Arab Academy for Science, Technology & Maritime Transport

College of Artificial Intelligence

Final Examination Paper

Course Title: Image Processing & Pattern Recognition

Course Code: IN322

Lecturer: Dr. Mohamed Waleed Fakhr

Date: **22** / June / **2023**

Time allowed: **2** Hours.

Marks: 40

اسم الطالب : ----------

Student's Name: ----------

Registration Number: ----------

Question #	**Marks**	
	Available	Actual
1		
2		
3		
4		
5		
6		
Total	**40**	
Lecturer	**Lecturer name**: Dr. Mohamed Waleed Fakhr	
	Lecturer signature:	
	Date:	

Question 1:

135	135	129	133	130	134	134	137
133	133	132	132	135	127	**55**	119
132	127	**222**	**200**	**65**	**55**	96	110
110	104	**210**	**65**	**55**	103	129	160
105	112	**65**	*45*	**250**	201	219	231
167	**65**	**55**	223	216	231	240	238
221	**55**	240	223	214	216	218	219
224	217	222	214	215	217	219	220

-1	0	1
-1	0	1
-1	0	1

a) For the (8-by-8) image block given, It is required to do edge detection using Prewitt operators (assume image already smoothed with Gaussian filter). Is the given above the Δ_y *or* $\Delta_x$operator? **Deduce the other one**. Which of them estimates horizontal edges and which estimates vertical edges? **(1.5)**

b) Apply the x-gradient and y-gradient Prewitt operators to pixel $[f(5,4) = 45]$ → **Find the values for** Δ_y ***and*** Δ_x**,** Hence Calculate the **strength and orientation** of the gradient at that pixel. **Does the orientation angle make sense according to the edge direction you see in the block**? **(2.5)**

c) In the Prewitt edge detection we apply the following processes $\Delta_x = M_x^{prewitt} * \{g(x,y) * f(x,y)\}$ and $\Delta_y = M_y^{prewitt} * \{g(x,y) * f(x,y)\}$. Explain **what will be different** if you want to use the Canny edge detection (**Re-Write the equations in this case**). **(2)**

d) Explain why the Canny approach is better than the Prewitt approach in edge detection? **(1)**

Question 2:

(a) For the 8-by-8 image above in (Question-1), apply the given normalized Gaussian filter on pixel $\boldsymbol{f(5,4) = 45}$ and find the pixel's new value. Has it been smoothed? Does this smoothing preserves edges? And why? **(2)**

0.075	0.124	0.075
0.124	0.204	0.124
0.075	0.124	0.075

(b) Explain briefly the main differences between the Median Filter, Gaussian Filter, Bilateral Filter and the Non-local-means filter for **Noise Removal** and show which of them preserves the edges and how. **(2)**

(c) The following equation represents the **Bilateral Filter**. Use the 8-by-8 image (Question-1) and a (3-by-3) normalized Gaussian filter (above).

$$BF[I]_{\mathbf{p}} = \underbrace{\frac{1}{W_{\mathbf{p}}}}_{\text{normalization}} \sum_{\mathbf{q} \in S} \underbrace{G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)}_{\text{space weight}} \underbrace{G_{\sigma_r}(|I_{\mathbf{p}}-I_{\mathbf{q}}|)}_{\text{range weight}} I_{\mathbf{q}}$$

(new: $\frac{1}{W_{\mathbf{p}}}$; not new: $G_{\sigma_s}(\|\mathbf{p}-\mathbf{q}\|)$; new: $G_{\sigma_r}(|I_{\mathbf{p}}-I_{\mathbf{q}}|)$)

Consider that the Bilateral filter is centered at pixel $\boldsymbol{f(5,4) = 45}$, Take $\sigma_r = 300$ and $W_p = 1.0$.
Calculate the new value for pixel $\boldsymbol{f(5,4) = 45}$ (use the pixel values from the image, and the 3-by-3 Gaussian filter given, as well as the range weights that you should calculate). **(3)**

(d) Explain the difference between **Low-pass, High-pass, Band-pass and Notch filters** in their frequency domain characteristics. Which of them would you use to get rid of a periodic 50Hz supply noise distorting an image? Justify your answer with a figure **(2)**

Question 3:

(a) Explain using equations: Why and How the Laplacian of Gaussian is used to detect blobs in images and how the Gaussian width "σ" determines the scale of the detected blob **(2)**

(b) Explain using a figure how many blob-scales can be detected in the standard SIFT algorithm? **(1)**

(c) Using 10,000 images, explain the *steps required to generate a SIFT codebook (dictionary)* with **256** centers. Assume each image will produce 200 SIFT descriptors (Blobs), show the size of the array used before the K-means and the size of the dictionary (number of rows and number of columns) **(2)**

(d) Explain how to extract a **256**-dimension (bag-of-words) feature vector for a new image using the dictionary in (c). Then show the extracted vector assuming the new image has 200 SIFT-interest points, where 100 of them match dictionary center #5 , 50 match center #11 and 50 match center #255. **(2)**

Question 4:

(a) A quantized Image has the following 5 pixel values shown in the table below with their number of occurrences in the image:

Pixel Value	Number of occurrences
0	5
1	10
2	170
3	10
4	5

(i) Design a Huffman code using the given image data showing the binary codes for all the 5 possible pixel values **(2)**

(ii) Find the total number of bits required to store this image using the designed Huffman code and the total number of bits required if we are using a fixed-length encoder**. (1)**

(b) For the image given by the table above:

(i) Plot the **Normalized Histogram** as well as the **cumulative distribution** of the image **(1.5)**

(ii) Apply the **Histogram Equalization Algorithm** on this image and find the new pixel values and Plot the histogram for the equalized image **(2.5)**

(c) An image has a Box with pixel Coordinates: $\{x_i, y_i\} = \{(10,10), (20,10), (10,20), (20,20)\}$. The Homography transform below is applied to the image:

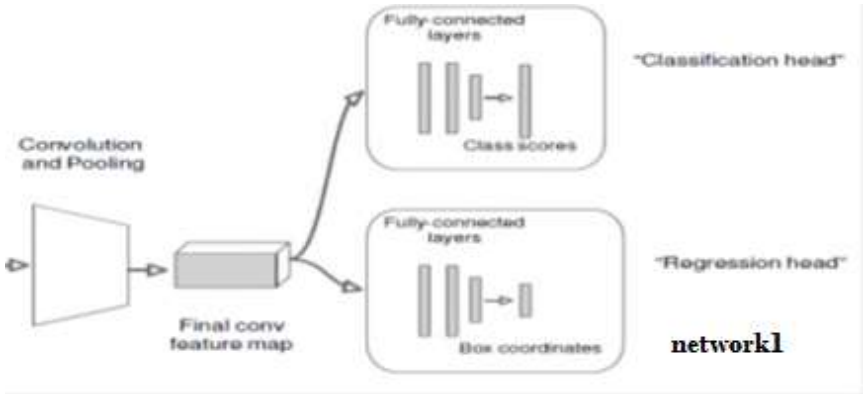
$$\begin{bmatrix} x'_i \\ y'_i \\ 1 \end{bmatrix} = \begin{bmatrix} 2 & 1 & 1 \\ 1 & 1 & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix}$$

i. Draw the Box before and after the transform. Explain what happened to the shape of the Box? **(2)**

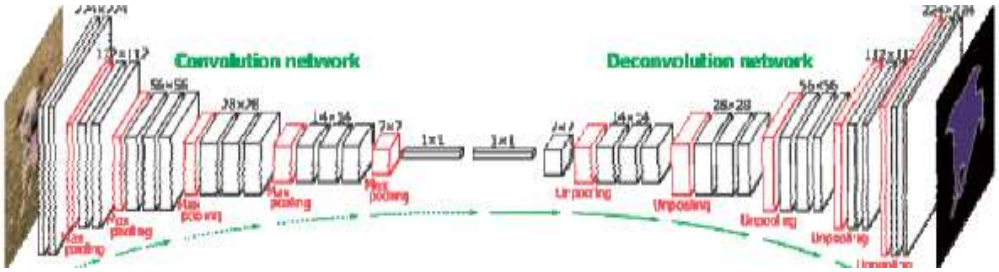
ii. Is this is a translation, Euclidean, Affine or projective transform? **(1)**

(c) For the Two deep learning networks shown below:

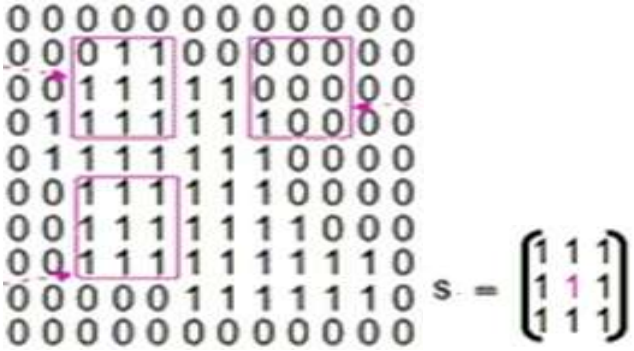
(i) Explain what **network1** is used for? What the training data for this network should look like? (Show example of input and output data during training and testing) and how the network is trained and what is its expected output? **(2)**



(ii) Explain what **network2** is used for? What the training data for this network should look like? (Show example of input and output data during training and testing) and how the network is trained and what is its expected output? **(2)**



network 2



(d)

i- Do an **"Erosion"** operation on the Binary image shown using the shown structuring element **(1)**

ii- Do a **"Dilation"** operation using the same structuring element on the Eroded image (**outcome of (i)) (1)**

iii- What is the name of the **process (i) followed by (ii)?** And what it is usually used for? **(1)**