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Spatial AI & Robotics Lab

CSE 473/573-A

L15: TEXTURE

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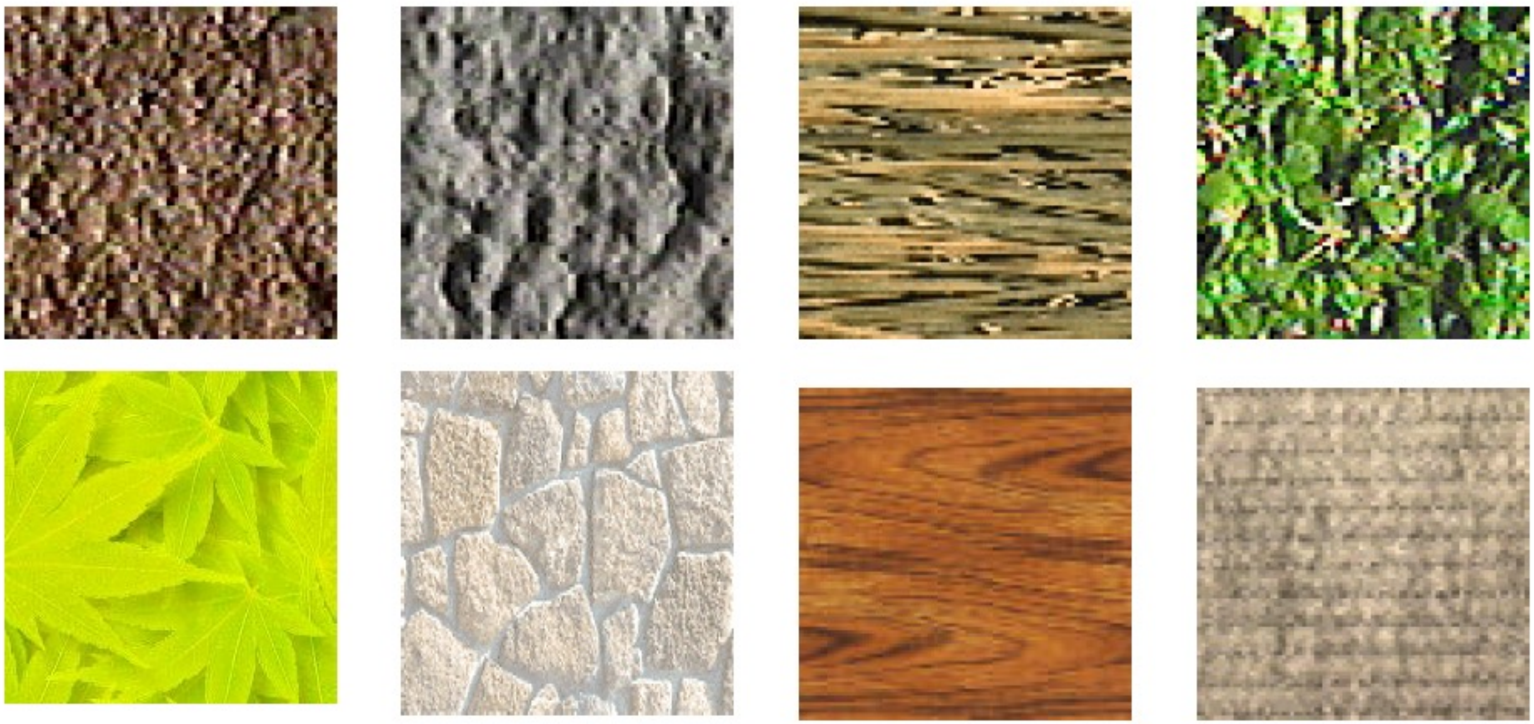
Many Slides from Dr. Chen Wang

Texture

- What defines a texture?



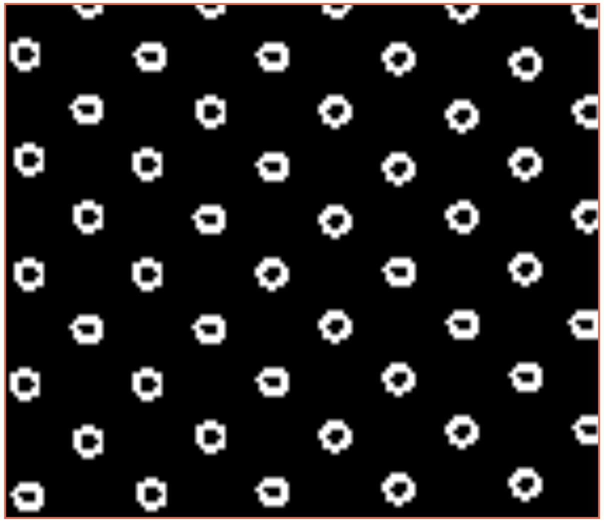
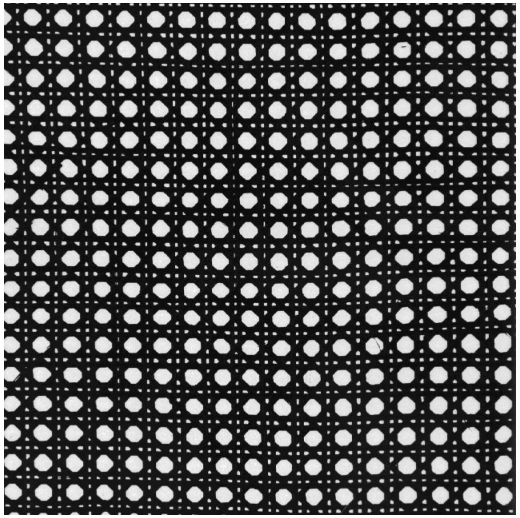
What is Texture?

- No Formal Definition
  - There will be **signficant variation** in intensity levels between pixels
  - these variations perform **repetitive** patterns- homogeneous at some scale
  - **local statistics** are constant and slowly varying

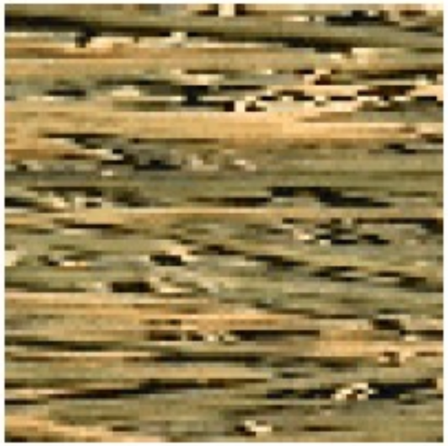
- Human visual systems perceived textures as **homogeneous regions** even though they don't have the same intensity

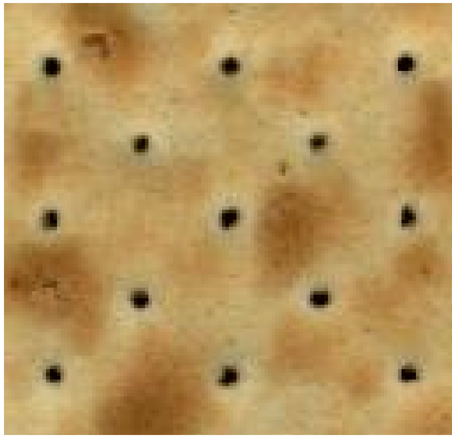
Regular (Repetitive) patterns

- We interpret this first image as a brick wall

Random patterns





Texture

- Is a property of a "group of pixels" or Area
  - a single pixel does not have texture
- It is **scale dependent**
  - at different scales textures have different properties
- It contains many possibly countless **primitive objects**
- It involves the **spatial distribution** of intensities
  - 2D histograms
  - Co-occurrence matrices

Scale

- Scale is important – consider sand
- Close up
  - "small rocks, sharp edges"
  - "rough looking surface"
  - "smoother"

- Far Away
  - "one object
  - ⇒ brown/tan color"

How would you describe a Texture?

- Coarseness
- Roughness
- Direction
- Frequency
- Uniformity
- Density

- How do you describe
  - dog fur, cat fur, wood grain, or cloth?

Textures has different instances.

- All images are different instances of the same texture
- We can differentiate between them, but they seem generated by the same process.





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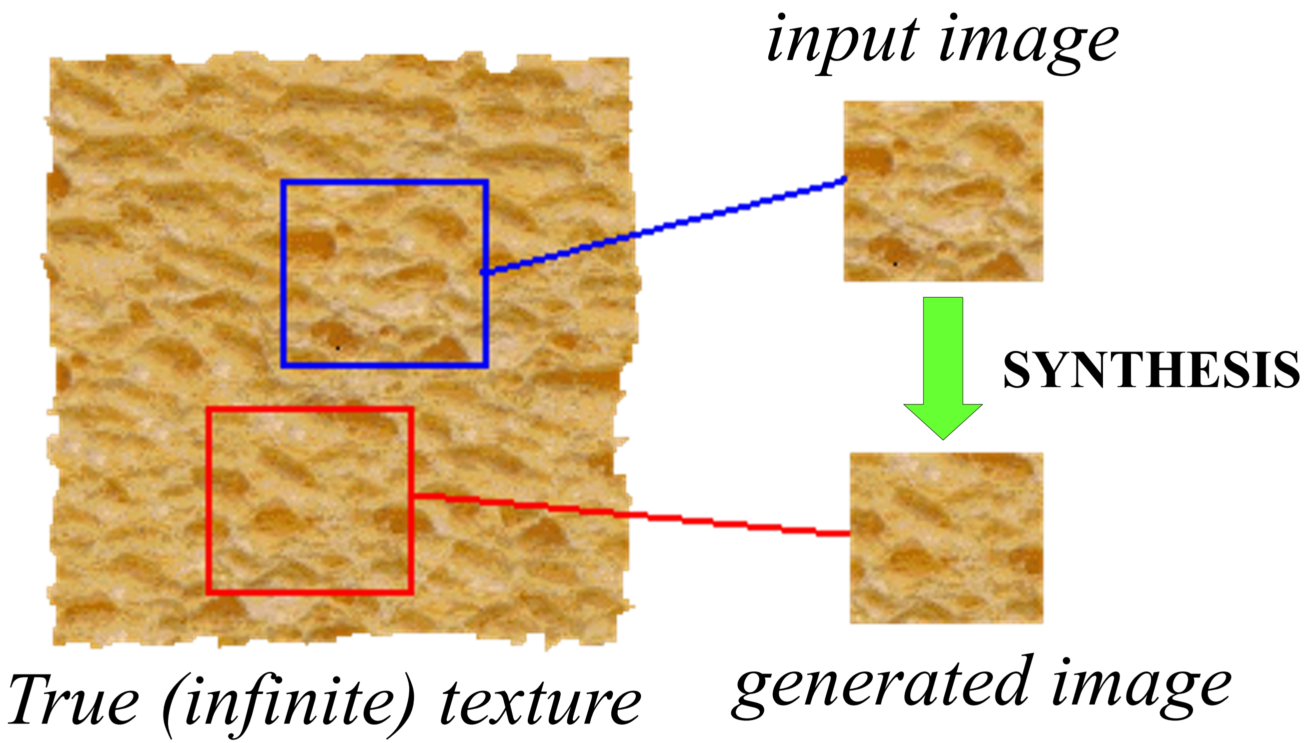
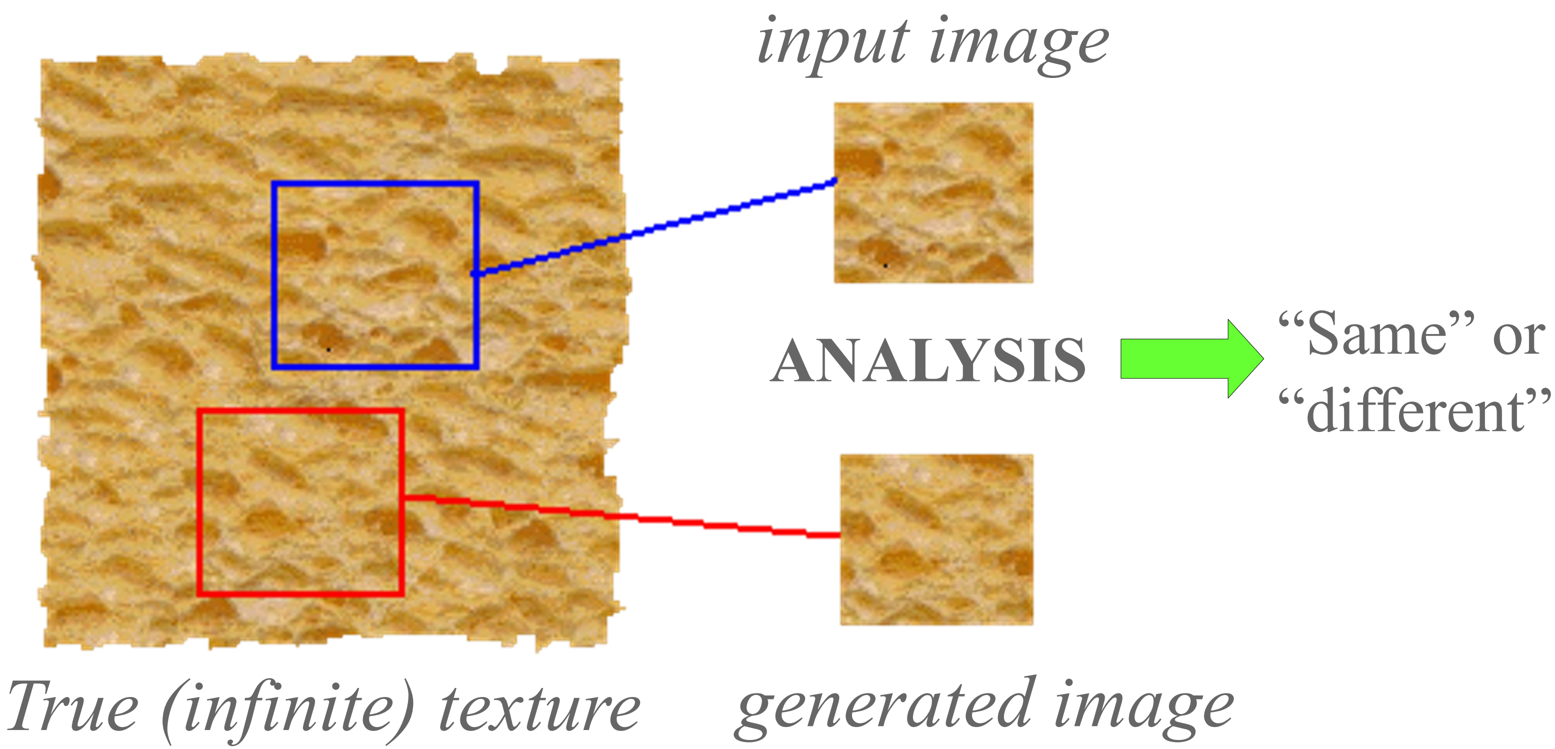
The Goal of Texture Synthesis

- Given a finite sample of some texture, the goal is to synthesize other samples from that same texture
- The sample needs to be "large enough“



The Goal of Texture Analysis

- Compare textures and decide if they're made of the same "stuff".



Scale: objects vs. texture

- The same thing can occur as texture or an object
  - depending on the **scale** we are considering.

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
- Distinguish between shape, boundaries, and texture

Technically:

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

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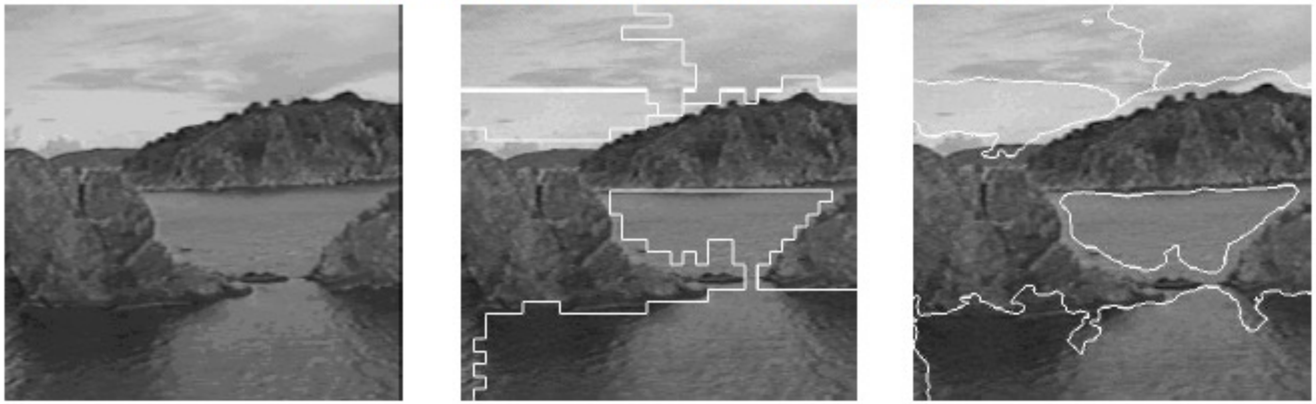
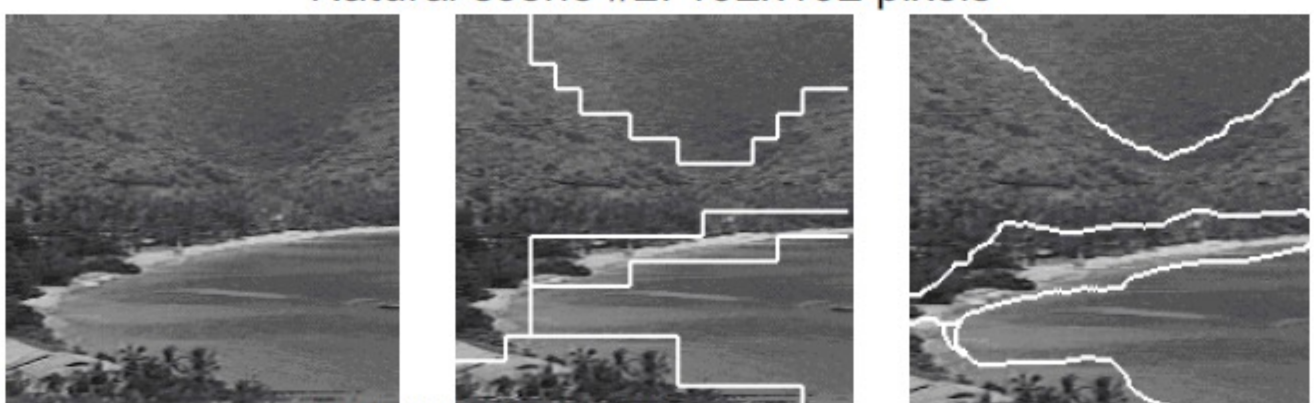
Why analyze texture?

Natural scene #1: 384x384 pixels



Natural scene #2: 192x192 pixels

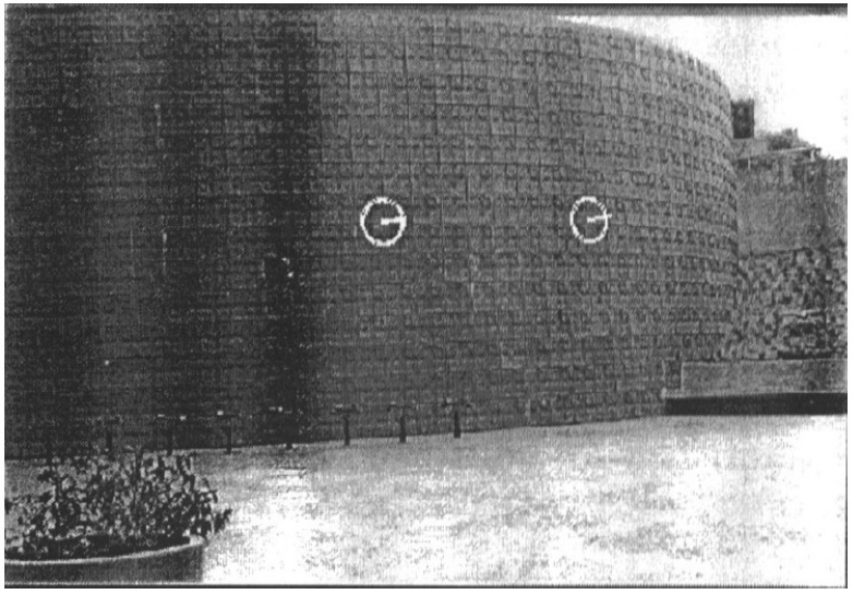


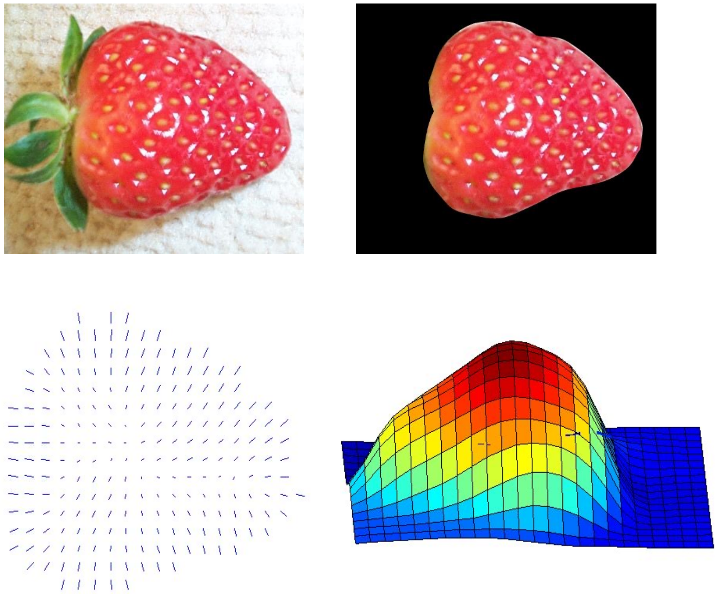
Texture-related tasks

- **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

Shape from texture

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









Texture-related tasks

- **Shape from texture**
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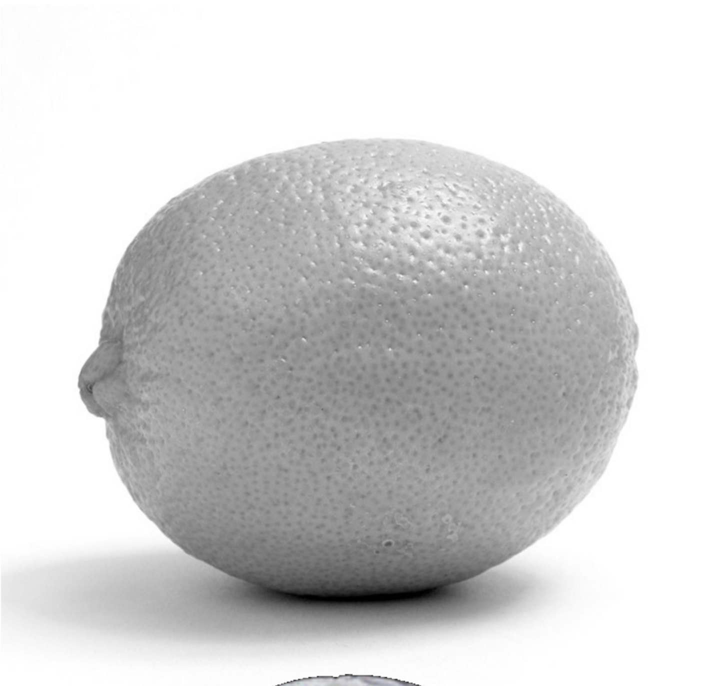
Texture-related tasks

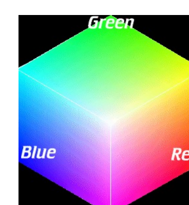



Texture-related tasks

http://animals.nationalgeographic.com/

Color vs. texture

- Recall: These looked very similar in terms of their color distributions (when our features were R-G-B)
- But how would their texture distributions compare?



Psychophysics of texture

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

Watch the next screen very carefully.

Are the **left** and **right** sides:

Same or different?

Pre-attentive processing is the subconscious accumulation of information from the environment. All available information is pre-attentively processed.

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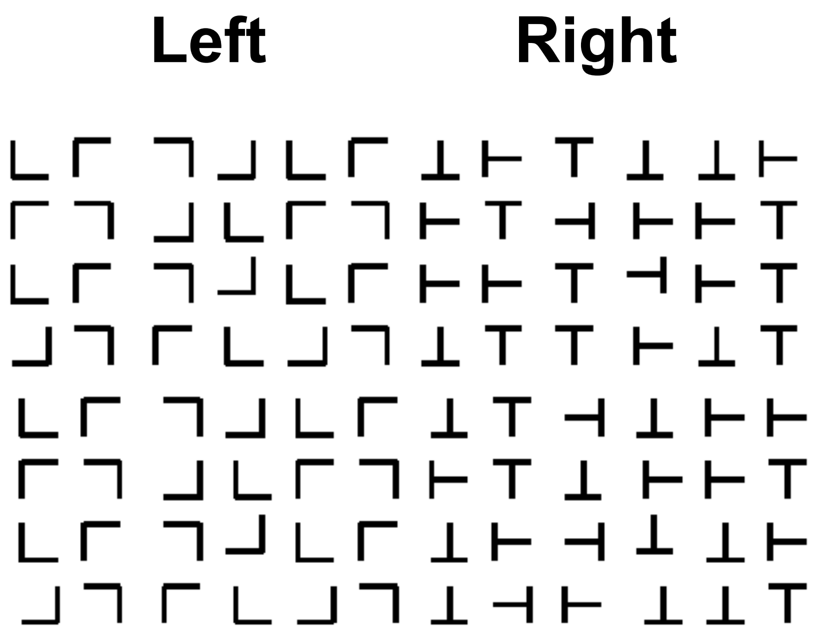
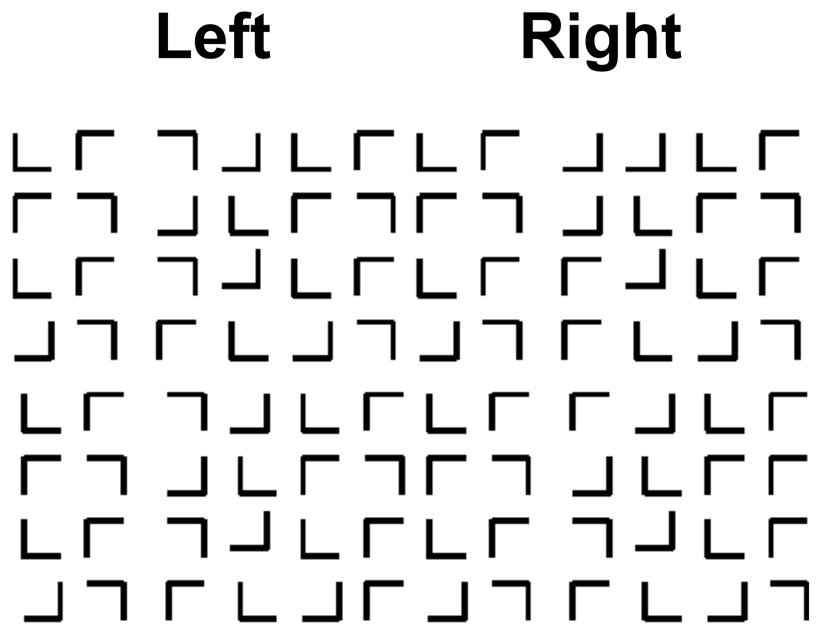
Ready? First Example

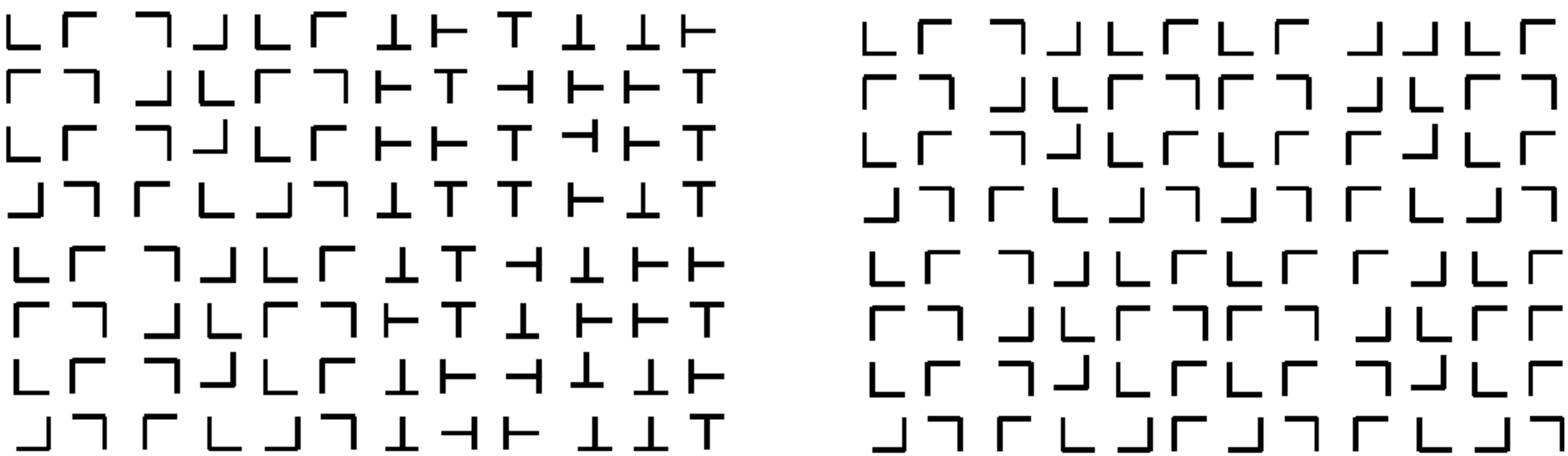


Ready? Second Example



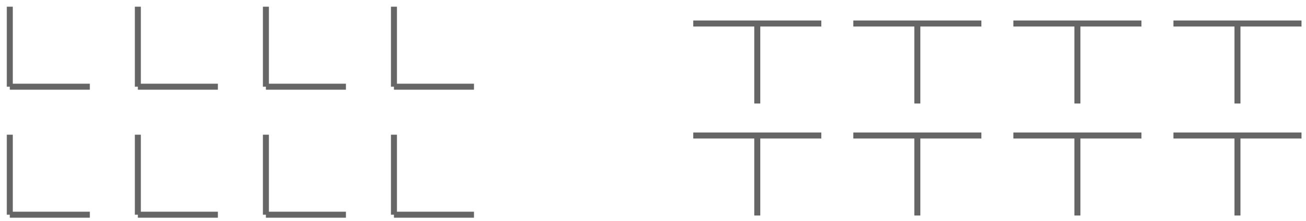
What you have seen

Left **Right** **Left** **Right**



Texture Analysis

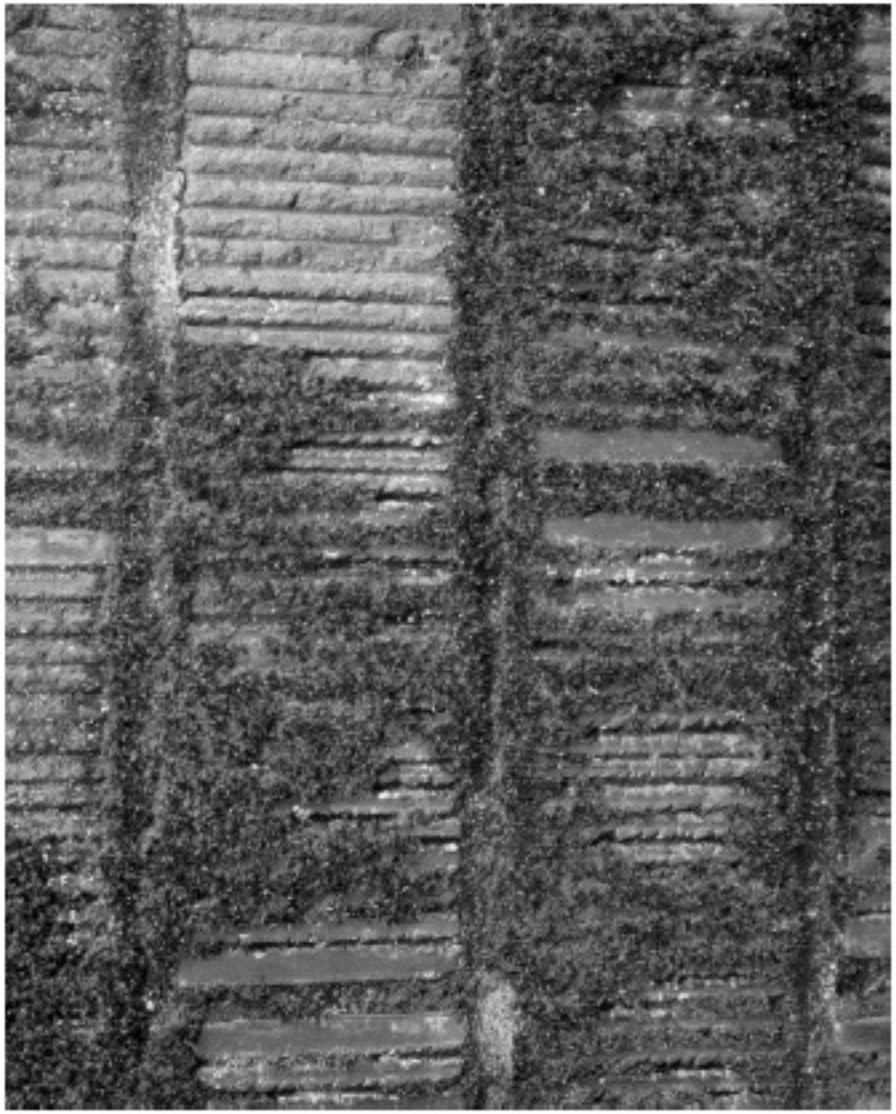
- Analyze the texture in terms of statistical relationships between fundamental texture elements
  - Called “textons”.
- It generally required a human to look at the texture in order to decide what those fundamental units were.



Texture representation

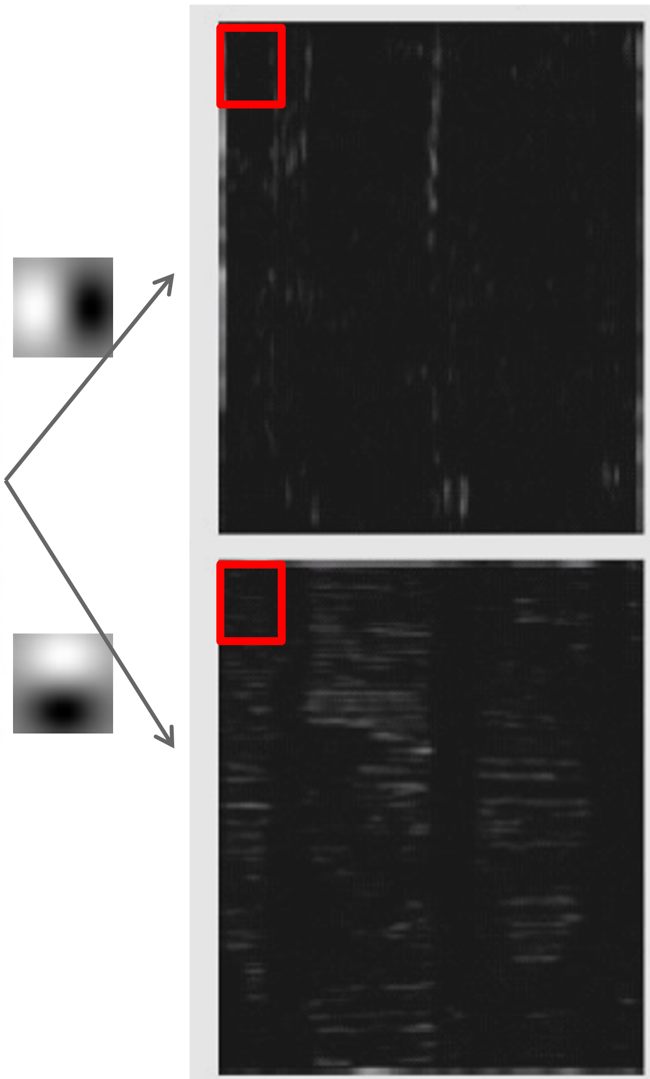
- Textures are made up of repeated local patterns:
  - How to find the patterns
    - Use filters that look like patterns
      - Spots, bars, raw patches…
      - Consider magnitude of response
    - Describe their statistics within each local window
      - Mean, standard deviation, etc.
    - Histogram of “prototypical” feature occurrences

Texture representation



Texture representation

original image



derivative filter responses, squared

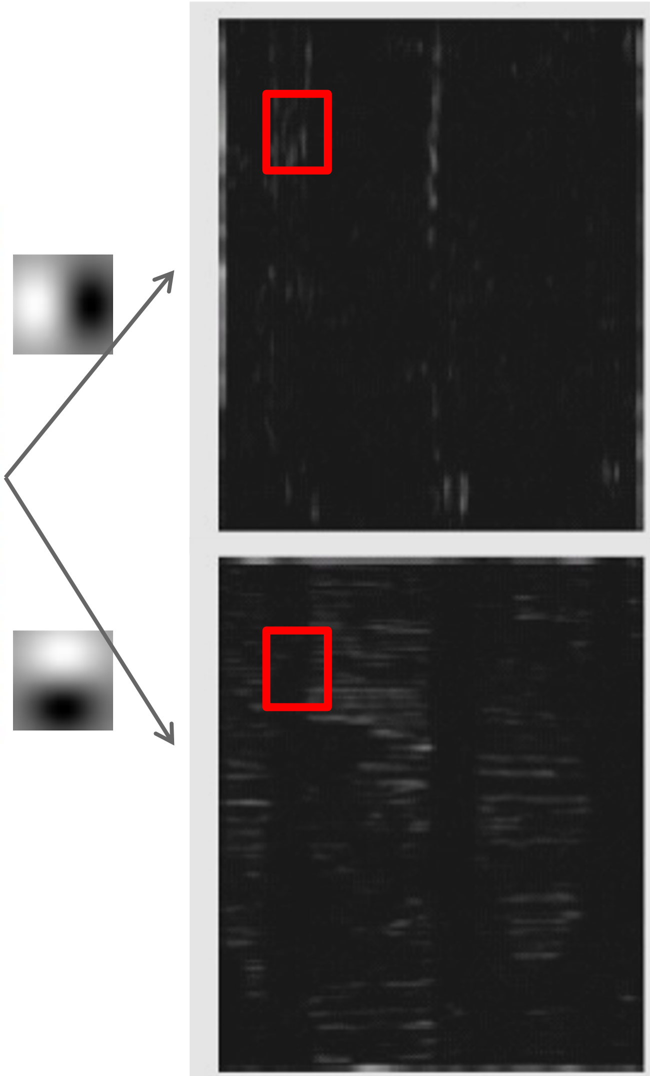
	mean d/dx value	mean d/dy value
Win. #1	4	10

⋮

statistics to summarize patterns in small windows

Texture representation

original image



derivative filter responses, squared

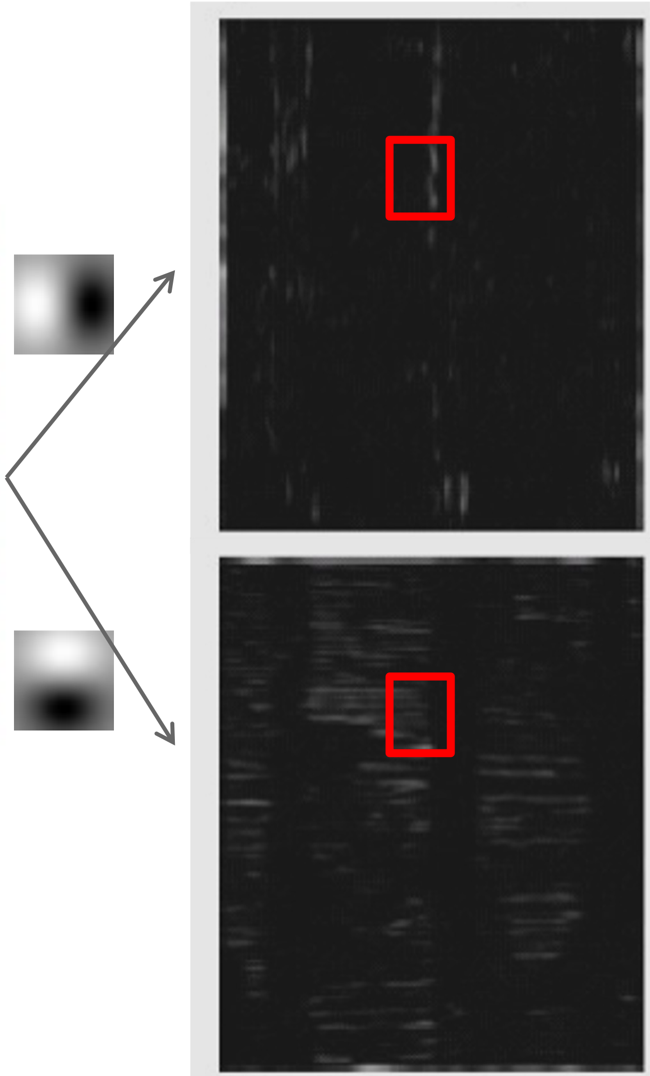
	mean d/dx value	mean d/dy value
Win. #1	4	10
Win.#2	18	7

⋮

statistics to summarize patterns in small windows

Texture representation

original image



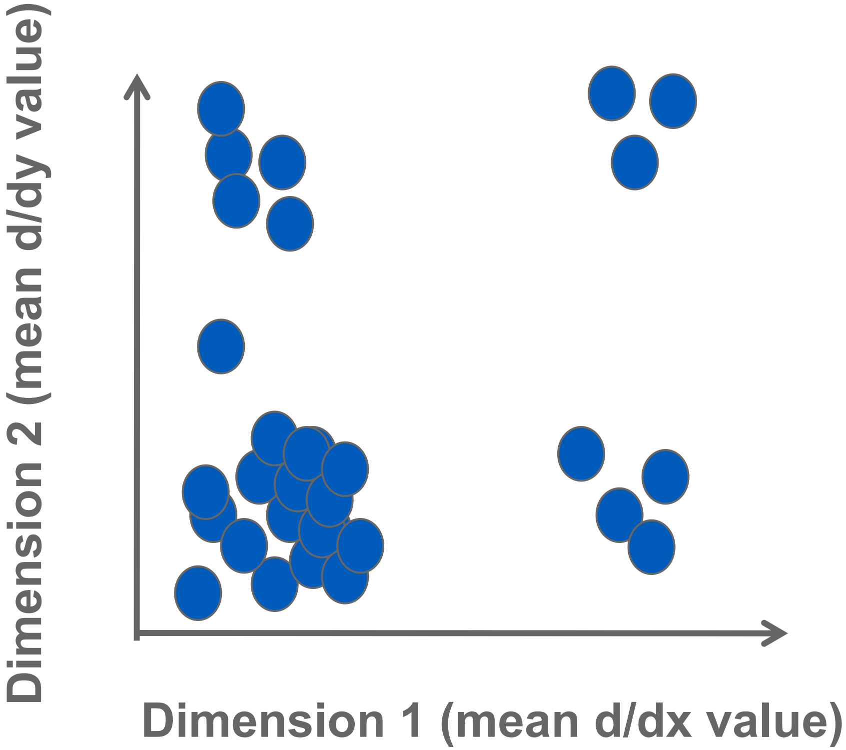
derivative filter responses, squared

	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

Texture representation: example

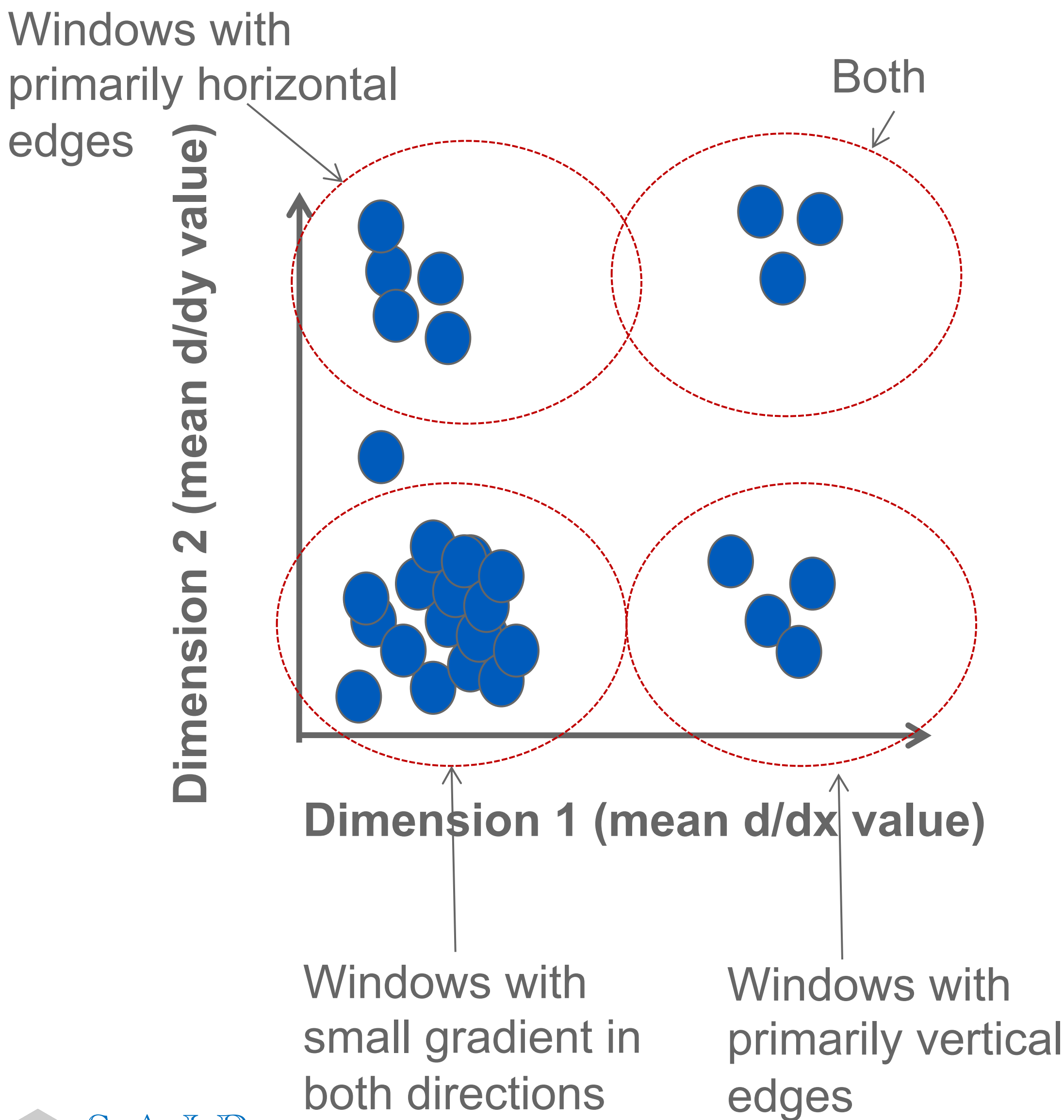


	mean d/dx value	mean d/dy value
Win. #1	4	10
Win.#2	18	7
:		
Win.#9	20	20

⋮

statistics to summarize patterns in small windows

Texture representation: example



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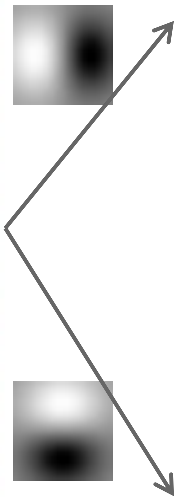
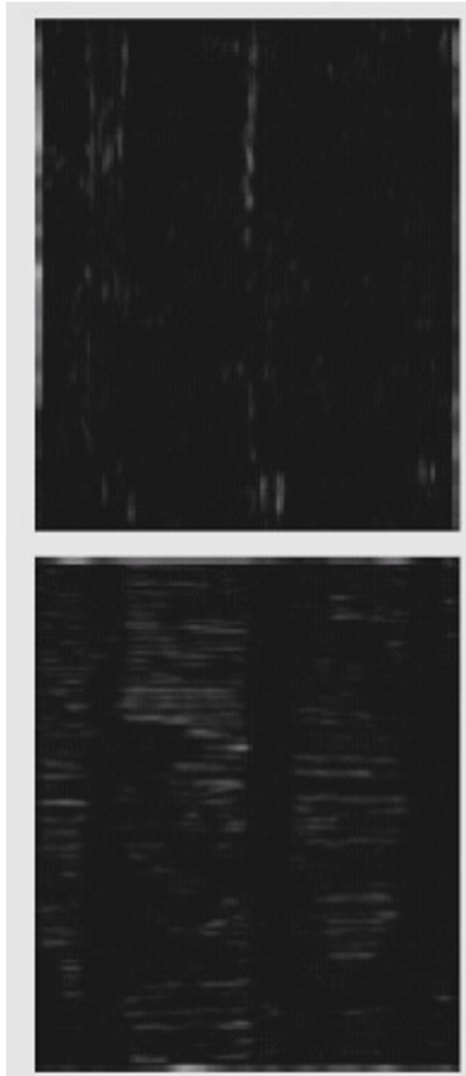
⋮

statistics to summarize patterns in small windows

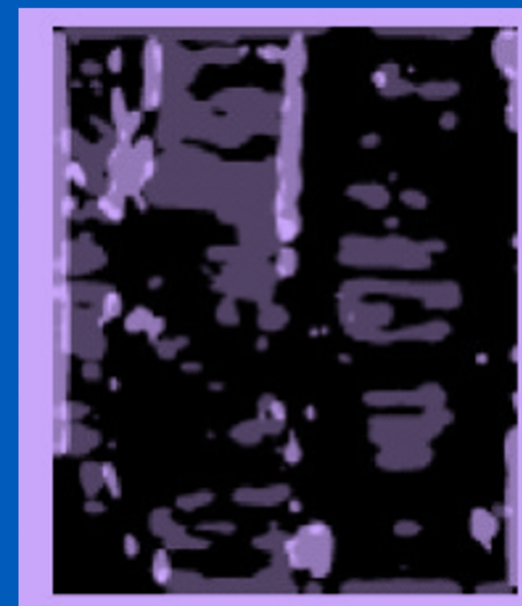
Texture representation: example

original image





derivative filter responses, squared



visualization of the assignment to texture "types"

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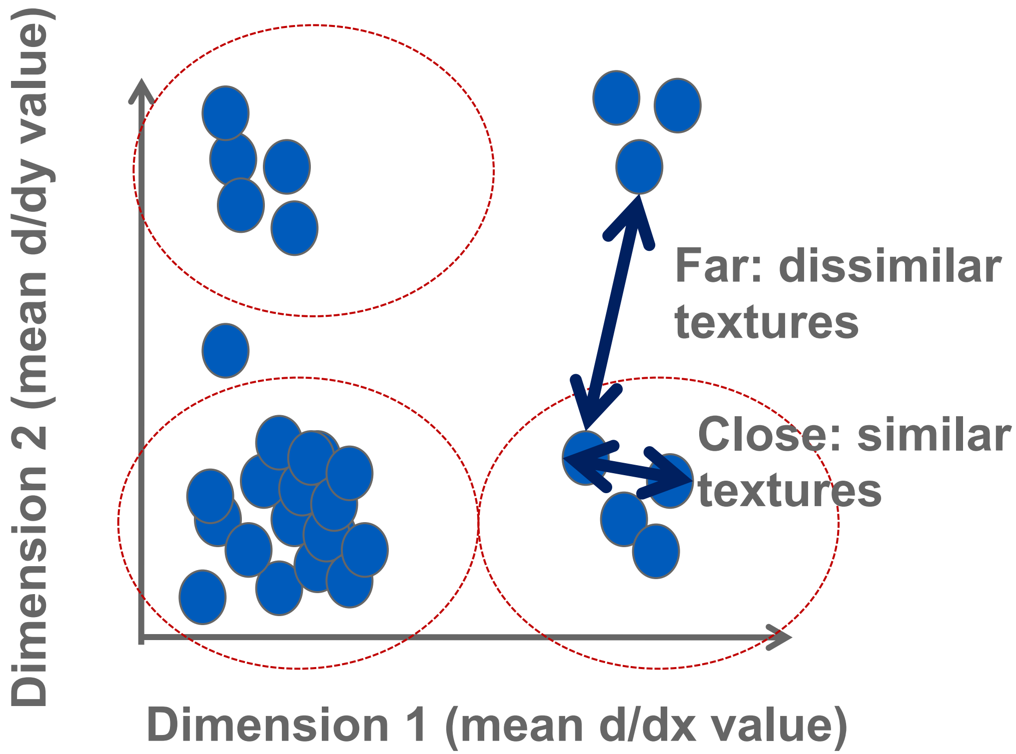
Texture representation: example



	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

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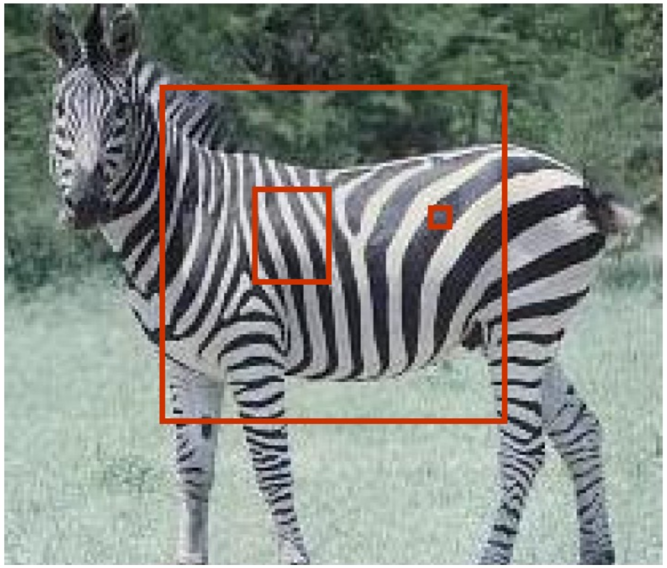
Texture representation: window scale

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

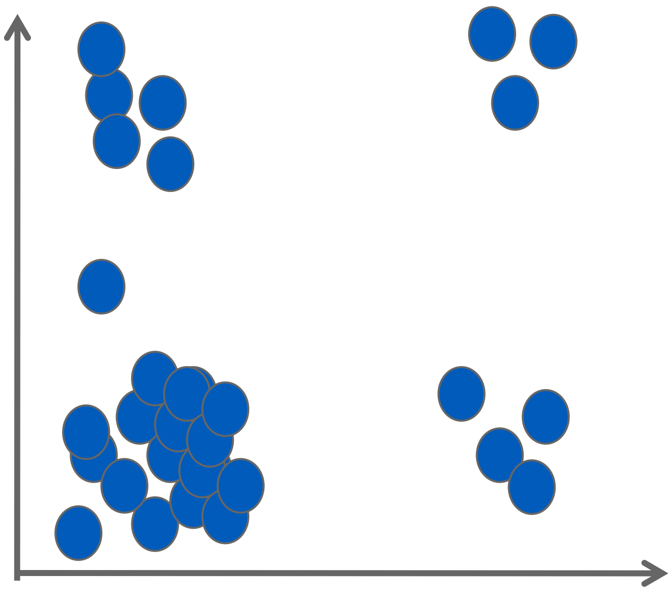


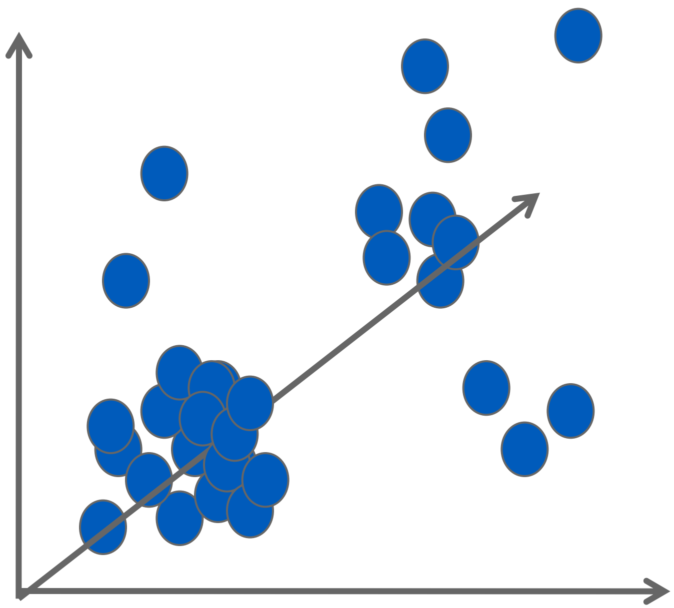
Possible to perform scale selection by looking for window scale where texture description not changing.

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"
  - Recall multi-channel convolution.
- Then our feature vectors will be *d*-dimensional.
  - still can think of nearness, farness in feature space

d-dimensional features

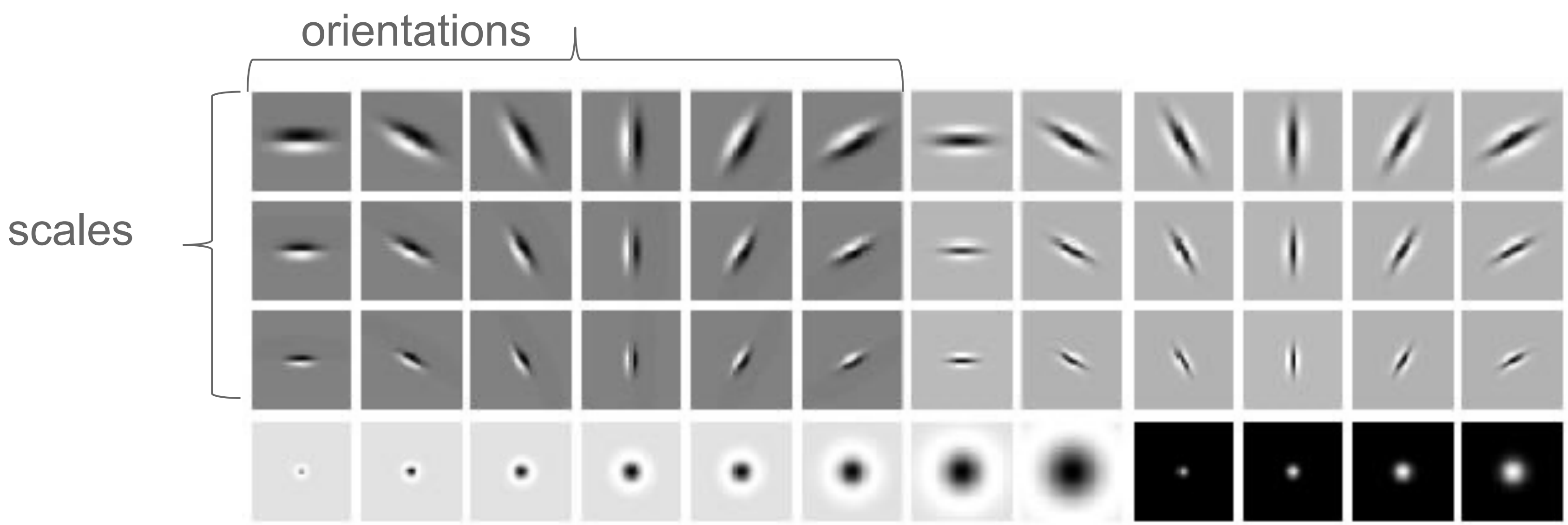




...

Filter banks

- What filters to put in the bank?
  - Typically we want a combination of scales and orientations, different types of patterns.



http://www.robots.ox.ac.uk/~vgg/research/texclass/filters.html

Pixel Neighborhood-based Feature

- The most important for texture analysis is to describe the spatial behavior of intensity values in any neighborhood.

- Different methodologies have been proposed.

- **Local binary pattern (LBP)** is one of the most-widely used approach – mainly for face recognition.

- LBP is used for texture analysis too.

Local Binary Pattern (LBP)

For each PIXEL of an image, a BINARY CODE is produced

$$LBP_{p,r}(N_c) = \sum_{p=0}^{P-1} g\left(N_p - N_c\right)2^p$$

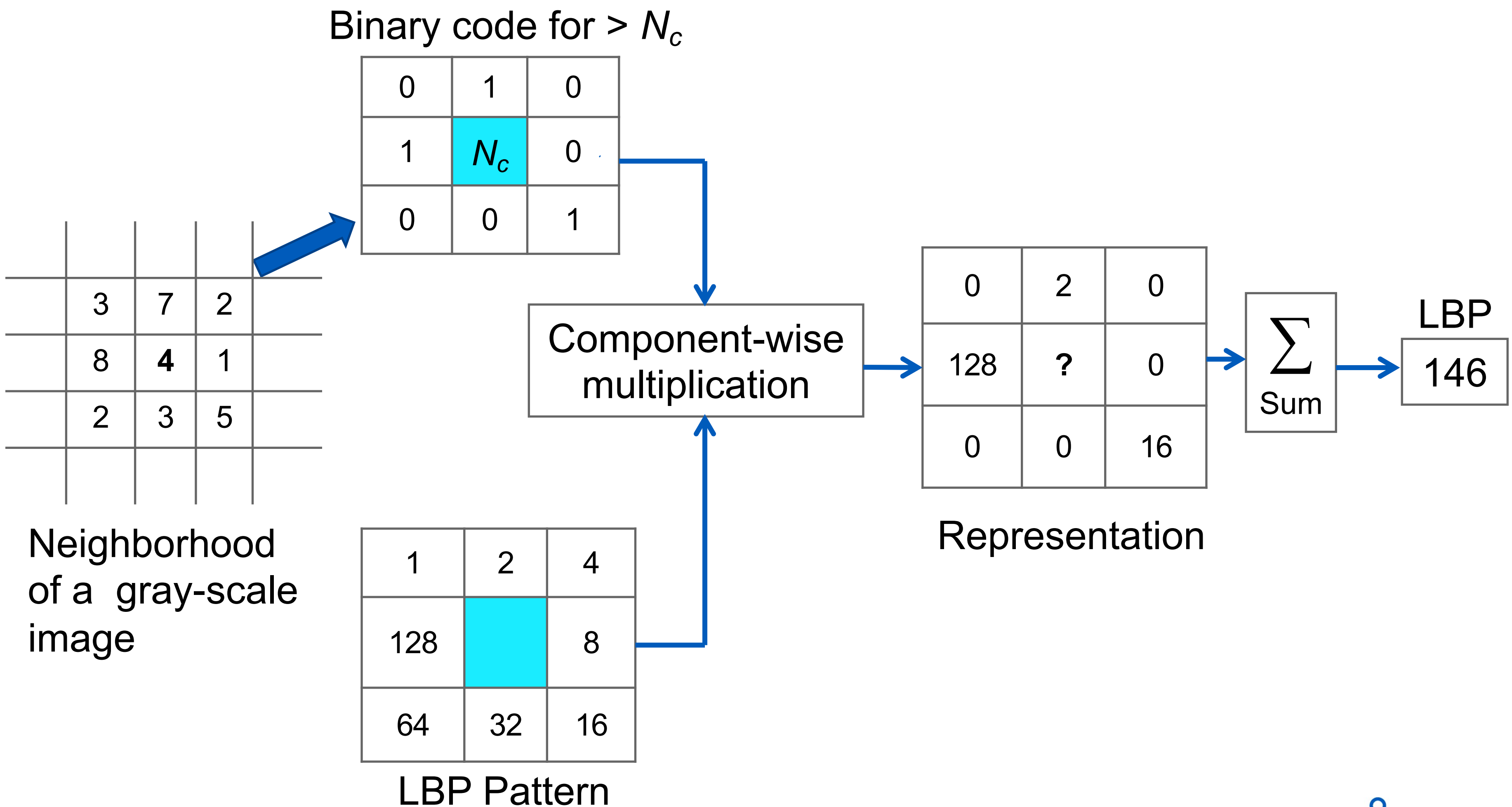
where

neighborhood pixels $\left(N_p\right)$ in each block → is thresholded by its center pixel (N_c)
p→ sampling points (e.g., $p = 0, 1, \ldots, 7$ for a 3x3 cell, where P = 8)
r → radius (for 3x3 cell, it is 1).

Binary threshold function $g(x)$ is,

$$g(x) = \begin{cases} 0, & x < 0 \\ 1, & x \geq 0 \end{cases}$$

Computation of Local Binary Pattern



Example of how the *LBP operator* works

Computation of Local Binary Pattern

6	5	2
7	6	1
9	8	7

Example

(LSB) 1	0	0
1		0
1	1	1

Threshold

1	2	4
128		8
64	32	16

Weights

Binary Pattern:	1 (MSB)	1	1	1	0	0	0	1 (LSB)

Code/Weight (2^p):	1×2^7	1×2^6	1×2^5	1×2^4	0×2^3	0×2^2	0×2^1	1×2^0
	= 128	= 64	= 32	= 16	= 0	= 0	= 0	= 1

LBP:	**1 + 0 + 0 + 0 + 16 + 32 + 64 + 128 = 241**

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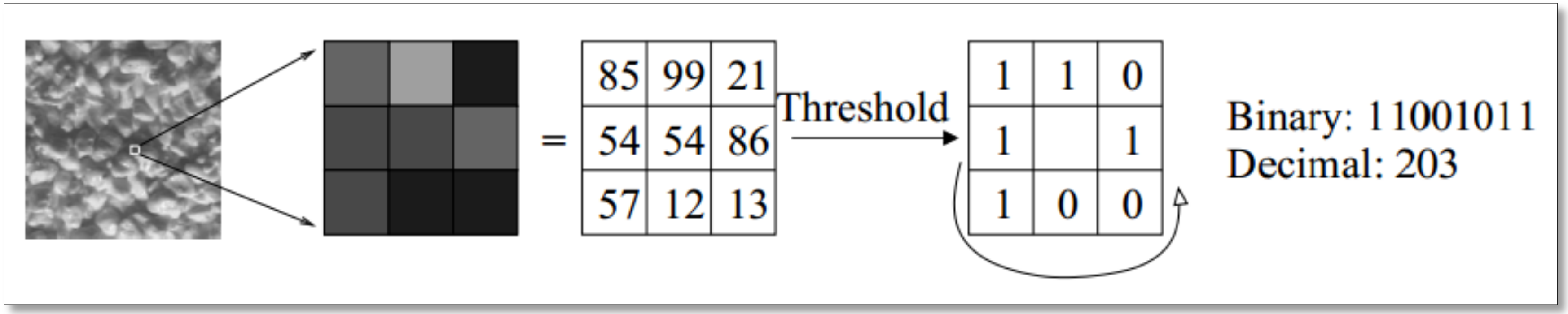
MSB stands for Most Significant Bit, while **LSB** is Least Significant Bit.

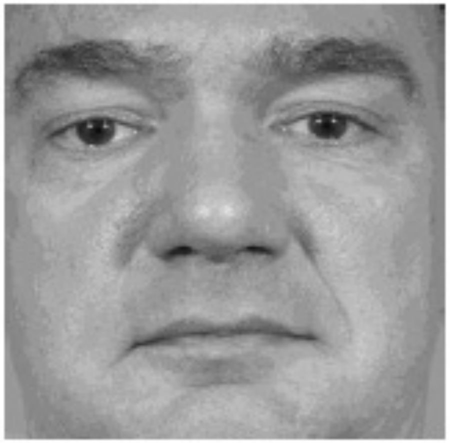
LBP

- One of the best performing texture descriptors
- A label is assigned to every pixel
- Use center pixel to threshold the 3x3 neighborhood
  - Result in binary number
- Histogram of the labels is used as a texture descriptor



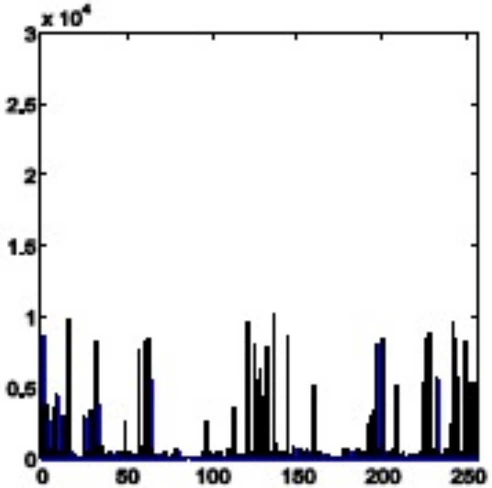
The Basic LBP operator

LBP hitogram



Input image

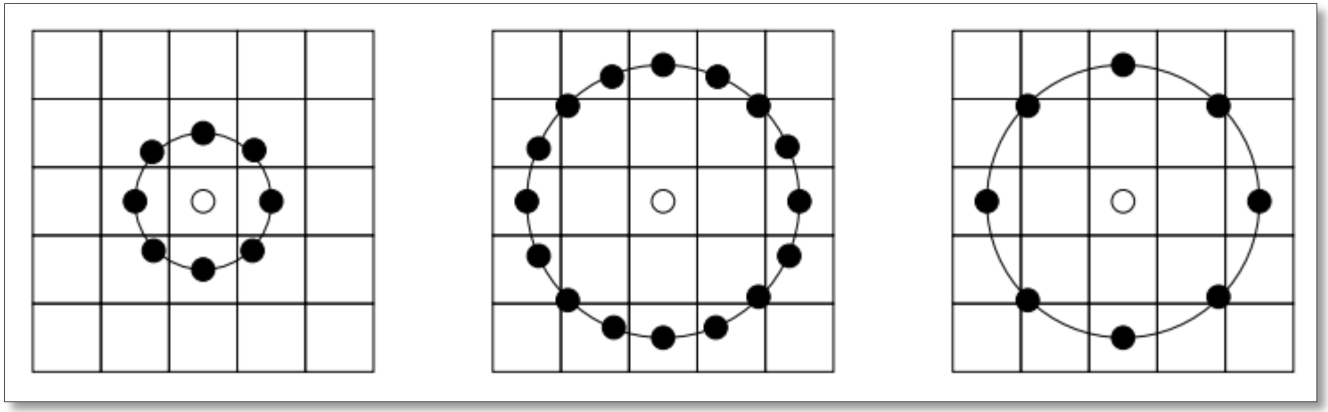
LBP image



LBP histogram

LBP

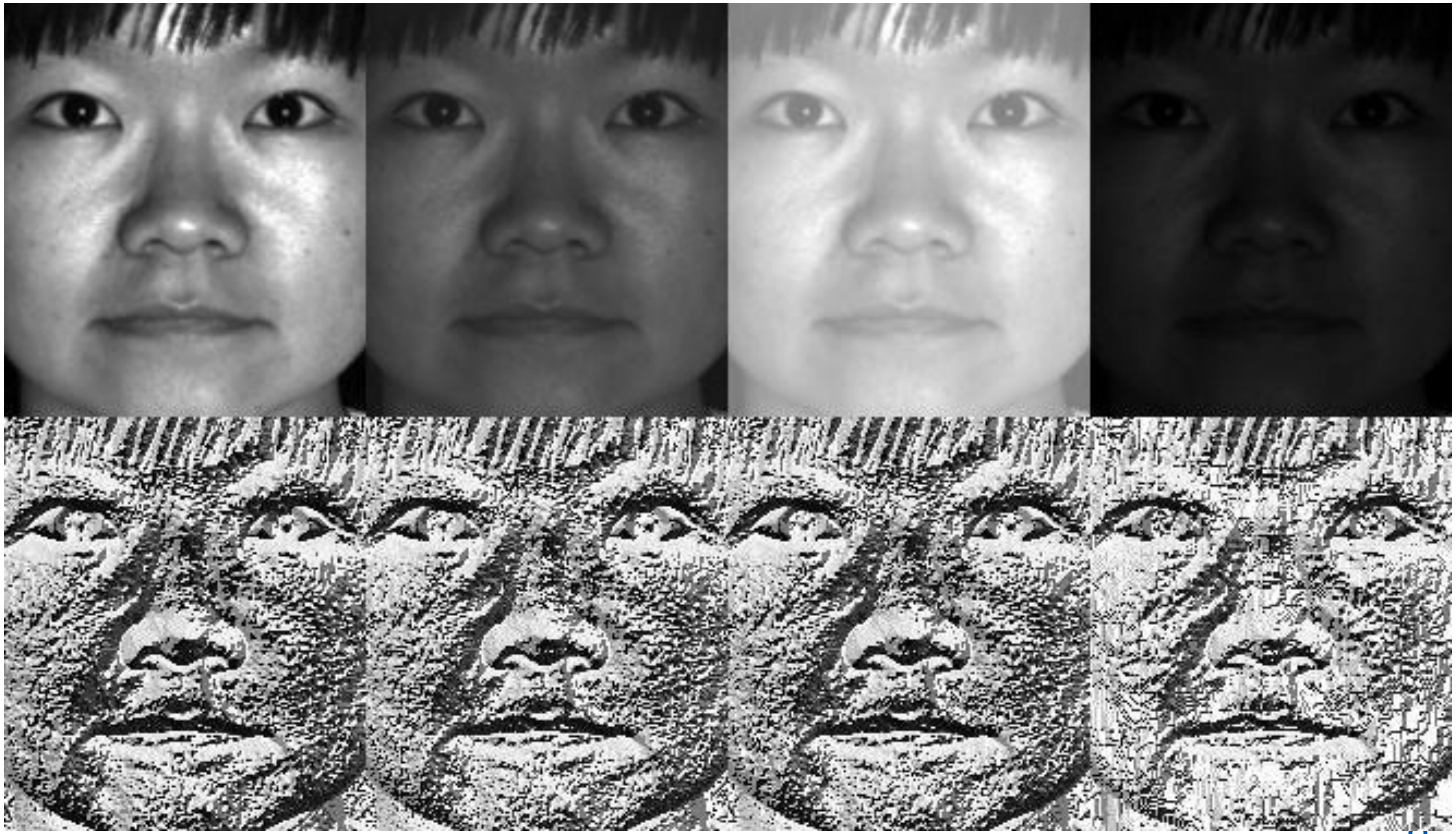
- LBP is extended to use different sizes of neighborhoods.
- Local neighborhoods is defined as a set of **sampling points**.
  - points evenly spaced on a circle centered at the labeled pixel.
- **(P, R) , P = number of sampling points, R = radius**
- **Bilinear interpolation** is used
  - If sampling point is not in the center of the pixel.



The circular (8,1), (16, 2) and (8, 2) neighborhoods.

LBP Example

- Notice how LBP feature are illumination invariant



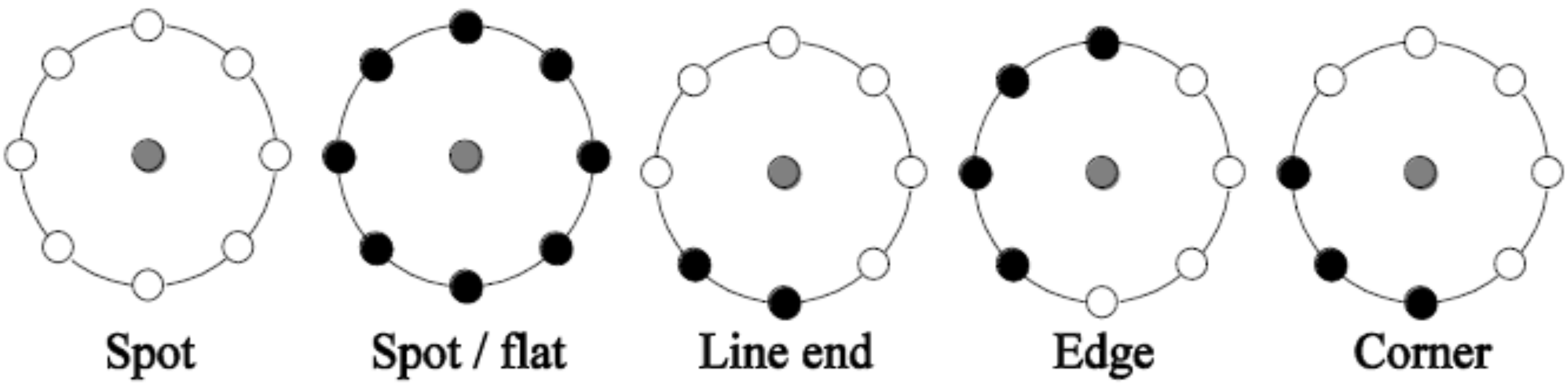
Uniform LBP

- Uniform patterns to further improve LBP.
  - Has at most 2 bitwise transitions in binary pattern.
  - Histogram
    - assigns separate bins for every uniform pattern.
    - assigns a single bin for all non-uniform pattern.

Uniform LBP

Texture primitives ("micro-textons") detected by the uniform patterns of LBP

1 = black
0 = white



Uniform LBP

- Uniform patterns examples
  - 00000000 (0 transitions)
  - 01110000 (2 transitions)
  - 11001111 (2 transitions)

- Non-uniform patterns examples
  - 11001001 (4 transitions)
  - 01010011 (5 transitions)

- 59 bins histogram
  - 58 uniform bins →
  - 1 non-uniform bin

Length of feature vector

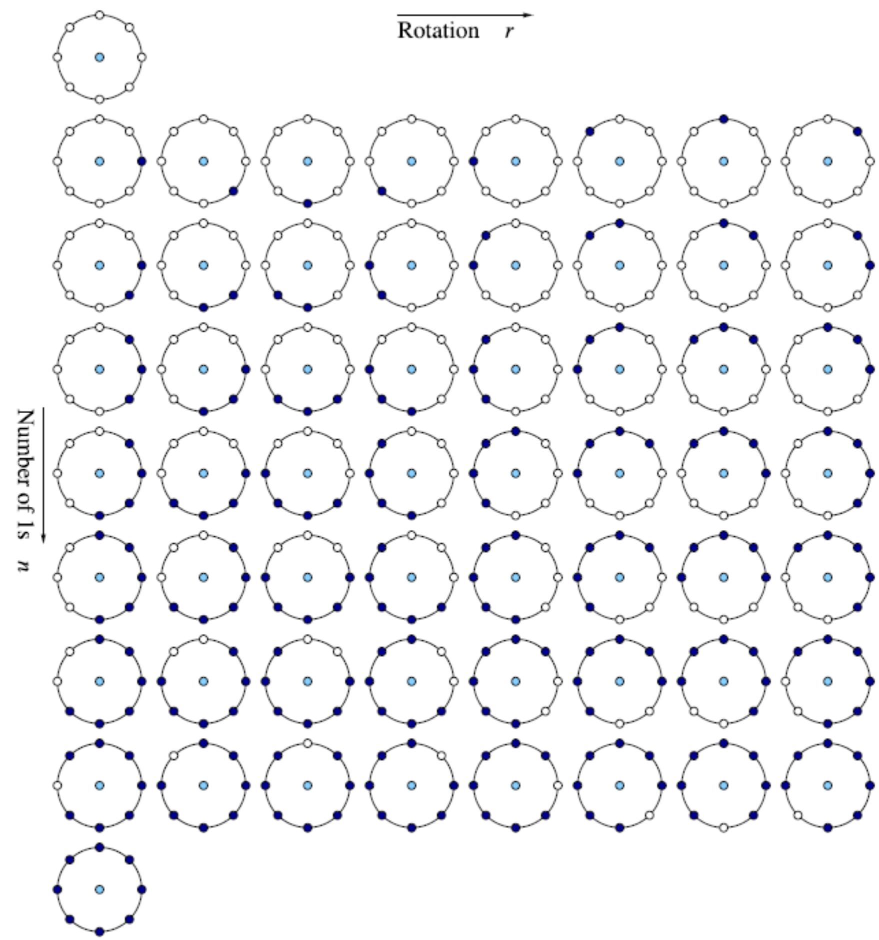
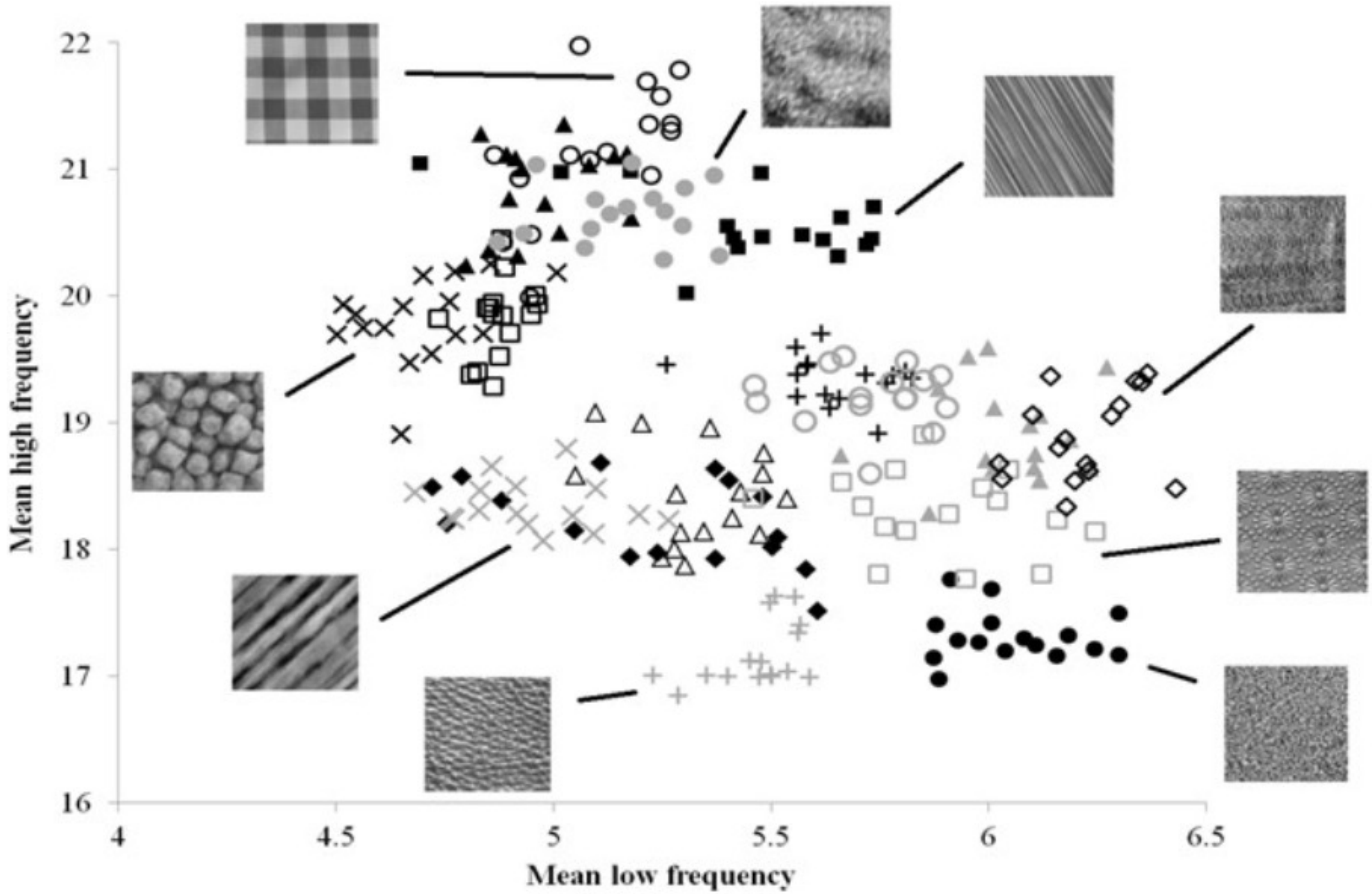


Fig. 2.4 The 58 different uniform patterns in (8, R) neighborhood

Other Measures of Texture (frequency)



Other Measures of Texture

Texture measure	Description	Equation*
Mean	Mean is the average grey level for each sample	$\sum_{i,j=0}^{N-1} i(P_{i,j})$
Variance	Variance is a measure of heterogeneity; it increases when the grey level values differ from their mean. In general, coarse-textured features are associated with higher variances	$\sum_{i,j=0}^{N-1} P_{i,j}(i-\mu_i)^2$
Homogeneity	This parameter measures image homogeneity as it assumes larger values for smaller grey tone differences in pair elements	$\sum_{i,j=0.}^{N-1} \frac{P_{i,j}}{1+(i-j)^2}$
Contrast	Contrast is a measure of spatial frequency, the difference between the highest and the lowest values of a contiguous set of pixels. A high contrast implies high coarse texture	$\sum_{i,j=0}^{N-1} P_{i,j}(i-j)^2$
Dissimilarity	Dissimilarity, akin to contrast, describes the heterogeneity of the grey levels. Higher values of dissimilarity in the GLC matrix indicate coarser textures	$\sum_{i,j=0}^{N-1} P_{i,j}\|i-j\|$
Entropy	Entropy measures the disorder of an image. When the image is not texturally uniform, many GLC matrix elements have very small values, which imply that entropy is very large	$\sum_{i,j=0}^{N-1} P_{i,j}\left(-\ln p_{i,j}\right)^2$
Angular second moment	This parameter measures textural uniformity. Thus, high angular second moment values occur when the grey level distribution over the window has either a constant or a periodic form	$\sum_{i,j=0}^{N-1} {P_{i,j}}^2$
Correlation	Correlation is a measure of grey-tone linear dependencies in the image. High correlation values imply a linear relationship between the grey levels of pixel pairs	$\sum_{i,j=0}^{N-1} P_{i,j}\left[\frac{(i-\mu_i)(j}{\sqrt{(\mathrm{SD}_i^2)}}\right.$