UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1997

MEng Honours Degrees in Computing Part IV
MEng Honours Degree in Information Systems Engineering 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

PAPER 4.18 / I4.2

COMPUTER VISION

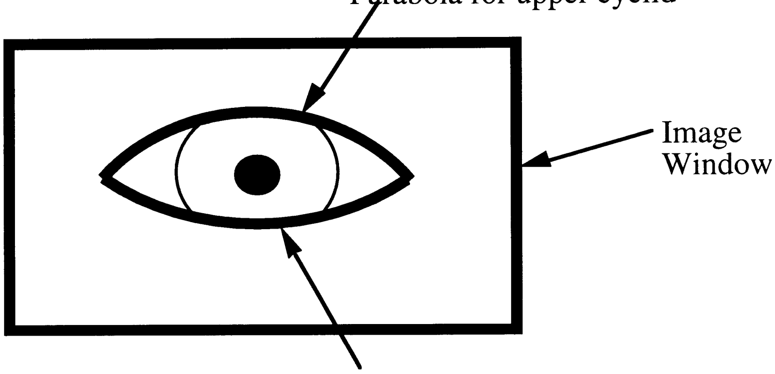
Friday, April 25th 1997, 2.30 - 4.30

Answer THREE questions

For admin. only: paper contains 4 questions

1. The Hough Transform

As part of a face recognition program the Hough transform is being used to determine the position of the eyes. The idea is to model the eyelids as a pair of parabolas as shown in the diagram.



The function used to describe the parabola is

$y = a\ (x - xc)^2 + yc$

It will be observed that the point [xc,yc] is the stationary point (or apex) of the parabola, and that the parameter a determines the shape of the parabola. Thus, if a is positive it will fit a lower eyelid and if negative an upper eyelid.

a. Assuming that the Hough transform will be performed in small windows of 32 by 32 pixels, suggest suitable bounds on the histogram array for the parameters.

b. Assuming a fixed value for the parameter *a*, describe the curve that will result in the [xc,yc] parameter space for an edge point at position [x,y] in the image. Indicate the effect that varying *a* will have.

c. Write an implementation for the generation of the histogram array for this Hough transform in the language (or pseudocode) of your choice. (You may assume that procedures exist to find the edge points in the image).

d. What constraints could you apply when searching the histogram for peaks that would indicate the presence of an eye?

The four parts carry, respectively, 25%, 25%, 35% , 15% of the marks.

2 Photometric Stereo Method.

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

$R(p,q) = \rho 0 \, \mathbf{n.s}/|\mathbf{n}||\mathbf{s}|$

where $\mathbf{n}=(p,q,-1)$ is the outward surface normal vector ($p=-dz/dx$ and $q=-dz/dy$),
s is the vector from the point on the object to the light source,
and $\rho 0$ 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=(0,–1,0)
s1=(1,2,2)
and
s2=(0,0,-1).

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

a. At a particular pixel (xi,yi) the measured intensities from these three light sources are 129 from **s0**, 250 from **s1** and 30 from **s2**. Calculate the normal vector of the object at that point.

b. Unfortunately, it turns out that there is a specular reflection at that pixel when the object is illuminated by light source **s1**. If the specular component accounts for one fifth of the light arriving at the pixel, compute the error in the [p,q] estimate at that point.

NB Specular reflections occur because objects are not perfectly matte. At a specular reflection some of the incident light is reflected in the direction of the camera, resulting in the measured intensity being higher than it would be for a truly Lambertian object. Frequently, specular highlights appear as bright spots in an image.

c. Given that you know the distance (Z_0) 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 between adjacent pixels Dx or Dy is exactly 1.

d. Briefly discuss the effect of specular reflections in calculation of the Z values using this method. Can you suggest any practical way of eliminating their effect?

/Turn Over

3. It is generally agreed that the best way to remove noise from an image is by convolving the image with a low pass, Gaussian filter. In most implementations this is done by a simple 3 by 3 mask as follows:

1/36	4/36	1/36
4/36	16/36	4/36
1/36	4/36	1/36

The operation is sometimes viewed as spreading out the effect of each individual pixel.

a. Consider the following hypothetical part of an image:

0	0	0	0	0
0	0	0	0	0
0	0	1	0	0
0	0	0	0	0
0	0	0	0	0

Assuming that all pixels outside this part of the image are zero, compute the result of convolving this image with the mask:

1	4	1
4	16	4
1	4	1

b. Use the result of part a and calculate the result of a second convolution with the same mask. Hence derive a 5 by 5 Gaussian mask for smoothing an image.

c. For a given application the noise level is such that it is appropriate to smooth the image using a five by five Gaussian mask. This could be achieved either by using the mask designed in part b or by convolving twice with the standard 3 by 3 mask. Which would be the best method, and why?

d. According to Marr and Hildreth, the best method to compute the differential at a pixel is to use a mask constructed from the differential of the Gaussian rather than smoothing the image with a Gaussian and then using a simple differential operator such as the central difference. Discuss this proposition in the light of your answer to part c.

4. Region based Segmentation

a. Define a quadtree, and explain how it could be used for splitting and for merging in region based image segmentation.

b. An alternative to using a quadtree would be to divide the image uniformly into squares of say 8 by 8, and computing the properties of each block. What would be the advantages and disadvantages of adopting this approach for region segmentation?

c. 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.

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

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

End of Paper