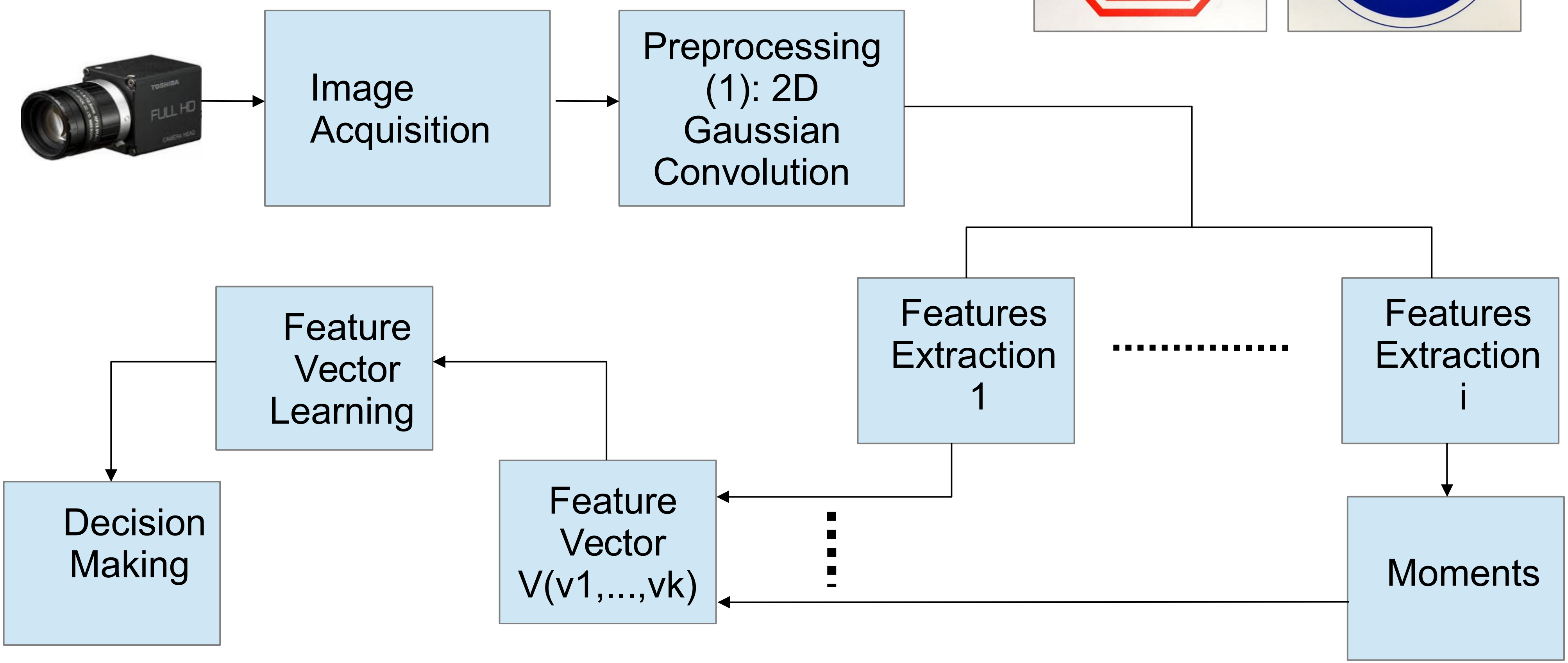
Separation of Floor Track Example With Practical Challenge

Intro to Moments for Objects Recognition

Objectives: Develop a technical to detect different shaped, different color, different size objects



Pattern Recognition For Binary Images

The tool box for pattern recognition for binary images

Note: Starting from binary images, extended to color images

1. Size
2. Moments

   $\overline{x}$

   $\overline{y}$

   $\overline{x^k}$

   $\overline{y^k}$ etc.
3. Perimeter
4. Orientation
5. Compositions of the above

   Perimeter and moments: vector
6. Invariant operators

   size invariant

   orientation invariant

   illumination invariant

Biologically inspired techniques

Rule 1. Proximity

Rule 2. Similarity

Rule 3. Closure

Rule 4. Good continuation

Rule 5. Symmetry

Rule 6. Simplicity

Note: 'Proximity' usage for clean up binary image and remove noise, as well as growing boundary points per 'good continuation' rule to form a better edge map.

Note: Similarity defines a interesting question, how to describe one object is similar, or somewhat similar to others, neural network and fuzzy logic may help.

Ground rule: signature of a image, tools including 3 invariant characteristics

Binary Image Processing

Extended to color images

- Size
  - Perimeter 1
  - Area
    - Noise Removal — Flood fill/Threshold 2
    - Size classification — Flood fill/Threshold

$$\int_I f(x,y)\,dl \qquad \ldots(1)$$

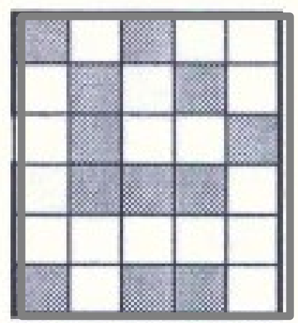
$$\iint_I f(x,y)\,dxdy \qquad \ldots(2)$$

- Shape
  - Enlongation axis 3
  - Center
    - Moment 4

$$\overline{x^k} = \frac{\iint_I x^k f(x,y)\,dxdy}{\iint_I f(x,y)\,dxdy} \qquad (3)$$

$$\overline{y^k} = \frac{\iint_I y^k f(x,y)\,dxdy}{\iint_I f(x,y)\,dxdy} \qquad (4)$$

Example:



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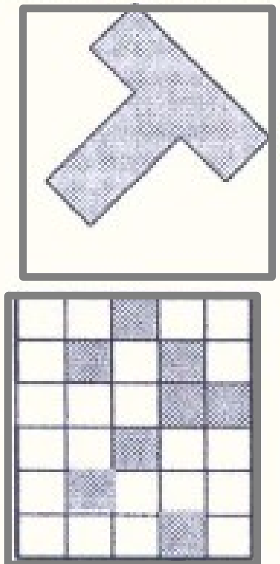
Skeletonization of 2D Binary Images

Example On Simple Pattern Recognition

Given two binary images, derived from two objects, T and O, design a technique to identify them



Example: Computation of
(1) Area (size);
(2) X-bar;
(3) Y-bar;
(4) Orientation, theta angle
(5) Perimeter of an object

Fig1(a),(b)

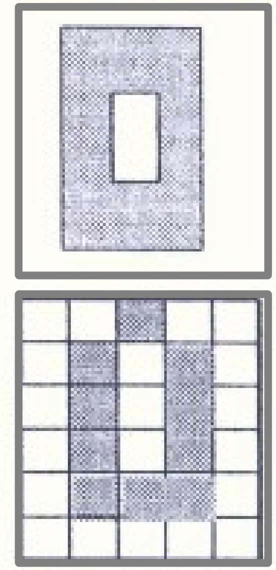


Fig2(a),(b)

Good continuation or noise? What to do with this noise?

Feature Vector		Size	X-bar	Y-bar	Orientation	Perimeter	
V_1(v1,..., v5)	T	v11	v12	v13	v14	v15	From Fig1(b)
V_2(v1,..., v5)	L	v21	v22	v23	v24	v25	From Fig2(b)

Intro Feature Characterization

Example: Fill out this table based on the characteristics of each feature

	Perimeter v1	Area v2	x_bar v3	y_bar v4	Theta v5	Moments v6-vi	Hu-Moments v(i+1)-vk
Illumination invariant							
Scale invariant			Y	Y	Y		Y
Orientation Invariant							Y

Perimeter:

$$P = \int_{\Omega} f(x,y)\, dl$$

Or,

$$P = \sum_{k_1=1}^{N} \sum_{k_2=1}^{M} B'(x,y)$$

Where B'(x,y) from object whose neighboring pixels belong to background

x_bar:

$$\bar{x} \triangleq \frac{\iint_{\Omega} x\, B(x,y)\, dx\, dy}{\iint_{\Omega} B(x,y)\, dx\, dy}$$

y_bar can be defined similarly

Moments:

$$M_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x,y)\, dx\, dy$$

Central moments:

And

$$\mu_{pq} \triangleq \frac{\iint_{\Omega} (x-\bar{x})^p (y-\bar{y})^q B(x,y)\, dx\, dy}{A}$$

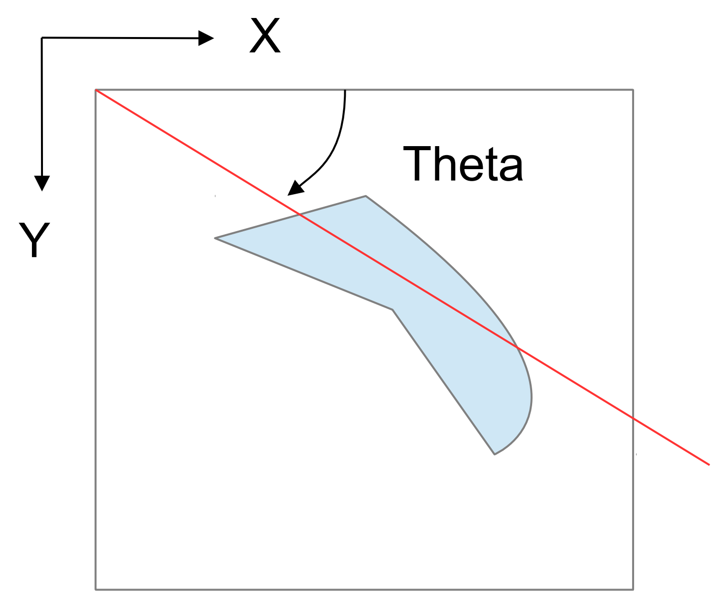
Orientation Computation

$$\tan 2\phi \triangleq \frac{b}{a-c}$$

$$a = \iint_{\Omega} (x-\bar{x})^2 B(x,y)\,dx\,dy \quad \cdots (2)$$

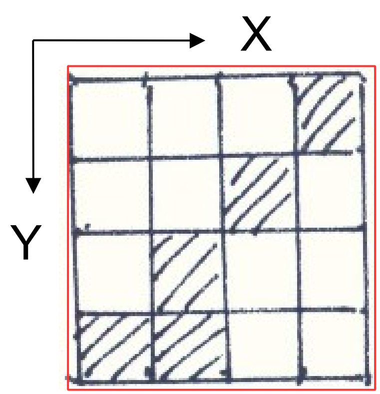
$$b = \iint_{\Omega} 2(x-\bar{x})(y-\bar{y}) B(x,y)\,dx\,dy \quad \cdots (3)$$

$$c = \iint_{\Omega} (y-\bar{y})^2 B(x,y)\,dx\,dy \quad \cdots (4)$$



Reference: Robot Vision, by BPK, Horn, Chapter 3, pp. 46-64

Example: See my handout



a = 7
b = -8
c = 6
Theta = -41.4375

Note: my hand calculation use integer, when have access to computer, use Float!
(x_bar = 2.8 changed to 3, and y_bar = 2.4 changed to 2)

Raw Moments

The "raw moment" of order (p + q) for image f(x,y) is defined as:

$$M_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^p y^q f(x,y)\,dx\,dy \qquad (1)$$

For the discrete function, we have:

$$M_{ij} = \sum_x \sum_y x^i y^j I(x,y) \qquad (2)$$

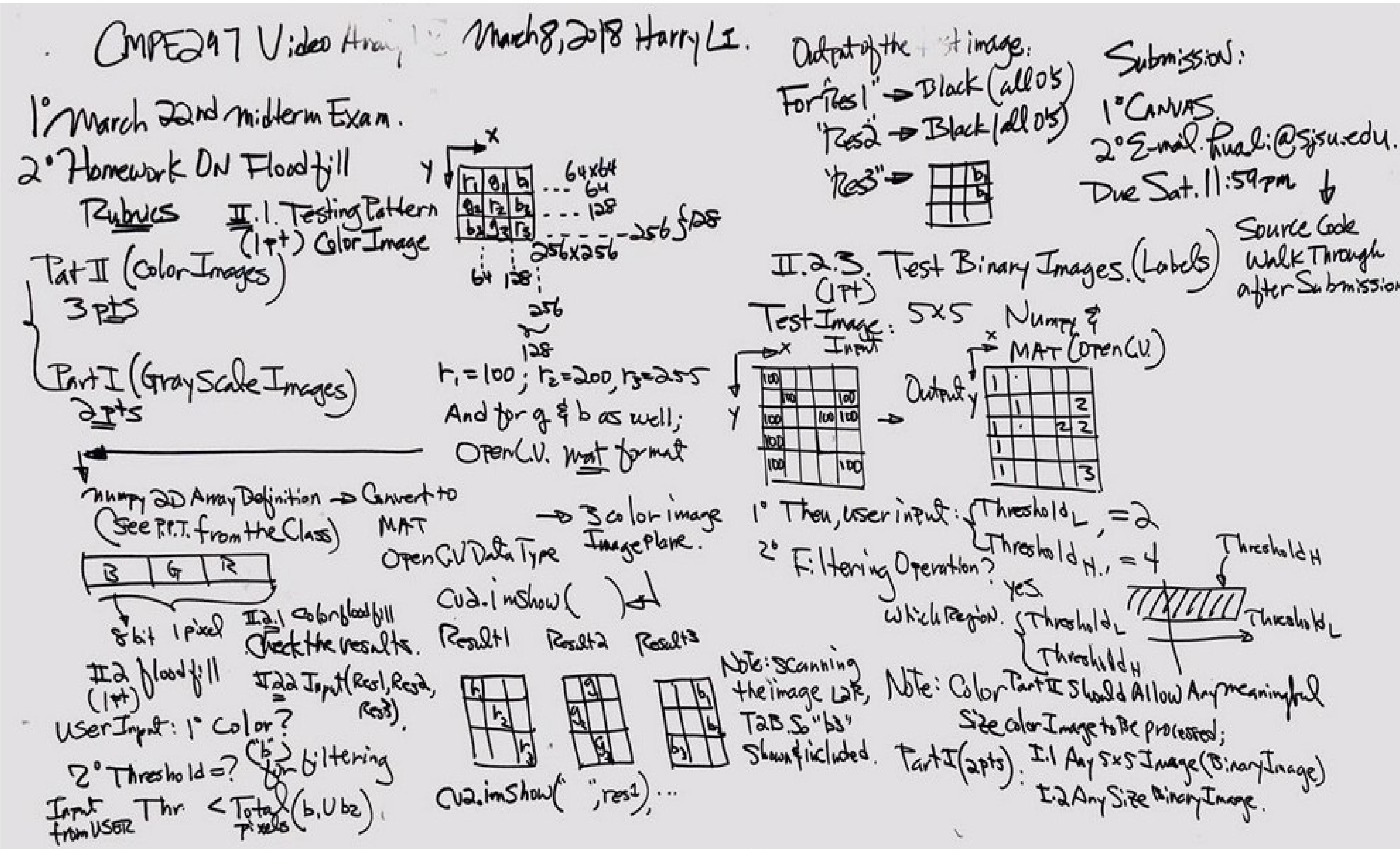
Note: image I(x,y) can be binary image or gray scale images. But we start the discussion from the binary images first.

We can treat image intensity as its probability density function

$$\sum_x \sum_y I(x,y) \qquad (3)$$

Reference: Robot Vision, by BPK, Horn, Chapter 3, pp. 46-64

Color Flood Fill Testing



Binary Image Features

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Size (AREA)

1. Perimeter $\boxed{\int_L B(x,y)\,dl}$ ...(1)

"8 Connected" Contour":

$B(x,y)$, Find its $P(x,y) = ?$

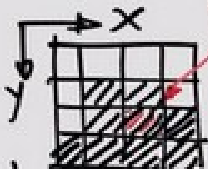


Fig 1.

$\sum_{l \in Contour} B(x,y) = P(B(1,1)) + P(B(1,2)) +$
$P(B(2,1)) + P(B(3,2)) + P(B(3,3)) +$
$P(B(2,3)) + P(B(1,3)) + P(B(0,3)) +$
$P(B(2,2)) = 9 = P_\Sigma$

"4" Connected Neighbours w/o Counting $B(2,2)$,
Hence, $P_\Sigma = 8 = P_\Sigma$

2. AREA, $A = \iint_\Omega B(x,y)\,dx\,dy$ ...(2)

Example: Given $B(x,y)$ in Fig.1. Find A=?

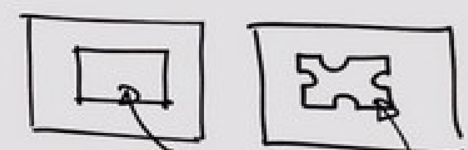
$A = \sum_y \sum_x B(x,y)$ ...(2*)

$A = A(B(1,1)) + A(B(2,1)) + A(B(1,2))$
$+ A(B(2,2)) + A(B(3,2)) + A(B(0,3)) +$
$+ A(B(1,3)) + A(B(2,3)) + A(B(3,3))$
$= 9$

Note: "Complexity" Describe

1° Shape of A given Binary Pattern:

Consider 2 patterns Below.



A_1 A_2

$A_1 = A_2 \triangleq \iint_\Omega B(x,y)\,dx\,dy$.

Index $\triangleq \frac{P}{A}$ ...(3)

2° "Signature" feature w/ unique mapping a Binary Image

3° Orientation Computation.

$\Downarrow$

First moments.

Moments

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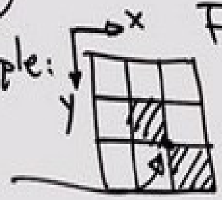
$$\overline{x^k} \triangleq \frac{\iint_\Omega x^k B(x,y)\,dx\,dy}{\iint_\Omega B(x,y)\,dx\,dy} \quad \cdots (3\text{-}1)$$

$$\overline{y^k} \triangleq \frac{\iint_\Omega y^k B(x,y)\,dx\,dy}{\iint_\Omega B(x,y)\,dx\,dy} \quad \cdots (3\text{-}2)$$

When $k=1$. $(\bar{x}, \bar{y})$ center of the Image

$B(x,y)$

Example:



$(\bar{x},\bar{y})$

Fig 1

Find $\bar{x} = \dfrac{\iint_\Omega x B(x,y)\,dx\,dy}{\iint_\Omega B(x,y)\,dx\,dy}$.

Sol: $A \triangleq \iint_\Omega B(x,y)\,dx\,dy = \sum_x \sum_y B(x,y)$

$= B(1,1)+B(2,2) = 1+1 = 2$; and $\iint_\Omega x B(x,y)\,dx\,dy =$

$\sum_{y=0}^{2}\sum_{x=0}^{2} x B(x,y) = 1\cdot B(1,1) + 2\cdot B(2,2) = 1+2 = 3 \quad \therefore \bar{x} = 3/2 = 1.5$

$\bar{y} = \dfrac{\iint_\Omega y B(x,y)\,dx\,dy}{\iint_\Omega B(x,y)\,dx\,dy} = \frac{1}{2}\left(\sum\sum y B(x,y)\right) = \frac{1}{2}\left(1\cdot B(1,1) + 2\cdot B(2,2)\right) = 3/2 = 1.5$

Now, Feature Vectors,

$\vec{V} = (P, A, \bar{x}, \bar{y})$

$= (V_1, V_2, V_3, V_4)$

If Adding Index $= P/A$

then 5th Dimension,

$\vec{V} = (P, A, \text{Index}, \bar{x}, \bar{y})$

$= (V_1, V_2, \cdots, V_5)$

Generalize Eqn (3-1), (3-2),

$$m_{pq} = \iint_\Omega (x-\bar{x})^p (y-\bar{y})^q B(x,y)\,dx\,dy \Big/ \iint_\Omega B(x,y)\,dx\,dy$$

$p, q = 0, 1, 2$, (3 or Bigger Not used often) $\quad \cdots (4)$

$m_{01}, m_{02}, m_{10}, m_{11}, m_{12}, m_{20}, m_{21}, m_{22}$ (8 Features)

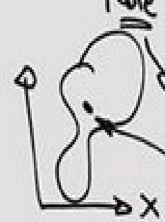
Example: Given Image in Fig. I. Compute m_{12}

Sol: $m_{12} \triangleq \iint_\Omega (x-\bar{x})^1 (y-\bar{y})^2 B(x,y)\,dx\,dy \,/\, A$

$= \sum_{y=0}^{2}\sum_{x=0}^{2} (x-\bar{x})^1 (y-\bar{y})^2 B(x,y) \,/\, 2 = \sum_{y=0}^{2}\sum_{x=0}^{2} (x-1.5)(y-1.5)^2 B(x,y)\cdot\frac{1}{2}$

$= (1-1.5)(1-1.5)^2 B(1,1)\frac{1}{2} + (2-1.5)^1(2-1.5)^2\cdot B(2,2)\frac{1}{2}$ "Hu"

Note



$= -0.5\times 0.25\times 1\times\frac{1}{2} + 0.5\times 0.25\times 1\times\frac{1}{2} = 0$

1° physical meaning, Spread from $(\bar{x},\bar{y})$. $(\leq 5+8)$

$(\bar{x},\bar{y})$

2° Not a Signature ; 3° Vector Feature Dimension up to 13 ($p=q=1$)

$\vec{V} = (P, A, \text{Index}, \bar{x}, \bar{y}, m_{01}, m_{02}, m_{10}, m_{11}, m_{12}, m_{20}, m_{21}, m_{22})$

Map To Feature Vectors