UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

1998-99

For the following qualifications :-

MSc VIVE

COURSE CODE	:	**MV**
TITLE OF EXAMINATION	:	**Machine Vision**
DATE	:	**12-MAY-1999**
TIME	:	**14.30**
TIME ALLOWED	:	**2 hours 30 minutes**

[TURN OVER]

*Answer **four** questions in total, **at least one** from each of sections A, B and C. Each question is worth 25 marks. The total time allowed is two and a half hours.*

SECTION A

Answer at least one question from this section.

Question 1

(a)

(i) Describe how the geometry of image formation may be represented by means of a projection matrix in homogeneous co-ordinates and use this model to explain the difference between perspective and weak perspective imaging. Include in your explanation the conditions under which each kind of projection is appropriate and give the form of the corresponding projection matrix.

(ii) Explain, with the aid of suitable diagrams, the difference between:

- weak perspective and orthographic projection,
- weak perspective and para-perspective projection.

[10 marks]

(b)

(i) Define an affine transformation of an image and show how it is represented in homogeneous co-ordinates.

(ii) Explain how an affine transformation may be calculated from a set of 3 or more control points.

(iii) Describe how it may be used to produce a warped version $I'(x', y')$ of an image $I(x, y)$.

[8 marks]

(c)

(i) Define what is meant by a homography, explain what homographies are used for, and indicate how they differ from the affine transformations discussed in (b) above.

(ii) Discuss why calculation of a homography is not as straightforward as calculation of an affine transformation.

[7 marks]

[TURN OVER]

Question 2

(a) An engineering company wishes to use machine vision to identify the type of gaskets used in the assembly of small, mechanical pumps. The gaskets are to be imaged in silhouette by passing them over a bright light and viewing them from directly above with a monochrome camera.

(i) Describe the image processing operations you would use to obtain a labelled, singly connected region describing the silhouette of each object as it passes under the camera.

(ii) Explain briefly the operation of any standard labelling algorithms you would use.

[8 marks]

(b)

(i) Explain how geometric moments may be used to characterise the shape of an object imaged under the conditions described in (a) above.

(ii) Discuss how you would try to ensure that your shape descriptors were insensitive or invariant to details of the set-up of the inspection cell such as the position and orientation of the objects, which way up they are and factors such as the camera's focal length, its height above the objects and its precise orientation.

[7 marks]

(c) In addition to analysing the external shape of the gaskets, similar methods are used to detect, locate and analyse the shape of several holes and slots in each of the gaskets.

(i) Describe how you would utilise the geometric moments discussed in (b) above *and* these additional measurements to identify the type of gasket by using an object recognition algorithm such as the interpretation tree.

(ii) Describe how you would deal with difficulties such as failure to detect some holes or slots and explain why you think the interpretation tree would help you discriminate many different types of gasket.

[10 marks]

[CONTINUED]

SECTION B

Answer at least one question from this section.

Question 3

(a)

(i) Explain what is meant by template matching in machine vision and describe how it could be used for the detection of a particular logo of fixed size, colour, orientation and resolution in a system designed to check automatically for violations of a company's copyright in Internet documents.

(ii) Describe how you would extend the above system also to locate as accurately as possible, the position of the logo, or logos, detected on each document page.

[9 marks]

(b)

(i) Explain what a receiver operating characteristic (ROC) curve is and describe how it could be used to characterise the performance of the logo *detection* system described in (a) above.

(ii) Explain how you would use the ROC to tune the performance of this detection system and indicate what other information you would need in order to do so.

[7 marks]

(c)

(i) Show that the following function:

$$(1-f)^{\alpha} + t^{\beta} = 1 \quad , \qquad (1)$$

where f is the false positive rate and t is the true positive rate may be used to model an ROC curve provided $\alpha, \beta > 1$.

(ii) Explain why larger values of α and β are indicative of a better system and discuss what factors you would expect to affect the values of the parameters α and β when (1) is fitted to empirical data from the performance of the above template matching detection system.

(iii) Indicate briefly what you might do further to improve the logo detection system's performance.

[9 marks]

[TURN OVER]

Question 4

(a)

(i) Describe the aim of principal components analysis and explain how the analysis is carried out.

(ii) Describe how principal components analysis is used in constructing a "flexible shape model" from observations in N training images, i=1,…N of the locations of a set of n distinct landmark points x(i) on an object. Assume the set of landmark points in each image is described by the vector $\underline{x}^T = (x_1, y_1, x_2, y_2, x_3, y_3, \ldots\ldots x_n, y_n)$.

(iii) Describe briefly what properties the imagery should, in principle, possess if the modelling is to be successful.

[10 marks]

(b)

(i) Explain the main steps in the Procrustes alignment procedure in the construction of a flexible shape model and describe what the procedure is designed to achieve.

(ii) Explain why this alignment is necessary and what properties the landmark points should possess.

[6 marks]

(c)

(i) Describe how a flexible shape model may be used as an active shape model to find new instances of a particular type of object in a series of previously unseen images which have been pre-processed in order to detect and locate edge features.

(ii) Explain what parameters have to be determined when each new object is found and describe the methods you would use to determine their optimal values.

(iii) Describe how you might extend the model in order to make detection of the object's boundary more robust.

[9 marks]

[CONTINUED]

SECTION C

Answer at least one question from this section.

Question 5

(a)

(i) Write down the motion constraint equation.

(ii) Explain what the motion constraint equation means.

(iii) Describe how and to what extent the motion constraint equation may be used to compute visual motion or optical flow.

(iv) Comment on the extent to which you would expect the motion constraint equation to yield a dense optical flow field.

[9 marks]

(b)

(i) Explain how optical flow is related to the motion field $\frac{d\mathbf{x}}{dt}$ of the image points $\mathbf{x}$ induced by movement of the camera and objects in a scene.

(ii) Use the ideal perspective projection to show that, if a camera is moved with rectilinear velocity $\mathbf{V} = (U, V, W)^T$ through a stationary scene, the image motion field may be written as:

$$\frac{1}{f}\frac{d\mathbf{x}}{dt} = -\left(\mathbf{x} - \mathbf{x}_{FOE}\right)\frac{1}{\tau} \quad . \quad . \quad (1)$$

(iii) Explain what the terms $\mathbf{x}_{FOE}$ and τ in (1) stand for and describe the form of the image motion.

[7 marks]

[Question 5 cont. over page]

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[Question 5 cont.]

(c) A robotic hovercraft may move in any direction in the horizontal XZ plane but only occasionally rotates.

(i) Show from equation (1) above how, in principle, when the craft is in rectilinear motion, the motion of horizontal edge features may be used to estimate τ and the motion of vertical edge features subsequently used to determine the craft's direction of motion.

(ii) Show further that, if the motion constraint equation is used, all image points may be used to obtain similar information via a least squares procedure.

[9 marks]

Question 6

(a) Describe the three different fundamental types of stereo matchers which have been developed to date and how two of them could be used co-operatively in a close-range application for 3D measurement of human faces.

[5 marks]

(b) Discuss what techniques you would need to perform when attempting to compare the accuracy of 3 independent stereo matching methods for close-range 3D measurement of human faces.

[10 marks]

(c)

(i) Compare and contrast the Canny and Model edge fitting edge extraction operators.

(ii) Suggest ways how these operators could be used to extract building hypotheses within a heavily cluttered aerial image and how the accuracy of these techniques could be measured.

[10 marks]

[END OF PAPER]