UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

1999-2000

For the following qualifications :-

MSc VIVE

COURSE CODE	:	**MV**
TITLE OF EXAMINATION	:	**Machine Vision**
DATE	:	**30 April-2001**
TIME	:	**14.30**
TIME ALLOWED	:	**2 hours 30 minutes**

[TURN OVER]

*Answer **three** questions. Each question is worth 33 marks. The total time allowed is two and a half hours. The use of electronic calculators is permitted.*

Question 1

(a) Write down equations describing quantitatively the geometry and photometry of the formation of a grey-level image by an idealised camera. Explain what each of the terms in your equations stands for and explain as fully as you can their physical origin.

[6 marks]

(b) Define what is meant by the term 'image grey-level histogram' and describe how it is related to the properties of the scene being imaged. Describe qualitatively what you would expect the grey-level histogram for the image in figure 1 below to look like and explain why.

[4 marks]

Figure 1. Image of a young person.

(c) Define what is meant by 'an image segmentation' and explain why segmentation is usually carried out. Explain why it would be difficult to obtain a good segmentation of the child's face in the image in figure 1 by use of a grey-level threshold alone.

[4 marks]

[Question 1 cont. over page]

[TURN OVER]

[Question 1 cont.]

(d) In an algorithm designed to separate an image such as that shown in figure 1 into the face and the background, the grey-level threshold to be used in the segmentation is defined as

$$T = \frac{1}{2}(\mu_1 + \mu_2) \qquad . \qquad (1)$$

Explain what the terms μ_1 and μ_2 in this equation mean, how the equation is used and why it has to be used this way. Describe one alternative method that might be used to set the threshold and discuss any advantages or disadvantages it has in comparison to the method based on use of equation (1).

[6 marks]

(e) Describe a 'region-growing' segmentation algorithm designed, for example, to try to segment the child's face in the image shown in figure 1. Explain why you would not expect such a region-growing algorithm to work well in this case.

[6 marks]

(f) Explain what is meant by a 'region-merging' algorithm and describe how, in principle, such an algorithm works. An adaptive region-merging algorithm uses the measure

$$L = \frac{\sigma_0^{m+n}}{\sigma_i^m \sigma_j^n} \qquad , \qquad (2)$$

where the variances σ_i, σ_j and σ_0 are defined over regions P_i, P_j and $P_0 = P_i \cup P_j$ respectively. Explain what the remaining terms used in equation (2) mean and why such a measure must be based on a function of this type irrespective of the underlying statistical model.

[7 marks]

[Total 33 marks]

Question 2

The components on a loaded printed circuit board are inspected automatically by means of a machine vision system which images the boards under controlled lighting conditions as they pass beneath a downwards looking camera mounted above the production line.

[Question 2 cont. over page]

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[Question 2 cont.]

(a) The components, which appear bright in the images, are to be isolated by use of grey-level morphological operations followed by application of a suitable threshold. Explain what type of such morphological operations you would use, indicate why you would use them, and describe how they may be defined.

[5 marks]

(b) An alternative method to that described in (a) above is to threshold the images and then to apply morphological operations. Describe what morphological operations you would use in this case and explain how they are related to those you described in (a) above. Explain why the two methods are not equivalent, indicate which you would prefer and explain why.

[5 marks]

(c) Explain what is meant by 'template-matching' and describe how, in principle, it may be used to check that components have been correctly placed on the circuit board.

[5 marks]

(d) Describe how L^1 and L^2 norms may be used in template matching and explain why, in practice, use of the L^1 norm might be preferred in the above inspection system.

[4 marks]

(e) Explain how the L^2 norm is related to an 'overlap' or 'cross-correlation' matching measure and describe how the latter may be extended to make it insensitive to: (i) the camera gain or image brightness, and (ii) also to bias of the image intensity. Indicate to what kind of transformations the extended measures in (i) and (ii) are invariant.

[6 marks]

(f) Describe what kinds of errors you would expect the inspection system to make and how, in principle, you would characterise its performance. Explain how, in principle, this characteristic could be used to optimise the system's performance. Briefly indicate what practical problems might make this performance characterization and optimisation difficult.

[8 marks]

[Total 33 marks]

[TURN OVER]

Question 3

(a) Describe how the equations for perspective projection may, in general, be written in matrix form by using homogeneous co-ordinates. Describe how the matrix form of the equations may be simplified if the object being imaged is flat.

[5 marks]

(b) Use the equations in (a) above to explain what is meant by (i) a Euclidean, (ii) an affine, and (iii) a projective geometric invariant of a planar object. Describe under what imaging conditions you would expect each type of invariant to be obtained and give one quantitative example of each type of invariant.

[8 marks]

(c) An automatic system is to be built to detect and identify flat, angular metal parts lying loosely in a work-tray by means of a camera mounted high above on a robot gantry. Describe what type of planar invariants might, in principle, be used for this task and explain what difficulties you would expect to encounter in their use.

[8 marks]

(d) The robot work-cell is modified by addition of a second camera near the gripper of the arm that is used to select the desired parts. Video imagery is used automatically to help guide the gripper to the parts. Describe what type of invariants you would use in this case and discuss what problems would have to be overcome in their use.

[6 marks]

(e) Describe how you might modify the system in (d) also to take account of characteristic curved regions of parts.

[6 marks]

[Total 33 marks]

[CONTINUED]

Question 4

(a) A research team wishes to describe as quantitatively as possible the shape and appearance variations of a particular species of starfish. They have collected over a hundred healthy, adult specimens each of which has been placed on a tray and photographed under controlled conditions by use of a standard, monochrome CCD camera fixed above the tray.

Describe how you would use this data to construct a flexible shape model of the shape of this species of starfish, paying particular attention to how:

(i) you would define a suitable set of landmark points from the images,

(ii) you would ensure that the images used in building the model are correctly registered or aligned with each other.

[9 marks]

(b) Describe how you would ensure that significant variations in the starfishes' shape were included in the model, yet noise and insignificant details were excluded and explain why alignment of the images in (a)(ii), above, is necessary.

[6 marks]

(c) Explain how you would, in addition to modelling the starfishes' shape as in (a) above, use similar techniques to model their appearance. Describe any practical problems you might encounter in doing so and how you would overcome them.

[7 marks]

(d) The team is called-in to help set up a monitoring station in an area where there is danger of a particular type of pollution which causes this species of starfish to develop unsightly lesions or spots, in particular in young fish. They propose to use machine vision techniques to check for such lesions on starfish in the weekly catch of local fishermen.

Describe how you would use the models constructed in (a) and (b) above to build such a monitoring system, paying particular attention to how you would ensure the system would be as automated as possible and could be used by officials not expert in image processing.

[6 marks]

[Question 4 cont. over page]

[TURN OVER]

[Question 4 cont.]

(e) Describe how you would ensure that only starfish of the required species were examined for lesions, and that lesions are reliably detected.

[5 marks]

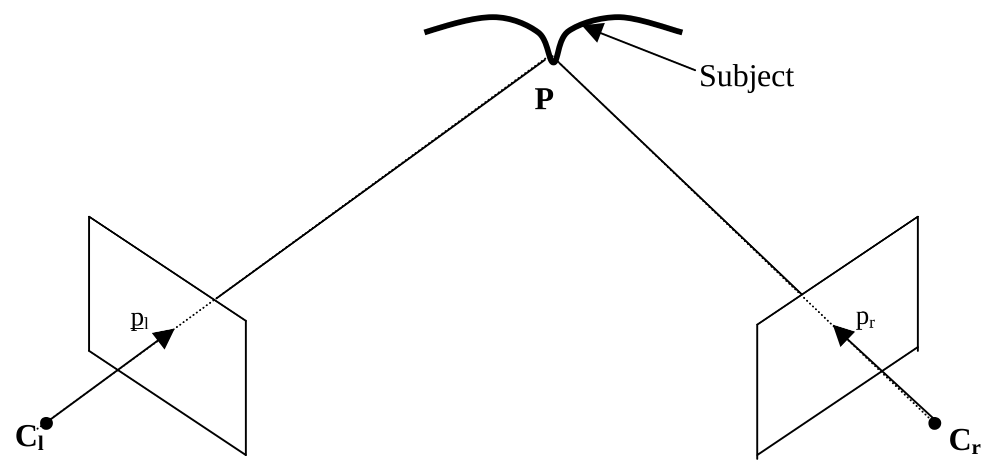
[Total 33 marks]

Question 5

(a) Define the *Fundamental Matrix* of a stereo system and explain how it relates points in two images of a stereo pair.

[6 marks]

(b) The stereo system below is used to reconstruct 3D surface representations of human faces. Two cameras with projection centres C_l and C_r view the subject's face from different directions. A horizontal cross-section of the surface (through the top of the nose) is shown, which contains a 3D point $\underline{P}$. The projections of $\underline{P}$ onto the left and right images are $\underline{p}_l$ and $\underline{p}_r$, respectively.



[Question 5 cont. over page]

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[Question 5 cont.]

The fundamental matrix of the system is known to be

$$F = \begin{pmatrix} 0 & 0 & \frac{\sqrt{3}}{2} \\ 0 & 0 & -\frac{1}{2} \\ 0 & 1 & 0 \end{pmatrix}$$

$\underline{p}_l$ is found to lie at at pixel location (9, 3) in the left image. Assume the focal lengths of the two cameras are the same and write down the equation (in pixel coordinates) of the line in the right hand image along which we expect to find the corresponding point, $\underline{p}_r$.

[7 marks]

(c) The corresponding point is identified by hand to be pixel location (11, 28) in the right image. Comment on this finding and describe briefly how you would obtain an estimate of the 3D position of $\underline{P}$.

[6 marks]

(d) Describe how a local image autocorrelation function or the local sum of squared intensity differences may, in principle, be used to detect points in an image that: (1) are completely different from their surroundings, (2) belong to one-dimensional image features, (3) belong to featureless, uniform regions.

[5 marks]

(e)

(i) Define the image structure tensor and show how it may be used to approximate a local image autocorrelation.

(ii) Show how the eigensolutions of the image structure tensor may be used to distinguish image points of types (1), (2) and (3) in (i) above.

(iii) Describe how the image structure tensor is used to construct a so-called “corner detector”.

[9 marks]

[Total 33 marks]

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