NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2016-2017

EE6222 – MACHINE VISION

November/December 2016 Time Allowed: 3 hours

INSTRUCTIONS

1. This paper contains 5 questions and comprises 4 pages.
2. Answer all 5 questions.
3. All questions carry equal marks.
4. This is a closed-book examination.

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1. (a) Explain the principles behind the edge detection operation using first-order differentiation and second-order differentiation.

(6 Marks)

(b) In the context of Canny edge detection, describe the following two operations in detail:

(i) Hysteresis Thresholding.

(ii) Accurate Edge Localization.

(8 Marks)

(c) Prove that an edge point in the image space will become a sinusoidal curve in the Hough Transform space in the case of straight line detection by using the Hough Transform.

(6 Marks)

2. (a) In the two step thinning algorithm, explain the roles of:

(i) The number zero-one transitions in a particular direction around the boundary pixel being considered for removal.

(ii) The number of object pixels around the boundary pixel being considered for removal.

(6 Marks)

(b) (i) What conditions should be satisfied in order to employ temporal averaging for noise removal?

(ii) Derive expressions for the mean and standard deviation of the noise in the averaged image, if M images are averaged, assuming the conditions for image averaging are satisfied. The mean and standard deviation of noise in one image are μ and η, respectively.

(9 Marks)

(c) Explain in detail how mathematical morphology can be used to extract the boundary of a binary object.

(5 Marks)

3. (a) Describe convolutional neural networks (CNN) in detail. Your description should include graphical illustration of the structure, invariances, and major training steps.

(10 Marks)

(b) An imaging system, with known focal length $f = 1000$ pixels, is shown in Figure 1. On the line ℓ, two image points a and b were found with x and y coordinates (100, 400) and (200, 300), respectively.

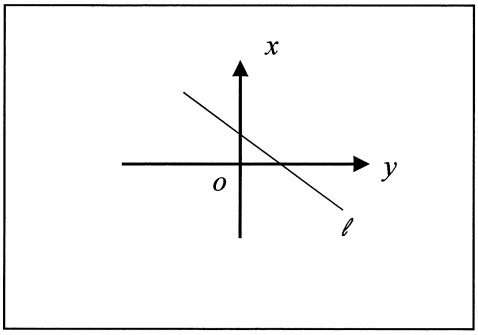

Figure 1

Note: Question No. 3 continues on page 3

(i) Convert these two points a and b into N-vectors.

(ii) Find the line ℓ in N-vector.

(6 Marks)

(c) What is N-velocity?

(4 Marks)

4. (a) What is a vanishing point?

(5 Marks)

(b) Show that for a planar surface with the unit normal

$$\boldsymbol{n} = \begin{pmatrix} n_1 \\ n_2 \\ n_3 \end{pmatrix}$$

the vanishing line is given as

$$n_1 x + n_2 y + n_3 f = 0$$

f is the camera's focal length.

(15 Marks)

5. (a) What is the fundamental matrix?

(5 Marks)

(b) Derive the projection equation

$$\begin{pmatrix} x \\ y \\ f \end{pmatrix} = \frac{f}{Z} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

where f is the camera's focal length, (X,Y,Z) is an arbitrary point in the 3D space, and (x,y) is the corresponding image point.

(5 Marks)

(c) A space line $\{\boldsymbol{n}, \boldsymbol{p}\}$ can be obtained by two 3D points

$$\boldsymbol{r}_1 = \begin{pmatrix} x_1 \\ y_1 \\ z_1 \end{pmatrix}$$

$$\boldsymbol{r}_2 = \begin{pmatrix} x_2 \\ y_2 \\ z_2 \end{pmatrix}$$

Note: Question No. 5 continues on page 4

Show that

$$\boldsymbol{n} = \pm N[\boldsymbol{r_1} \times \boldsymbol{r_2}]$$

$$\boldsymbol{p} = \pm \frac{\boldsymbol{r_2} - \boldsymbol{r_1}}{\|\boldsymbol{r_1} \times \boldsymbol{r_2}\|}$$

(5 Marks)

(d) Two image points are observed in two images. Their *N*-vectors are given as $\boldsymbol{m}_1$ and $\boldsymbol{m}_1'$ in the first frame, and $\boldsymbol{m}_2$ and $\boldsymbol{m}_2'$ in the second frame. Show that the *N*-vector of the focus of expansion is given by

$$\boldsymbol{u} = \pm N\left[N[\boldsymbol{m}_1 \times \boldsymbol{m}_1'] \times N[\boldsymbol{m}_2 \times \boldsymbol{m}_2']\right]$$

(5 Marks)

END OF PAPER

EE6222 MACHINE VISION

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.