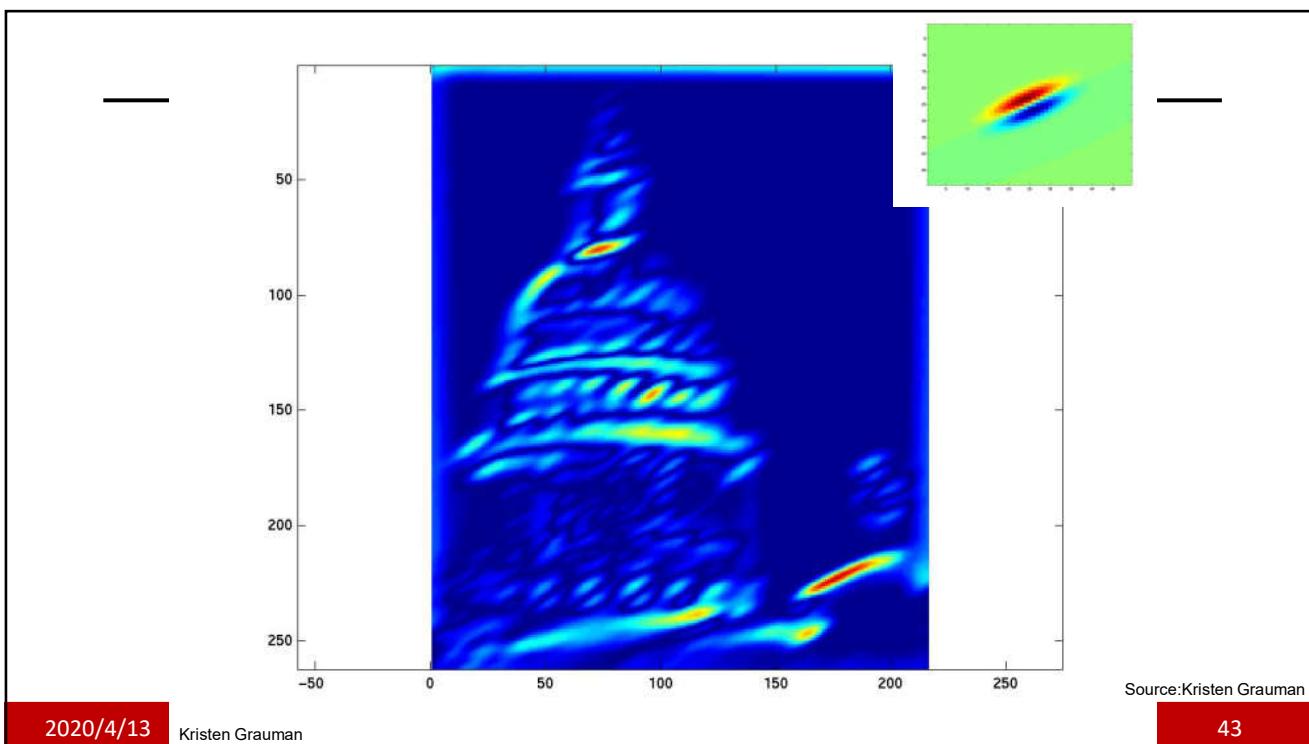
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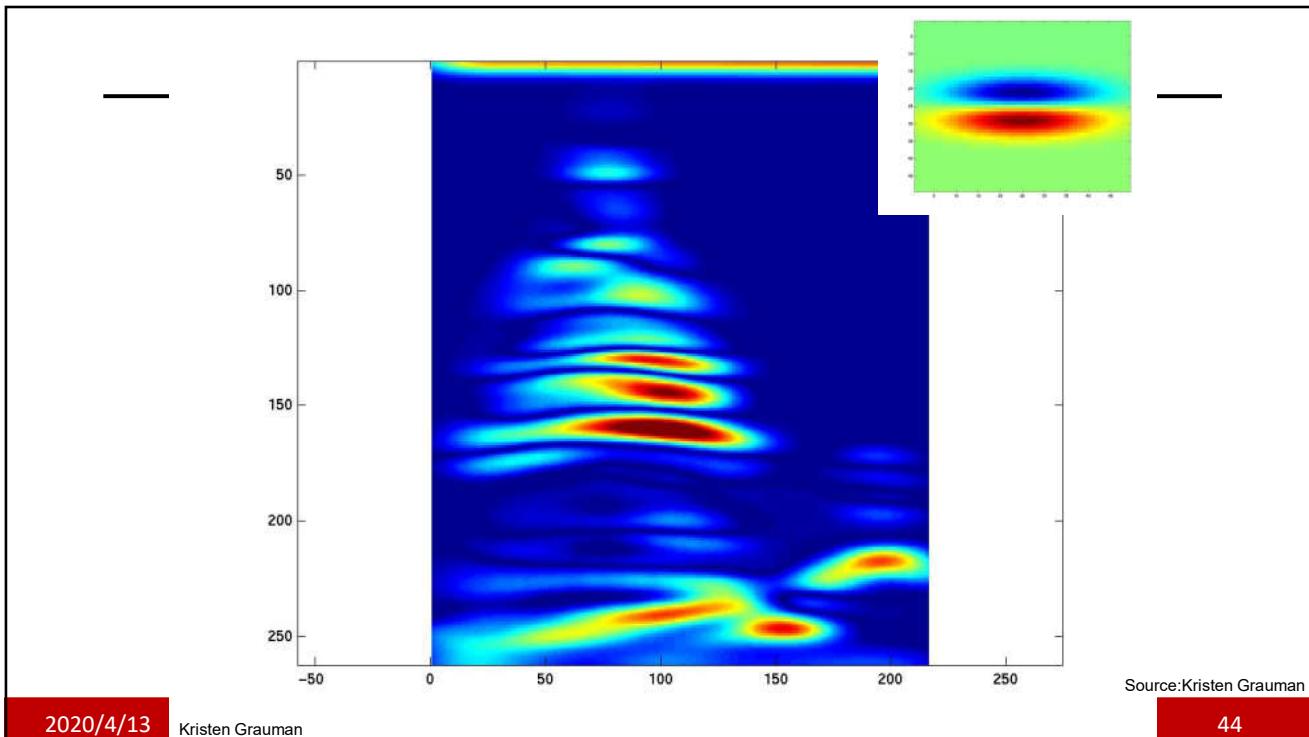
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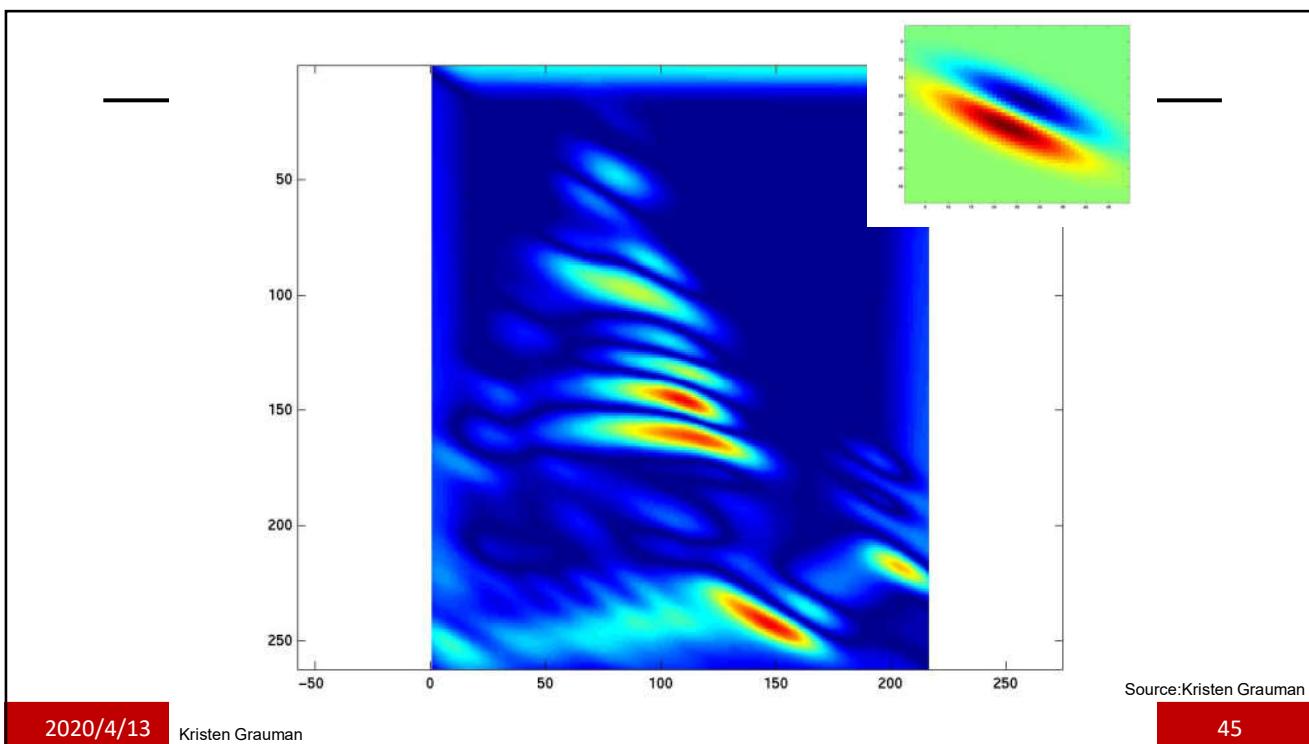


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Kristen Grauman

Source:Kristen Grauman

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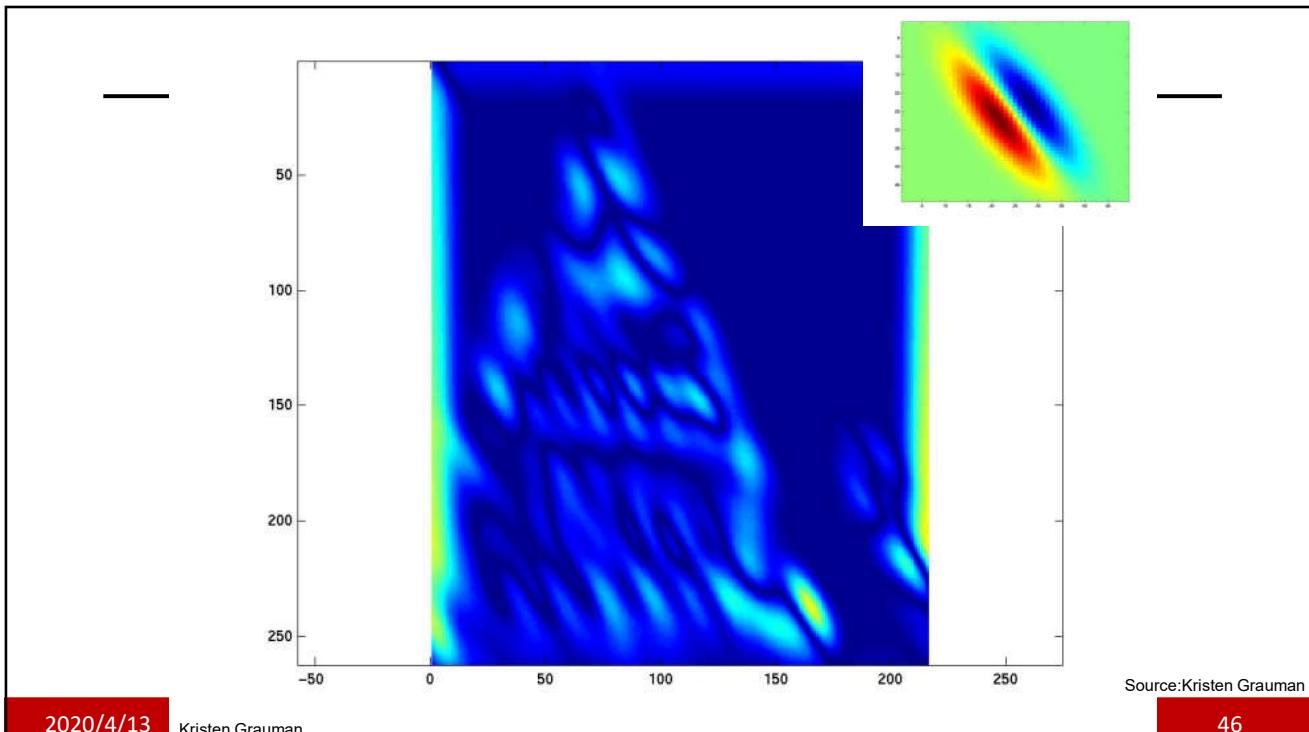


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Kristen Grauman

Source:Kristen Grauman

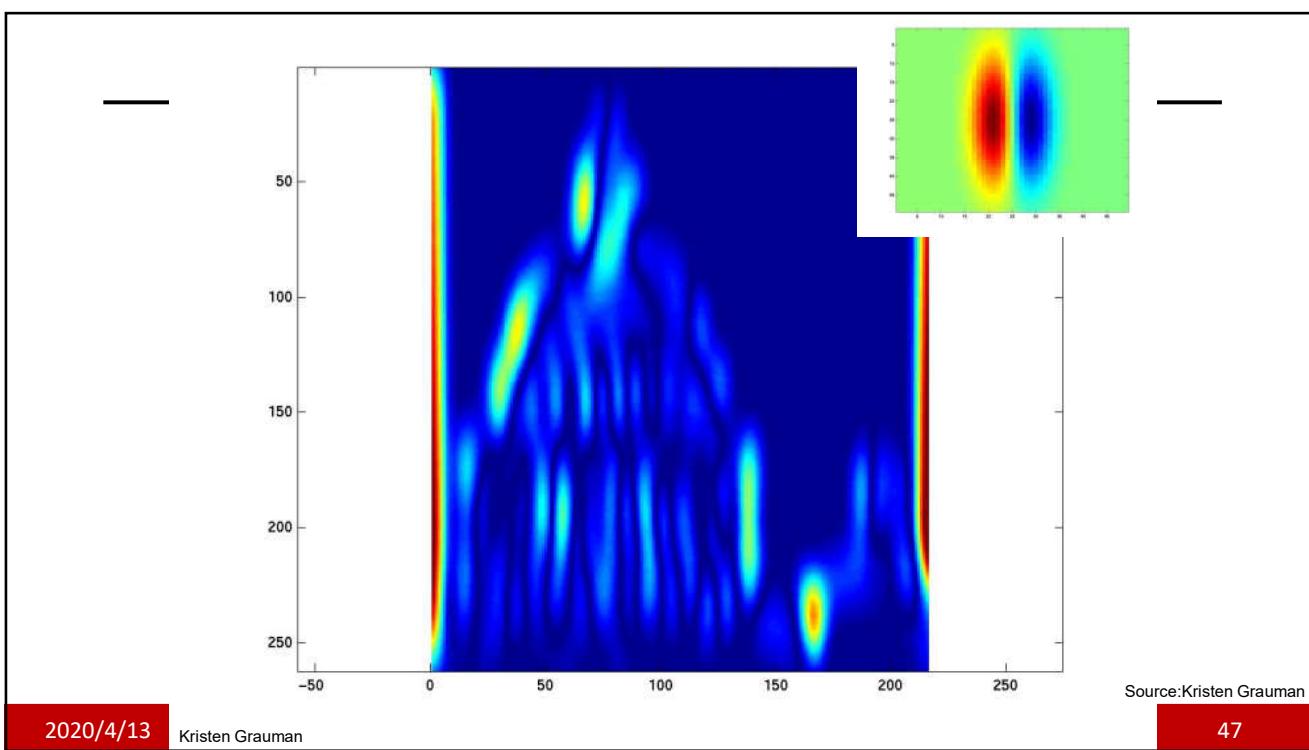
45



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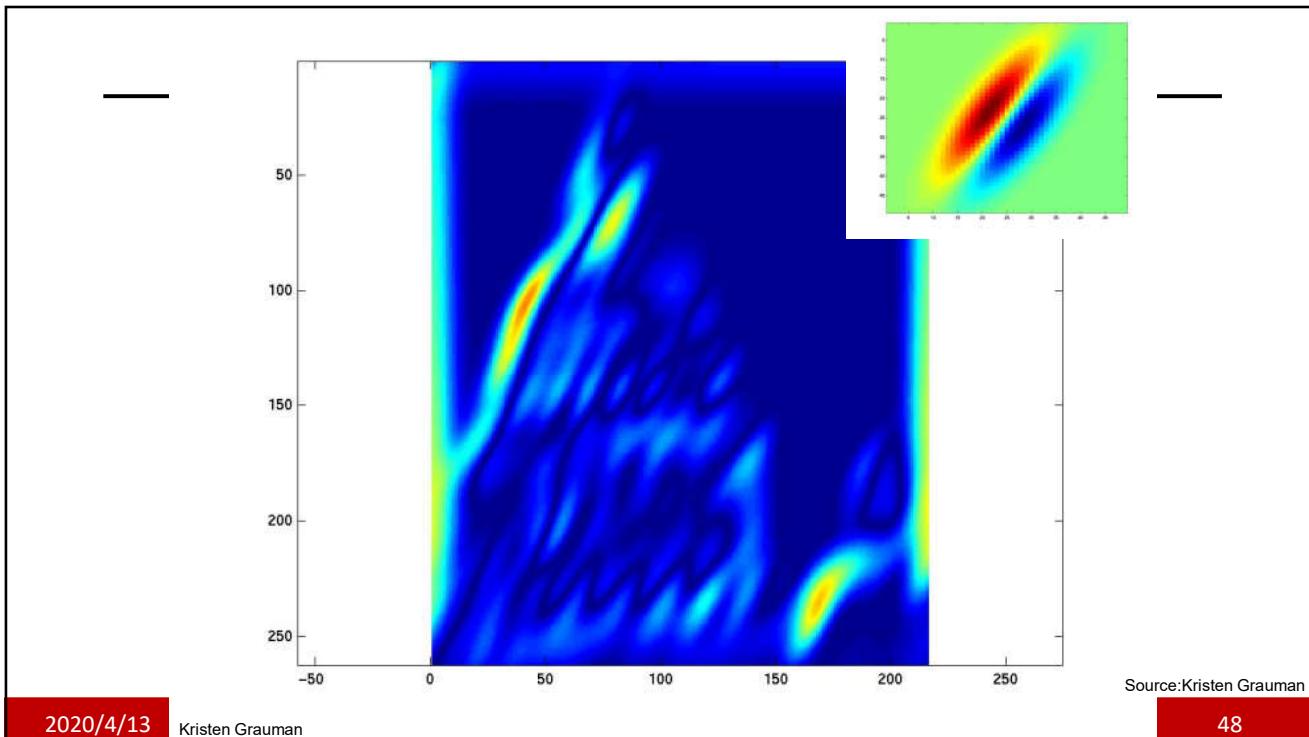
46



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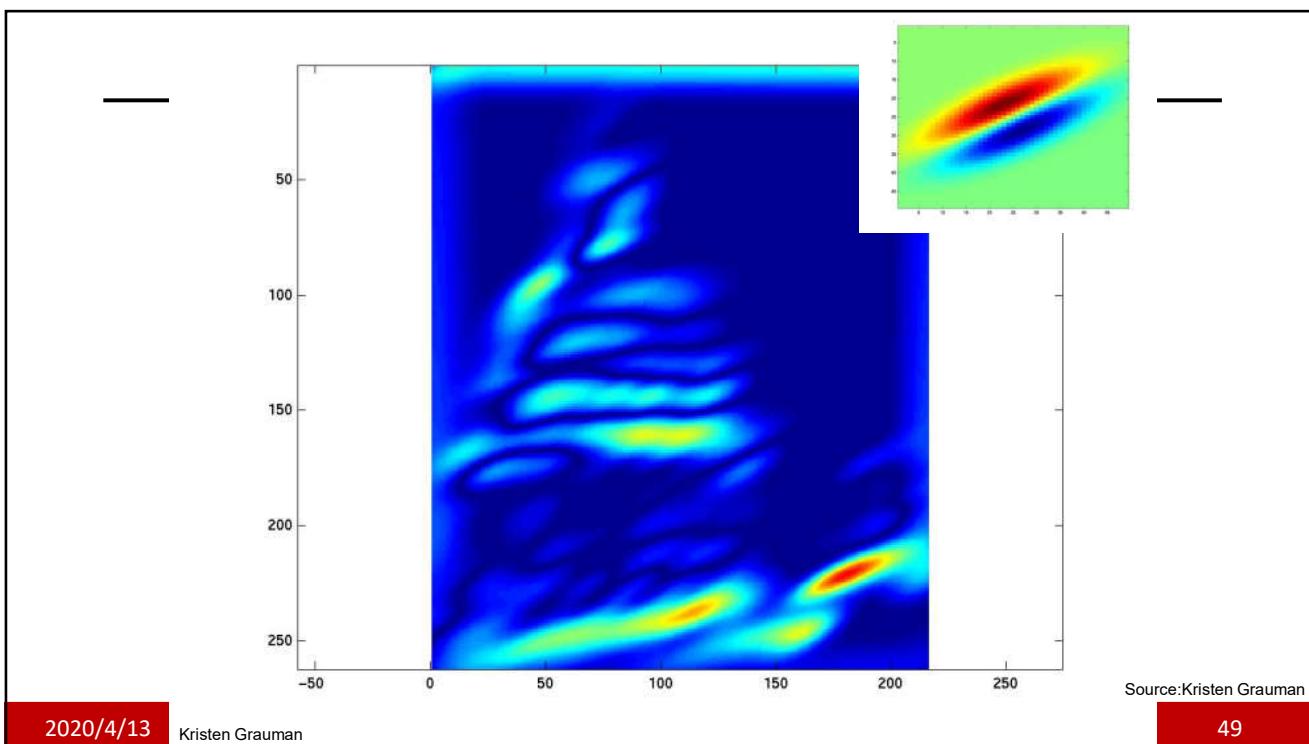
47



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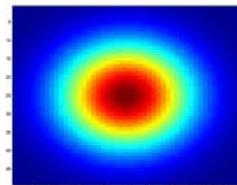
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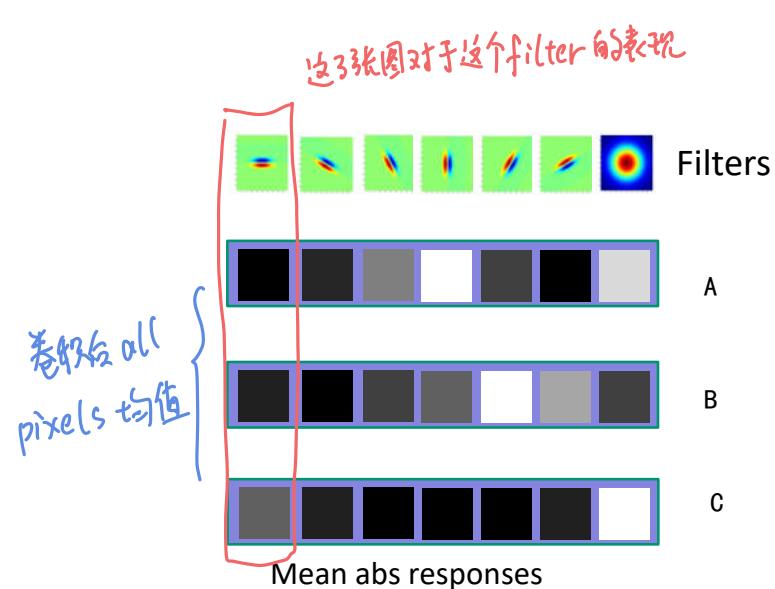
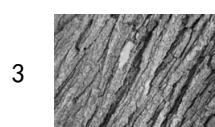
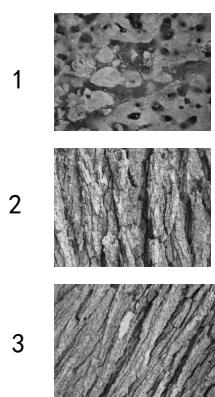
Source:Kristen Grauman

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

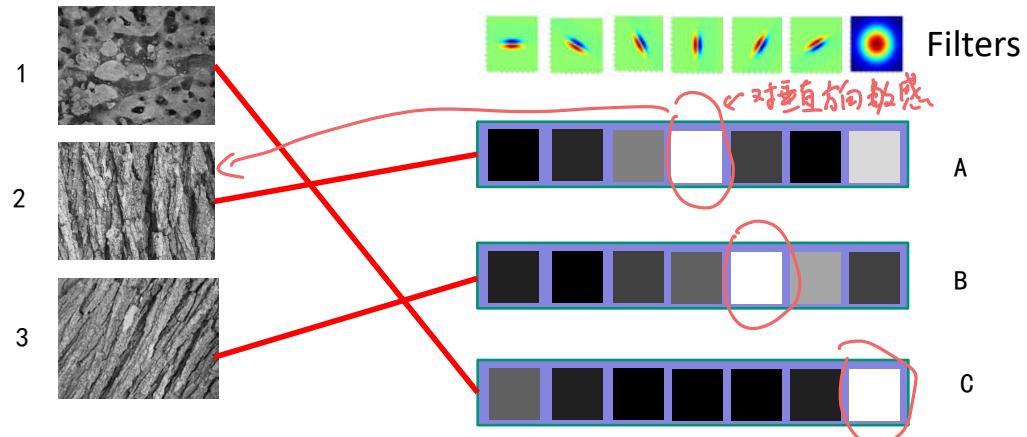


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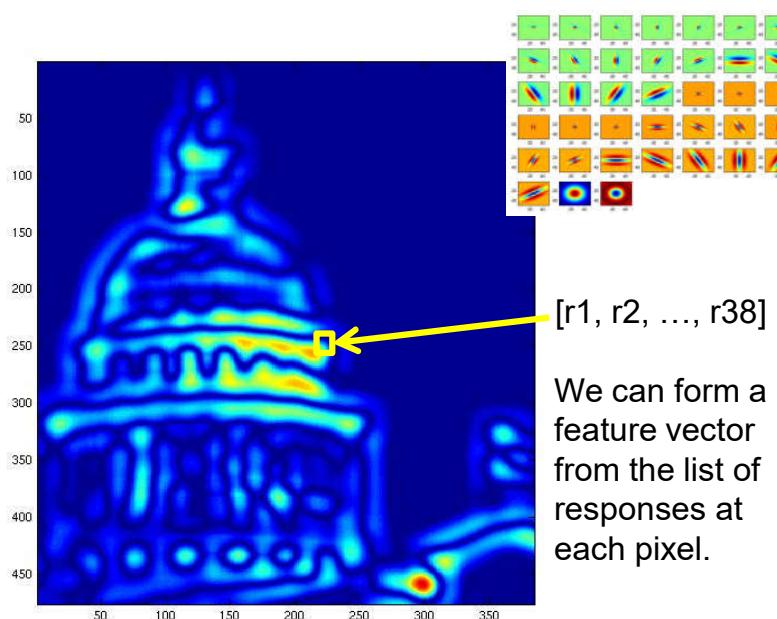
## Representing texture by mean abs response



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Source: Kristen Grauman

2020/4/13 Kristen Grauman

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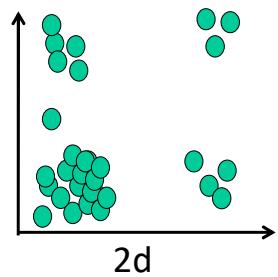
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## ***d*-dimensional features**

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

Euclidean distance ( $L_2$ )



Source:Kristen Grauman

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## **Example uses of texture in vision: analysis**

## Classifying materials, “stuff”



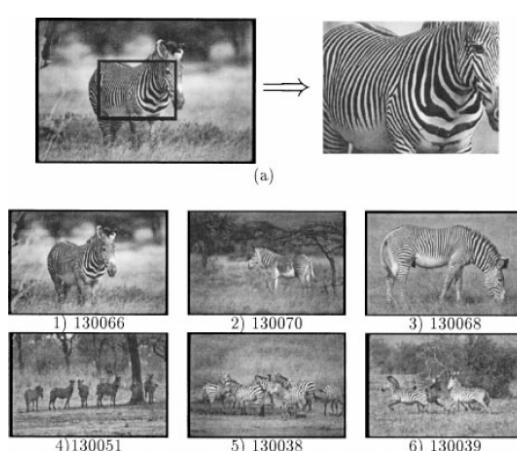
Source: Varma & Zisserman

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## Texture features for image retrieval



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

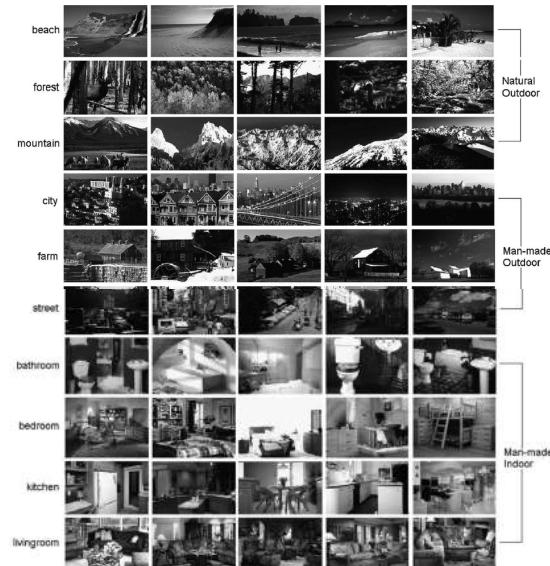
Source: Kristen Grauman

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## Characterizing scene categories by texture



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

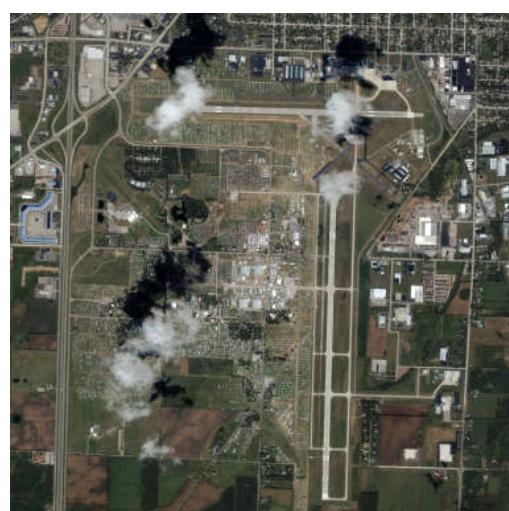
Source:Kristen Grauman

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## Segmenting aerial imagery by textures



[http://www.airventure.org/2004/gallery/images/073104\\_satellite.jpg](http://www.airventure.org/2004/gallery/images/073104_satellite.jpg)

Source:Kristen Grauman

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## Summary

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Texture is a useful property that is often indicative of materials, appearance cues

**Texture representations** attempt to summarize repeating patterns of local structure

**Filter banks** useful to measure redundant variety of structures in local neighborhood

- Feature spaces can be multi-dimensional

Source:Kristen Grauman