UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

1997-98 and RESIT

For the following qualifications :-

M.Res

COURSE CODE	**:**	**MV**
TITLE OF EXAMINATION	**:**	**Machine Vision**
DATE	**:**	**24 February-1998**
TIME	**:**	**09.30**
TIME ALLOWED	**:**	**2 hours 30 minutes**

*Answer **three** questions in total, **one** from each of sections A, B and C. Each question is worth 33 marks. The total time allowed is two and a half hours.*

SECTION A

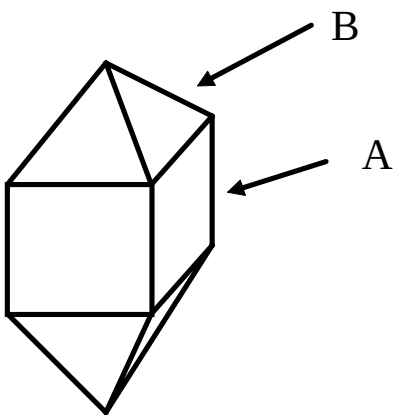
Answer one question from this section.

Question 1

(a) By use of a suitable imaging model, explain what is meant by (i) an affine geometric invariant, and (ii) a projective geometric invariant, and describe the conditions under which geometric invariants of each type may be computed from an image. Give two examples of quantities that are affine invariants, but not projective, and indicate what corresponding quantities you would measure as invariant in the projective case.

[10 marks]

(b) A precious object has ten vertices lying at the eight corners of a cube at $(\pm 1, \pm 1, \pm 1)$ and at the points $(0,0,\pm 2)$. In an image, the object often has the appearance sketched below and its vertices and edges may be detected and located automatically by use of appropriate image processing operations. Describe how you would use geometric invariants to detect whether the object was or was not present in a series of images each containing a large number of geometric shapes. Indicate what difficulties you would expect to encounter and how you would overcome them. **[10 marks]**



[Question 1 cont. over page]

[TURN OVER]

[Question 1 cont.]

(c) There is an inscription on one of the square faces, A, of the object that has been imaged at an oblique angle as sketched above. Describe what you would do to help see the inscription more clearly, for example, as though from normal incidence. Close inspection reveals a second inscription on face B. Describe what you would do to see this more clearly.

Include in your descriptions, the difficulties you would expect to encounter in trying to enhance the appearance of these inscriptions and indicate what you would do to overcome them.

[13 marks]

Question 2

(a) The leaves of a certain species of tree have five characteristic lobes as sketched below. A botanist has collected a few hundred such leaves and wishes to describe their shape as quantitatively as possible. Knowing that image processing and machine vision techniques are likely to be useful, the botanist has sought your assistance. Describe how you would construct a suitable model and what image processing techniques you would use to help reduce the laborious nature of the task.

[11 marks]

(b) One of the botanist's students has a second collection of several thousand leaves, but it is suspected that these belong to several species. Describe how you would use the model constructed in (a) above, automatically to select leaves of the desired species.

[9 marks]

[Question 2 cont. over page]

[CONTINUED]

[Question 2 cont.]

(c) Inspection of the leaves selected in (b) above indicates that they appear to contain a mixture of mature and young leaves of different sizes, whereas those collected originally by the botanist (a) appear all to be mature and of similar size. The botanist thinks that the trees may leaf only during two relatively short periods during the summer. Describe what you would do:

(i) to test the hypothesis that all the leaves collected by the botanist (a) are mature,

(ii) to show that those collected by the student (b) do belong to two populations.

Describe how you would subsequently use this information to separate the young and mature leaves. It is then observed that the young leaves, when viewed under ultra-violet light, are much brighter than the mature ones. Indicate how you would use this additional information to assess the success of your classification.

[13 marks]

[TURN OVER]

SECTION B

Answer one question from this section.

Question 3

(a) A medical researcher wishes to measure the speed of small microbial parasites as they move across a culture towards a food source as it is known that the most virulent move the most quickly. The parasites appear as small, bright specs, scarcely bigger than a pixel in size, in each frame of a sequence of time-lapse images captured on a computer attached to a camera looking directly down on the culture.

Describe how you would use a Kalman filter to measure the speed of each parasite. Include in your description: (i) details of the equations you would use to implement the filter, and (ii) how you would use the filter to help track each parasite.

[12 marks]

(b) The parasites are initially located very close together in a cluster at the centre of the culture, but as they always move directly towards the nearest food source, the medical researcher inserts the food in a ring around the edge of the culture to ensure the parasites move radially and spread out. Describe how you would modify your Kalman filter to model this experimental set-up, and show how, in principle, you would refine your filter to test the hypothesis that the parasites do move directly towards the nearest food source.

[10 marks]

(c) Just before you begin taking measurements, an experienced machine vision researcher points out that initially it will be very difficult to track the parasites but that there is an analogy with optical flow that may help.

Describe what you would do to overcome this difficulty and discuss:

(i) how your solution helps make the most effective use of the available data,

(ii) how you might utilise the optical flow analogy to improve your solution still further.

[11 marks]

[CONTINUED]

Question 4

(a) Explain what is meant by "optical flow field" in computer vision and describe to what extent it may be computed from the image intensity, I, and its first order derivatives. Your description should include a clear account of:

(i) the assumptions you have to make,

(ii) the aperture problem,

(iii) the limitations of the approach,

(iv) the difficulties encountered in applying it to digital imagery,

(v) what you would do in practice to improve the reliability and accuracy of the results.

Indicate how higher order derivatives might be used to overcome the aperture problem and discuss the limitations and difficulties in trying to use them in this way in practice.

[13 marks]

(b) Describe an alternative method for obtaining the optical flow field by cross-correlation, explaining:

(i) how it can overcome some of the problems encountered in using the derivatives of the image intensity as in (a) above,

(ii) the practical difficulties encountered in implementing a cross-correlation method and how they might be alleviated.

[11 marks]

(c) It has been decided to use the differential approach (a) to build a system based on use of the optical flow field for detecting static or slow-moving obstacles in the path of an indoor, factory robot vehicle. Explain why you think such a decision might be taken in favour of alternative (b), indicate what variant of (a) you would expect to be used, and describe how you would try to ensure that the system had a low false alarm rate and also a low failure rate as it is important that the robot vehicle should neither brake or swerve unnecessarily nor crash into undetected objects.

[9 marks]

[TURN OVER]

SECTION C

Answer one question from this section.

Question 5

(a) Explain how feature extraction can be applied to the automated extraction of 3D object corners using a robotic eye-hand system and what factors you would need to consider when trying to establish what the accuracy requirements would be.

[8 marks]

(b) Given an image of a natural outdoor scene containing buildings and vegetation, what segmentation techniques could be applied to try to extract atomic regions and what difficulties are you likely to encounter? Suggest ways in which these difficulties could be overcome.

[8 marks]

(c) Explain how edge operators can be used with Hough transforms to extract process plant (e.g. pipework) information for construction of "as built" CAD models. Suggest ways in which a CAD modelling system could be used to identify particular structures within the scene for remote tele-operation within a hazardous environment.

[17 marks]

[CONTINUED]

Question 6

(a) Describe what is meant by a reflectance map and how this concept can be used to retrieve surface shape information within a constrained industrial environment, highlighting the strengths and limitations of such an approach.

[8 marks]

(b) Discuss the similarities and differences between passive stereo and photometric stereo approaches to the retrieval of information on surface shape of ice and snow as viewed from aircraft.

[8 marks]

(c) Describe how measurements of surface shapes with very little natural texture (e.g. human faces) can be retrieved using stereo and what advantages and disadvantages such an approach has when compared with active laser triangulation.

[17 marks]

[END OF PAPER]