UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1996

MEng Honours Degrees in Computing Part IV
MSc Degree in Foundations of Advanced Information Technology
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the
Diploma of Membership of Imperial College
Associateship of the City and Guilds of London Institute

PAPER 4.18

COMPUTER VISION

Wednesday, May 8th 1996, 10.00 - 12.00

Answer THREE questions

For admin. only: paper contains
4 questions
3 pages (excluding cover page)

1. Shape from Motion

a. Given that an object is moving with velocity components [u,v,w] in the directions of the Cartesian axes, and is being filmed by a camera placed at the origin, derive an expression for the focus of expansion of the object in the image. You can assume that the camera has a focal length of 1.

   (Hint: Consider the position that a point on the object [xi,yi,zi] moves to after a time interval t)

b. The time to adjacency equation is normally written as:

   $$D(t)/V(t) = z(t)/w(t)$$

   explain what is meant by the four variables D(t), V(t), z(t) and w(t), and why it is called the time to adjacency equation.

c. Show how can the time to adjacency equation might be used to estimate relative depth of an object moving with constant velocity? Discuss whether a practical algorithm could be based on this approach.

d. By expanding the intensity function I(x+dx,y+dy,t+dt), show that the change in intensity at a pixel is related to the velocity of the object seen from that pixel by the equation:

   $$(\partial I/\partial x)\, u + (\partial I/\partial y)\, v + \partial I/\partial t = 0$$

   Clarify the assumptions that need to be made about the illumination if this is to be made into an algorithm for determining object motion. NB you are **not** required to set up the error function used for minimisation or to show how it is solved.

2. The Hough Transform

a. If a Hough transform is used to extract straight lines, it is necessary to define a two dimensional parameter space. Briefly describe three such spaces, and indicate their advantages and disadvantages in the transform.

b. Write a pseudo-code implementation of the Wallace transform to extract short line segments from small windows on to an image. Assume that the windows will not be bigger that 16 by 16 pixels, and that the computation is to be performed as fast as possible.

c. How would bias affect the transform that you have implemented in part b? Suggest one possible strategy for avoiding it.

The three parts carry, respectively, 30%, 50%, 20% of the marks.

3. Relaxation Labelling

A relaxation labelling scheme is defined by the following equations

$$q^s{}_j(a_i:\lambda_l) = \sum_{k=1}^{m} r([a_i:\lambda_l],[a_j:\lambda_k])\, P^s(a_j:\lambda_k)$$

$$Q^s(a_i:\lambda_l) = \sum_{j=1}^{n} C_{ij}\, q^s{}_j(a_i:\lambda_l)$$

$$P^{s+1}(a_i:\lambda_l) = P^s(a_i:\lambda_l)\ \{\ Q^s(a_i:\lambda_l) / \sum_{k=1}^{m} P^s(a_i:\lambda_k)\, Q^s(a_i:\lambda_k)\ \}$$

The scheme is to be used for determining the edge pixels in an image.

a. What possible values could the labels λ take?

b. Explain what is meant by function $r([a_i:\lambda_l],[a_j:\lambda_k])$ and suggest a suitable definition

c. Explain the use of the symbol C_{ij} (note that C is a function of i and j), and suggest a suitable definition for it.

d. Explain what the quantities $q^s{}_j(a_i:\lambda_l)$ and $Q^s(a_i:\lambda_l)$ mean.

e. Indicate how an initial estimate of the probability that a pixel is an edge could be made.

f. Given that in a certain area of the image, after s iterations of the above scheme using your definitions for part b and part c, the pixels have the following probabilities of being edges, compute the $s+1^{th}$ estimate of the probability of the central pixel being an edge.

0.4	0.7	0.9
0.7	1.0	0.9
0.9	0.1	0.1

The six parts carry, respectively, 10%, 30%, 10%, 20%, 10%, 20% of the marks.

/Turn Over

4. Region based Segmentation

a. Explain the difference between splitting and merging algorithms for segmentation.

b. Define a quadtree, and explain how it could be used for splitting and for merging.

c. Explain the criterion used in the Horowitz and Plavidis algorithm for determining whether a region could be split. Explain the circumstances in which it would be preferable to use the variance of the region as an alternative to their criterion.

d. Under certain circumstances, it is possible to characterise a region of an image by the mean and variance of its pixel intensities. Briefly explain the circumstances under which this can be done, and give an example where it would be wrong to do so.

e. Briefly describe an alternative method for characterising image regions, in cases where mean and variance cannot be used.

The five parts carry, respectively, 10%, 30%, 20%, 20%, 20% of the marks.

End of Paper