INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY TRIVANDRUM
AVIONICS DEPARTMENT

End Semester Examination -- 2026

Course: Computer Vision / Computer Vision and Advanced Image Processing

Time: 3 Hours   Date:04-05-2026   Max Marks: 50

Instructions:

1. Answer all questions part-wise and write the answers for each part together.
2. Do not scatter answers from different parts throughout the answer script.
3. Assume suitable data wherever necessary.
4. Draw neat diagrams wherever required.

Part A: Objective / True-False / Short Type Questions (10 Marks)

Answer any five questions. Each questions carries 2 mark. If you answer more than five questions, only the first five will be graded.

1. Explain the eight-point algorithm for estimating the fundamental matrix.
2. To decrease the size of an input image with minimal content loss, we should (choose the correct option and give a suitable reasoning):
   (a) High-pass filter and down-sample the image
   (b) Crop the image
   (c) Apply a Hough transform
   (d) Down-sample the image
   (e) Low-pass filter and down-sample the image
3. Differentiate between object detection, recognition, and instance segmentation.
4. What are the main components of a CNN?
5. Explain the role of hysteresis thresholding in Canny edge detection.
6. True or False: Histogram Equalization improves image contrast. Give a short reasoning.
7. Given a 3×3 Difference-of-Gaussians (DoG) patch:

$$\begin{bmatrix} 5 & 2 & 6 \\ 3 & 9 & 3 \\ 4 & 1 & 2 \end{bmatrix}$$

Determine whether the center pixel is a keypoint candidate.

Part B: Short Questions (12 Marks)

Answer any three questions. Each carries 4 marks.If you answer more than three questions, only the first three will be graded.

1. Explain the RANSAC? You are given a dataset where 40% of the points are outliers. You want to use RANSAC to fit a line model, where the minimal number of points required is 2. Compute the minimum number of iterations N required to ensure. with probability $p = 0.99$, that at least one sample is free from outliers.

2. why the Difference of Gaussians (DoG) is a good approximation to the Laplacian of Gaussian (LoG)? Show that the Difference-of-Gaussians (DoG) is an approximation to the scale-normalized Laplacian of Gaussian (LoG):

$$\text{DoG} \approx \sigma^2 \nabla^2 G$$

Gaussian kernel is given by:

$$G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right)$$

The Difference-of-Gaussians is defined as:

$$\text{DoG} = G(x, y, k\sigma) - G(x, y, \sigma)$$

3. Show that

$$\frac{\partial G}{\partial \sigma} = \sigma \nabla^2 G$$

4. Input image size is 32×32. A convolution layer uses:

- Filter size $F = 5$
- Padding $P = 2$
- Stride $S = 1$
- Number of filters = 8

Find output size.

Part C: Short Numerical / Theory Questions(8 Marks)

Solve any 2 questions, 4 marks each. If you answer more than four questions, only the first four will be graded.

1. Derive the epipolar constraint equation using the fundamental matrix:

$$x'^T F x = 0$$

Explain how it reduces the stereo correspondence search. (4 Marks)

2. Explain Mean Shift segmentation algorithm. Derive the mean shift vector and explain why the algorithm converges to the mode. (4 Marks)

3. A HOG-based pedestrian detector uses:

   - Image size: 128×64
   - Cell size: 8×8
   - Block size: 2×2 cells
   - Block stride: 1 cell
   - 9 orientation bins

   Compute the total number of HOG features extracted. (4 Marks)

Part D: Long Numerical / Theory Questions (20 Marks)

4. **Optical flow** (10 Marks)

   (a) Starting from the **brightness constancy assumption**, derive the optical flow equation:

   $$I_x u + I_y v + I_t = 0$$

   (2 marks)

   (b) Explain why this equation alone is insufficient to uniquely determine optical flow. (2 marks)

   (c) Consider the Horn–Schunck energy functional:

   $$E(u, v) = \iint \left[(I_x u + I_y v + I_t)^2 + \alpha^2(|\nabla u|^2 + |\nabla v|^2)\right] dx\, dy$$

   Derive the **Horn–Schunck update equations.** (4 marks)

   (d) Numerical: Given

   $$I_x = 2, \quad I_y = 1, \quad I_t = -3, \quad \alpha = 1$$

   Assume:

   $$\bar{u} = 0, \quad \bar{v} = 0$$

   Compute one iteration of the Horn–Schunck update. (2 marks)

5. Explain the difference between Essential matrix and Fundamental matrix. Now, Given a translation vector (5 Marks)

$$\mathbf{t} = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

and a rotation matrix corresponding to a rotation about the z-axis by 90°:

$$R = \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix} = [$$

(a) Construct the skew-symmetric matrix $[\mathbf{t}]_\times$.

(b) Compute the essential matrix:

$$E = [\mathbf{t}]_\times R$$

(c) Verify that the matrix E is of rank 2.

6. 3D affine registration. Let $\{X_i \in \mathbb{R}^3\}_{i=1}^N$ be a set of points in $\mathbb{R}^3$ that are transformed by a 3D affine transformation (A, T), where $A \in \mathbb{R}^{3\times 3}$ and $T \in \mathbb{R}^3$, to produce another set of points $\{Y_i \in \mathbb{R}^3\}_{i=1}^N$. Suppose that the transformed points Y_i are corrupted by noise E_i, i.e.,

$$Y_i = AX_i + T + E_i \quad \text{for all } i = 1, \dots, N.$$

Show that the transformation (A, T) that minimizes the sum of squared errors

$$E(A,T) = \sum_{i=1}^{N} \|Y_i - AX_i - T\|_2^2 \tag{1}$$

is given by

$$T^* = \bar{Y} - A^*\bar{X}, \quad A^* = (YX^T)(XX^T)^{-1},$$

where $\bar{X} = \frac{1}{N}\sum_i X_i$, $X = [X_1 - \bar{X}, \cdots, X_N - \bar{X}]$, and similarly for $\bar{Y}$ and Y. Show that 4 is the minimum number of points needed to find the transformation. **(5 Marks)**

***** End of Question Paper *****