Texture

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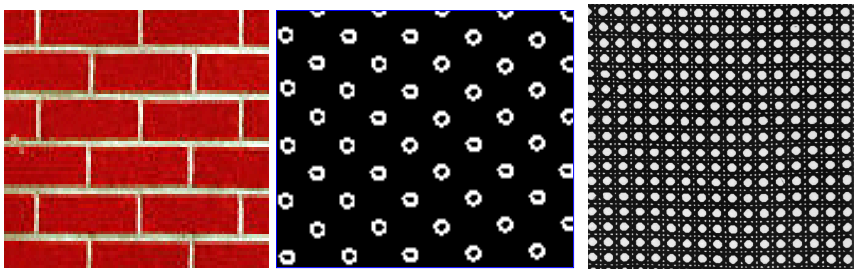
Machine Vision Technology							
Semantic information				**Metric 3D information**			
Pixels	Segments	Images	Videos	Camera		Multi-view Geometry	
Convolutions Edges & Fitting Local features Texture	Segmentation Clustering	Recognition Detection	Motion Tracking	Camera Model	Camera Calibration	Epipolar Geometry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

Today: Texture

What defines a texture?

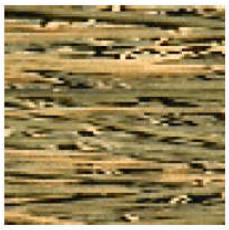
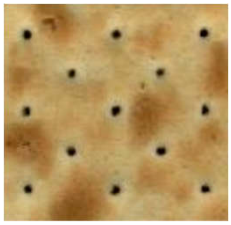
Includes: more regular patterns



Source:Kristen Grauman

Includes: more random patterns



Source:Kristen Grauman

Texture-related tasks

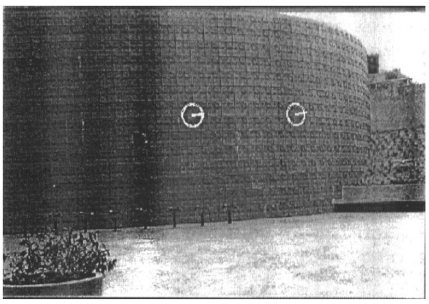
Shape from texture

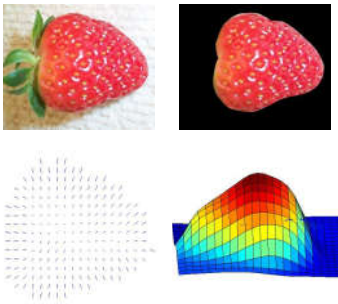
- Estimate surface orientation or shape from image texture

Source:Kristen Grauman

Shape from texture

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





Source:Kristen Grauman

Texture-related tasks

Shape from texture

- Estimate surface orientation or shape from image texture

Segmentation/classification from texture cues

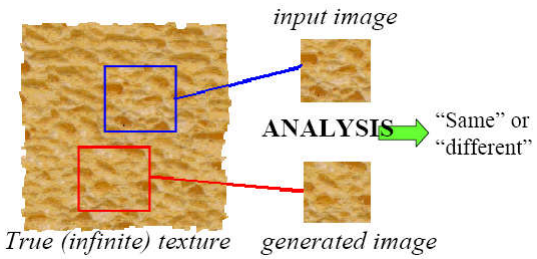
- Analyze, represent texture
- Group image regions with consistent texture

Synthesis

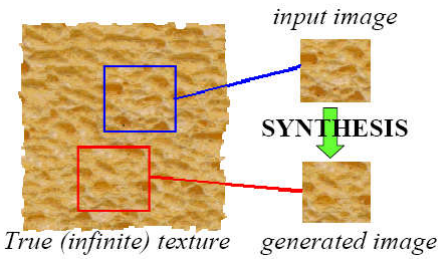
- Generate new texture patches/images given some examples

Source:Kristen Grauman

Analysis vs. Synthesis



Why analyze texture?



Source: Bill Freeman, A. Efros

Texture-related tasks

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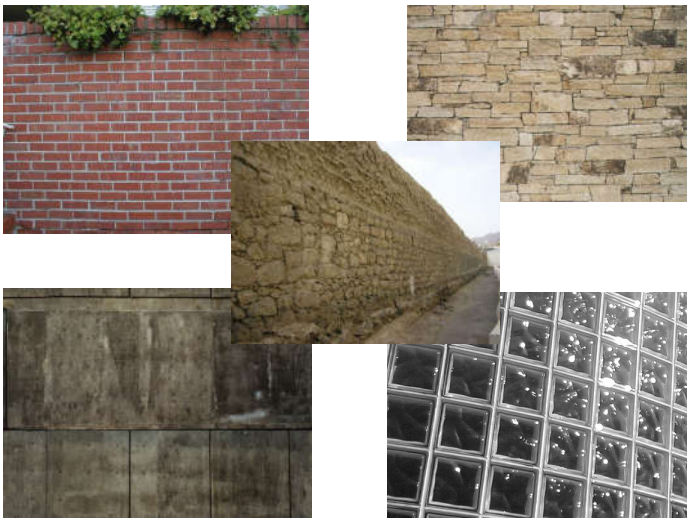
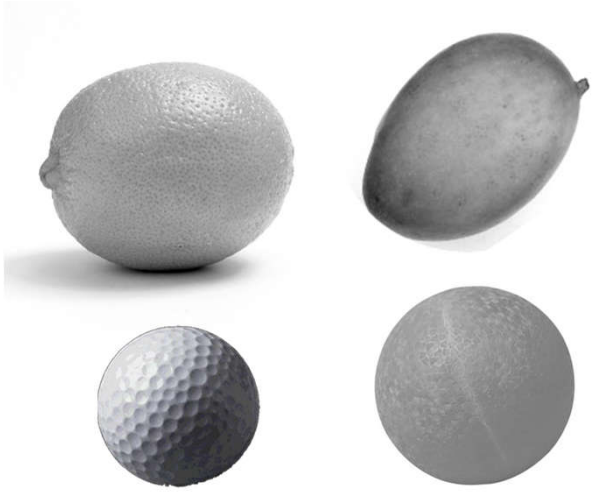


Source:Kristen Grauman



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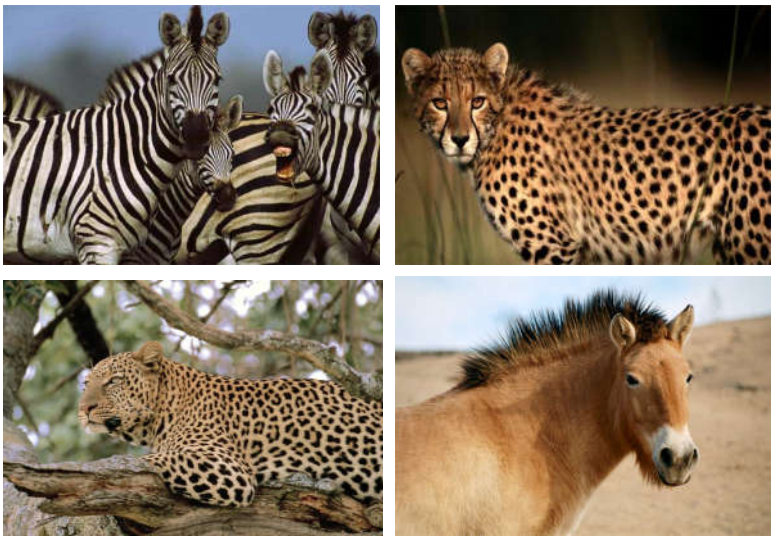


http://animals.nationalgeographic.com/

Source:Kristen Grauman

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

Images from Malik and Perona, 1990

…and for this image?

Source: D. Forsyth

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

Texture representation

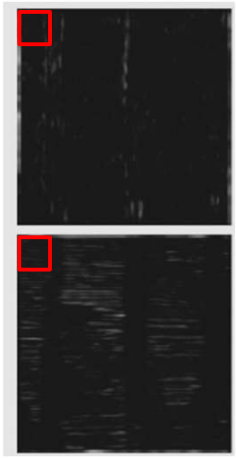
Textures are made up of repeated local patterns, so:

- 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

Texture representation: example

original image



derivative filter responses, squared

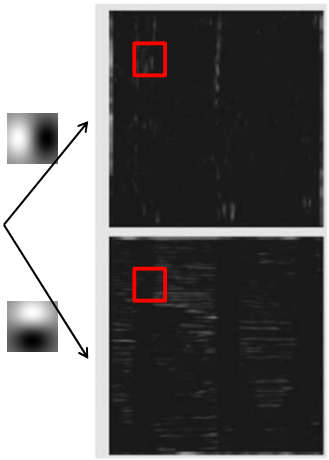
	mean d/dx value	mean d/dy value
Win. #1	4	10

statistics to summarize patterns in small windows

Source:Kristen Grauman

Texture representation: example

original image



derivative filter responses, squared

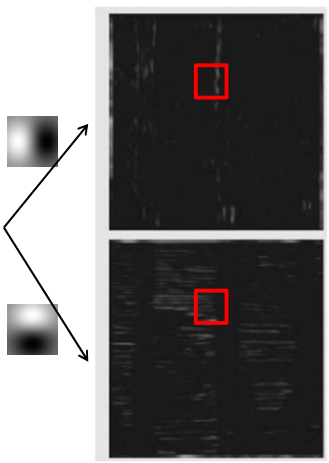
	mean d/dx value	mean d/dy value
Win. #1	4	10
Win.#2	18	7	

statistics to summarize patterns in small windows

Source:Kristen Grauman

Texture representation: example

original image



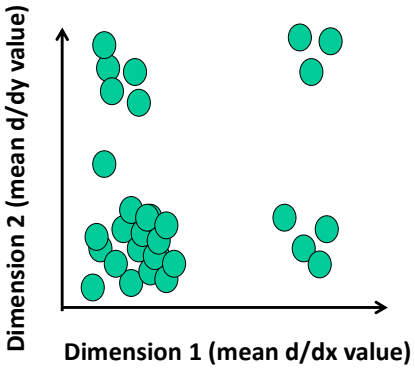
derivative filter responses, squared

	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

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

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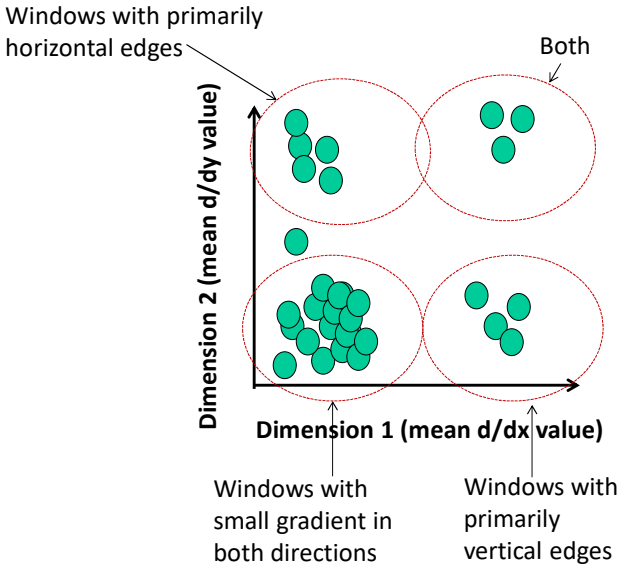
Texture representation: example

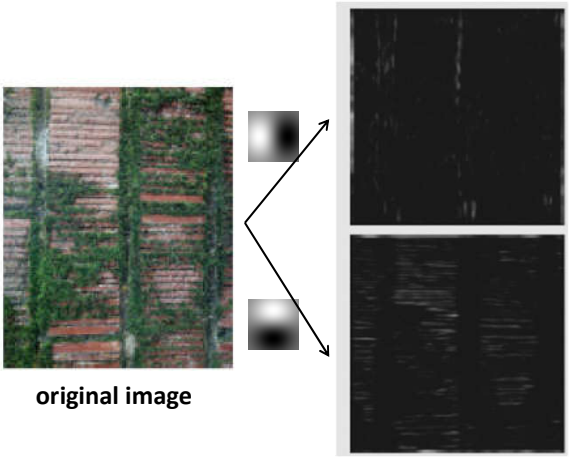


	mean d/dx value	mean d/dy value
Win. #1	4	10
Win.#2	18	7
⋮		
Win.#9	20	20	

statistics to summarize patterns in small windows

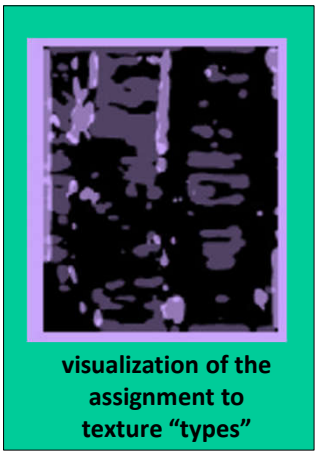
Source:Kristen Grauman

Texture representation: example



original image

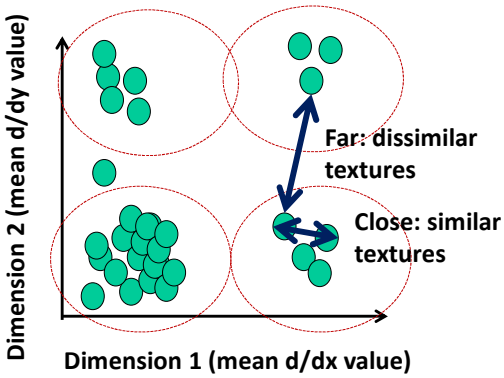
derivative filter responses, squared



visualization of the assignment to texture “types”

Source:Kristen Grauman

Texture representation: example



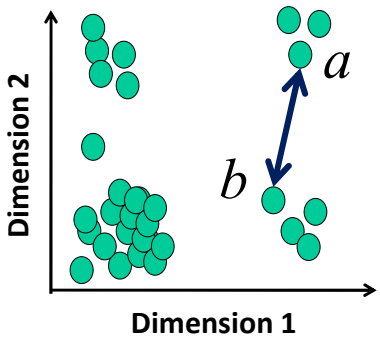
	mean d/dx value	mean d/dy value
Win. #1	4	10
Win.#2	18	7
⋮		
Win.#9	20	20

⋮

statistics to summarize patterns in small windows

Source:Kristen Grauman

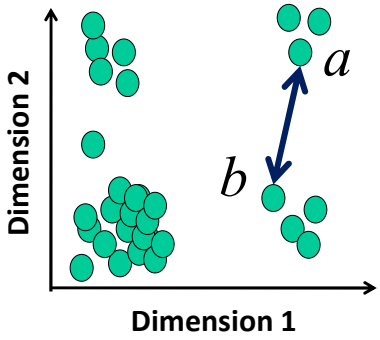
Texture representation: example



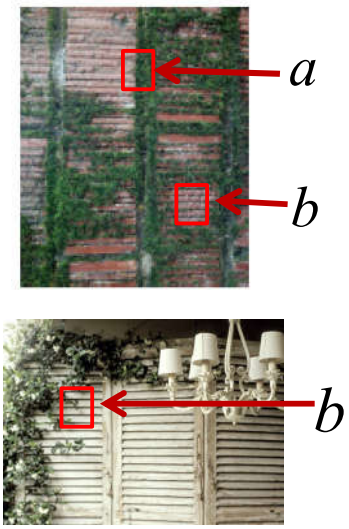
$$D(a,b)=\sqrt{(a_1-b_1)^2+(a_2-b_2)^2}$$

Source:Kristen Grauman

Texture representation: example



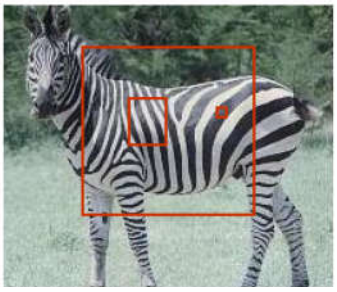
Distance reveals how dissimilar texture from window a is from texture in window b.



Source:Kristen Grauman

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

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.

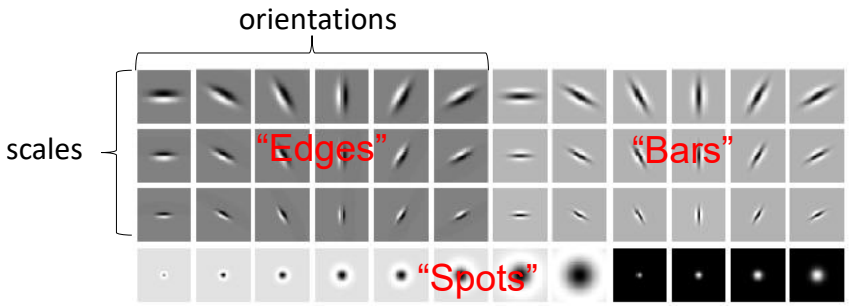
- still can think of nearness, farness in feature space

Source:Kristen Grauman

Filter banks

What filters to put in the bank?

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

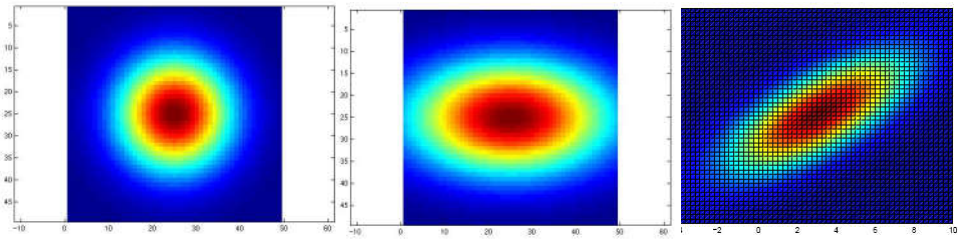


Matlab code available for these examples:
http://www.robots.ox.ac.uk/~vgg/research/texclass/filters.html

Source:Kristen Grauman

Multivariate Gaussian

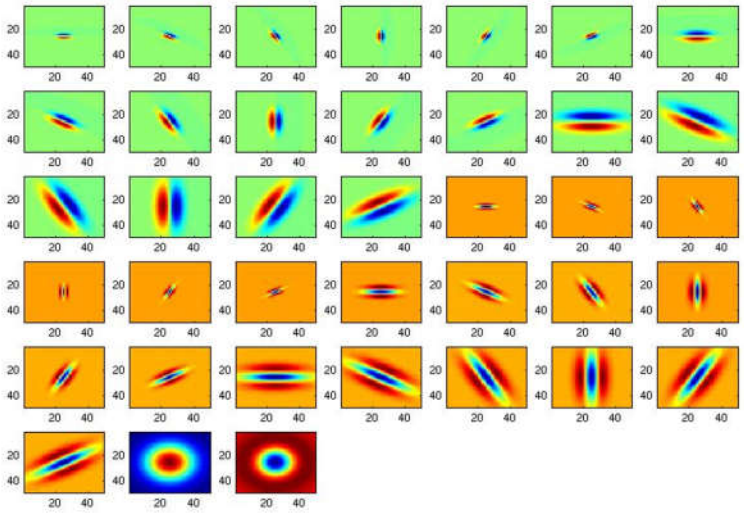
$$p(x;\mu,\Sigma) = \frac{1}{(2\pi)^{n/2}|\Sigma|^{1/2}} \exp\left(-\frac{1}{2}(x-\mu)^T\Sigma^{-1}(x-\mu)\right)$$



$$\Sigma = \begin{bmatrix} 9 & 0 \\ 0 & 9 \end{bmatrix} \qquad \Sigma = \begin{bmatrix} 16 & 0 \\ 0 & 9 \end{bmatrix} \qquad \Sigma = \begin{bmatrix} 10 & 5 \\ 5 & 5 \end{bmatrix}$$

Source:Kristen Grauman

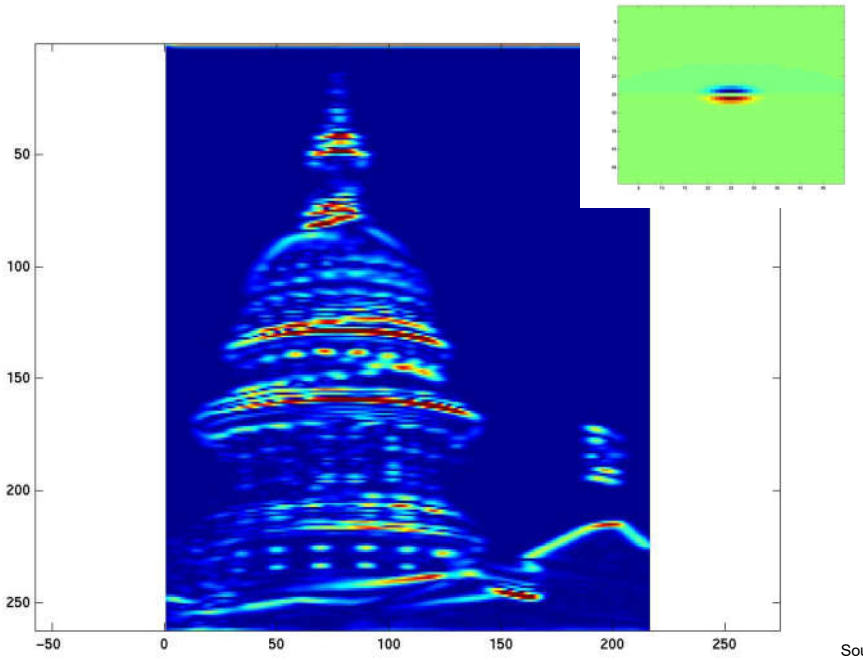
Filter bank



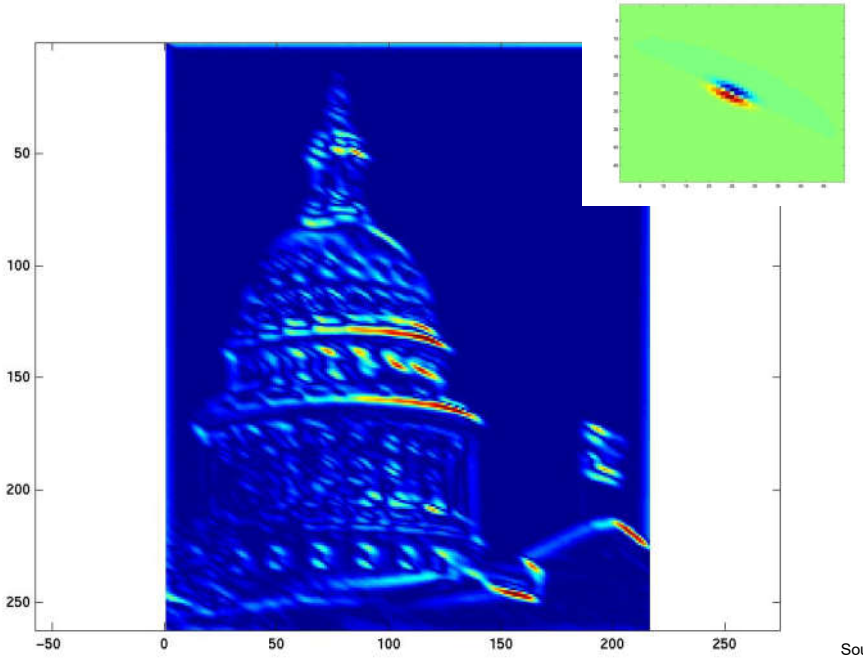
Source:Kristen Grauman

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

Source:Kristen Grauman



Source:Kristen Grauman



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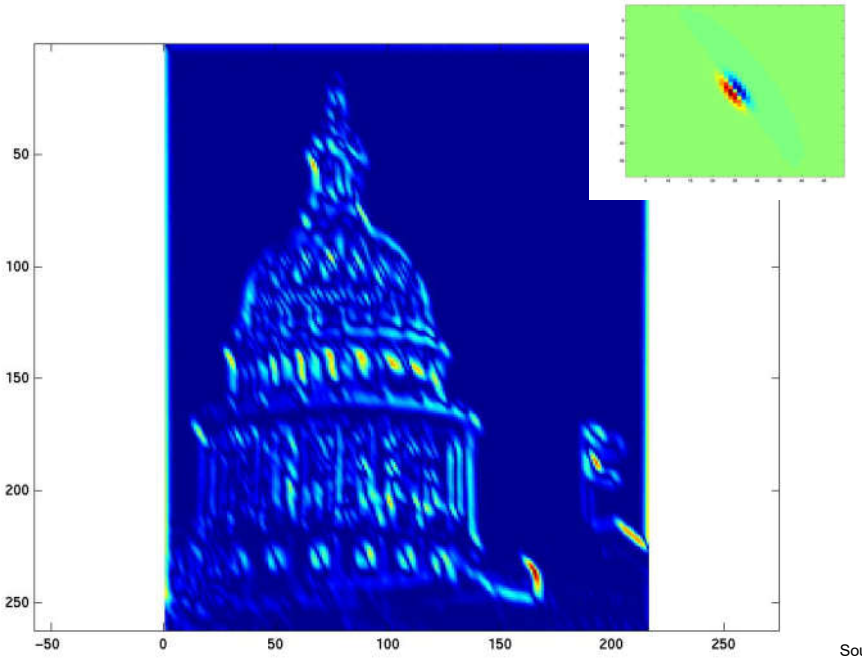

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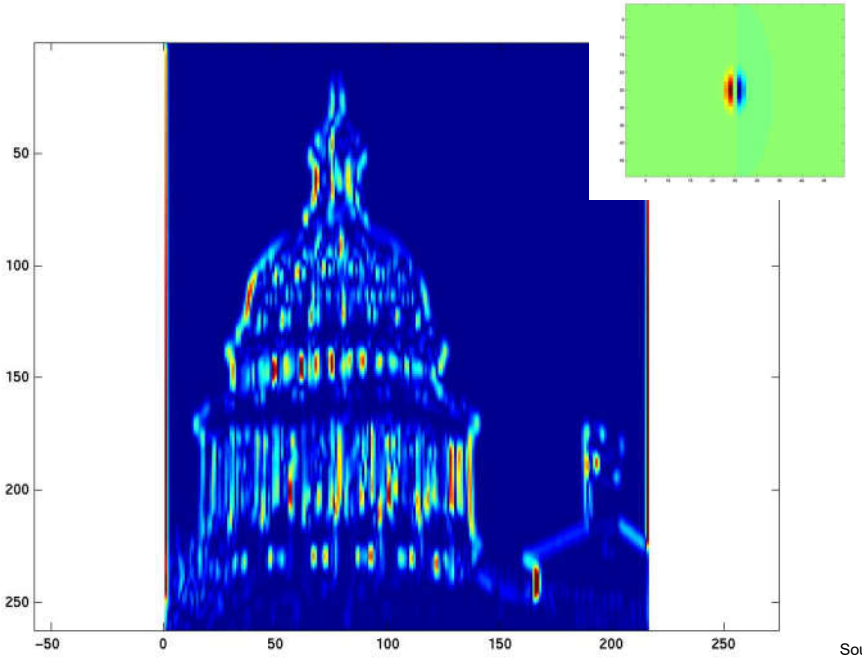

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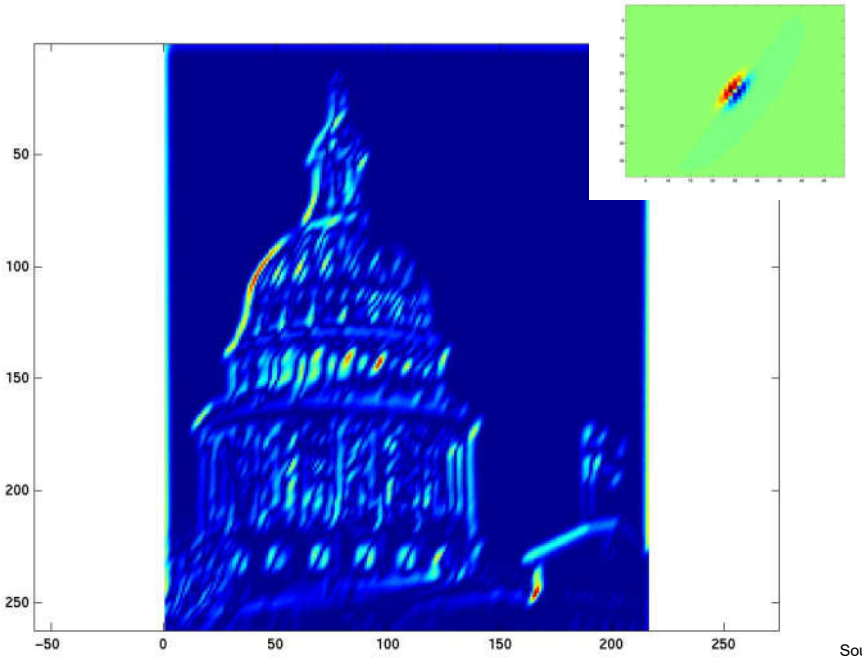

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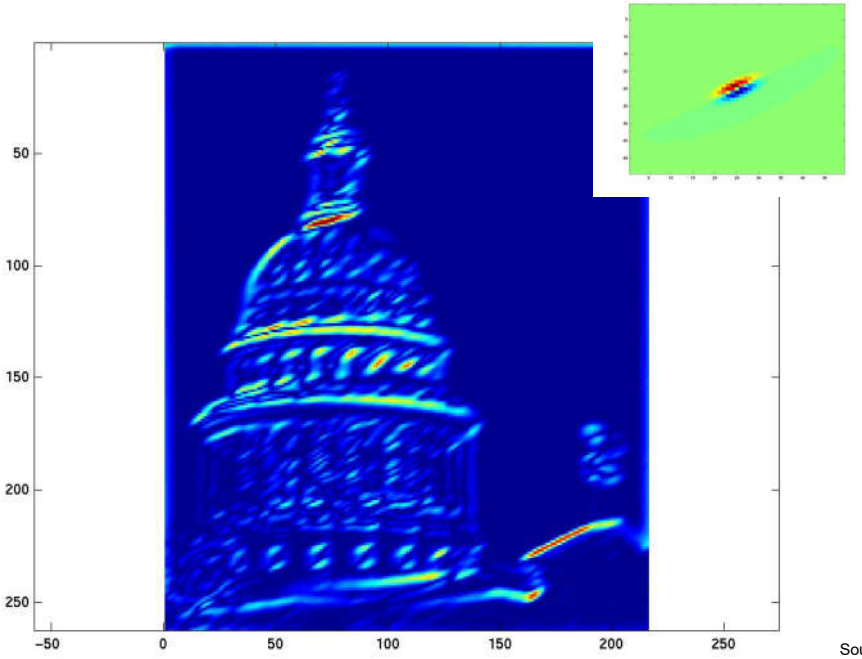

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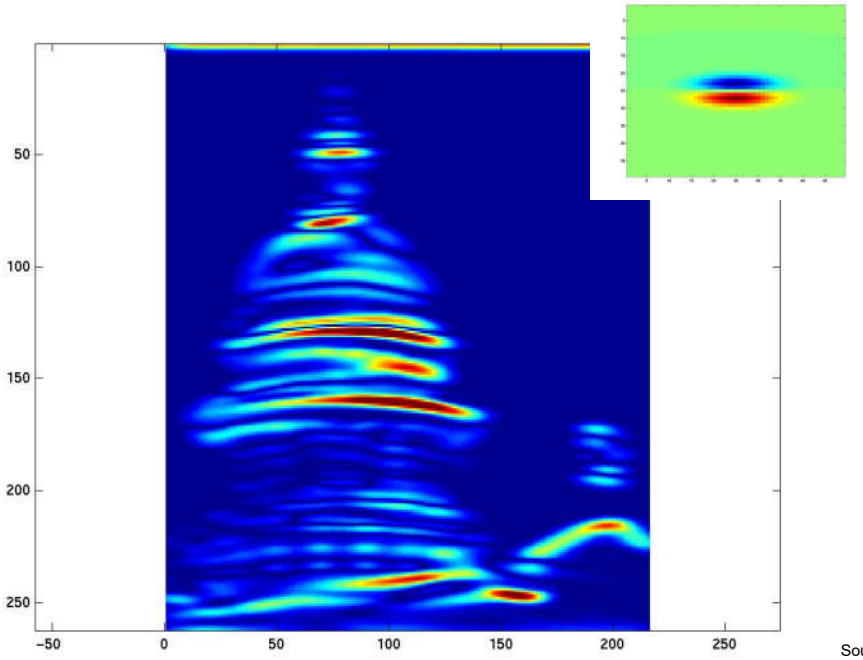

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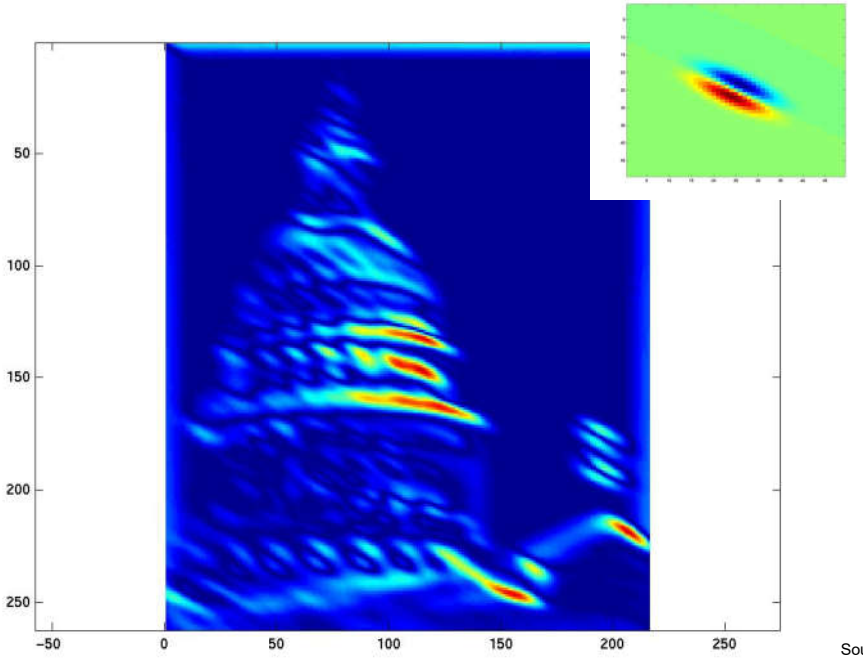

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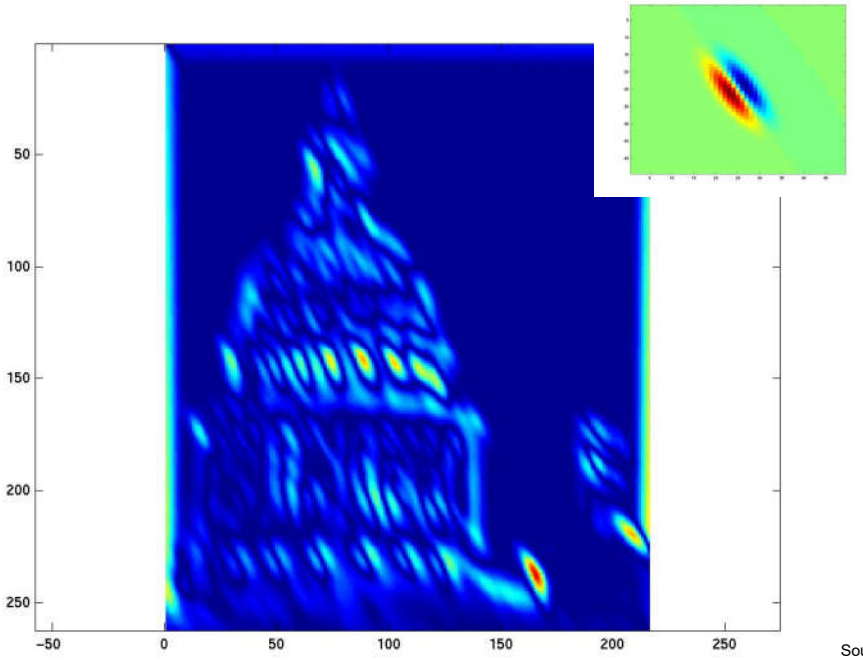

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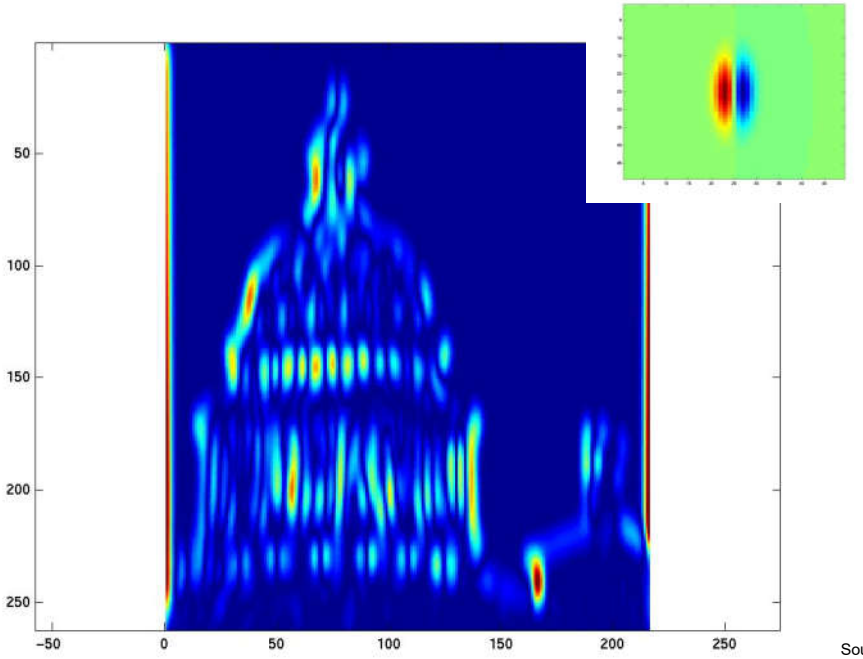

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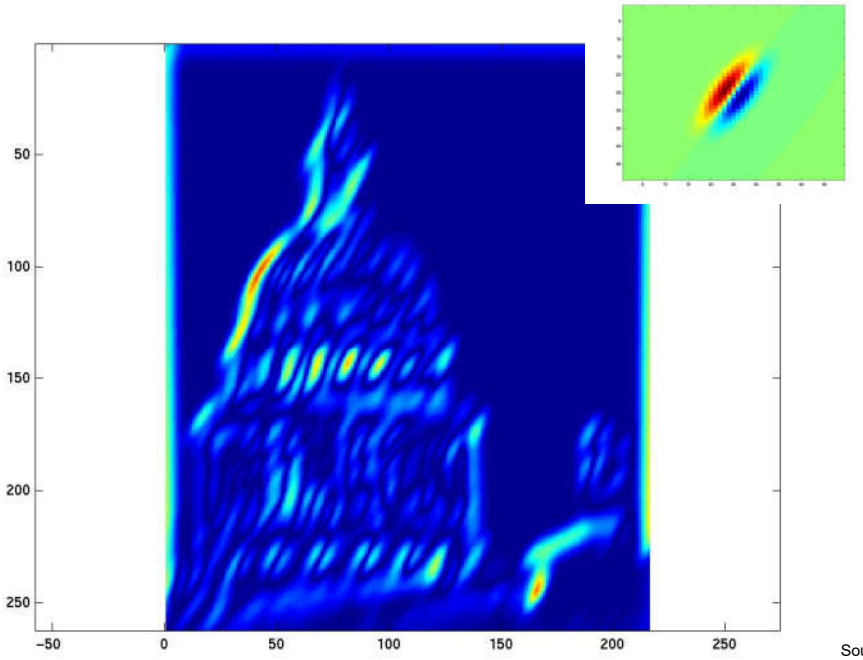

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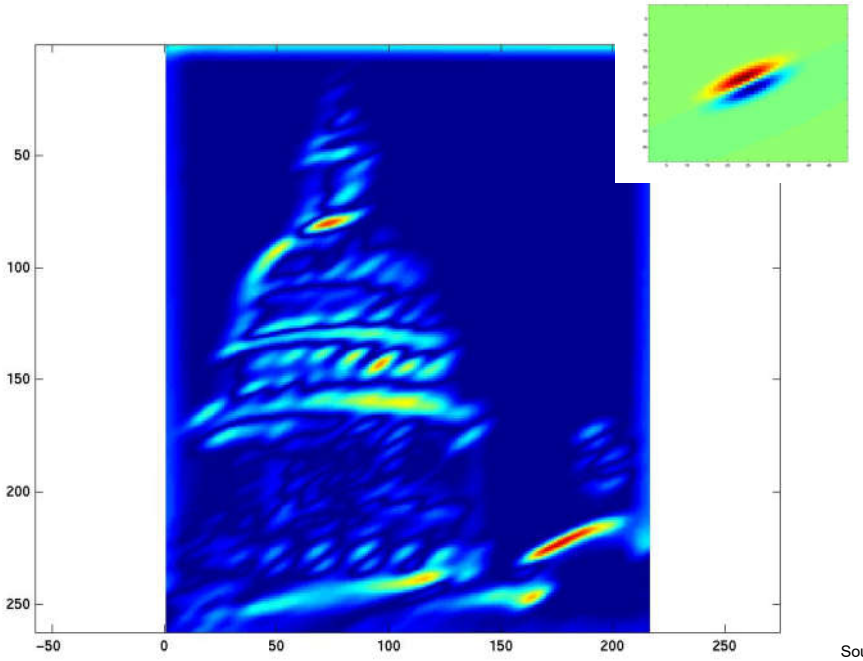

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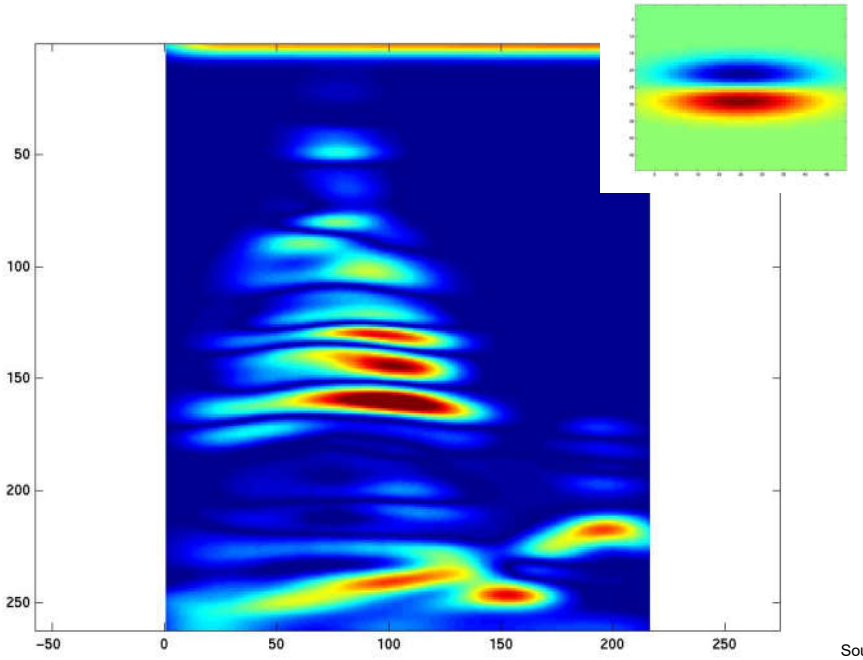

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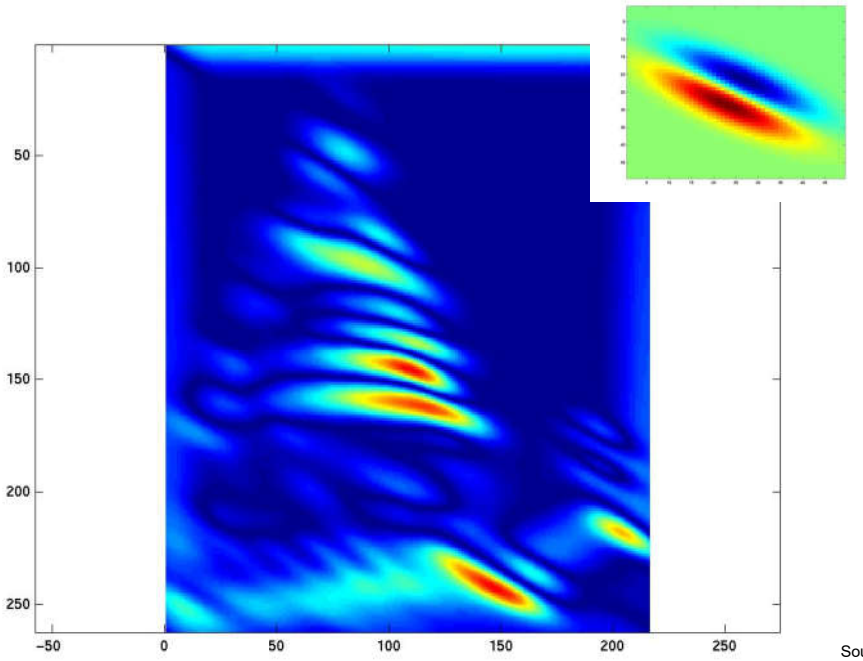

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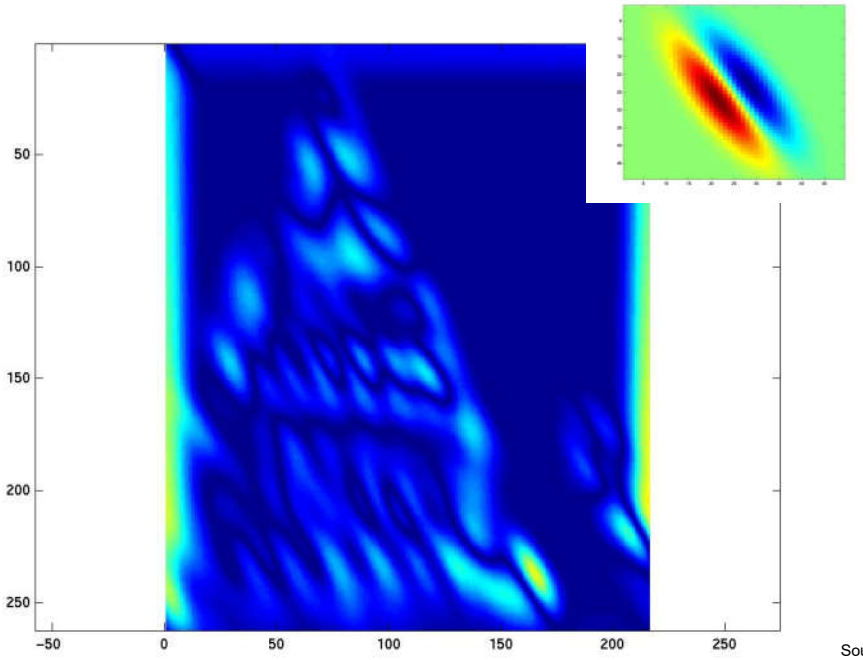
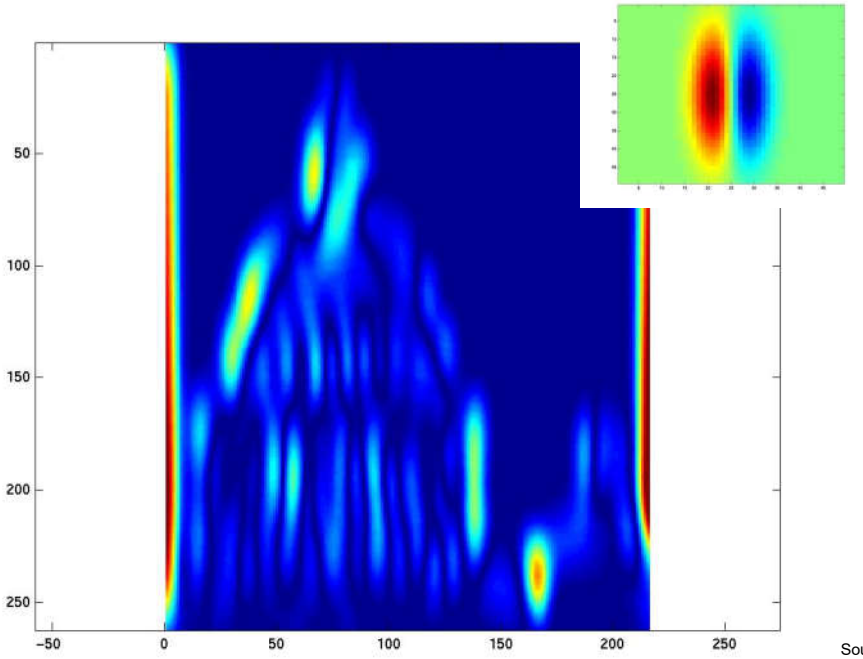
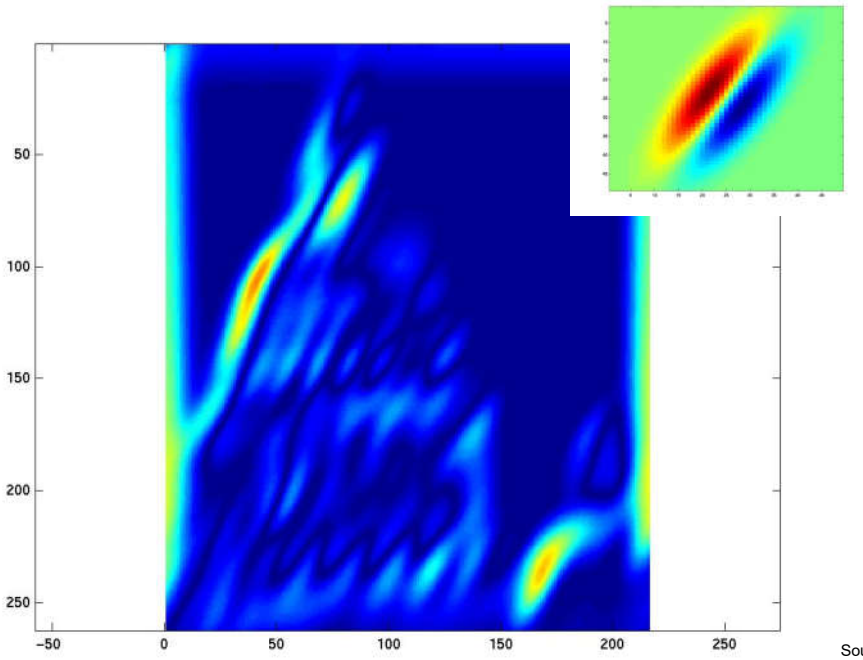


Source:Kristen Grauman



Source:Kristen Grauman



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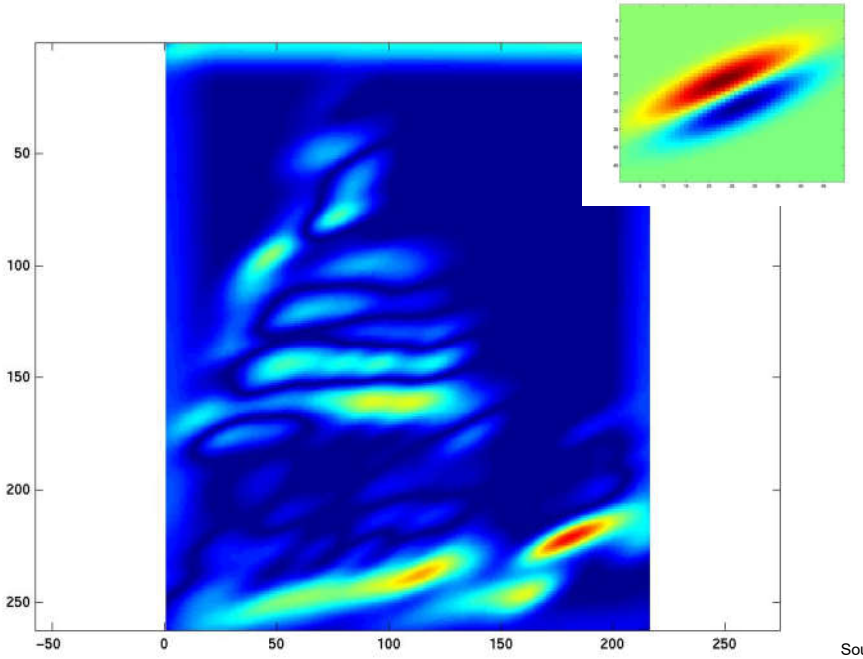
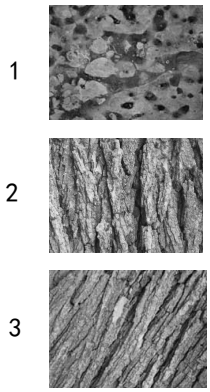
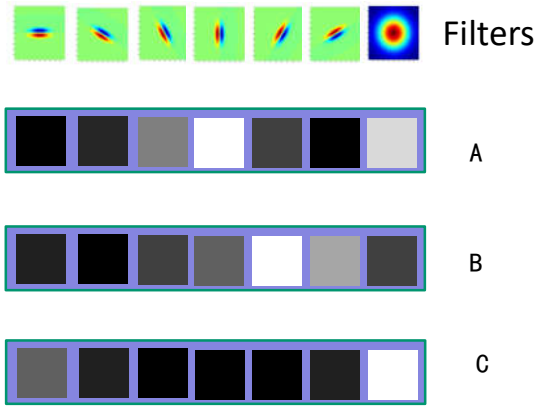


Source:Kristen Grauman

Source:Kristen Grauman

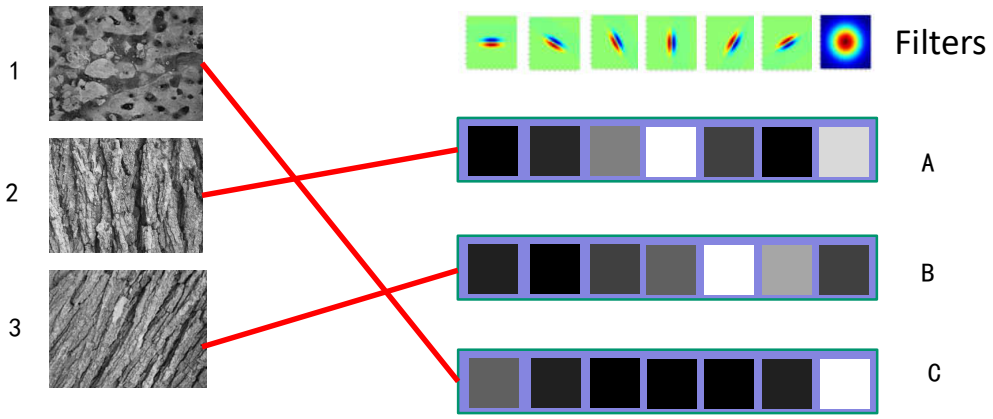
You try: Can you match the texture to the response?

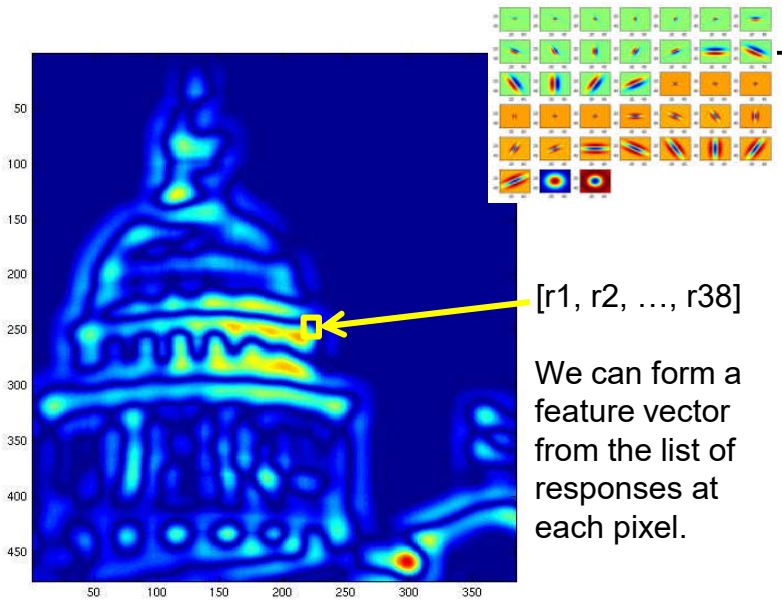




Mean abs responses

Representing texture by mean abs response





[r1, r2, …, r38]

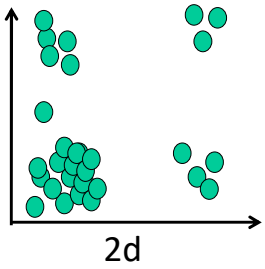
We can form a feature vector from the list of responses at each pixel.

Source:Kristen Grauman

d-dimensional features

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

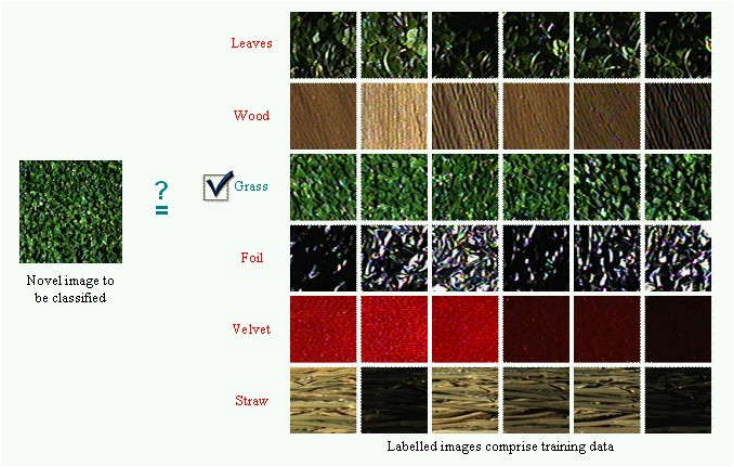
Euclidean distance (L_2)



Source:Kristen Grauman

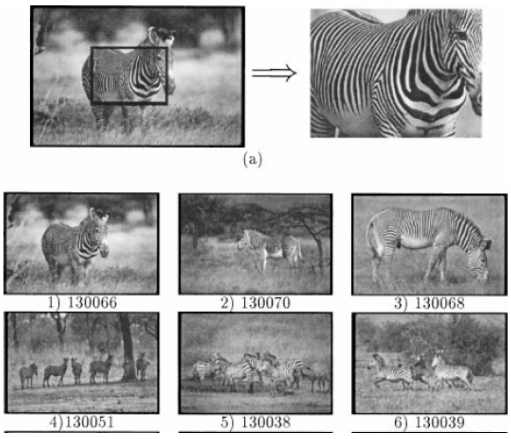
Example uses of texture in vision: analysis

Classifying materials, “stuff”



Source: Varma & Zisserman

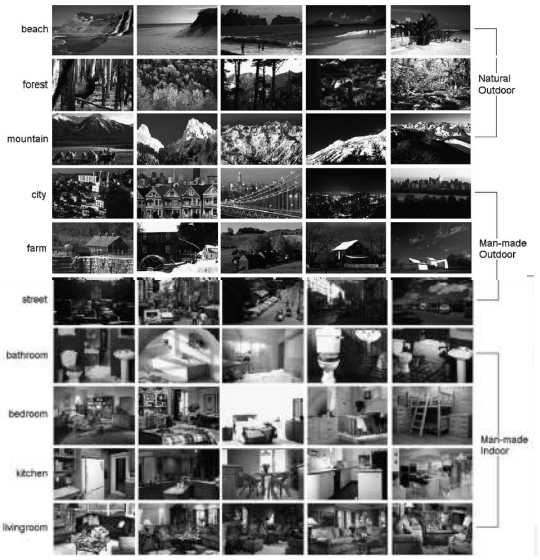
Texture features for image retrieval



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

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

Segmenting aerial imagery by textures

http://www.airventure.org/2004/gallery/images/073104_satellite.jpg

Source:Kristen Grauman

Summary

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