

# Advanced Image Matching Methods



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# Advanced Image Matching Methods



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- Introduction
  - Reliability of Approach
- Extracted Features
  - Interest Points
  - Edges
  - Regions
  - Shapes
- Methods
  - Feature & Shape Based approach
  - Relational Based Approach

# Flowchart of Shape Based Matching

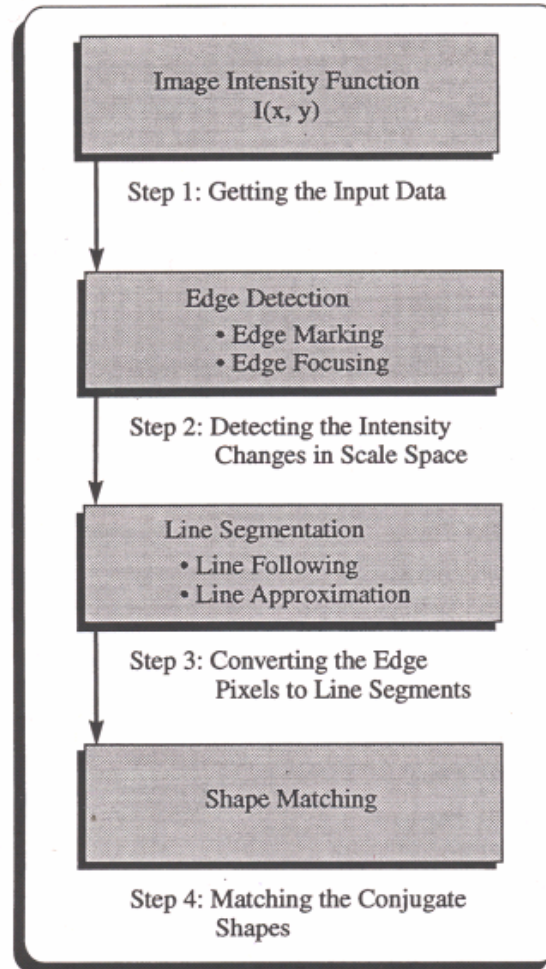


Figure 3.1: Shape-Based Matching Procedure



# Feature-Based Matching

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- FBM employs as conjugate entities features extracted from the original gray levels
  - Edges are the most important features
  - Stereo vision of Human eye is based on finding conjugate edges

# Feature Extraction

## ■ Interest Points

- To identify areas with high variance
- Interest operator performs the extraction process
- Points with distinct features are called interest points

## ■ Operators

### ■ Moravec

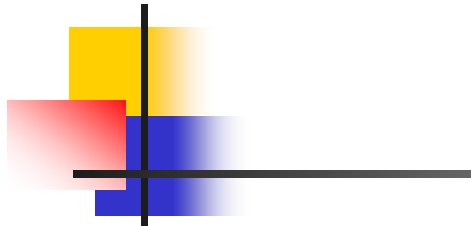
- (measures distinctness of an image patch compared to its surroundings)

$$E_w(x, y) = \sum_{u,v} w_{u,v} |I_{x+u,y+v} - I_{u,v}|^2$$

### ■ Forstner

- (Rotation invariant and sub-pixel accuracy)
- Corner points and Circular features are detected

$$N = \begin{bmatrix} \sum g_x^2 & \sum g_x g_y \\ \sum g_x g_y & \sum g_y^2 \end{bmatrix} \quad w = \frac{\det N}{\text{trace} N} \quad q = \frac{4 \det N}{\text{trace}^2 N}$$

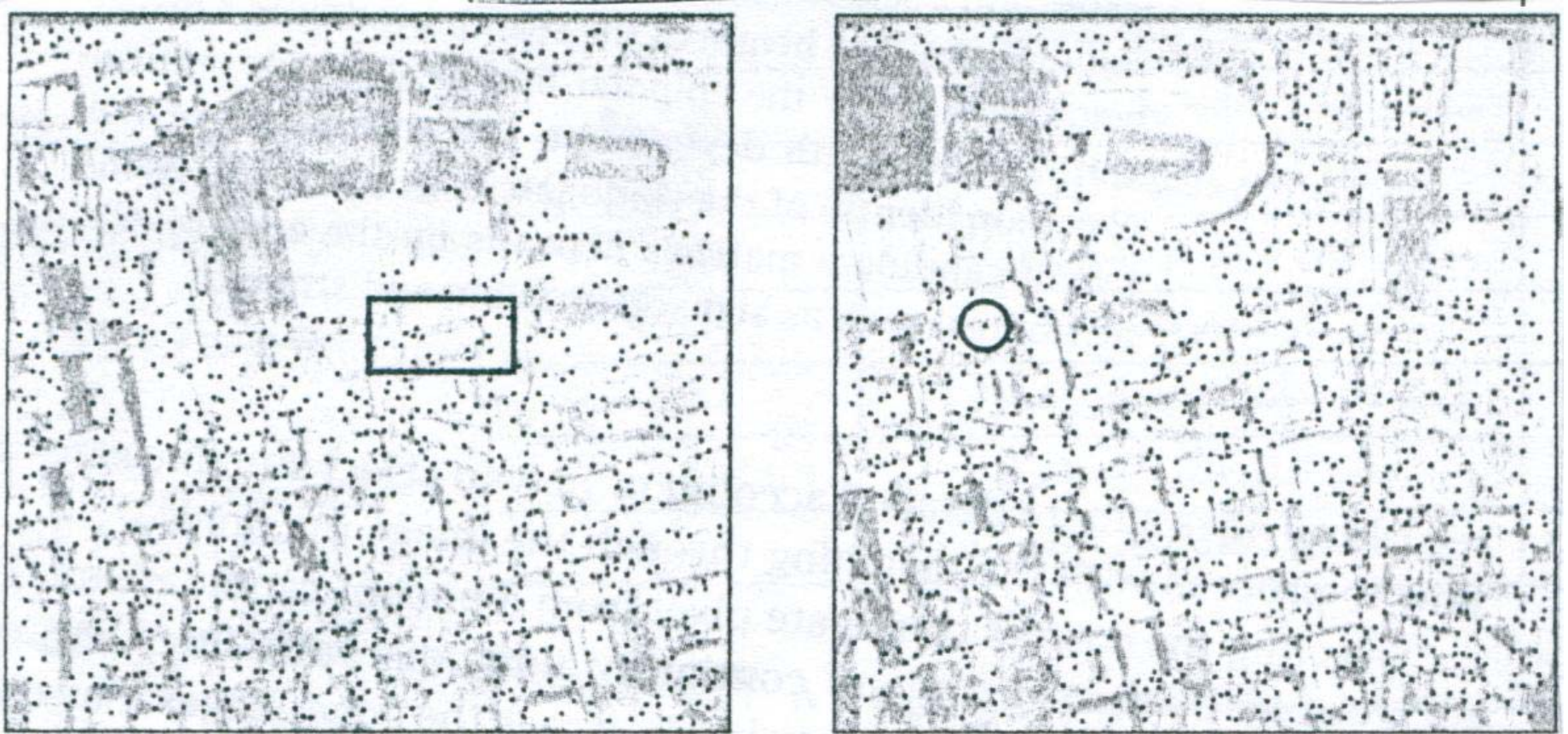


	$g_x$	$g_y$																		
Normal Gradient	<table border="1"><tr><td>-1</td><td>1</td></tr></table>	-1	1	<table border="1"><tr><td>1</td></tr><tr><td>-1</td></tr></table>	1	-1														
-1	1																			
1																				
-1																				
Roberts Operator	<table border="1"><tr><td>0</td><td>1</td></tr><tr><td>-1</td><td>0</td></tr></table>	0	1	-1	0	<table border="1"><tr><td>1</td><td>0</td></tr><tr><td>0</td><td>-1</td></tr></table>	1	0	0	-1										
0	1																			
-1	0																			
1	0																			
0	-1																			
Prewitt Operator	<table border="1"><tr><td>-1</td><td>0</td><td>1</td></tr><tr><td>-1</td><td>0</td><td>1</td></tr><tr><td>-1</td><td>0</td><td>1</td></tr></table>	-1	0	1	-1	0	1	-1	0	1	<table border="1"><tr><td>1</td><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>-1</td><td>-1</td><td>-1</td></tr></table>	1	1	1	0	0	0	-1	-1	-1
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-1	0	1																		
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Sobel Operator	<table border="1"><tr><td>-1</td><td>0</td><td>1</td></tr><tr><td>-2</td><td>0</td><td>2</td></tr><tr><td>-1</td><td>0</td><td>1</td></tr></table>	-1	0	1	-2	0	2	-1	0	1	<table border="1"><tr><td>1</td><td>2</td><td>1</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>-1</td><td>-2</td><td>-1</td></tr></table>	1	2	1	0	0	0	-1	-2	-1
-1	0	1																		
-2	0	2																		
-1	0	1																		
1	2	1																		
0	0	0																		
-1	-2	-1																		

Table 2.3: Some Gradient Operators



# Extracted interest points





# Feature Extraction

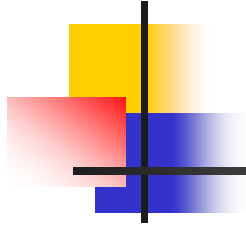
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- Edge Detection
  - Involves the identification of edge pixels and grouping of edge pixels into entire edges
  - Edges correspond to brightness differences in the images
    - Sharp edges
    - Smooth edges
    - Edges occur at all orientations requiring a direction independent operator
    - n-order differences

# Extracted Edges (LoG operator applied)



# Feature Extraction



- Extracting Regions
  - To find areas in an image which are small, distinct, and invariant to illumination differences and perspective views
  - Image segmentation
    - Histogram thresholding
    - Texture segmentation

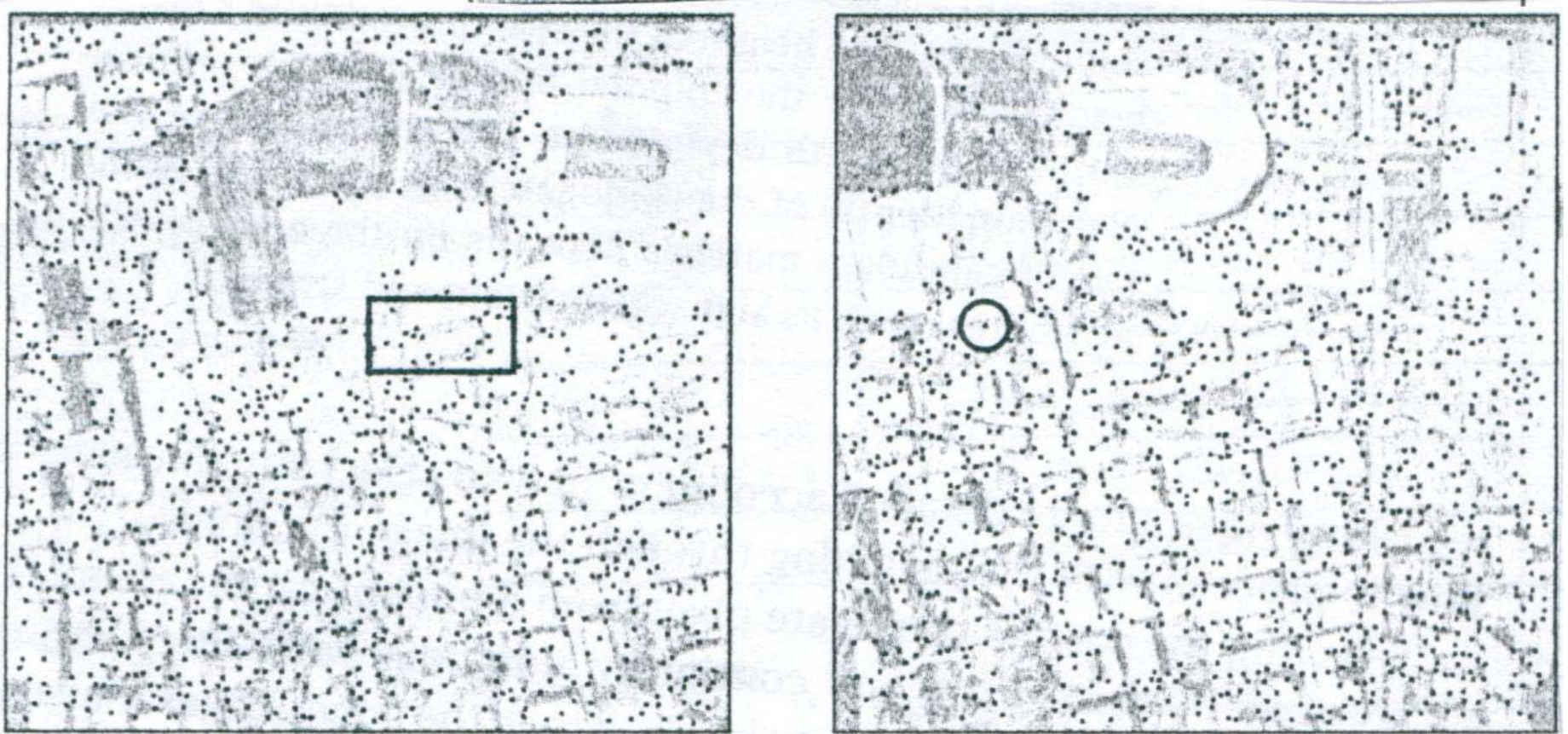
# Matching Interest Points



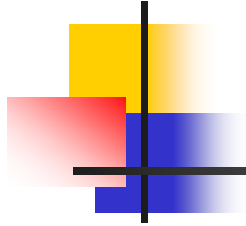
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- ABM is the easiest way
- More logical than ABM applied on the original image
- Problems
  - Forshortening, breaklines, occolusion

# Matching Interest Points (Forstner operator applied)



# Matching Edge Pixels



- Matching Scenario
  - To Normalize the images
  - To Determine Search window in the matching patch (Its centre and dimension)
  - To eliminate some candidates based on incompatible attributes (sign of Zero crossing, orientation, strength)
  - To determine all pixel parallaxes between pixel to be matched and candidate matches
  - Dominant parallaxes can be found by analyzing the histogram of all possible parallaxes
  - To consider additional edge attributes for solving ambiguous situations (strength)

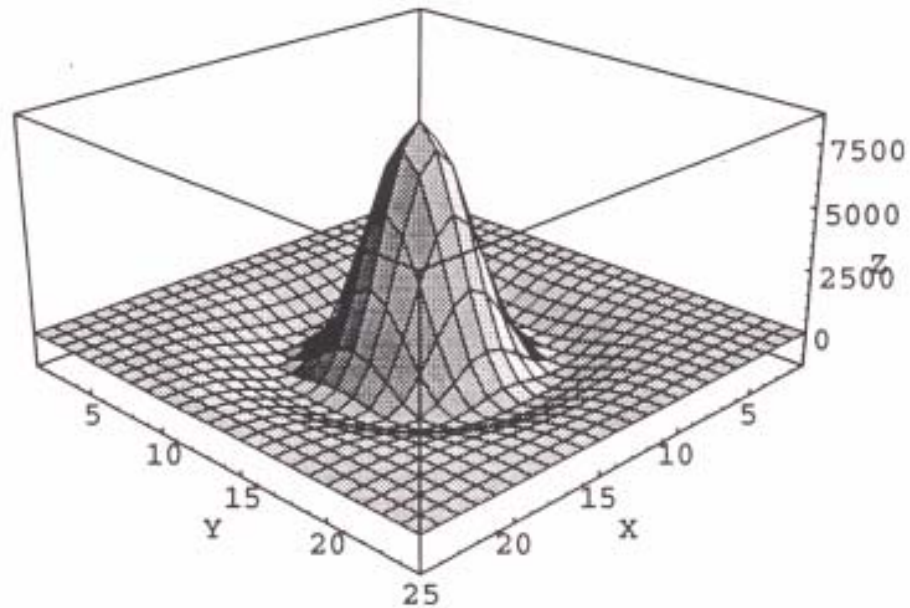
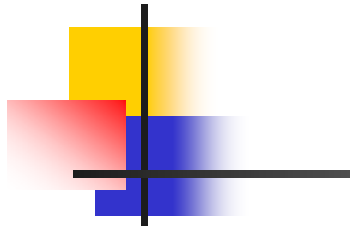
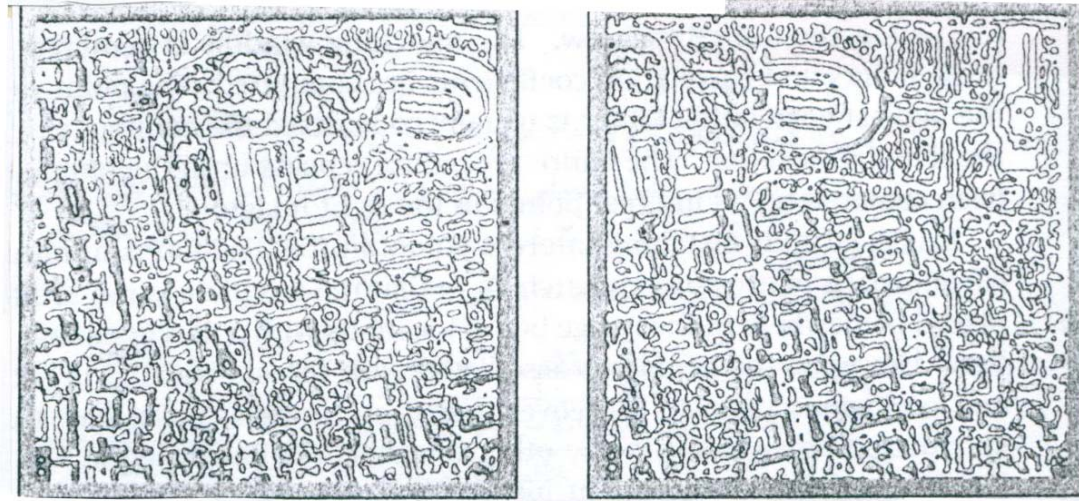
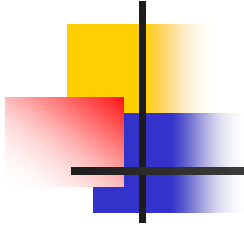


Figure 3.5: Laplacian of Gaussian (LoG) Mask Filter

# Matching Edge Pixels



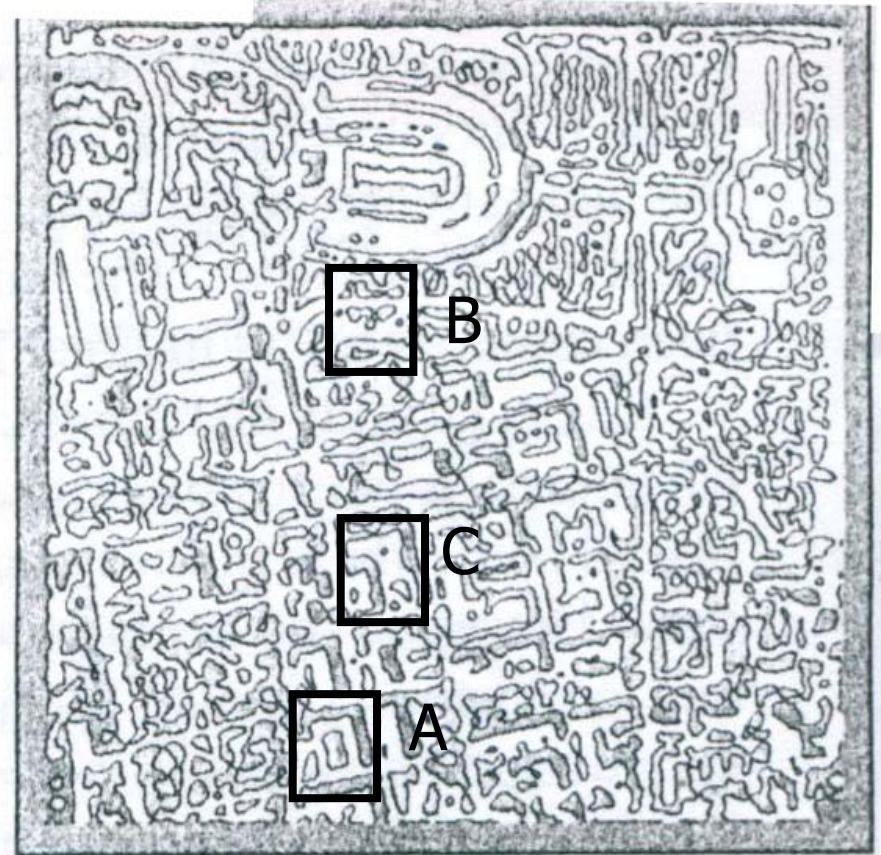
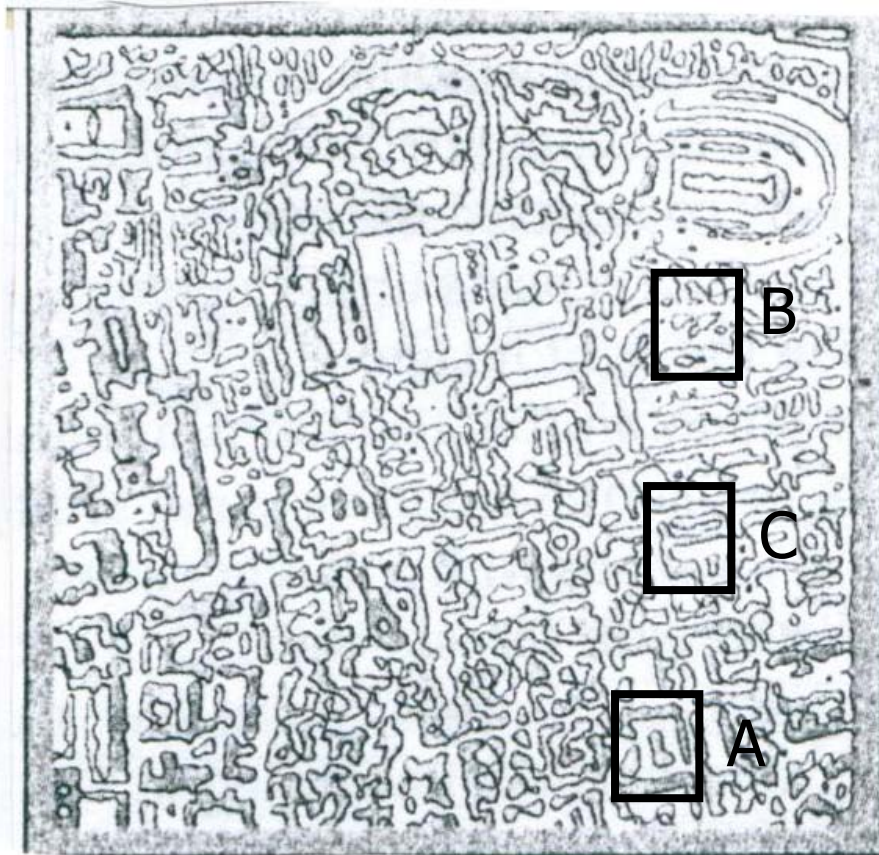
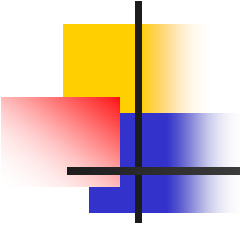
# Matching Entire Edges



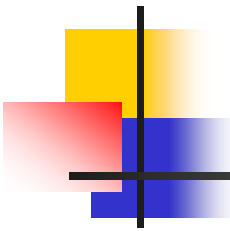
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- Matching entity is an entire edge rather than individual pixels
- Suitable for relative orientation
- Depends on suitable representation of the shape characteristics of edges
- Steps:
  - extraction
  - Representation
  - Shape comparison
- Approaches
  - $\Psi$ -S curve
  - Generalized Hough transform

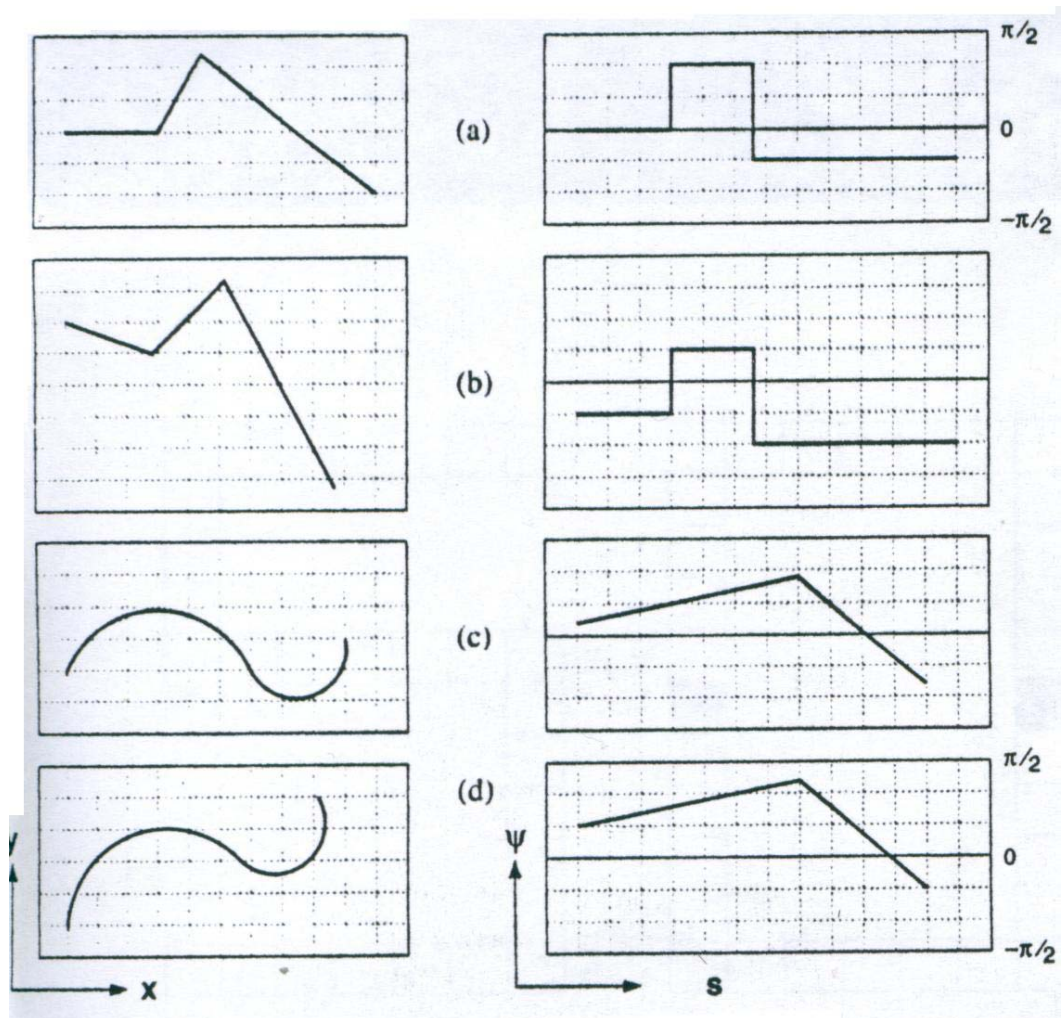
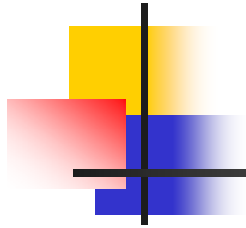
# Matching Entire Edges



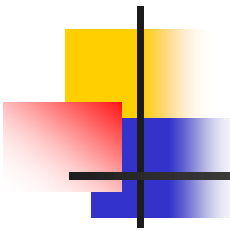
# $\Psi$ -S Approach

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- Representation of a line where the arc length  $S$  is the parameter of tangent  $\Psi$
  - straight line in spatial domain correspond to horizontal straight line in  $\Psi$ - $S$  domain
  - Advantages:
    - Invariant wrt to edge's position in the image
    - Edges are represented as a sequence of edge pixels, chain codes
    - Possible to extract distinct shape features

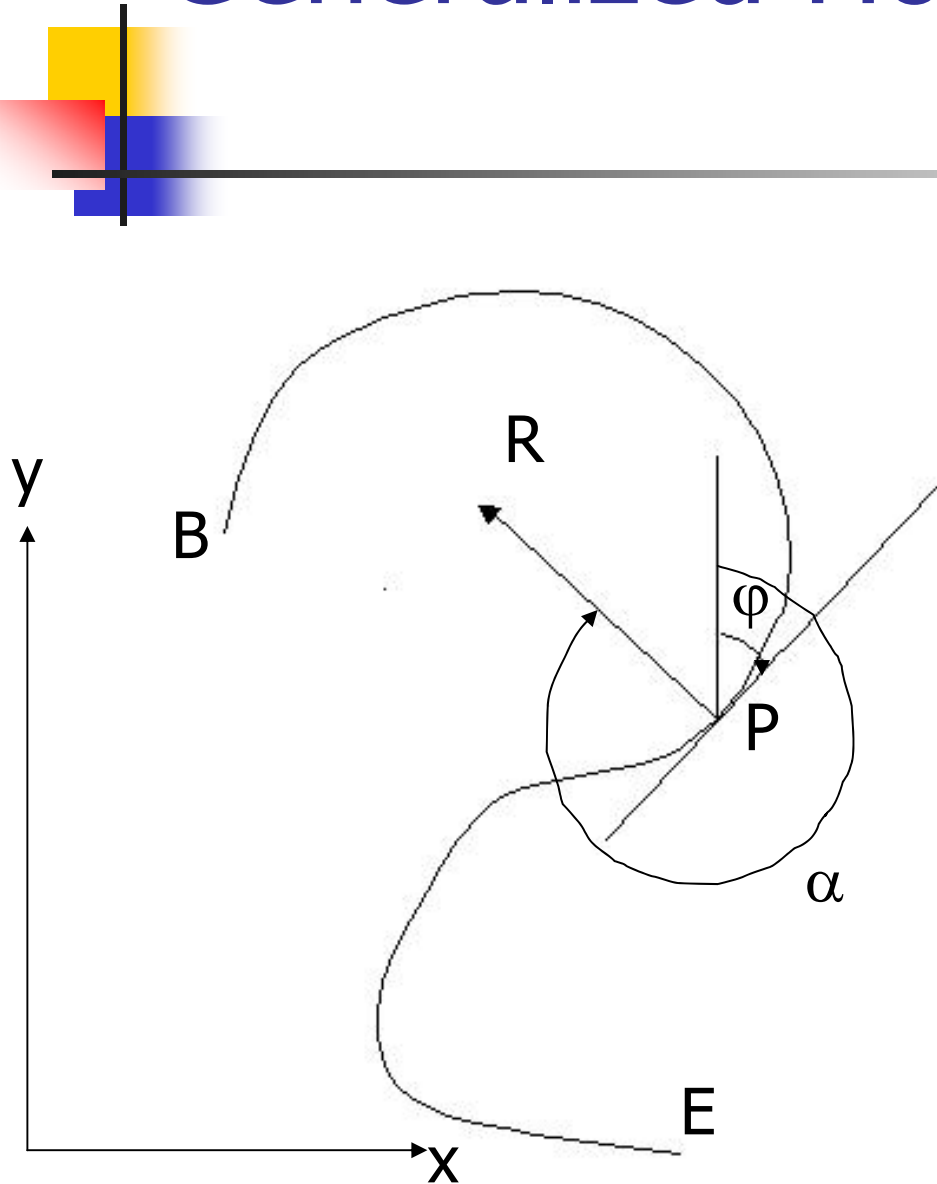
# $\Psi$ -S Approach



# $\Psi$ -S Approach

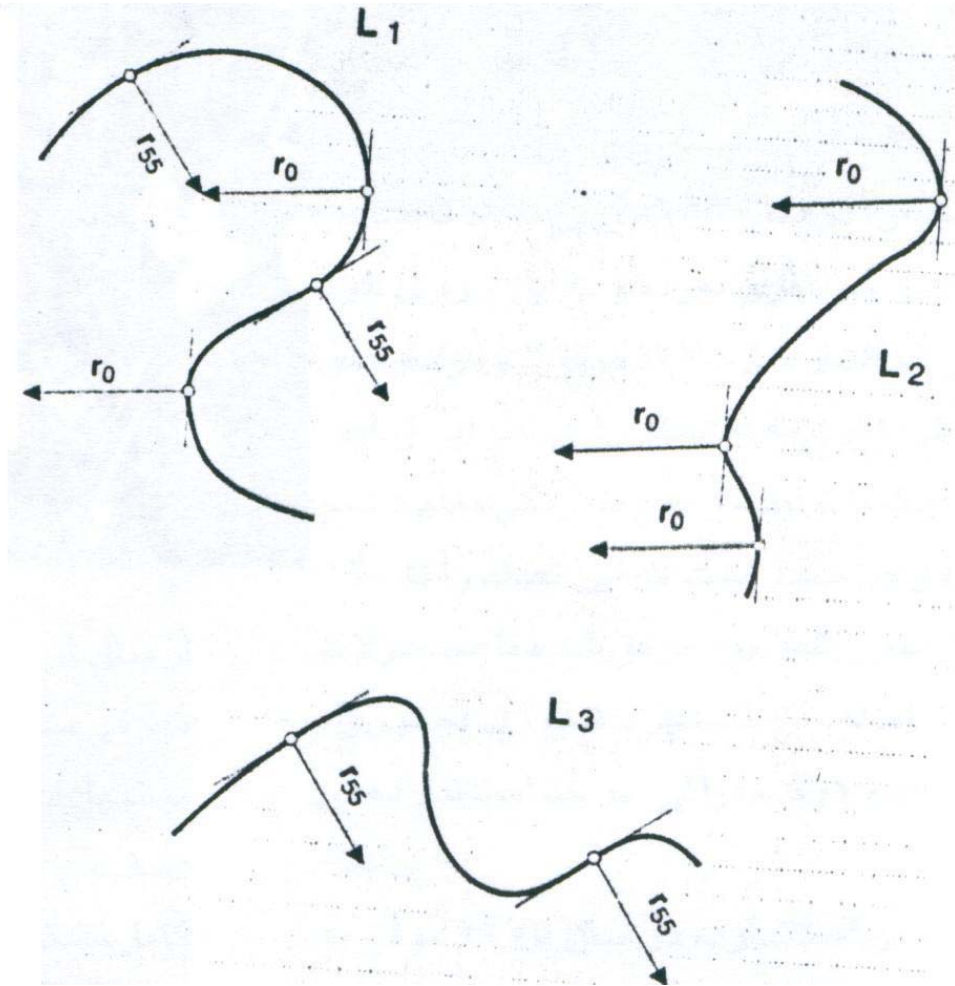
- 
- To segment the  $\Psi$ -S curve into a sequence of straight lines
  - To extract shape features by analyzing the segmented  $\Psi$ -S curve
  - To find similar vertices
  - To check local and global consistency

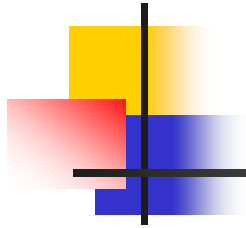
# Generalized Hough Transform



Pixel	Tangent	Polar Coordinates	
		r(mm)	$\alpha$
B	20	46	100
1	21	45	103
.	.	.	.
P	43	39	301
.	.	.	.
E	28	85	338

# Generalized Hough Transform





# Relational Matching

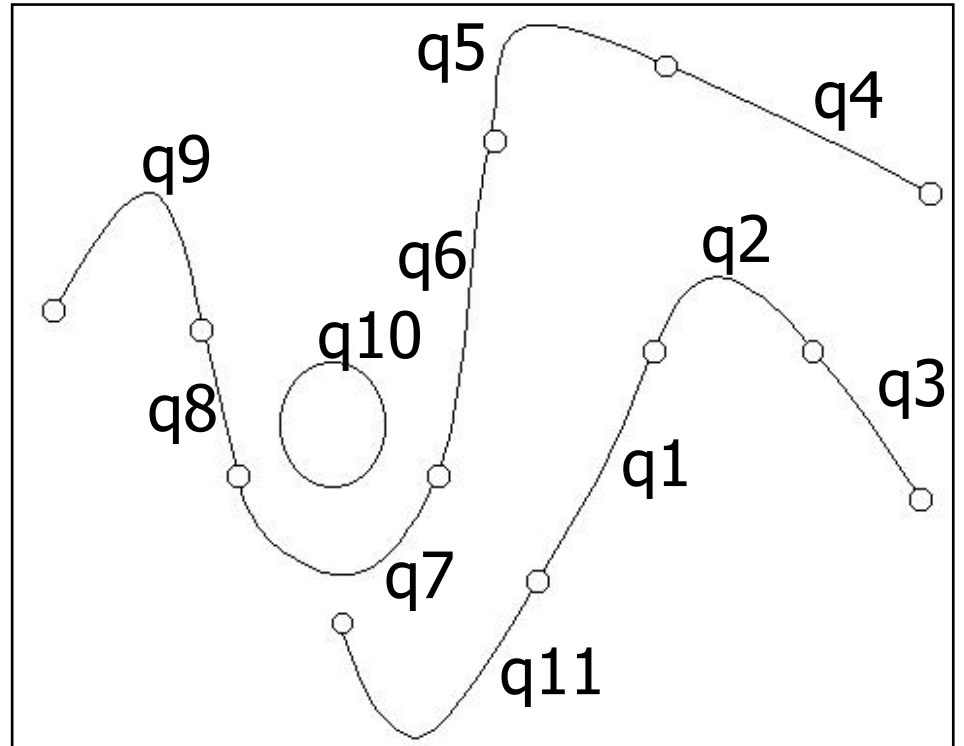
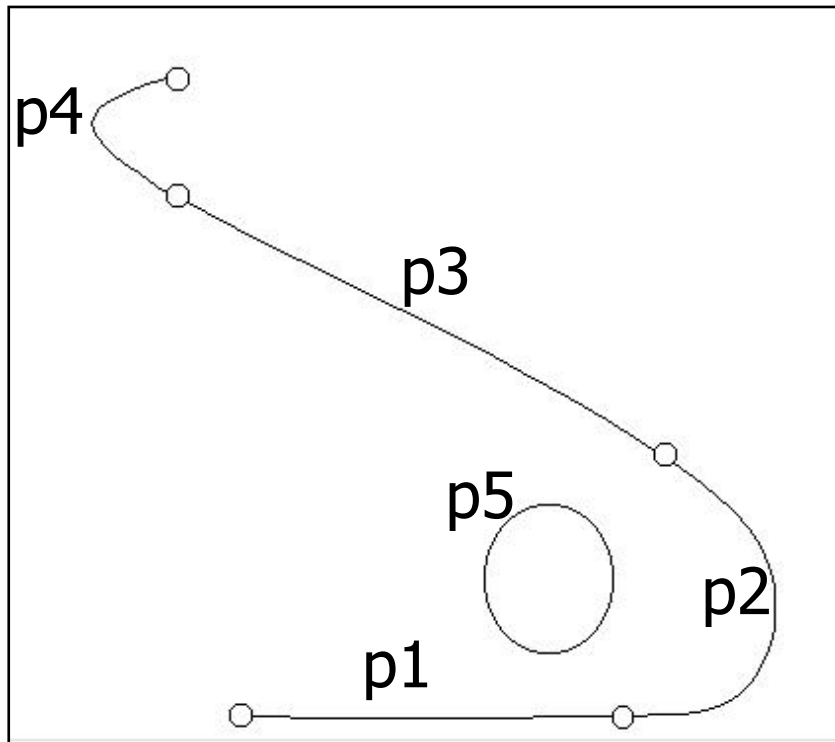
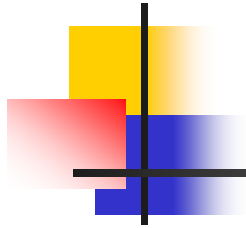
# Description of Primitives Relations



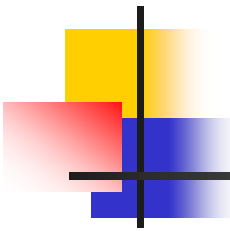
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$$p_i = \{Centroid(x_i, y_i), Length(l_i), Curvature(c_i), arc(\alpha_i)\}$$

# Description of Primitives and Relations



# Description of Primitives and Relations



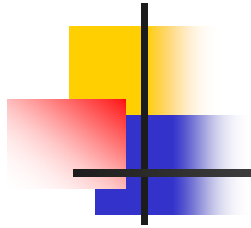
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*(Connection)*  $\{p_2 p_1\}, \{p_3 p_2\}, \{p_4 p_3\}$

*(Neighbor)*  $\{p_5 p_1\}, \{p_5 p_2\}, \{p_5 p_3\}$

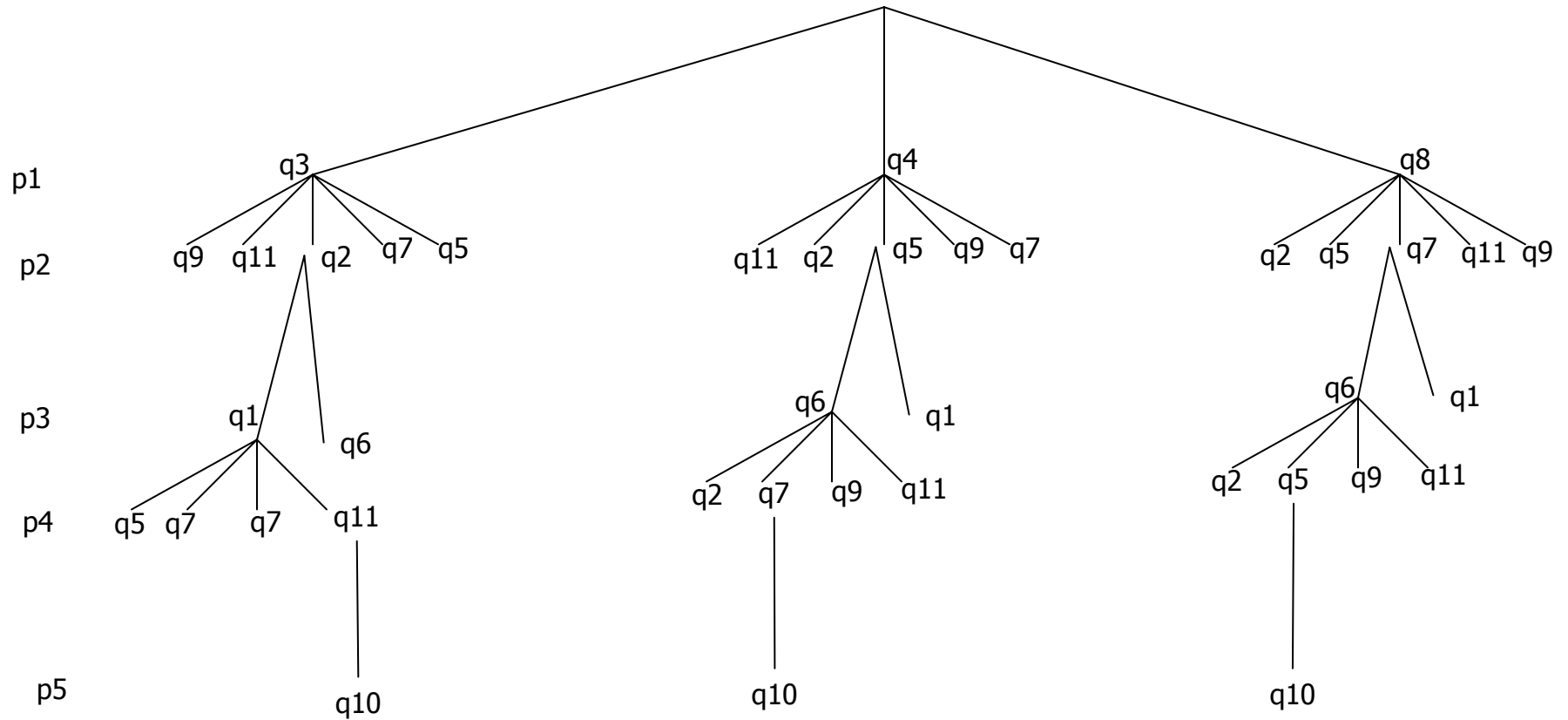
*(Neighbor)*  $\{p_5 p_2\}$  (*distance* – 12)

$\{p_5 p_1\}$  (*distance* – 18)

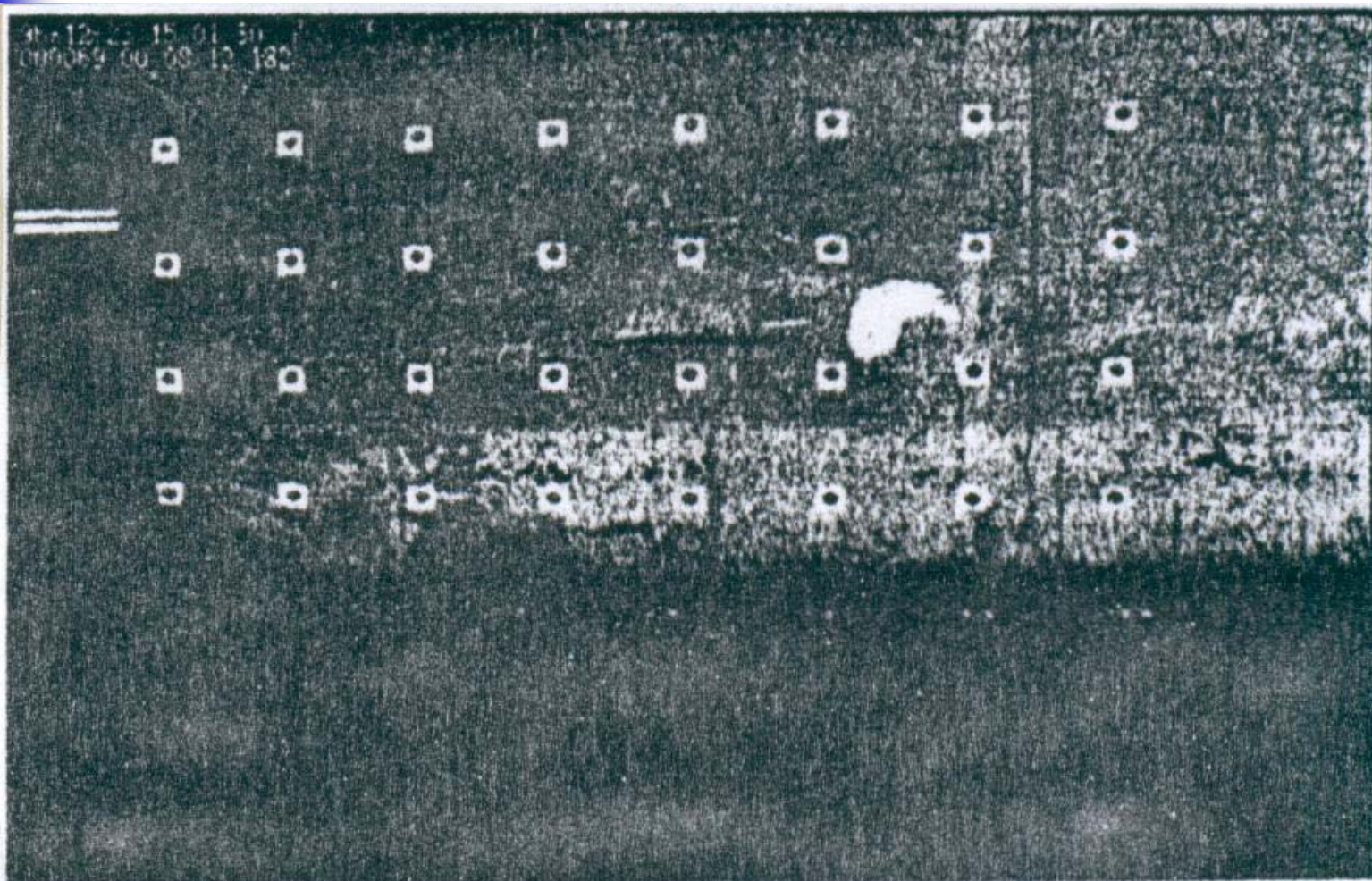


# Evaluation Function

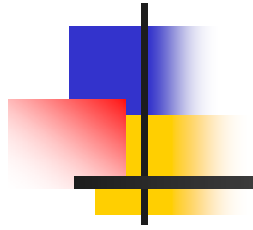
# Tree Search



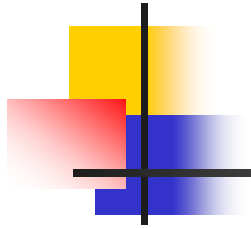
# Template Matching



# Matching Environment

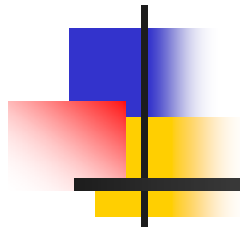


- Illumination
- Object Space
- Image Space



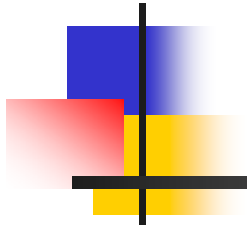
# Matching Strategy

# Target Detection



- Computational Approach
- Histogram Thresholding
- Cross-Correlation
- Feature-Based Matching

# Precise Localization



- Area-Based Methods
- Feature-Based Methods



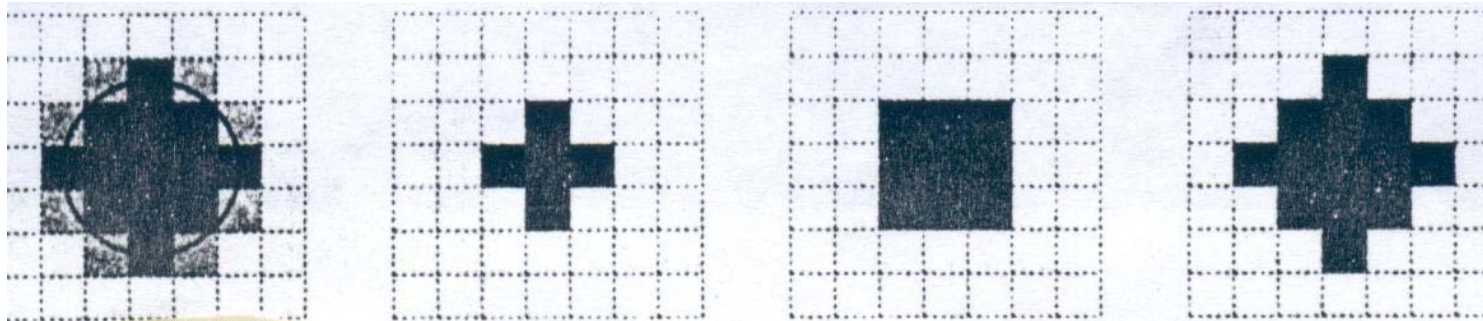
# Area-Based Methods

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$$m_r = \frac{1}{m_0} \sum_{i=1}^N \sum_{j=1}^M f(i, j) j$$

$$m_c = \frac{1}{m_0} \sum_{i=1}^N \sum_{j=1}^M f(i, j) i$$

# Area-Based Methods

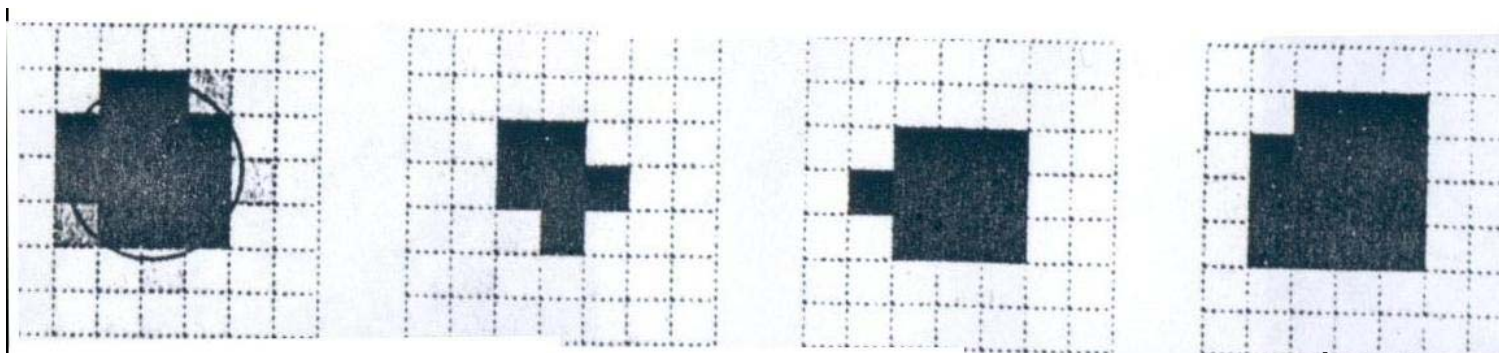


a

b

c

d



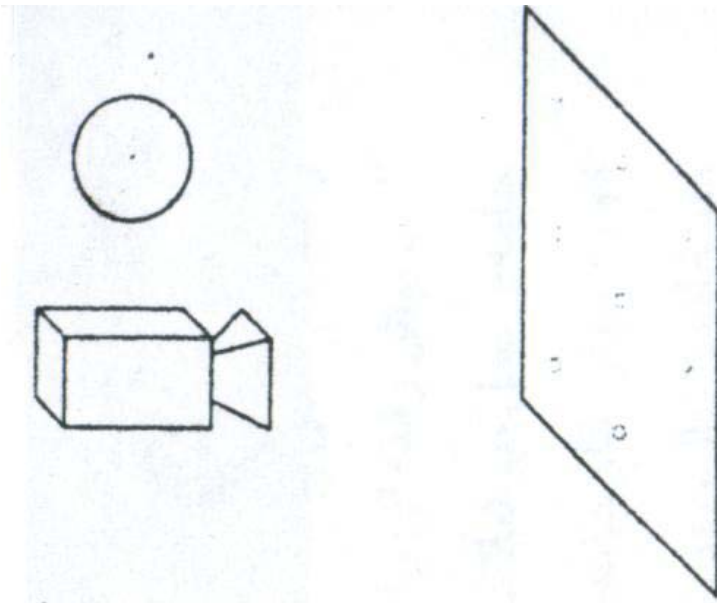
a

b

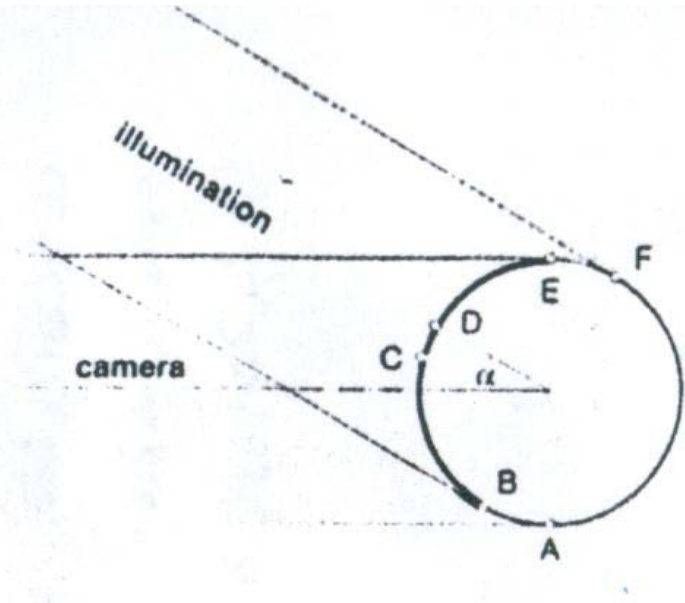
c

d

# Area-Based Methods



a



b

# References



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- T. Schenk, “ Digital Photogrammetry”, Terra Science, 1999
- M. Kasser and W. Egels, “ Digital Photogrammetry”, Taylor and Francis, 2002
- H. Ebadi, “ Advanced Analytical Aerial Triangulation”, Lecture Note, K.N.Toosi University of Technology, 1999
- T.C.Tang, “Digital Image Correlation”, UCSEm Report, 1988