UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

# EXAMINATIONS 2002

MEng Honours Degree in Electrical Engineering Part IV
MEng Honours Degree in Information Systems Engineering Part IV
MSci Honours Degree in Mathematics and Computer Science Part IV
MEng Honours Degrees in Computing Part IV
MSc 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 Associateship of the City and Guilds of London Institute*
*This paper is also taken for the relevant examinations for the Associateship of the Royal College of Science*

## PAPER C418=I4.2

## COMPUTER VISION

Wednesday 24 April 2002, 10:00
Duration: 120 minutes

*Answer THREE questions*

Paper contains 4 questions
Calculators required

## 1. Image Segmentation

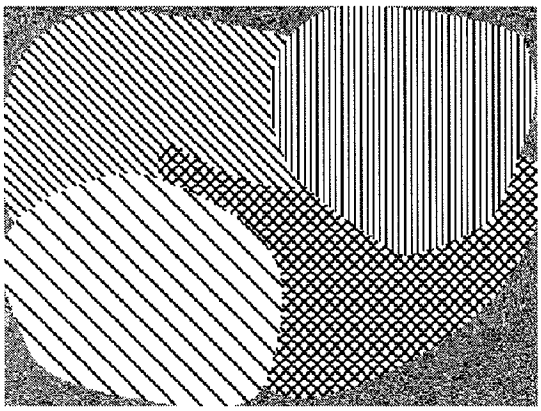
(a) Explain the terms: ***edge-based segmentation*** and ***region-based segmentation***.

(b) Explain how a graph search method can be used for linking edge points into boundary contours. Provide **three** heuristics that could be used to enhance the search strategy.

(c) Describe the general concept involved in using dynamic programming for linking edge segments into boundary contours.

(d) Given Fischer's criterion: $\frac{|\mu_1 - \mu_2|}{\sqrt{\gamma_1^2 + \gamma_2^2}}$, where $\mu_i$ and $\gamma_i$ *(i=1,2)* are the mean and variance of the pixels within each region. Explain how it can be used to determine whether two regions should be merged or separated.

(e) Given a textured pattern shown below, propose a practical segmentation technique for separating different regions.



*The five parts carry, respectively, 15%, 20%, 20%, 15%, 30% of the marks.*

## 2. Computational Stereo

(a) Two cameras are set up to view a three dimensional scene. The left hand camera is placed at the origin and is facing in direction $(0, 0, 1)$ (along the z axis). The right hand camera is at the point $C = (c_x, 0, 0)$ and also points in direction $(0, 0, 1)$. Both cameras have focal length $f$.

(i) Find the equation of the plane through the centres of the two cameras and a pixel $P = (x_p, y_p, f)$ belonging to the camera located at the origin. (The equation is in the form of $ax+by+cz = 0$ where $(a, b, c)$ is a normal vector to the plane).

(ii) Use the result above to derive an expression for the epipolar line corresponding to the pixel P.

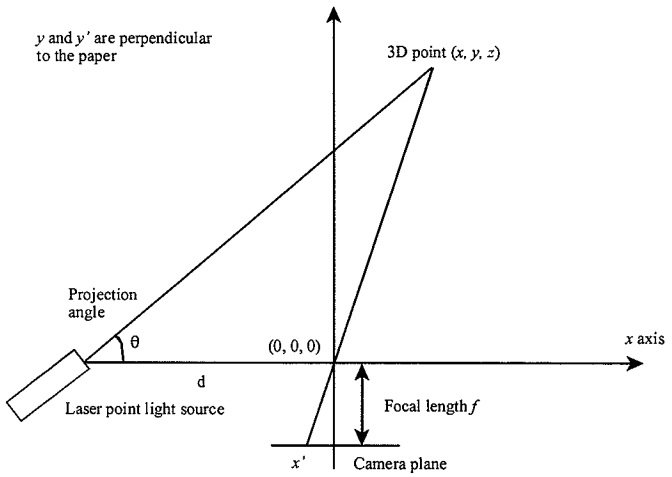
(iii) Given that the pixel P is in the centre of the image plane, and therefore has coordinate $(0, 0, f)$, sketch the epipolar line in the right hand camera, assuming both cameras are aligned vertically.

(b) Imaging using structured lighting is common in industrial vision applications, where the scene is illuminated by a known geometrical pattern of light. In a simple point projection system, a laser light source is used with a camera separated by a baseline distance $d$ as shown in the following figure. To compute the depth at all points, the scene is illuminated one point at a time.

i) Derive the equation for calculating the depth of each point, assuming the projection angle θ of the laser light source is known.

ii) In practice, accurate measurement of the projection angle θ may be difficult, explain how to alleviate this problem by introducing a second camera.

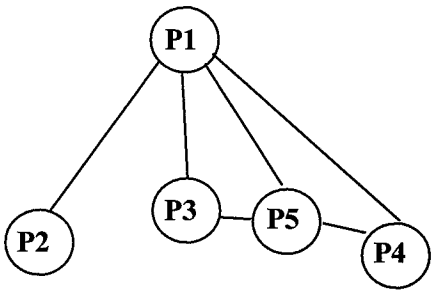
iii) What is the main advantage of using structured lighting for computational stereo?




*The two parts carry, respectively, 50%, 50% of the marks.*

### 3. Matching Relational Structures

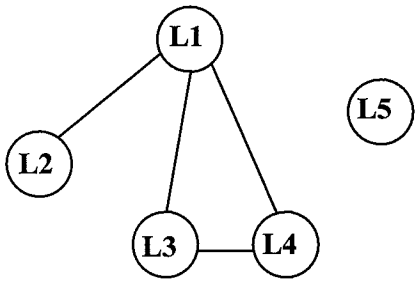
A simple semantic model for a bicycle is shown in the following figure:




| Node | Name | Type |
|---|---|---|
| P1 | Frame | Quadrilateral |
| P2 | Front Wheel | Large Circle |
| P3 | Chain Wheel | Small Circle |
| P4 | Rear Wheel | Large Circle |
| P5 | Chain | Line Pair |

The relations shown are all "connected"

When a number of primitives are extracted from an image the following relational structure is found:




| Name | Type |
|---|---|
| L1 | Large Quadrilateral |
| L2 | Large Circle |
| L3 | Small Circle |
| L4 | Line Pair |
| L5 | Large Circle |

(a) Construct an association graph between the semantic net and the extracted structure, noting that the association graph has a node for each possible matching node pair and arcs for matching node pairs where all relations agree or there are no relations.

(b) Indicate how you would interpret the graph.

(c) Suggest a way in which primitives extracted, but unmatched by the association graph method, could be interpreted.

(d) Briefly outline a method for measuring how good the match between image primitives and the semantic net might be.

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

## 4. Photometric Stereo

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

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

where $\mathbf{n}=(p, q, -1)$ is the surface normal vector ($p = dz/dx$ and $q = dz/dy$), $\mathbf{s}$ is the vector from the point on the object to the light source, and $\rho$ 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**=(0.5, 1, 1) and **s2**=(0, 0, -1). It is assumed that the object is perfectly Lambertian.

(a) At a particular pixel $(x_i, y_i)$ the measured intensities from these three light sources are 60 from **s0**, 250 from **s1** and 30 from **s2**. Calculate the normal vector of the object at that point.

(b) In practice, specular reflections, typically appearing as bright spots in an image, occur because objects are not perfectly matt. 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. If there is a specular reflection when the object is illuminated by light source **s1** and the specular component accounts for 40% of the light arriving at the pixel, compute the error in the [p, q] estimate at that point.

(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, and suggest a practical way of eliminating their effect.

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