IMAGE SEGMENTATION

- Goal
- Connectivity
- Segmentation Methods
  - Amplitude
  - Region
  - Clustering
- Edge Detection

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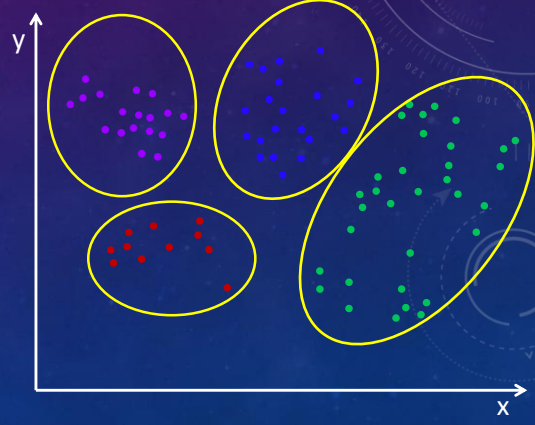
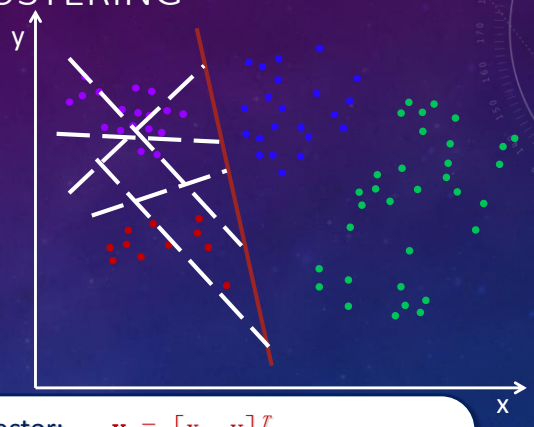
CLUSTERING

- A vector $\mathbf{v_{ij}} = [x,\ y,\ z,\ \ldots]^T$ of measurements at each pixel coordinate (*i*, *j*) in an image.
- The measurement could be point gray values, point color components, derived color components, etc.
- They could also be neighborhood feature measurements such as moving window mean, standard deviation, mode, etc.



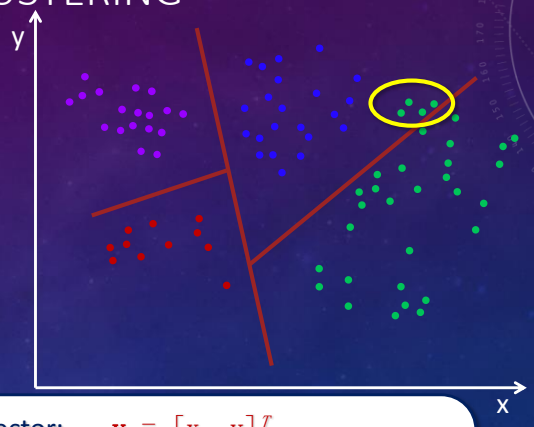
CLUSTERING



- **Classification**: find the line(plane) that separates different classes with the maximum margin
  - Information gain

- x, y coordinates of feature vector: $\mathbf{v} = [x, y]^T$
- Dash line defined by parameter a, b is the separating function : $f_n(\mathbf{v}) = ax + by$
- The actual hyperplane is determined by the threshold: t_n
- Purple, blue, red, green dots indicate 4 different samples

CLUSTERING



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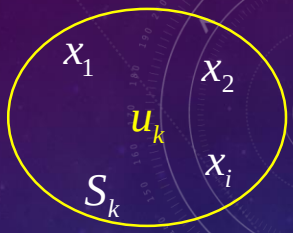
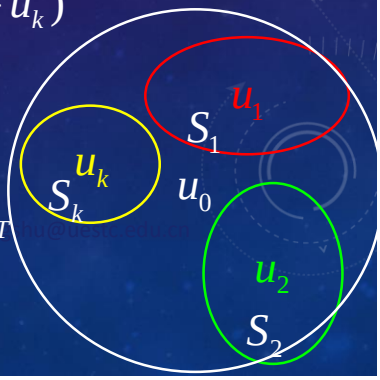


- Within-cluster scatter matrices

$$S_W = \frac{1}{K}\sum_{k=1}^{K}\frac{1}{M_k}\sum_{x_i \in S_k}(x_i - u_k)(x_i - u_k)^T$$

- Between-cluster scatter matrices

$$S_B = \frac{1}{K}\sum_{k=1}^{K}(u_k - u_0)(u_k - u_0)^T$$



CLUSTERING

$$\beta = tr\{S_W\}tr\{S_B\}$$

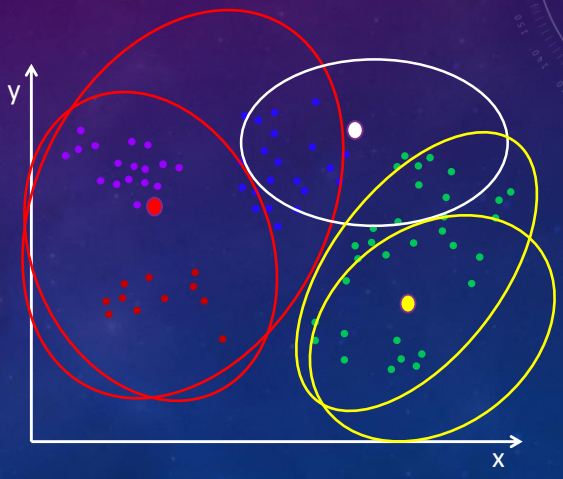


IMAGE SEGMENTATION

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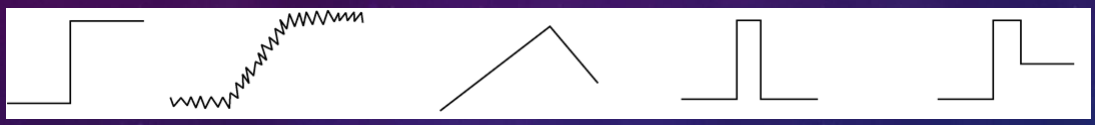
EDGE DETECTION



Different edges

- Gradients:

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

EDGE DETECTION

- Roberts

$$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \qquad \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

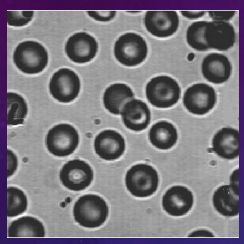
- Prewitt

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

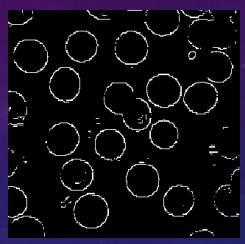
- Sobel

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

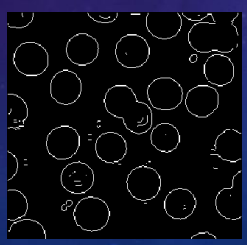
EDGE DETECTION



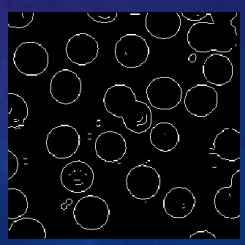
(a) Original



(b) Roberts



(c) Prewitt



(d) Sobel

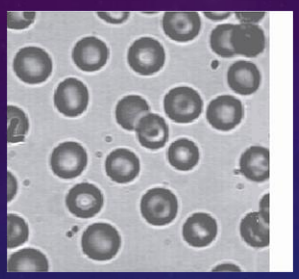
EDGE DETECTION

- Laplacian

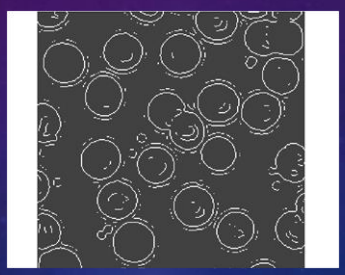
$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

（a）Original （b）Robert （c）Sobel （d）Laplace

EDGE DETECTION



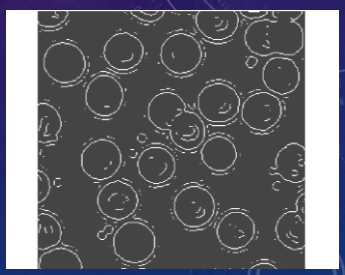
（a）original



（b）LoG

Laplacian of Gaussian

Difference of Gaussian



（c）canny

EDGE LINKING

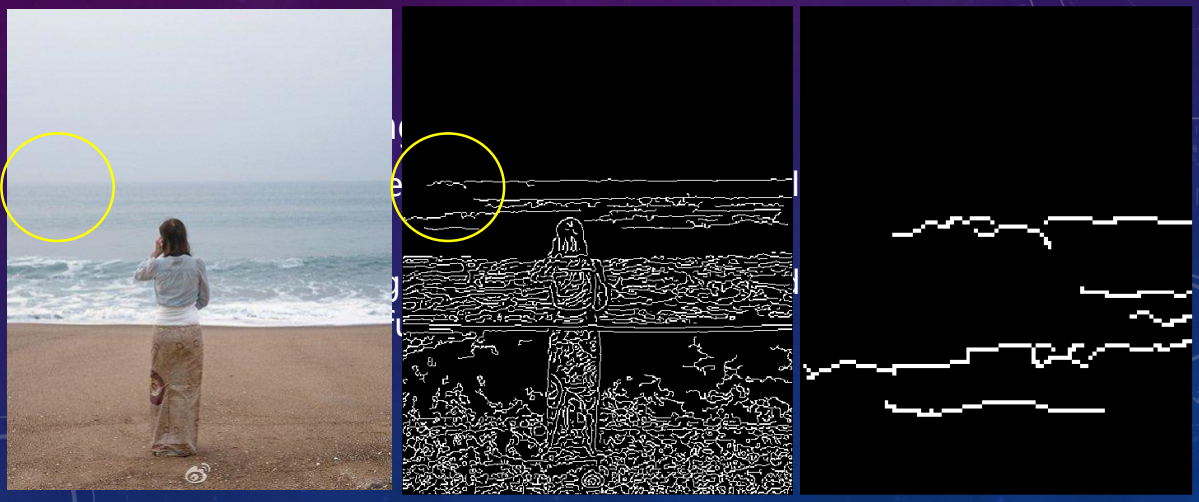
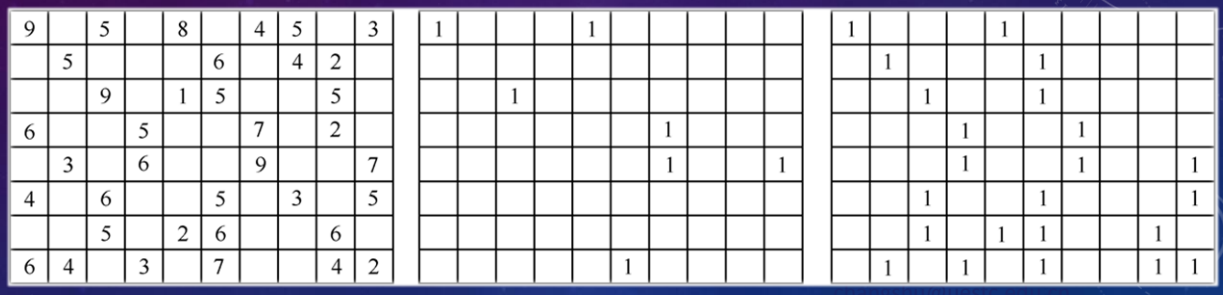


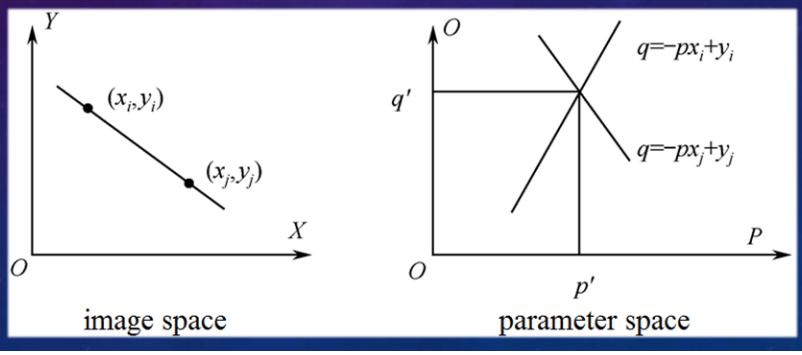
IMAGE SEGMENTATION



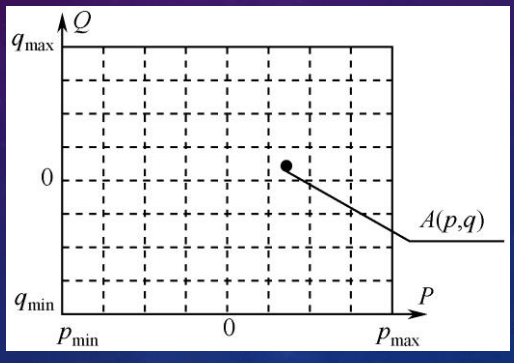
（a）input image （b）thresholding （c）edge linking based on intensity

HOUGH TRANSFORM

- Hough Transform
  - Point – line duality between xy-plane and pq-plane ;
  - The principal lines in image plane could be found by identifying points in parameter space where large numbers of parameter-space lines intersect



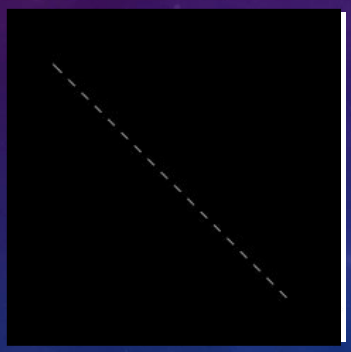
HOUGH TRANSFORM

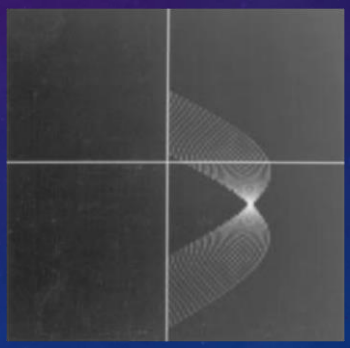


Accumulator cells in parameter space

HOUGH TRANSFORM

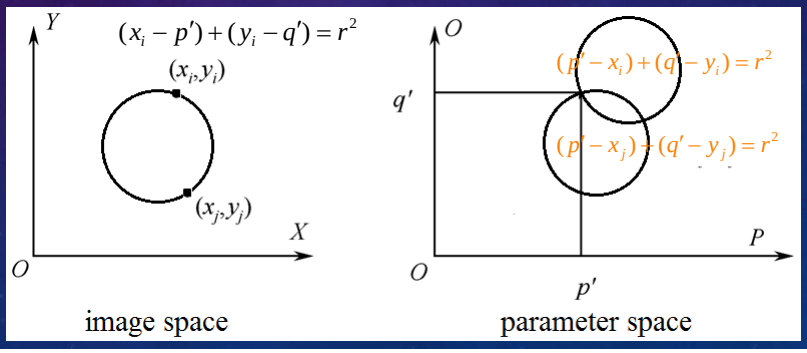
$$x\cos\theta + y\sin\theta = \rho$$



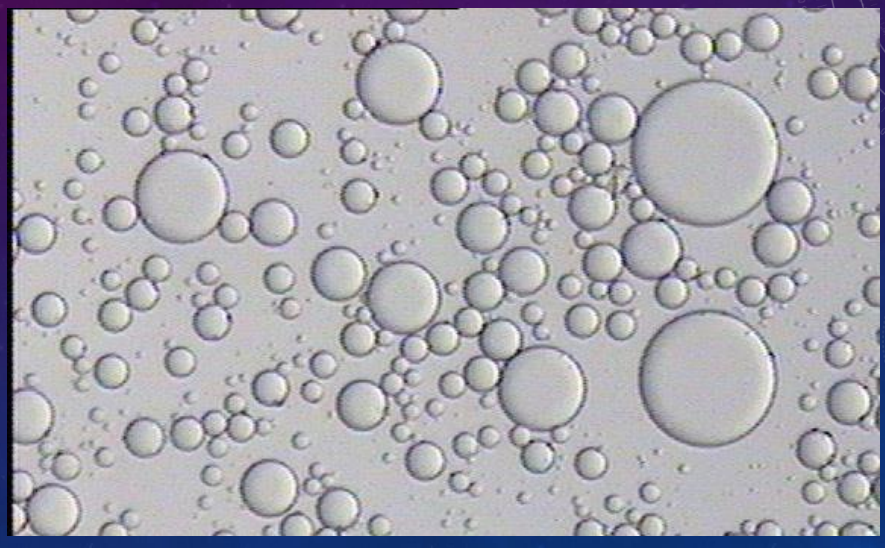


HOUGH TRANSFORM

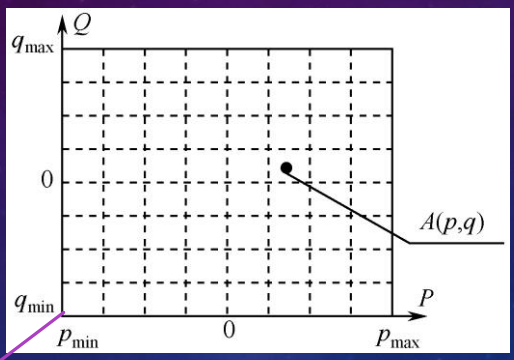
- Hough Transform
  - Point – circle duality between xy-plane and ab-plane ;
  - The principal circles in image plane could be found by identifying points in parameter space where large numbers of parameter-space circles intersect



HOUGH TRANSFORM



HOUGH TRANSFORM



r

Accumulator cells in parameter space

IMAGE SEGMENTATION

- Goal
- Connectivity
- Segmentation Methods
  - Amplitude
  - Region
  - Clustering
- Edge Detection
  - Gradient based methods
  - Hough Transform
  - Snakes/Energy Minimizing Splines
  - Graph Cut Techniques

CONTOUR DETECTION

- Snakes—— internal forces, image forces, external constraint forces, molding a closed contour to the boundary of an object in an image

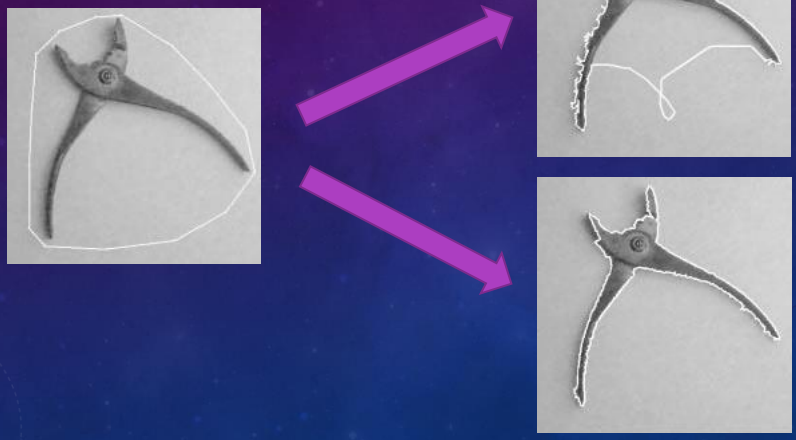
$$E_S = \int_0^1 E_N\{v(s)\}ds + \int_0^1 E_I\{v(s)\}ds + \int_0^1 E_T\{v(s)\}ds \qquad v(s) = [x(s), y(s)]$$

$$E_S = \sum_{n=1}^{N} E_N\{v_n\} + \sum_{n=1}^{N} E_I\{v_n\} + \sum_{n=1}^{N} E_T\{v_n\} \qquad v_n = [x_n, y_n]$$

$$E_N = \alpha(n)E_C\{v_n\} + \beta(n)E_K\{v_n\}$$

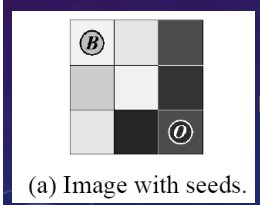
$$E_C = \frac{d - |v_n - v_{n-1}|}{\max\{d - |v_n(j) - v_{n-1}|\}} \qquad E_K = \frac{|v_{n-1} - 2v_n + v_{n+1}|^2}{\max\{|v_{n-1} - 2v_n(j) + v_{n+1}|^2\}}$$

CONTOUR DETECTION

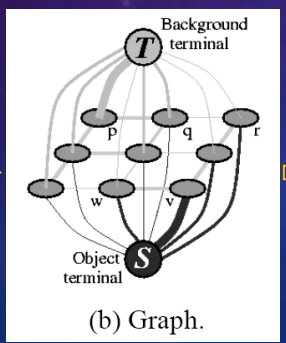


GRAPH CUT

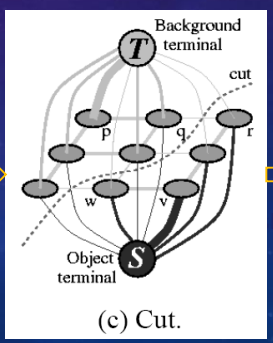
- Graph cut techniques—— a graph is used to represent the image, pixels in the image are represented by nodes on the graph, then a Min-Cut/Max-Flow algorithm is used to segment the graph.



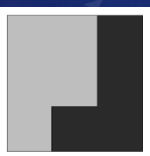
(a) Image with seeds.



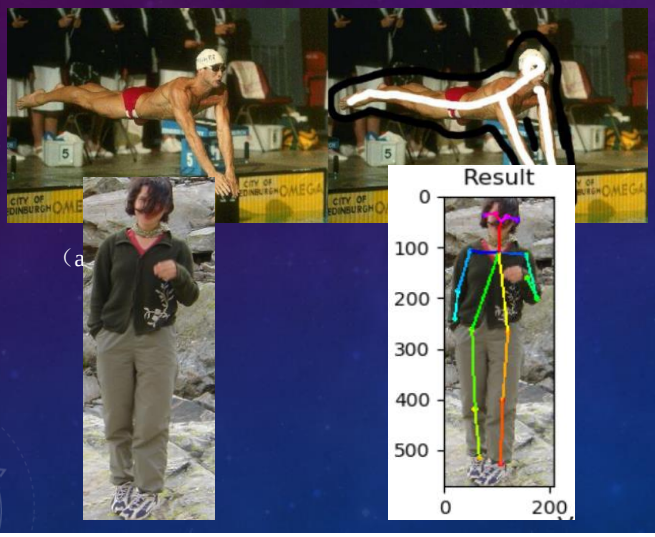
(b) Graph.



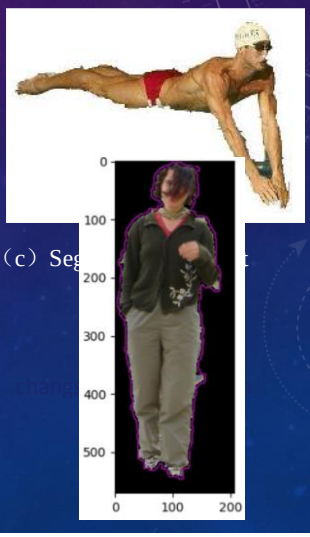
(c) Cut.


(d) Segmentation results.

GRAPH CUT



（a



（c）Seg

SUMMARY

- Goal —— to help IA & IU / separate
- Connectivity —— 4 / 8
- Segmentation Methods
  - Amplitude —— bi-level/multi-level/color
  - Region —— grow/split/merge
  - Clustering —— classification
- Edge Detection —— sobel/canny/laplacian/Marr…/Hough/Snakes