NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2021-2022

EE6222 – MACHINE VISION

November/December 2021 Time Allowed: 3 hours

INSTRUCTIONS

1. This paper contains 5 questions and comprises 3 pages.
2. Answer all 5 questions.
3. All questions carry equal marks.
4. This is a closed-book examination.
5. Unless specifically stated, all symbols have their usual meanings.

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1. (a) Explain the need for applying a smoothing operation prior to performing a differentiation operation and explain the attractive properties of the Gaussian smoothing operation.

(7 Marks)

(b) Derive the most computationally efficient smoothing procedure to be used when performing first-order gradient computations and quantify the computational savings.

(8 Marks)

(c) Describe the medial axis transformation-based thinning algorithm for a binary object.

(5 Marks)

2. (a) Describe the following operations in detail:
   (i) Closing (binary images)
   (ii) Law's textural energy feature extraction (10 Marks)

(b) An intermediate node in an orthogonal random forest receives 8 training samples, as shown in Table 1 (on page 2). Among 10 features of each sample, three features were randomly selected to perform the splitting of the training samples.

(i) Compute the Gini impurity score before splitting the data.
(ii) Assuming an orthogonal split using only Feature 5, compute the Gini impurity scores associated with the most promising splits.

Note: Question No. 2 continues on page 2.

(iii) Explain the steps to be taken to identify the best split for the given training samples to the left and right branches using Features 2, 5 and 7.

(10 Marks)

Table 1

	Feature 2	Feature 5	Feature 7	Class
Sample 1	0.44	0.21	-0.46	1
Sample 2	0.85	0.15	-0.12	1
Sample 3	0.62	0.36	-0.05	1
Sample 4	0.23	0.31	0.22	2
Sample 5	0.11	0.46	0.33	2
Sample 6	0.32	0.39	0.25	2
Sample 7	0.41	0.43	0.35	2
Sample 8	0.05	0.54	0.49	2

3. (a) Describe the random vector functional link (RVFL) network in detail. Your descriptions must include a graphical illustration of its architecture, important equations, major training steps and possible alternatives.

(10 Marks)

(b) Derive the line equation from 2 image points with vector product, and turn this line equation into an N-vector so that

$$\boldsymbol{n} = \pm N[\begin{pmatrix} A \\ B \\ C/f \end{pmatrix}]$$

where $N[\ ]$ denotes the normalization of a 3D vector.

(10 Marks)

4. (a) SVD can be used to estimate full 3D motion. Given two sets of corresponding 3D points

$$X = \{x_1, \ldots, x_{N_p}\} \text{ and}$$
$$P = \{p_1, \ldots, p_{N_p}\},$$

describe the steps to find the translational motion

$$t = \mu_x - R\mu_p ,$$

where μ_x , μ_p and R are the centers of two sets of points and a rotation matrix, respectively.

(7 Marks)

Note: Question No. 4 continues on page 3.

(b) Given the rotation angle Ω and rotation axis $\boldsymbol{l} = (l_1, l_2, l_3)^T$, the rotation matrix can be derived as

$$R = \begin{pmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{pmatrix} = \begin{pmatrix} C + l_1^2 V & l_1 l_2 V - l_3 S & l_1 l_3 V + l_2 S \\ l_2 l_1 V + l_3 S & C + l_2^2 V & l_2 l_3 V - l_1 S \\ l_3 l_1 V - l_2 S & l_3 l_2 V + l_1 S & C + l_3^2 V \end{pmatrix}$$

where $S = \sin(\Omega)$, $C = cos\ (\Omega)$ and $V = 1 - cos\ (\Omega)$.

(i) Show that the rotation angle and rotation axis can be recovered as

$$\Omega = \arccos \frac{trace(R) - 1}{2}$$

$$\boldsymbol{l} = N\left[\begin{pmatrix} r_{32} - r_{23} \\ r_{13} - r_{31} \\ r_{21} - r_{12} \end{pmatrix}\right]$$

where $N[\ ]$ denotes the normalization of a 3D vector.

(ii) Derive the equivalent quaternion $q = (q_0, q_1, q_2, q_3)^T$ from R.

(13 Marks)

5. (a) Describe the steps for obtaining optimized points-based motion parallax with full 3D motion, namely translation and rotation of the ego motion.

(15 Marks)

(b) Binocular stereo imaging is a reduced problem of the motion parallax. Derive the full 3D location of a point by image disparity from a parallel binocular image pair.

(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.