RKMVERI

MSc. Big Data Analytics, Year 2022
Mid-term Examination
Computer Vision
Maximum Marks 60

Time: 120 minutes Date: ____/04/2023

Answer any 15 questions (2 marks each):

1. State two difference between rod cells and cone cells.

Any two:	
Rod cells	**Cone cells**
Sensitive to low intensity light.	Sensitive to high intensity light and colour.
Smaller is size.	Larger in size.
More in number at periphery (away from fovea).	More in number around fovea.

2. Give one example of each of 2D scene and 3D scene.
   3D scene example: usual outdoor scene or usual indoor scene.
   2D scene example: document page or micrograph or satellite image or x-ray image
3. What is the name of the opening through which light enters into a camera? What is its centre called?
   Aperture, and Optical Centre
4. What are two transforms that take place within a camera?
   (a) Geometric transformation, and (b) Photometric transformation
5. Write down three main properties of perspective projection.
   Three properties are
   - Straight lines in 3D scene (world) map into straight lines in image.
   - Distant objects (in scene) appear smaller in the image.
   - A set of parallel lines in 3D, not perpendicular to optical-axis maps to a set of concurrent lines in 2d image.
6. What is meant by camera calibration?
   World or scene coordinate is related to pixel coordinate in digital camera by the transformation

$$\begin{bmatrix} \gamma_i x_i \\ \gamma_i y_i \\ \gamma_i \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \end{bmatrix} \begin{bmatrix} u_i \\ v_i \\ w_i \\ 1 \end{bmatrix}$$

   Determining the elements a_{ij} is termed as camera calibration.

7. What is 'correspondence problem' in binocular stereo vision?
   Given a point in the image plane of one camera, the correspondence problem refers to the problem of finding a point in the image plane of the other camera such that both the points are images of same 3D world point.
8. Define epipole of a camera with respect to another camera? Whose image point is the epipole?
   Each of the points in the image plane of a camera forms an epipolar line in the image plane of the other camera. The meeting point of all such epipolar lines is called epipole.
   Epipole of the image plane of a camera is the image of optical centre of the other camera.
9. What is epipolar constraint?
   For any point on the image plane of Camera-1, corresponding point lies on its epipolar line on the image plane of Camera-2 and *vice versa*. This is *epipolar constraint*.
10. Mention percentage of red, green and blue filters in Bayer pattern used in digital colour camera.
11. Why is [R,G,B] colour triplet called additive primaries?
    R+G+B=W (white)
12. Suppose there are two points (x_1, y_1) and (x_2, y_2) in discrete domain. Write down the formulae for calculating (i) city-block distance, and (ii) chess-board distance.
    (i) city-block distance: $|x_1 - x_2| + |y_1 - y_2|$, and
    (ii) chess-board distance: $max|x_1 - x_2| + |y_1 - y_2|\}$
13. Suppose the graylevels $f(x, y)$ of pixels in an image are in the range $[92,143]$. The contrast of the image is enhanced by linear histogram stretching. What will be the output value $g(x, y)$ at the pixel (x, y), if input value $f(x, y) = 107$?

$$g(x,y) = \frac{L_{max} - L_{min}}{r_{max} - r_{min}}(f(x,y) - r_{min}) + L_{min} = \frac{255 - 0}{143 - 92}(107 - 92) + 0$$
$$= \frac{255}{51}(107 - 92) = 75$$

14. Mention one advantage and one disadvantage of median filter compared to mean filter for noise smoothing.
    Advantage: preserves edges better, disadvantage: higher computational cost
15. What are two main approaches of image segmentation?
    (a) Region extraction, and (b) edge detection
16. Write down the kernels of Prewitt operator.

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

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

17. Given an image $f(x, y)$, write down the formula for (i) gradient magnitude and (ii) gradient direction at the pixel (x, y).
    Gradient magnitude: $|\nabla f| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$, and gradient direction: $\theta = tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$
18. Write three major steps of Canny's edge detector.

Three major steps:

- Short any Convolution with derivative of Gaussian
- Non-maximum Suppression
- Hysteresis Thresholding

4 questions (5 marks each):

19. List the intrinsic parameters of a digital camera. Write down the expression to find image point coordinate (x, y) of that digital camera due to a 3D object point (u, v, w) in matrix-vector notation. If needed you may adopt homogeneous coordinate system.

Intrinsic parameters are $f, \psi_x, \psi_y, d_x, d_y$

$$\begin{bmatrix} u' \\ v' \\ w/f \end{bmatrix} = \begin{bmatrix} \psi_x & 0 & 0 & d_x/f \\ 0 & \psi_y & 0 & d_y/f \\ 0 & 0 & 1/f & 0 \end{bmatrix} \begin{bmatrix} u \\ v \\ w \\ 1 \end{bmatrix}$$

20. Suppose the tip of a tree forms an image on the image plane of a digital camera having focal length 1.2 cm and image plane of size 8 cm x 4.5 cm. If the tip of the tree be at (-2 m., 5 m. 10 m.) with respect to the optical centre of the camera, find the image coordinate of the corresponding image point. Given that the photoreceptor density is 1000/cm in both horizontal and vertical direction.

$$f = 1.2\ cm,\ \ \psi_x = \psi_y = 1000,\ \ \ image\ plane\ S_x \times S_y = 8cm \times 4.5cm$$

$$x = f\frac{u\psi_x}{w} + d_x = 1.2\frac{(-2) \times 1000}{10} + \frac{8 \times 1000}{2} = -240 + 4000 = 3760$$

$$y = f\frac{v\psi_y}{w} + d_y = 1.2\frac{5 \times 1000}{10} + \frac{4.5 \times 1000}{2} = 600 + 2250 = 2850$$

21. Suppose with respect to the world coordinate system the given camera is rotated by 30° and shifted by 10 unit along horizontal axis and 5 unit along vertical axis. Determine the geometric transformation matrix assuming the homogeneous coordinate system.

$$R_w = \begin{bmatrix} cos30^o & sin30^o & 0 \\ -sin30^o & cos30^o & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} \sqrt{3}/2 & 1/2 & 0 \\ -1/2 & \sqrt{3}/2 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad R_u = R_v = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \boldsymbol{t} = \begin{bmatrix} -10 \\ -5 \\ 0 \end{bmatrix}$$

$$R = R_u R_v R_w = \begin{bmatrix} \sqrt{3}/2 & 1/2 & 0 \\ -1/2 & \sqrt{3}/2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Transformation matrix in homogeneous system $T = \begin{bmatrix} R & \boldsymbol{t} \\ \mathbf{0} & 1 \end{bmatrix} = \begin{bmatrix} \sqrt{3}/2 & 1/2 & 0 & -10 \\ -1/2 & \sqrt{3}/2 & 0 & -5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

22. Two cameras having same intrinsic parameters and same orientation. However, one camera is shifted by a translation vector $[t_x, t_y, 0]^T$ with respect to the other. If an object point is imaged at (x_1,y_1) and (x_2,y_2) respectively in two cameras, prove that

$$\frac{t_x}{x_1 - x_2} = \frac{t_y}{y_1 - y_2}$$

Let the 3D object point is (u, v, w) and focal length of the camera be f then

$x_1 = f\frac{u}{w}$ and $x_2 = f\frac{u-t_x}{w}$, so $x_1 - x_2 = f\frac{t_x}{w}$ or $\frac{w}{f} = \frac{t_x}{x_1 - x_2}$ ..... (1)

$y_1 = f\frac{v}{w}$ and $y_2 = f\frac{v-t_y}{w}$, so $y_1 - y_2 = f\frac{t_y}{w}$ or $\frac{w}{f} = \frac{t_y}{y_1 - y_2}$ .....(2)

from equations (1)and (2): $\frac{t_x}{x_1 - x_2} = \frac{t_y}{y_1 - y_2}$

23. Graylevel frequency count of an 8-level image of size 10x10 is given by the following table.

Graylevel	0	1	2	3	4	5	6	7
Frequency count	0	4	13	7	35	25	16	0

If its contrast is enhanced by histogram equalization technique, what will be the graylevel frequency count of the output image?

Input val. r_i	0	1	2	3	4	5	6	7	**Total**
No. of occ. f_i	0	4	13	7	35	25	16	0	100
$p_i=f_i/\text{Total}$	0.0	0.04	0.13	0.07	0.35	0.25	0.16	0.0	1.0
$C_j=\sum_{i=0}^{j} p_i$	0.0	0.04	0.17	0.24	0.59	0.84	1.00	1.00	n/a
$7xC_i$	0.0	0.28	1.19	1.68	4.13	5.88	7.00	7.00	n/a
Output val. s_i	0	0	1	2	4	6	7	7	n/a
Rearranged s_i	0	1	2	3	4	5	6	7	n/a
Modified no. of occ. F_i	4	13	7	0	35	0	25	16	100

24. Suppose the fundamental matrix of Camera-2 with respect to Camera-1 is given by

$\begin{bmatrix} 0.005 & 0 & -2 \\ 0.001 & 0.002 & 0 \\ 0.08 & -0.06 & 5 \end{bmatrix}$, find the equation of epipolar polar line in the image plane of Camera-2 due to point $(1000, \quad 1500, \quad 1)$ in the image plane of Camera-1.

Epipolar line in camera-2 due to point $(1000, \quad 1500, \quad 1)$ in camera-1:

$$l_1 \equiv [1000 \quad 1500 \quad 1]\begin{bmatrix} 0.005 & 0 & -2 \\ 0.001 & 0.002 & 0 \\ 0.08 & -0.06 & 5 \end{bmatrix}^T \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = (3 \quad 4 \quad -5)\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = 3x + 4y - 5 = 0$$

Answer any 1 question (10 marks each)

25. Considering two-view geometry, derive the equation of epipolar line for real camera in terms of fundamental matrix.
26. Suppose a graylevel image contains two types of regions R_1 and R_2 whose pixel values follow Gaussian distribution with (μ_1, σ) and (μ_2, σ). Given the *apriori* probability of pixels to belong to those regions is P_1 and P_2 respectively, derive the expression of threshold for image segmentation by graylevel thresholding.