UNIVERSITY OF LONDON

MSci EXAMINATION 2005

For Internal Students of

Royal Holloway

DO NOT TURN OVER UNTIL TOLD TO BEGIN

PH4760A: IMAGE ANALYSIS AND RECOGNITION

Time Allowed: **TWO AND A HALF** hours

Answer ***THREE QUESTIONS*** only

No credit will be given for attempting any further questions

Approximate part-marks for questions are given in the right-hand margin

Only CASIO fx85WA Calculators or CASIO fx85MS Calculators are permitted

PH4760A/30

2004-05

GENERAL PHYSICAL CONSTANTS

Permeability of vacuum	μ_0	=	$4\pi \times 10^{-7}$	H m^{-1}
Permittivity of vacuum	ε_0	=	8.85×10^{-12}	F m^{-1}
	$1/4\pi\varepsilon_0$	=	9.0×10^{9}	m F^{-1}
Speed of light in vacuum	c	=	3.00×10^{8}	m s^{-1}
Elementary charge	e	=	1.60×10^{-19}	C
Electron (rest) mass	m_e	=	9.11×10^{-31}	kg
Unified atomic mass constant	m_u	=	1.66×10^{-27}	kg
Proton rest mass	m_p	=	1.67×10^{-27}	kg
Neutron rest mass	m_n	=	1.67×10^{-27}	kg
Ratio of electronic charge to mass	e/m_e	=	1.76×10^{11}	C kg^{-1}
Planck constant	h	=	6.63×10^{-34}	J s
	$\hbar = h/2\pi$	=	1.05×10^{-34}	J s
Boltzmann constant	k	=	1.38×10^{-23}	J K^{-1}
Stefan-Boltzmann constant	σ	=	5.67×10^{-8}	W m^{-2} K^{-4}
Gas constant	R	=	8.31	J mol^{-1} K^{-1}
Avogadro constant	N_A	=	6.02×10^{23}	mol^{-1}
Gravitational constant	G	=	6.67×10^{-11}	N m^2 kg^{-2}
Acceleration due to gravity	g	=	9.81	m s^{-2}
Volume of one mole of an ideal gas at STP		=	2.24×10^{-2}	m^3
One standard atmosphere	P_0	=	1.01×10^{5}	N m^{-2}

MATHEMATICAL CONSTANTS

$e \cong 2.718$ $\pi \cong 3.142$ $\log_e 10 \cong 2.303$

TURN OVER

1. (a) What is template matching? Explain why it is useful to locate objects from their features rather than as whole objects. Explain also why 'inference' rather than deduction methods are needed to locate whole objects in this way. Give the names of two of the main relevant inference techniques, and state with what classes of features they are commonly used. **[5]**

(b) Describe the stages in the design of template matching methods for locating corners of objects in grey-scale images. You should explain clearly why zero-mean masks must be used for this purpose, and you should arrive at a complete set of masks for corner detection. **[4]**

(c) Template matching is also to be used for detecting edge segments, line segments and small holes. Obtain suitable masks for each of these cases, and contrast the number of masks needed in each case with the number needed for corner detection. **[5]**

(d) Why should the number of template matching masks needed for edge detection be different from the number of masks normally used for edge detection – e.g. using the Sobel operator? **[3]**

(e) Comment on the accuracy with which feature orientation can be achieved by template matching. How does it compare with the accuracy of the Sobel operator when estimating edge orientation? **[3]**

PART MARKS

2. (a) Outline the operation of the Hough transform approach to object location. Explain what its important characteristics are in comparison with (for example) the centroidal profile (r, θ) approach, and why these characteristics arise. **[4]**

(b) Describe how the Hough transform is applied to the location of circles of known radius. Explain how the method may be extended to search for circles of arbitrary radius. **[6]**

(c) A student who does not know the standard Hough transform method for locating circles develops the following method for locating circles of known radius R. When his algorithm locates any edge point, it places in parameter space a whole circle of votes of radius R centred at the edge point. Consider how well this method would work in practice, and how much computation it would require in comparison with the standard method. **[5]**

(d) Show that the diameter–bisection method for ellipse detection can be applied to locate circles of arbitrary size. Determine whether this approach would confer any advantages or disadvantages, in comparison with the extended version of the standard circle Hough transform you discussed in (b). Pay particular attention to the amount of computation required by, and the discriminatory power of, each method. **[5]**

3. (a) Give a basic one-pass algorithm for labelling and counting separate objects in binary images: the one-pass algorithm should use a normal forward scan over the image. Give examples of the types of object shape for which the algorithm would work: (i) straightforwardly with no errors; (ii) with errors that may be corrected by small amounts of further processing; (iii) with substantial numbers of errors that are best tackled by further data processing in a tabular format. **[8]**

(b) In a certain lace production line, it is important to check that the various pieces of lace are connected together in a large network, with no unattached pieces, such as the one appearing at the bottom of Figure 1. Show how the basic (forward scan) algorithm leads to considerable confusion in this case, but that a tabular method can overcome the problem systematically and give the correct result. (In this question, significant credit will be given for correctly setting up the initial table, and for a correct approach to the problem demonstrating the right principles.) **[9]**

(c) Consider how many iterations will be required to analyse the table in the general case where a maximum of n adjacent detachments can occur in any one row of lace threads. (In Figure 1, n has the value 2.) **[3]**

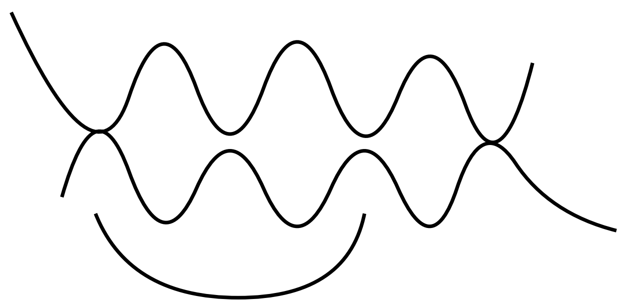

Figure 1. In this figure the various lines show threads of lace, all of which should be regarded as forming the initial binary objects.

PART MARKS

4. (a) Define the terms vergence, disparity D and baseline b for a binocular stereo system. Draw a ray diagram for a binocular vision system which is viewing a distant image point. Use your diagram to help derive the following equation for disparity: **[7]**

$$D = \frac{bf}{Z}$$

and explain the various parameters in the equation. Show how the equation allows an estimate to be made of the depth of the image point in the scene.

(b) Consider the accuracy with which the depth can be computed if the main source of inaccuracy results from lack of image resolution (i.e. an error of ±0.5 pixel arises in making any measurement from the image). By drawing clear diagrams for large and small baselines, show how the accuracy depends on b. **[4]**

(c) What are the main disadvantages of systems in which b is large? To what extent does the epipolar line approach to image matching overcome this problem? **[4]**

(d) A smooth unpatterned cylindrical chimney is viewed by a binocular vision system, which is able to locate vertical edges in the images. By drawing a clear ray diagram, show that distinct errors will arise in estimating the size and position of the chimney. An eagle with very sharp eyesight is able to see ants crawling up the chimney. How does this change the situation? **[5]**

PART MARKS

5. (a) Explain what is meant by an invariant. Illustrate you answer by considering the circularity parameter used in shape analysis. Under what conditions will a simple 'ratio of distances' parameter be of use when analysing shapes distorted by oblique viewing? **[4]**

(b) What is a cross ratio? Explain under what types of projection it can validly be applied. **[3]**

(c) Give the formula for the cross ratio of four points on a line. If the value of the cross ratio is κ for a given set of four points taken in a given order, determine its value when the numbering of the points is reversed (as could happen in a real image before interpretation). Does the result mean that an additional value of κ has to be remembered by the system? **[4]**

(d) Use clear diagrams to explain how the cross ratio concept can be applied in each of the following cases: **[6]**

(i) three collinear points and two points that are not collinear with the others.

(ii) two arbitrary lines and two points.

(iii) four concurrent lines (i.e. a pencil of four lines).

(iv) five arbitrary points in a plane.

(e) Consider whether any of these cases would require several values of κ to be remembered by the system, depending on the order in which the points or lines arose in any image. **[3]**

END