Indian Institute of Space Science and Technology Trivandrum

I SEMESTER , 2025

ExamType: Mid-Term I

DEPARTMENT OF AVIONICS.

computer vision/ computer vision and advanced image processing

(Time allowed: TWO hours)

NOTE: Read all questions first. **There are questions worth 30 marks.** If something is missing in a problem description, clearly mention your assumptions with your solution. If require, use sketches to illustrate your findings. Date: 12-03-2025, 9:30 AM-11:30 AM

1. image projection and Camera Calibration(15 Marks)

(a) Given the 3×4 camera matrix

$$P = \begin{bmatrix} 5 & -14 & 2 & 17 \\ -10 & -5 & -10 & 50 \\ 10 & 2 & -11 & 19 \end{bmatrix}$$

and a 3D point in homogenous coordinates $X = [0, 2, 2, 1]^T$.

(i) What are the Cartesian coordinagte of the point X in 3D? (1 mark)

(ii) What are the Cartesian image coordinate (u, v), of the projection of X? (1 mark)

(b) An ideal pinhole camera has focal length $5mm$ Each pixel is $0.02mm \times 0.02mm$ and the image principal point is at pixel (500,500). Pixel coordinate starts at (0,0) in the upper-left cporner of the image.

(i) What is the 3×3 camera calibration matirx, K, for this camera configuration? (2 marks)

(ii) Assuming the world coordinate frame is aligned with the camera coordinate frame (i.e., their origins are the same and their axes are aligned), and the origins are at the cameras pinhole, what is the 3×4 matrix that represents the extrinsic, rigidbody transformation between the camera coordinate system and the world coordinate system? (2 marks)

(iii) Combining your results from (i) and (ii), compute the projection of scene point (100, 150, 800) into image coordinates. (2 marks)

(c) Write the equation for perspective projection(homogenous and non-homogenous way). Clearly describe terms. Consider a scene that contains 5 collinear features, A, B, C, D, and E, where collinearity is defined in 3D coordinates. We know that under perspective projection, the projected features are also collinear in the 2D image plane. (2 marks)

(i) Suppose A, B, C, D, and E are all equidistant. Will the order of the projected points (along the projected line) always be the same in the camera image? If yes, argue why this must be the case. If no, provide a counterexample. (1 mark)

(ii) Will the observed features also be equidistant in the image plane? If yes, argue why. If not, argue why not. (1 mark)

(iii) *Try not to spend too much time on this question.* Prove the claim in the introduction: under perspective projection the projected features are collinear in the 2D image plane. (1 mark)

(d) True and false (with a brief reasoning) (5 marks)

(i) Any perspective projection is also an affine transform.

(ii) An image may have no more than three vanishing points.

(iii) The result of applying a scale, rotation, and translation (in that order) to a vector $\mathbf{v}$ is equal to the result of applying the same rotation, translation, and scale (in that order) to the same vector $\mathbf{v}$.

(iv) Pincushion distortion modifies the image only along the vertical direction and barrel distortion modifies the image only along the horizontal direction.

(v) Assuming the camera coordinate system is the same as the world coordinate system, the intrinsic and extrinsic parameters of the a camera can map any point in homogenous world coordinates to a unique point in the image plane.

2. Image processing

(a) Show how an approximation to the first derivative of an image can be obtained by convolving the image with the kernel [1 -1] where the image is defined as

$$[56, 64, 79, 98, 115, 126, 132, 133]$$

ignore computing a value for the first and last image pixels (in other words, your result will be 6 values). In addition to showing the result of the convolution, indicate where edges would be detected and why. (2 marks)

(b) What property of the coefficients of a kernel ensures that an appropriate output is obtained for regions of constant intensity in an image when (2 marks)

(i) The kernel is approximating a first derivative.

(ii) The kernel is approximating a second derivative.

(iii) The kernel is approximating a Gaussian.

(c) Describe a major advantage or disadvantage of using an isotropic operator instead of a non-isotropic operator with respect to the following issues: (2 marks)

(i) Computational efficiency.

(ii) Noise in the image.

(iii) Give one example of both iso-tropic and non-isotroic operator in image processing.

(d) What is the purpose of (i) non-maxima suppression and of (ii) hysteresis that are done in the Canny edge detector? (2 marks)

3. Which of the following factor does not affect the intrinsic parameters of a camera model? (1 mark)

(a) Focal length

(b) Offset of optical center

(c) Exposure

(d) Image resolution

4. Is the following convolution kernel separable? If so, separate it. If not, prove that it is not. (1 mark)

$$H = \begin{bmatrix} 2 & 3 \\ 1 & 1 \end{bmatrix}$$

5. Write the matrix representation and distinctions among Projective, Affine, Similarity, and Isometric transformations. Highlight the degrees of freedom and specify what gets preserved in each transformation. (2 marks)
