National University of Computer and Emerging Sciences

Islamabad Campus

Computer Vision (AI4002)

Course Instructor(s):
Ms. Khadija Mahmood
Section(s): AI-K and AI-J

Sessional-I Exam

Total Time (Hrs): 1
Total Marks: 40
Total Questions: 4

Date: Sep 21, 2024

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Roll No	**Course Section**	**Student Signature**

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Attempt all the questions.

[CLO:3 & 5. Apply appropriate image processing methods for image filtering, image restoration, image reconstruction, segmentation, classification and representation]

Q1: Attempt the MCQ's on provided bubble sheet. **[15 marks]**

1. If a point P=(x,y) is reflected across the line y=x, what transformation matrix should be used?

a) $\begin{vmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

b) $\begin{vmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

c) $\begin{vmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

d) $\begin{vmatrix} 0 & -1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

2.How do you convert a homogeneous coordinate (4, 6, 2) back to Cartesian coordinates?

a) (4, 6)

b) (2, 3)

c) (8, 12)

d) (6, 4)

3.In homogeneous coordinates, a 2D transformation matrix is typically of what size?

a) 2x2

b) 3x3

c) 4x4

d) 5x5

4. A point P=(2,3) is first translated by (dx,dy)=(4,5) and then rotated by 45° counterclockwise about the origin. What is the resulting point in Cartesian coordinates (rounded to two decimal places)? Select the closest one.

a) (0.71,9.19)

b) (4.95,7.42)

c) (2.83,6.36)

d) (1.41,8.19)

5. Which of the following best describes the role of gradients in the HOG algorithm?

a) Gradients measure the color intensity in different regions of the image.

b) Gradients capture changes in image intensity along edges and corners.

c) Gradients are used to resize the image to a lower resolution.

d) Gradients measure the texture of an object.

6. Which of the following is NOT a typical use case of image pyramids?

a) Image blending

b) Object detection

c) Texture analysis

d) Image compression

7. Why is the SIFT algorithm considered robust to affine transformations?

a) It uses deep learning techniques

b) It generates keypoints and descriptors that are invariant to scale, rotation, and illumination changes

c) It relies on pixel color intensities

d) It applies region-based segmentation techniques

8. Given an image of size 1024×1024, how many levels can be generated in a Gaussian pyramid if the image is down sampled by a factor of 2 at each level until the smallest image is 1×1?

a) 8

b) 9

c) 10

d) 11

9. In a Gaussian pyramid, how is the image down sampled at each level?

a) By reducing the pixel intensity values.

b) By removing alternate rows and columns of pixels.

c) By applying edge detection before resizing.

d) By averaging the color channels.

10. What causes aliasing to occur in a digital image?

a) Oversampling the image

b) Applying a high-pass filter to the image

c) Sampling an image at a rate lower than the Nyquist rate

d) Using a large Gaussian filter during downsampling

11. How does the SIFT algorithm achieve scale invariance during keypoint detection?

a) By detecting keypoints at a fixed resolution

b) By applying Gaussian smoothing to the image at multiple scales

c) By normalizing the pixel intensities

d) By downsampling the image and applying histogram equalization

12. If a high-frequency component in a signal or image is undersampled, how will it appear after reconstruction?

a) As noise distributed across the image

b) As a lower-frequency component (alias)

c) As a blurred section of the image

d) As a high-contrast edge

13. Which of the following conditions must hold for a function to have a Fourier Series representation?

a) The function must be differentiable.

b) The function must be integrable over its period.

c) The function must be periodic.

d) The function must be continuous.

14. What is the primary difference between the Fourier Transform and the Fourier Series?

a) Fourier Transform is used for periodic signals, while Fourier Series is used for non-periodic signals.

b) Fourier Series is used for periodic signals, while Fourier Transform is used for non-periodic signals.

c) Both are used for periodic signals.

d) Both are used for non-periodic signals

15. What is the length of the standard SIFT descriptor for each keypoint?

a) 64

b) 128

c) 256

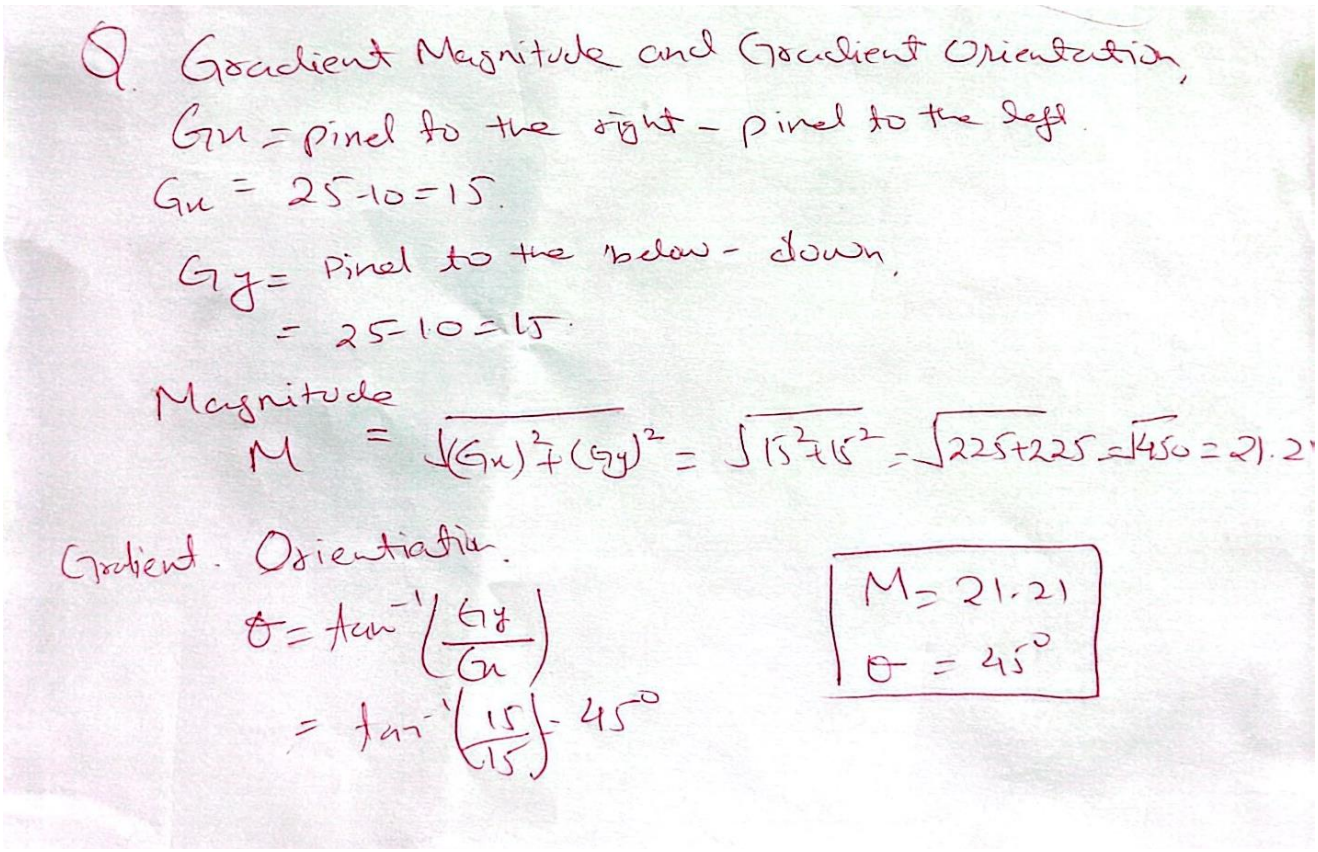
d) 512

Short Questions [10 marks]

[CLO:3 & 5. Apply appropriate image processing methods for image filtering, image restoration, image reconstruction, segmentation, classification and representation]

Q2: Given a 3x3 patch around a detected key point, calculate the gradient magnitude and orientation. Calculate the gradients in the x-direction (Gx) and y-direction (Gy) for the central pixel (20). Use these gradients to compute the magnitude and orientation of the keypoint.
[5 marks]

$$\begin{vmatrix} 5 & 10 & 15 \\ 10 & 20 & 25 \\ 15 & 25 & 30 \end{vmatrix}$$



Q3: Describe the Key-Point detection working in SIFT algorithm. **[5 marks]**

Answer

- **Scale-Space Construction**: The image is blurred at multiple scales using Gaussian filters to capture features at different sizes.
- **Difference of Gaussians (DoG)**: The blurred images are subtracted from one another to highlight edges and corners, which helps in detecting potential key-points.
- **Key-Point Localization**: The algorithm searches for local extrema (maxima/minima) in the DoG images across both spatial and scale dimensions.
- **Key-Point Refinement**: Unstable points (e.g., along edges or low contrast points) are filtered out, retaining only the robust key-points.

Long Question [15 marks]

[CLO 5: Assess which methods to use for solving a given problem, and analyse the accuracy of the methods Skills]

Q4: Given an image represented by a 4×4 grayscale matrix, construct a Laplacian Pyramid for the image by typical down sampling method to a lower resolution e.g 2×2 and then reconstruct the image back to its original resolution according to "Laplacian Pyramid" algorithm.

Use the following details where required. Hint: For up sampling you may copy the rows and cols.

Image Matrix: The original image is represented as a 4×4 matrix as follows:

$$\begin{vmatrix} 45 & 50 & 55 & 60 \\ 47 & 53 & 58 & 62 \\ 49 & 52 & 56 & 59 \\ 48 & 51 & 57 & 61 \end{vmatrix}$$

Gaussian Filter:

$$G(x,y) = 1/9 \begin{vmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{vmatrix}$$

Algorithm of Lapalcian Pyramid.

1 Downsample first

Repeat:
- filter
- Compute residual.
- Subsample

until min resolution reached.

then,

2 Upsample

repeat:
- Upsample
- Sum with residual.

until orig resolution reached.

Original Matrix = $\begin{vmatrix} 45 & 50 & 55 & 60 \\ 47 & 53 & 58 & 62 \\ 49 & 52 & 56 & 59 \\ 48 & 51 & 57 & 61 \end{vmatrix}$ 2

$G(x,y) = \frac{1}{9}\begin{vmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{vmatrix}$

45
$(1,1) = \frac{1}{9}(45\times2 + 50\times1 + 47\times1 + 53\times1) = 26$

50
$(1,2) = \frac{1}{9}(45 + 50\times2 + 55 + 47 + 53 + 58) = 40$

(1,3)
55 $= \frac{1}{9}(50 + 55\times2 + 60 + 53 + 58 + 62) = 43.6$

(1,4)
60 $= \frac{1}{9}(55 + 60\times2 + 58 + 62) = 32.7$

(2,1)
47 $= \frac{1}{9}(45 + 50 + 47\times2 + 53 + 49 + 52) = 38.$

53
$(2,2) = \frac{1}{9}(45 + 50 + 55 + 47 + (53\times2) + 58 + 49 + 52 + 56) = 57.5$

$(2,3) = \frac{1}{9}(50 + 55 + 60 + 53 + (58\times2) + 62 + 52 + 56 + 59) = 62.5$
58

62
$(2,4) = \frac{1}{9}(55 + 60 + 58 + (62\times2) + 56 + 59) = 45.7$

49
$(3,1) = \frac{1}{9}(47 + 53 + 49\times2 + 52 + 48 + 51) = 38.7$

52
$(3,2) = \frac{1}{9}(47 + 53 + 58 + 49 + (52\times2) + 56 + 48 + 51 + 57) = 58$

$\overset{56}{(3,3)} = \frac{1}{9}(53+58+62+52+(56\times2)+59+51+57+61) = 62.7$

$\overset{59}{(3,4)} = \frac{1}{9}(58+62+56+(59\times2)+57+61) = 45.77$

3

$\overset{48}{(4,1)} = \frac{1}{9}(49+52+(48\times2)+51) = 27.5$

$\overset{51}{(4,2)} = \frac{1}{9}(49+52+56+48+(51\times2)+57) = 40.4$

$\overset{57}{(4,3)} = \frac{1}{9}(52+56+59+51+(57\times2)+61) = 43.6$

$\overset{61}{(4,4)} = \frac{1}{9}(56+59+57+(61\times2)) = 32.6$

(5-marks)

Original

$$\begin{vmatrix} 45 & 50 & 55 & 60 \\ 47 & 53 & 58 & 62 \\ 49 & 52 & 56 & 59 \\ 48 & 51 & 57 & 61 \end{vmatrix} = \begin{vmatrix} 26 & 40 & 44 & 33 \\ 38 & 58 & 63 & 46 \\ 39 & 58 & 63 & 46 \\ 28 & 40 & 44 & 33 \end{vmatrix}$$

Blurred

Removing Alternate Rows and Columns and computing the residual.

(2-marks)

$$\begin{vmatrix} 26 & 44 \\ 39 & 63 \end{vmatrix}$$

Residual between Original and Blurred, Original-blurred.

(3-marks)

$$\begin{vmatrix} 19 & 10 & 11 & 27 \\ 9 & -5 & -5 & 16 \\ 16 & -6 & -7 & 13 \\ 20 & 9 & 13 & 28 \end{vmatrix}$$

Upsampling (2-marks)

$$\begin{vmatrix} 26 & 44 \\ 39 & 63 \end{vmatrix} = \begin{vmatrix} 26 & 26 & 44 & 44 \\ 26 & 26 & 44 & 44 \\ 39 & 39 & 63 & 63 \\ 39 & 39 & 63 & 63 \end{vmatrix}$$

Upsampled.

4

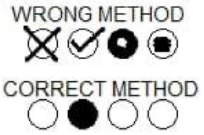
Residual + Upsampled (3-marks)

$$\begin{vmatrix} 19 & 10 & 11 & 27 \\ 9 & -5 & -5 & 16 \\ 10 & -6 & -7 & 13 \\ 20 & 9 & 13 & 28 \end{vmatrix} + \begin{vmatrix} 26 & 26 & 44 & 44 \\ 26 & 26 & 44 & 44 \\ 39 & 39 & 63 & 63 \\ 39 & 39 & 63 & 63 \end{vmatrix}$$

Final Image.

$$\begin{vmatrix} 45 & 36 & 55 & 71 \\ 35 & 21 & 39 & 60 \\ 49 & 33 & 56 & 46 \\ 59 & 48 & 76 & 91 \end{vmatrix}$$

This is our final image after upsampling, it should be matched with original image, but for the sake we have utilized dummy filters and upsampling technique for the sake of simplicity. Due to this reason the values aren't same that much. The main goal of this algo is to achieve same resolution with similar pixels which is achieved.

Instruction for filling the sheet 1. This sheet should not be folded or crushed 2. Use only blue/black ball pen or 2HB pencil 3. Circle should darkened completely and properly 4. Erase marked circle completely for deselect	
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