MILITARY COLLEGE OF SIGNALS
FINAL EXAM
BESE 13
EE 481 Digital Image Processing

Instructor: A/P Dr. Imran Siddiqi **Time: 2.5 Hours**
Max Marks: 50

Instructions

- Be concise in your answers and avoid unnecessary descriptions.
- Understanding the questions is a part of examination and do NOT request for your instructor to be called in the examination hall.
- This question paper comprises **4** pages.

(3+3+2)

1. **a.** An image *f(x,y)* is considered a function of two variables. In a similar manner, a video may be considered as a function of three variables *f(x,y,t)*. Suggest an expression to compute $\partial f / \partial t$ and state what it actually extracts from the video?

Solution:

$$\partial f / \partial t = f(x, y, t+1) - f(x, y, t)$$

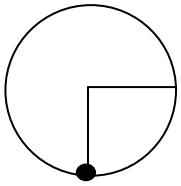
This operator simply takes the difference of successive frames and detects moving objects in the video.

b. What is the double line effect of *Laplacian* filter and how can it be removed?

Solution:

The laplacian operator is based on the second derivative which produces a double response (-K and +K) on edges. When the result of applying the laplacian filter is displayed as an image, a double line is visible due to these positive and negative values. It can be removed by keeping only the positive responses of the laplace filter.

c. Consider the RGB color cube standing on the vertex (1,1,1). State the hue, saturation and intensity values of the color represented by the dot if the following is obtained by slicing the cube at 25% of its height.

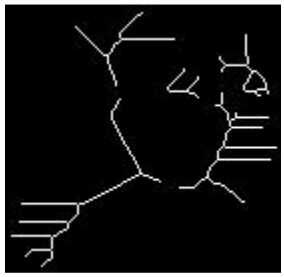


Solution

Hue = 270°
Saturation=1
Intensity = 0.75

(5+7.5+2)

2. **a.** Using hit-and-miss transform, propose an algorithm to detect end points in one pixel thin objects like the one shown in the following image. You need to mention the structuring element(s) and the steps the algorithm should perform. Be precise and to the point and do NOT provide descriptive details.



Solution

In order to detect the end points, following structuring elements can be employed.

0	0	0
0	1	0
X	X	X

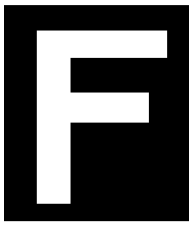
X	X	X
0	1	0
0	0	0

X	0	0
X	1	0
X	0	0

0	0	X
0	1	X
0	0	X

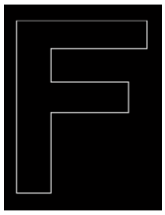
- With each of the structuring elements, apply hit and miss transform on the input image.
- Take the union of the four output images to get the end points.

b. For the following image of character 'F', show the results of applying the listed morphological operators with 3x3 structuring element. (Assume that the size of structuring element is small with respect to the size of the object). Clearly indicate which parts of image are white and which are black.

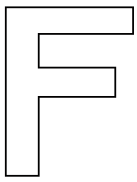


Solution

i. $(A \oplus B) - A$



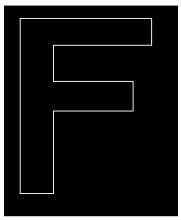
ii. $((A \oplus B) - (A \ominus B))^c$



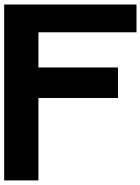
iii. $(A^c \ominus B) \cap (A \oplus B)$

Black Image

iv. $A \cap (A^c \oplus B)$



v. $(A \cup (A \circ B))^c$



c. Given A = {(1,1),(1,-1),(-1,-1),(-1,1),(0,0)}, B={(0,0),(0,-1),(0,1)} and z={(3,0)} find the $(A)_z$ and $\hat{B}$.

Solution

$(A)_z$ = {(3,1),(3,-1),(2,-1),(2,1),(3,0)}

$\hat{B}$ ={(0,0),(0,1),(0-1)}

(4+4+6)

3. **a.** For the 5x5 gray scale image below, compute the coding redundancy if the variable length codes in the following table are used instead of 8-bit natural coding.

5	5	5	5	5
5	5	5	5	5
200	200	200	200	200
2	150	2	2	150
2	150	2	2	150

Image

Gray Level	Code
2	001
5	1
150	000
200	01

Variable Length Codes

Solution

Probabilities of gray levels in the image

P(5) = 10/25

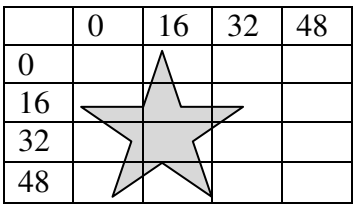
P(200)=5/25
P(150)=4/25
P(2)=6/25

Average number of bits required to encode the image:
=1*10/25 + 2*5/25 + 3* 4/25 + 3 * 6/25
=10/25+10/25+12/25+18/25
=50/25
=2 bits/pixel

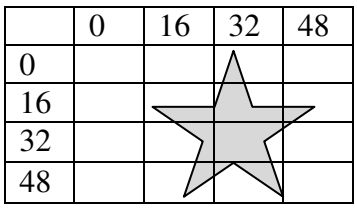
Compression ratio = 2/8=4
Coding Redundancy = 1-1/4 = 0.75

75% data in the image is redundant.

b. Consider two successive frames *t* and *t+1* of a video. Frame *t* is an *I* frame while frame *t+1* is a *P* frame predicted from the *I* frame. Both frames are shown divided into macro-blocks and the starting coordinates of each macro-block are indicated on the top and left of each frame. Assuming the frame *t+1* is to be encoded, compute the motion vectors for each macro-block in frame *t+1*. The vectors are to be computed with reference to the starting point of each macro-block. For simplicity, only consider the macro-blocks containing the object.

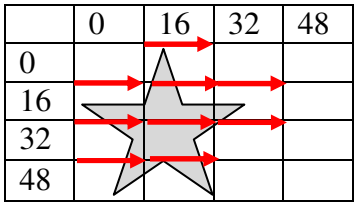


Frame t



Frame t+1

The object has translated in the horizontal direction so each macro-block will have horizontal motion vectors (16,0) as indicated in the following.



c. You have received the number **0.2572167752** that has been encoded using Arithmetic coding. Given the probability and range of each character as indicated in the following table, decode the message.

Character	**Probability**	**Range**
SPACE	0.1	[0.0 0.1)
A	0.1	[0.1 0.2)
B	0.1	[0.2 0.3)

E	0.1	[0.3 0.4)
G	0.1	[0.4 0.5)
I	0.1	[0.5 0.6)
L	0.2	[0.6 0.8)
S	0.1	[0.8 0.9)
T	0.1	[0.9 1.0)

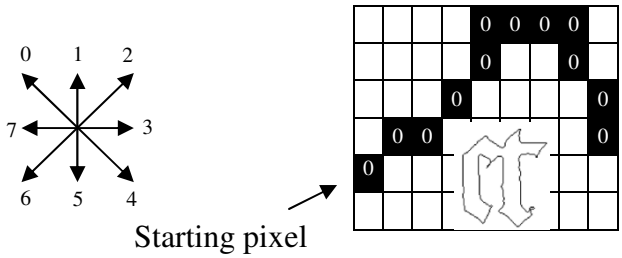
Solution

Applying the decoding alogrithm.

Encoded Number	Output Symbol	Low	High	Range
0.2572167752	B	0.2	0.3	0.1
0.572167752	I	0.5	0.6	0.1
0.72167752	L	0.6	0.8	0.2
0.6083876	L	0.6	0.8	0.2
0.041938	SPACE	0.0	0.1	0.1
0.41938	G	0.4	0.5	0.1
0.1938	A	0.2	0.3	0.1
0.938	T	0.9	1.0	0.1
0.38	E	0.3	0.4	0.1
0.8	S	0.8	0.9	0.1
0				

(3+3+6+1.5)

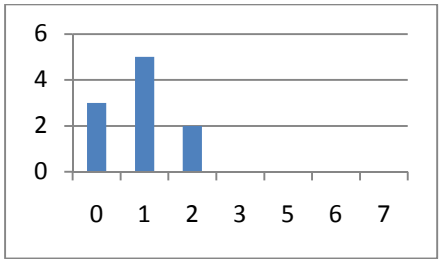
4. **a.** Consider the small portion of the contour of a character in the figure below. Starting at the given position and using clock-wise traversal, compute the histogram of the differential chain code for the given segment of the character.



Chain Code = 2 3 2 2 1 3 3 3 5 4 5

Differential Chain Code = 1 1 0 1 2 0 0 2 1 1

Histogram of Differential chain code



b. For the following object (represented by 0s), compute the horizontal and vertical '*Crossings*' vectors.

	0	0	0	0	0		
	0		0		0		
	0		0		0		
	0	0	0	0	0		
	0				0		
	0	0	0	0	0	0	0

Solution

Crossings = No of transitions in each row (horizontal) and each column (vertical) of the image.

Horizontal Crossings Vector = 0 1 3 3 1 2 1 0

Vertical Crossings Vector = 0 1 3 2 3 1 1 1

c. A system needs to inspect and divide a bunch of 10 pens into 3 different classes. The measurable attributes are the *length* and *diameter* of each pen and have the values as indicated in the following table:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Length	3	8	4	1	6	7	2	5	3	7
Diameter	2	4	7	1	4	5	3	8	9	3

Taking P1, P3 and P6 as the initial cluster centers, run the first iteration of the *k-means* algorithm and show:

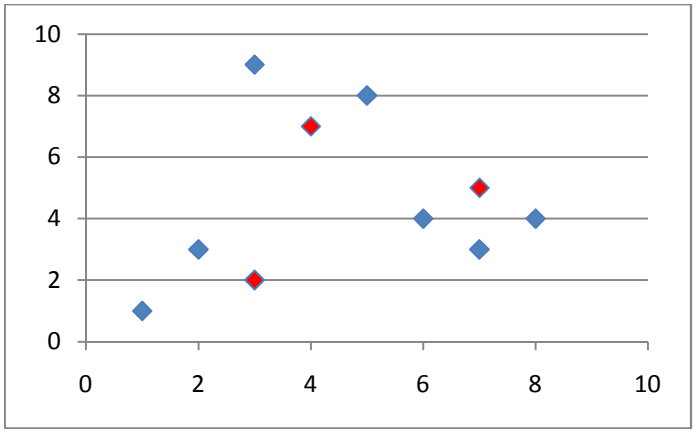
i. Clusters after first iteration – Which pens belong to which cluster

ii. Centers of clusters after first iteration

iii. How many more iterations are required for convergence?

Use the following definition of distance between P_i and P_j

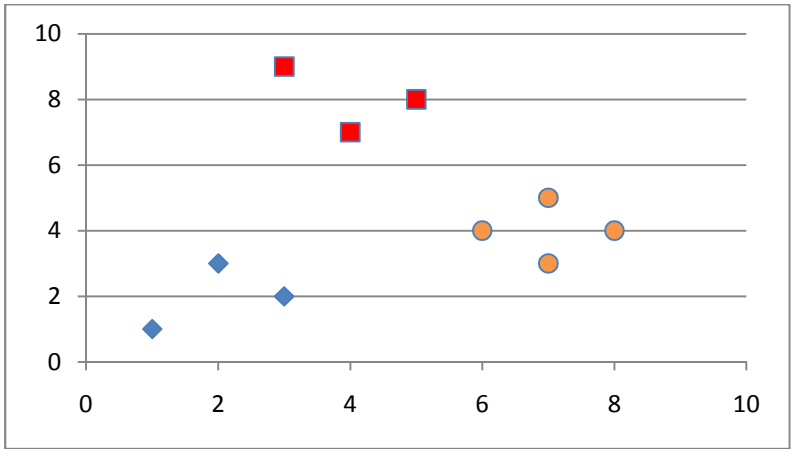
$$D(P_i,P_j) = |(length)_i - (length)_j| + |(diameter)_i - (diameter)_j|$$



1 Data points and initial cluster centers

After first iteration the following clusters are formed.

Cluster 1
P1, P4, P7 – C1(2,2)
Cluster 2
P3, P8, P9 – C2(4,8)
Cluster 3
P2, P5, P6, P10 – C3(7,8)



2 Three clusters after first iteration

The next iteration also produces the same clusters (and centers) and the algorithm converges.

d. In the context of classification, what does the term '*good features*' refer to?

Solution

Good features are the ones which allow discriminating between different classes. In other words, the features should have similar values for the elements of the same class and distinct values for the elements of different classes.

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