UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1999

MEng Honours Degrees in Computing Part IV
MEng Honours Degree in Information Systems Engineering Part IV
MSci Honours Degree in Mathematics and Computer Science Part IV
MSc Degree in Advanced Computing
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
Associateship of the Royal College of Science

PAPER 4.18 / I 4.2

COMPUTER VISION

Tuesday, May 11th 1999, 10.00 – 12.00

Answer THREE questions

For admin. only:
paper contains 4 questions

1. Photometric Stereo Method

The light intensity reflected from a point on a perfectly Lambertian object is given by:

$R(p,q) = r0\, \mathbf{n.s}/|\mathbf{n}||\mathbf{s}|$

where $\mathbf{n}=(p,q,-1)$ is the outward surface normal vector,
s is the vector from the point on the object to the light source,
and r0 is a constant called the albedo.

In an experiment, three distant light sources are used to illuminate an object in an otherwise darkened room. They have directions:

$s0=(1,0,0)$
$s1=(1,1,0)$
and
$s2=(0,0,-1)$.

It is assumed that the object is perfectly Lambertian (matte).

a. At a particular pixel (xi,yi) the measured intensities from these three light sources are 105 from s0, 210 from s1 and 35 from s2. Calculate the outward surface normal vector of the object at that point.

b. At a particular pixel (xi,yi) the part of the object that is seen can be approximated by a small planar patch with normal $\mathbf{n} = (p,q,-1)$. Show that $p=\partial z/\partial x$ and $q=\partial z/\partial y$.

c. Given that you know the distance (Z0) between one point on the object and the camera, explain how you could calculate the Z co-ordinate of its neighbouring points in the image. Assume that the distance between adjacent pixels, Δx or Δy, is exactly 1.

d. What can we say about the surface if:
(i) either $|p|$ or $|q|$ is very large,
(ii) both p and q are close to zero.
Under which condition would you expect the method to perform better?

e. Explain the difference between a local and a global shape from shading algorithm.

f. In a global algorithm, an error function, consisting of two parts is minimised. Briefly describe what the two parts are, and how they affect the solution, especially at object boundaries.

The six parts carry, respectively, 20%, 15%, 15%, 15%, 15%, 20% of the marks.

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 Hough transform to extract line segments from small windows on to an image using the r-θ parameter space.

c. Given that the windows may be small (less than 16 by 16 pixels), 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. Active Contours

A vision system is to be constructed to extract curved object boundaries.

a. One strategy is to extract edge points using a Sobel (or equivalent) operator, and then link them into boundary contours. For a given contour, defined as a list of pixels $\mathbf{p}_0, \mathbf{p}_1, \mathbf{p}_2, \ldots \mathbf{p}_n$, define a suitable function of the pixel gradients whose value will tell us how well the contour represents a boundary in the image.

b. Explain briefly how dynamic programming (or a similar search method) can be applied at the pixel level to make an optimal choice of contour, using the function of part a.

c. In order to speed up the computation, a smooth contour is approximated by a few pixels joined by straight line segments. Given that a contour has been defined somewhere near to an object boundary, describe a practical algorithm for adjusting the contour to make it fit the real boundary closely.

d. What term could be added to the otpimisation function defined in part a, to favour smooth boundaries?

e. For the algorithm of part b there is a danger that adjacent points on the boundary may move apart and so degrade the approximation. Explain how a term could be added to the optimisation function, defined in part a, to prevent this happening.

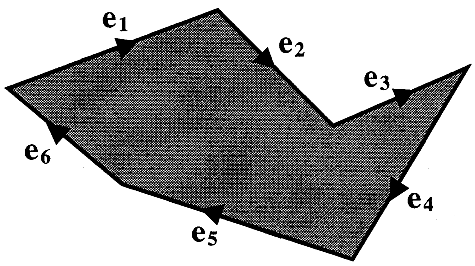
f. Given that an approximate boundary has been found by your algorithm of part c, explain how it could be improved using a divide and conquer approach.

The six parts carry, respectively, 15%, 20%, 15%, 20%, 15%, 15% of the marks.

Turn over

4. Shape Descriptors

In part of a computer vision system the boundary of an object has been found and is described by a set of edge vectors, **e1**, **e2**, **e3**, **. . .** as shown in the figure below. It is necessary to compute some measures that describe its shape.



a. Given that the edge vectors are known, briefly describe how you would calculate the area and the perimeter of the object.

b. The second moment of the object is given by the formulae:

$$M_{20} = \frac{\sum_{Object}(x - xm)^2 I(x, y)}{Area} \qquad M_{02} = \frac{\sum_{Object}(y - ym)^2 I(x, y)}{Area}$$

where x and y are the pixel intensities, I(x,y) is a nominal pixel intensity (taken to be 1 if a pixel is part of the object of interest, and 0 otherwise), and (xm,ym) is the object centre of gravity.

Briefly explain what the quantities M02 and M20 tell us about the shape of the object and its orientation.

c. If we plot the distance of a pixel from an object's centre of gravity as a function of the distance of the pixel along the boundary from some arbitrary starting point, we obtain a periodic function. The Fourier transform of that function, called the Fourier descriptor, gives us a measure related to its shape. Explain three main advantages of using the Fourier descriptor for characterising an object's shape.

d. If the object to be recognised is a perfect circle of radius r, what will its Fourier descriptor be?

The four parts carry, respectively, 25%, 25%, 30%, 20% of the marks.

End of Paper