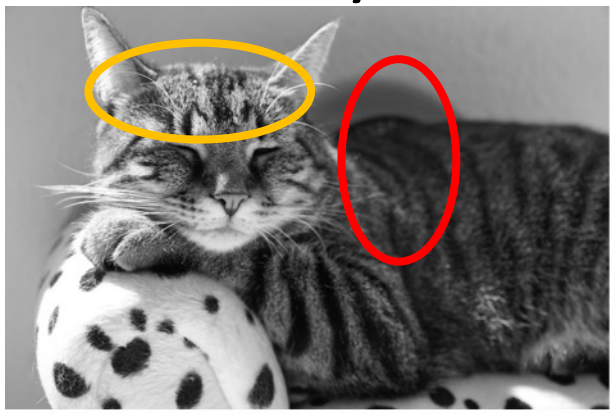
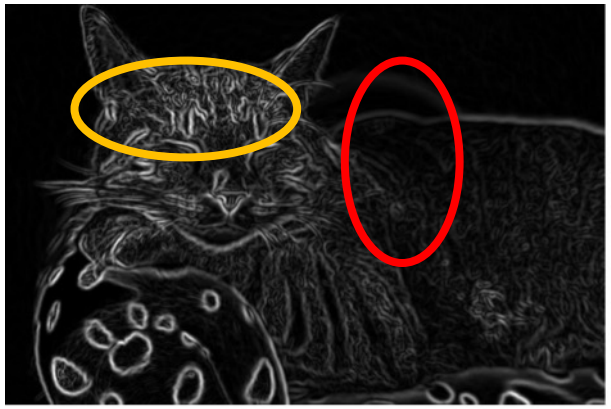
Grouping/Segmentation

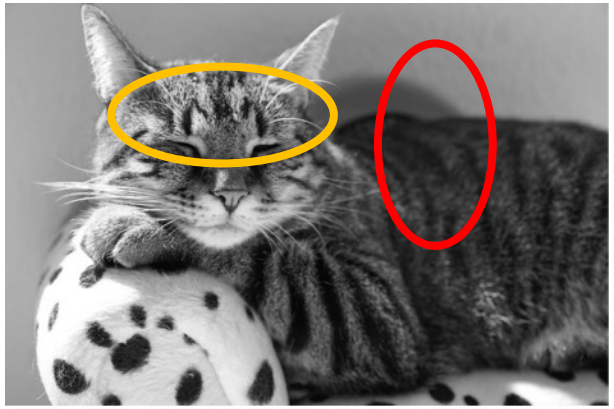
Does Canny always work?





The challenges of edge detection

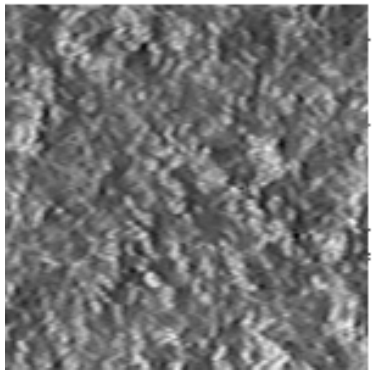
- Texture
- Low-contrast boundaries



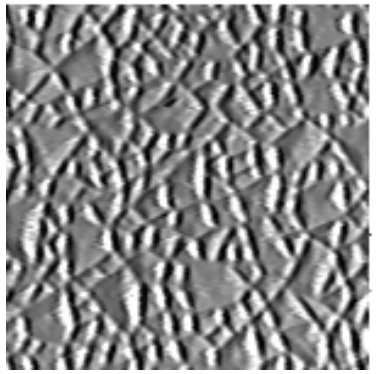
What is texture?

- Hard to define, ambiguous concept
- Some sort of pattern consisting of repeating elements
- That we perceive as a pattern rather than individual elements
- Often an indicator of:
  - Material: fur, sand, grass
  - Shape

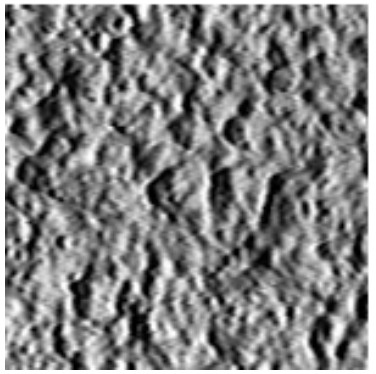
Textures



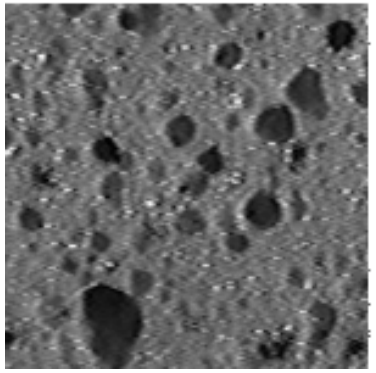
Terrycloth



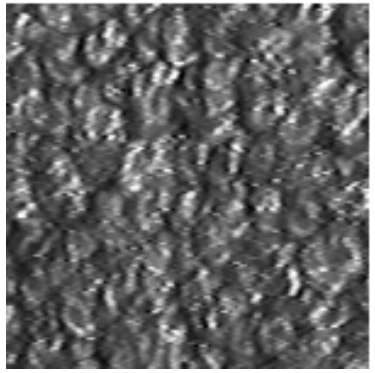
Rough Plastic



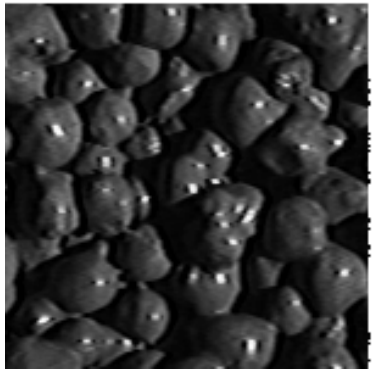
Plaster-b



Sponge



Rug-a



Painted Spheres

Columbia-Utrecht Database (http://www.cs.columbia.edu/CAVE)

Textures

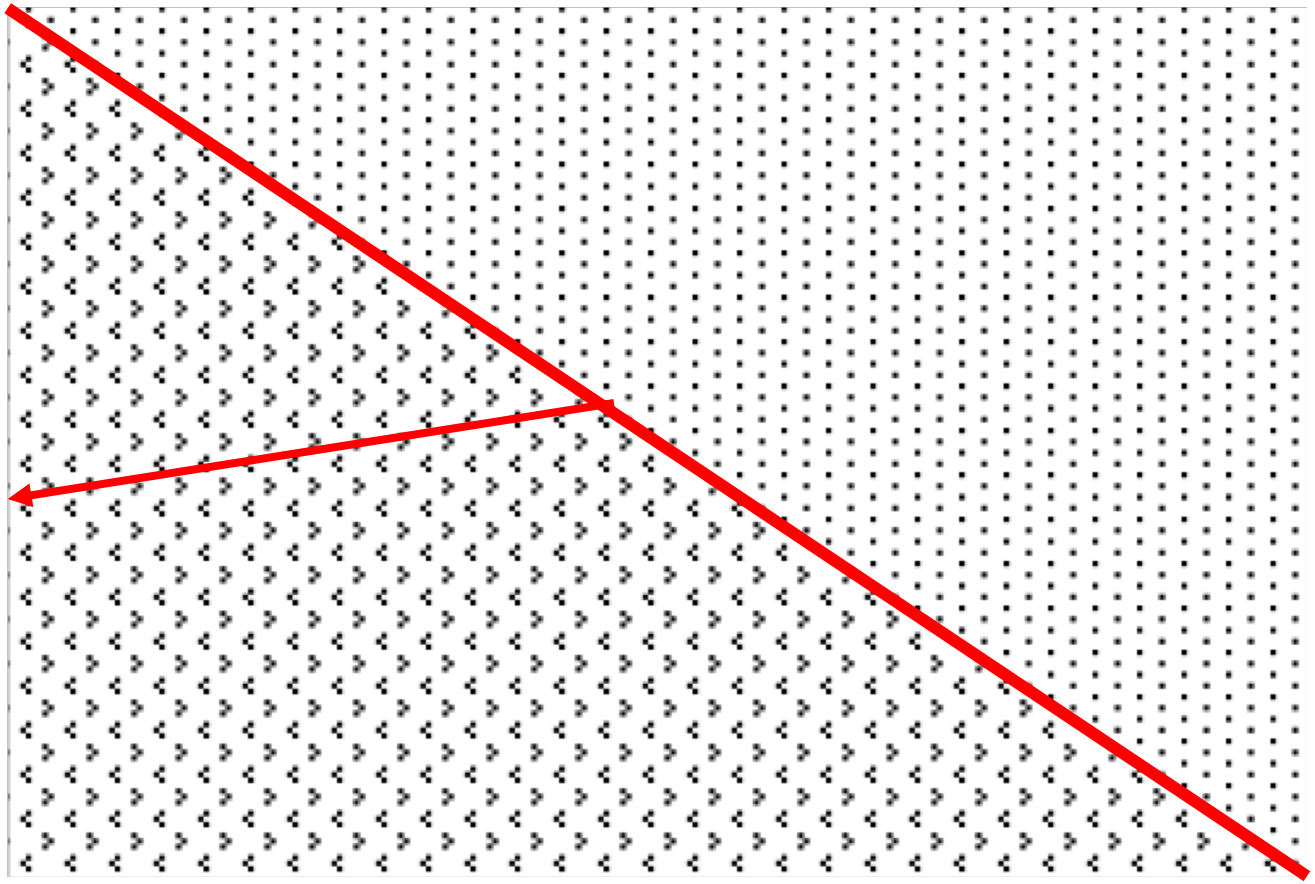
A large collection of objects (birds/leaves) can also appear as texture

Creator: WalterBaxter-2016
Information extracted from IPTC Photo Metadata

Texture edges

- When can we detect texture boundaries?

Texture boundary



Julesz's texton theory

- Human Vision operates in two distinct modes:
  - **Pre-attentive vision** - parallel, instantaneous
  - **Attentive vision** - serial search by focusing on individual things
- Texture discrimination occurs in the pre-attentive mode
  - We don't look at individual patterns but at statistics of the region
- What kind of statistics?
  - Not just average color
  - But density of certain elements – "textons"

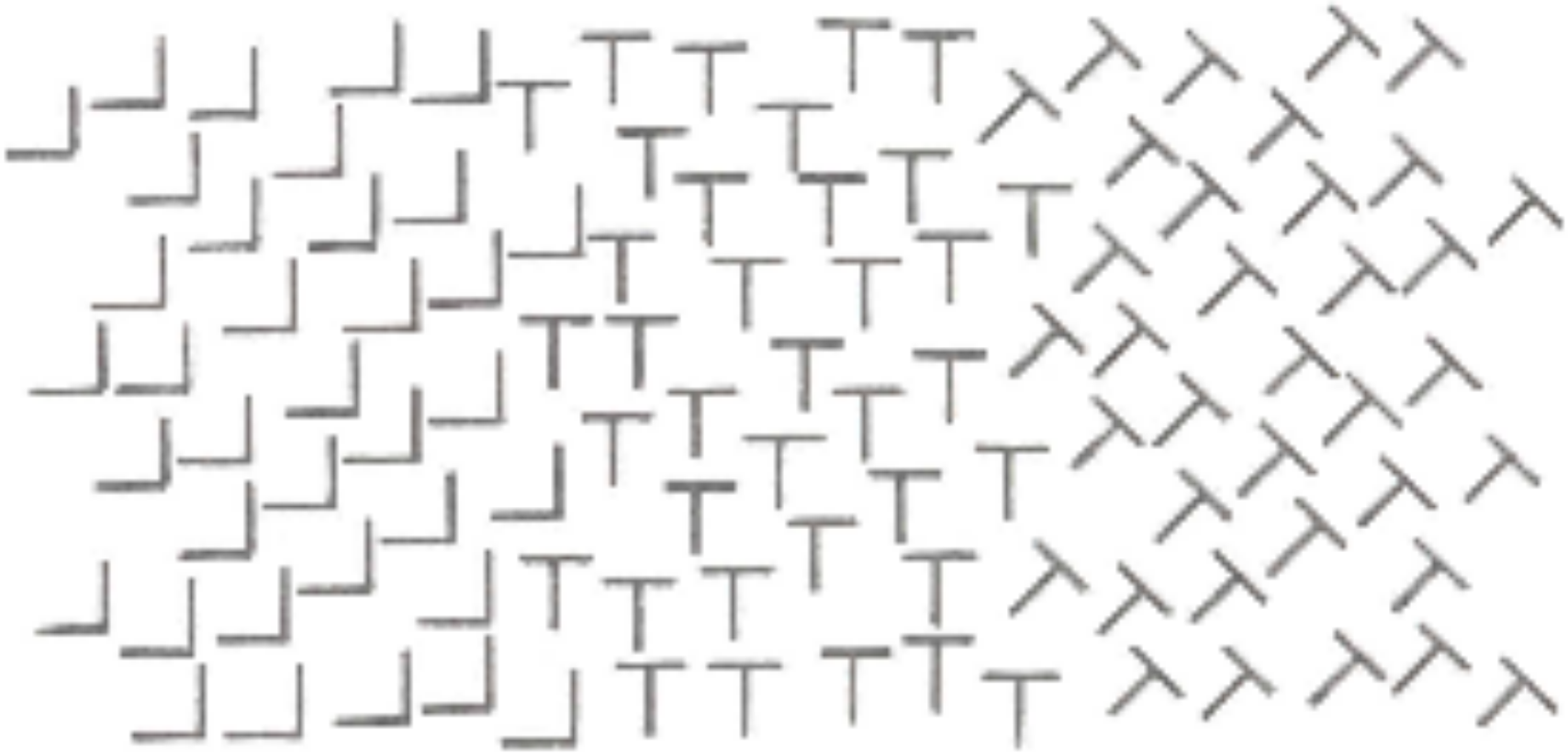
Slide adapted from Jitendra Malik

Julesz's texton theory

- Textons are:
  - Elongated blobs - e.g. rectangles, ellipses, line segments with specific orientations, widths and lengths
  - Terminators - ends of line segments
  - Crossings of line segments
- Julesz arrived at these by experimenting on which textures were distinguishable

Slide adapted from Jitendra Malik

Distinguishable textures



Slide adapted from Jitendra Malik

Distinguishable textures

(a)

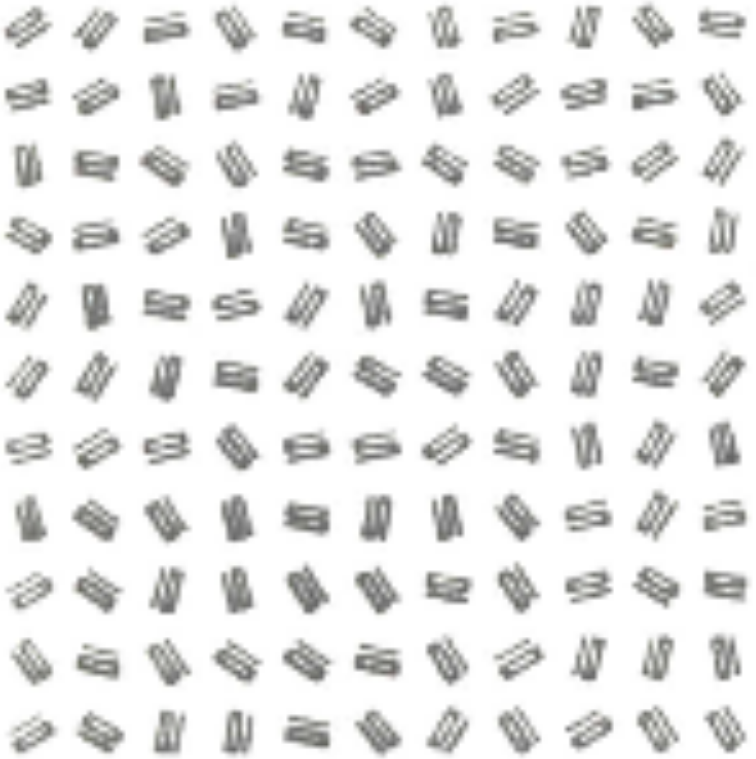
(b)

(c)

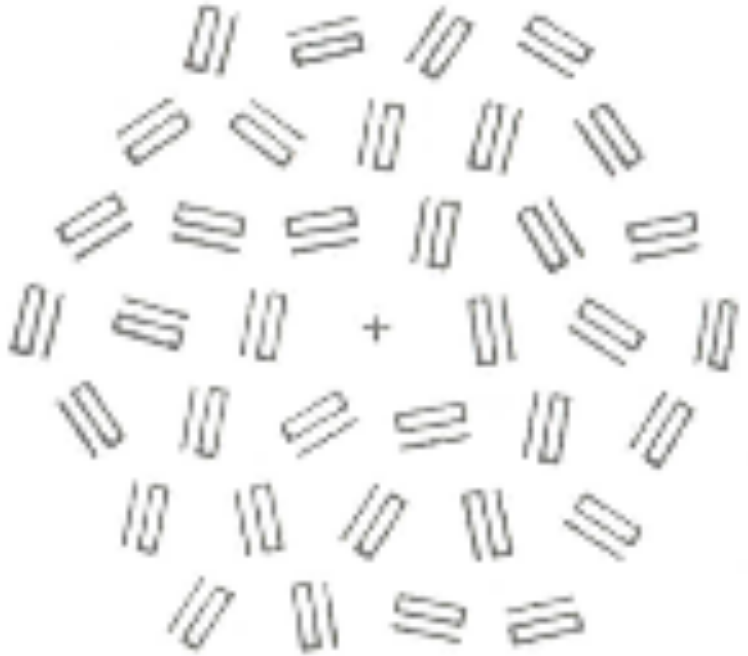
Slide adapted from Jitendra Malik

Indistinguishable textures

(a)



(b)



Slide adapted from Jitendra Malik

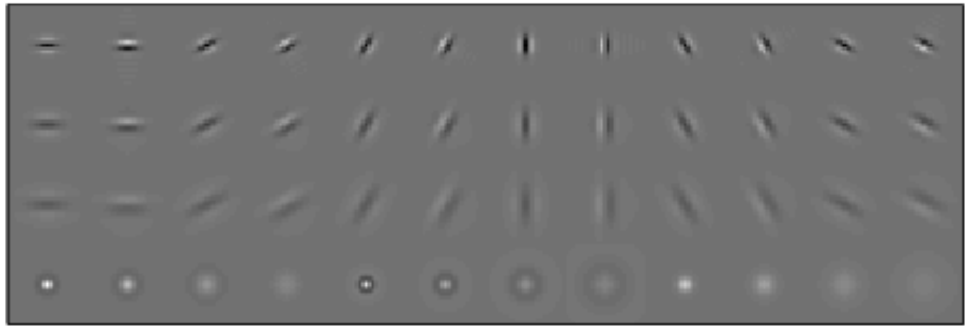
How do we define textons?

- Use filter bank (i.e, set of filters) to detect oriented edges, spots etc
- Identify repeated structures
  - Consider filter bank responses as “features” of a patch
  - Cluster patches: cluster centers form textons

2D Textons

- Goal: find canonical local features in a texture;

  1) Filter image with linear filters:



  2) Run k-means on filter outputs;

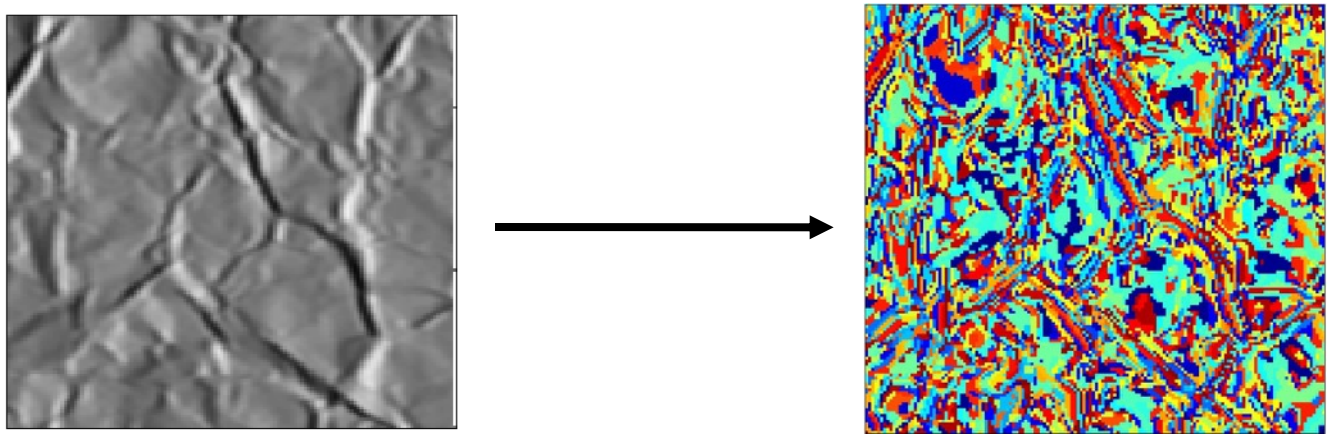
  3) k-means centers are the textons.

- Spatial distribution of textons defines the texture;

Slide adapted from Jitendra Malik

Texton Labeling

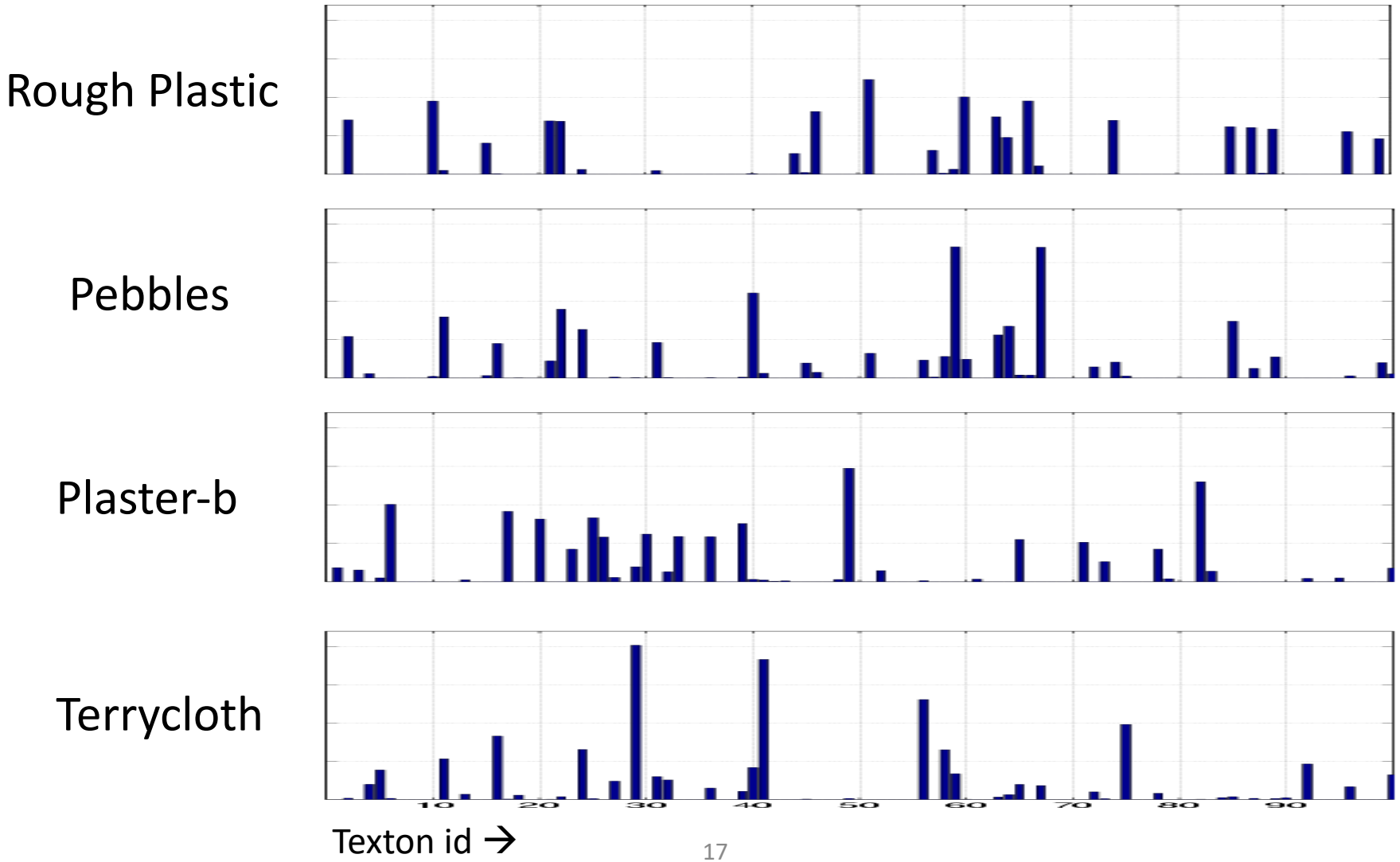
- Each pixel labeled to texton *i* (1 to K) which is *most similar in appearance*;
- Similarity measured by the Euclidean distance between the filter responses;



Material Representation

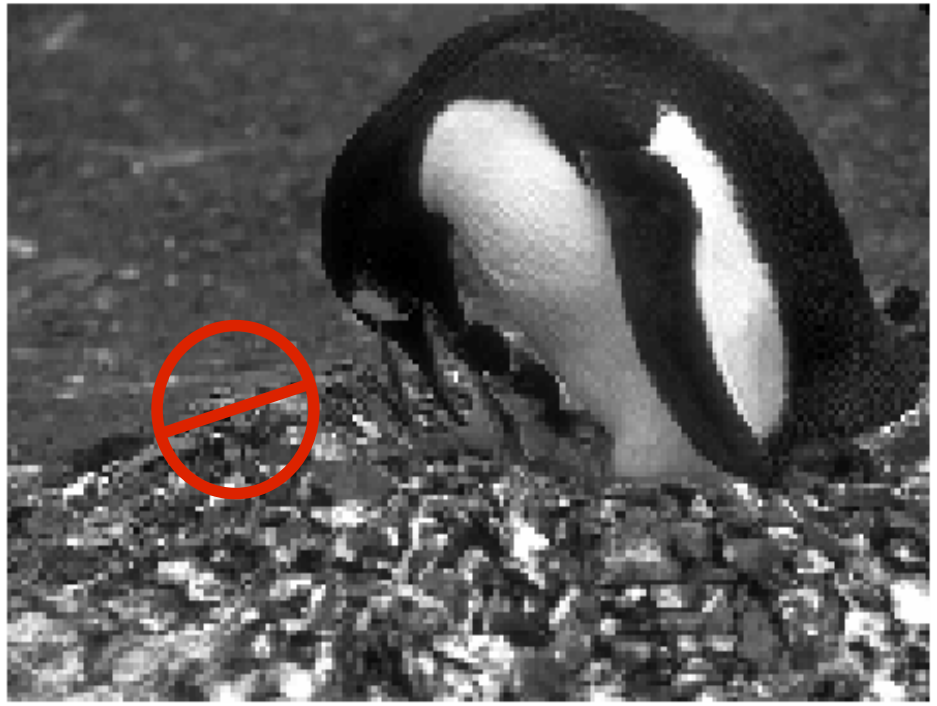
- Each material is now represented as a spatial arrangement of symbols from the texton vocabulary
- Texture is defined by first order statistics of texton distribution, i.e., average density
- For a given region, compute a *histogram* of textons as the representation: vector storing number of occurrences of each texton

Histogram Models for Recognition (Leung & Malik, 1999)



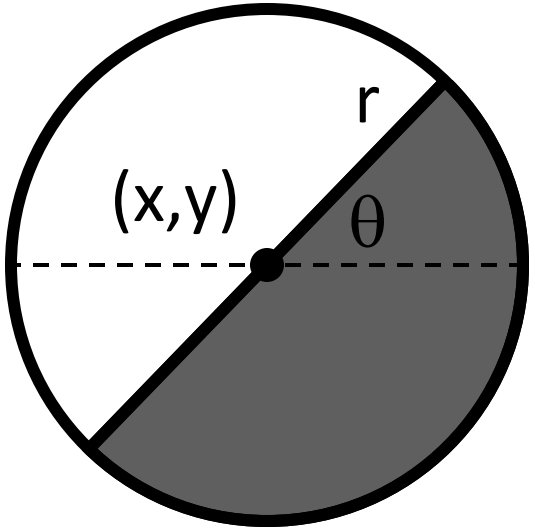
Using textons to identify boundaries

- At every location, try to identify texture boundaries for every orientation
- Consider a disc at that location, split into two halves by a diameter of a particular orientation
- Want to measure the difference in texture between the two halves

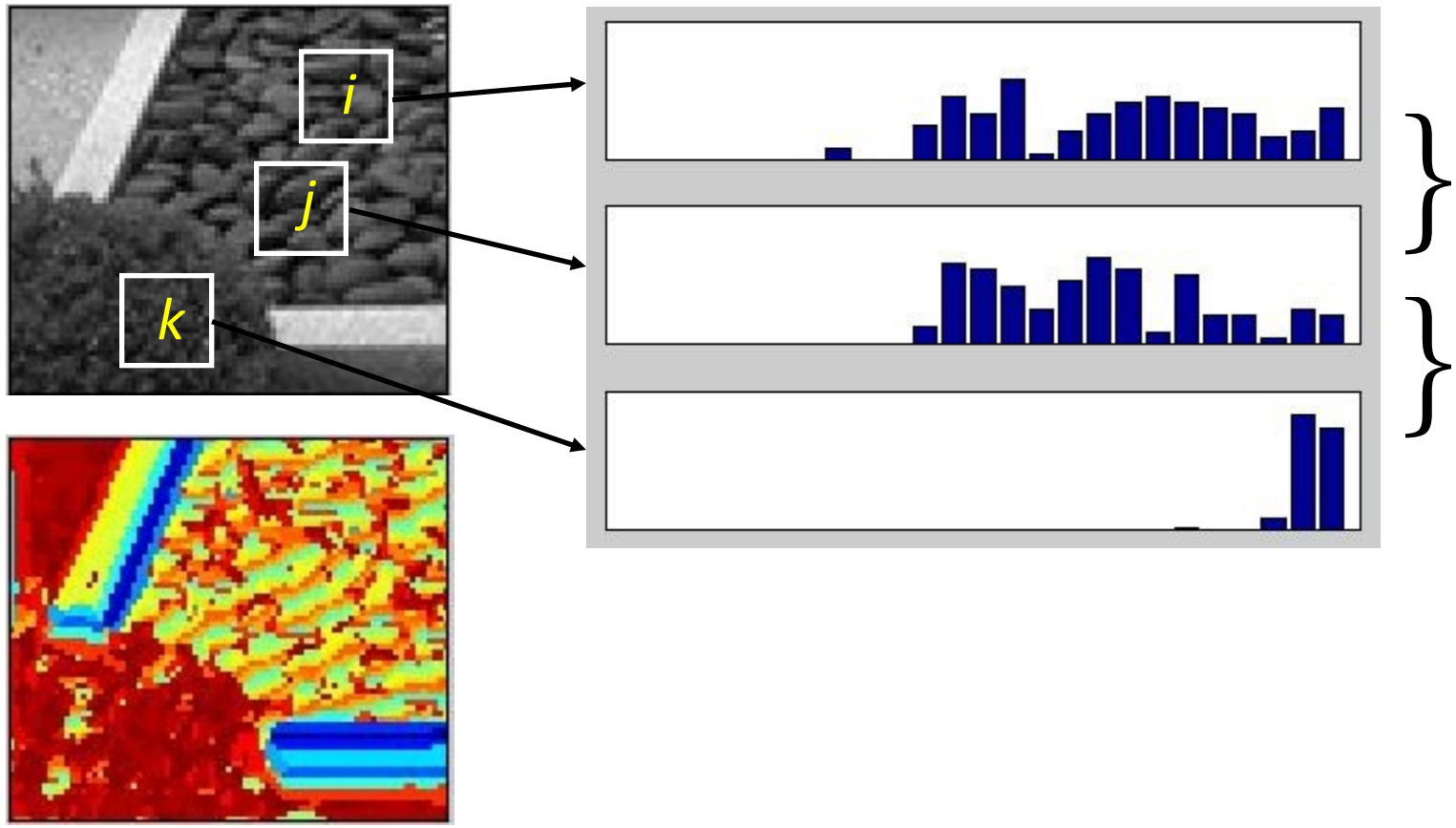


Texture gradient

- Texture Gradient TG(x,y,r,θ)
- In each half, compute histogram of textons
  - For each texton compute number of occurrences
- Compute distance between histograms
  - A histogram is a vector ➔ L2 distance
  - Better distance metrics available



Texture gradient = distance between texton histograms in half disks across edge



Texture gradient

Why the double edge?

Texture gradient

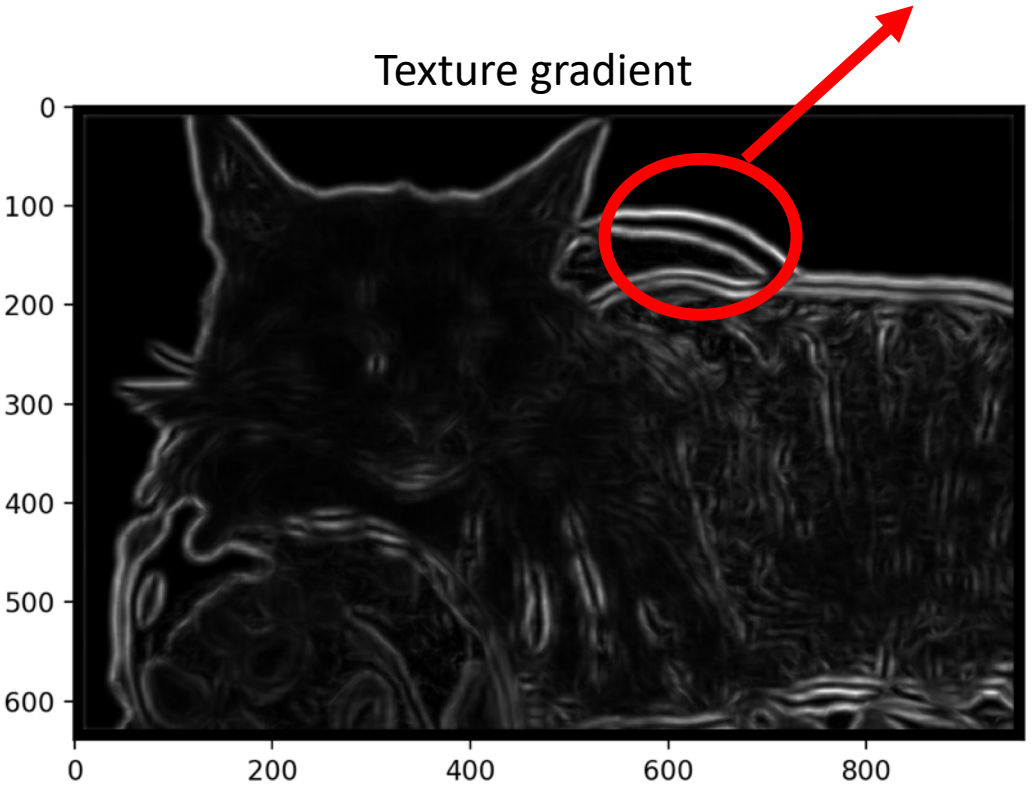
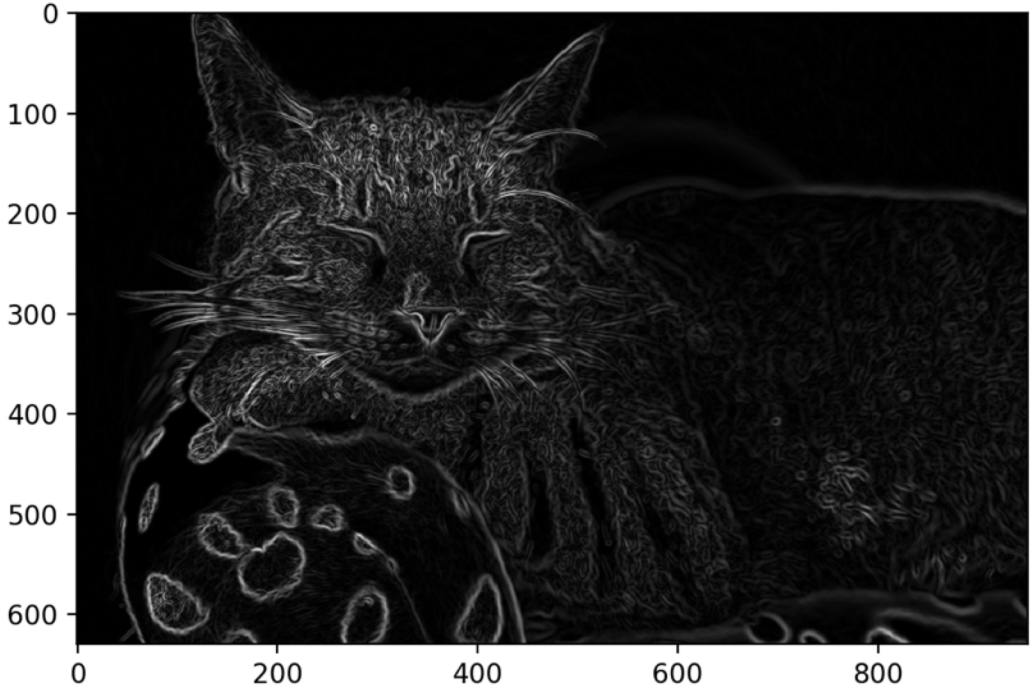


Image gradient



Other techniques for grouping / segmentation

- Better contour detection
  - Learning-based edge detection (random forests, neural networks)
  - Contour completion and forming closed boundaries
- Better clustering
  - Graph-based clustering techniques (spectral clustering)
  - Clustering techniques that take contour information into account

Grouping/Segmentation: a summary

- Goal: group pixels into objects
- Simple solutions: edge detection, k-means
- Challenges:
  - Texture: Possible solution: texture gradient
  - What is k?
- Grouping still a research problem!