UNIVERSITY OF LONDON

MSci EXAMINATION 2006

For Internal Students of

Royal Holloway

<u>DO NOT TURN OVER UNTIL TOLD TO BEGIN</u>

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

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 a *texture*? State the main characteristics that are exhibited by textures. Describe to what extent these characteristics apply to: (i) a pile of sand, (ii) a fingerprint, and (iii) a bowl of spaghetti. **[4]**

(b) An *idempotent* operator f is one which, when applied several times, has the same effect as f: i.e. $f^p = f$, where p is an integer greater than 1. Give arguments (i) showing that dilation and erosion are *not* idempotent operators, and (ii) supporting the idea that opening and closing *are* idempotent operators. In this question, you should assume that the operators are applied to images containing a normal amount of structure. **[4]**

(c) Explain how 'error–reject tradeoff' can be used to reduce the error rate of a pattern classifier by placing 'difficult' patterns into a reject category. What problem results if attempts are made to reduce the error rate too far by this means? **[4]**

(d) A Bayes classifier is used to determine the classification probabilities $P(C_i | x)$ for a 2-class problem in a 1-dimensional feature space. Show, e.g. by a geometrical argument, that the minimum error rate occurs for the value of x at which the probabilities of the two classes are equal.
(*Hint:* start by sketching the two probability distributions, and then investigate those areas under the distributions that represent error rates for a typical decision threshold x_t.) **[4]**

(e) When attempting to measure the motions of objects between two successive frames (images) of an image sequence, the following formula summarises the various intensity changes between frames:

$$\partial I/\partial \mathrm{t} = -\nabla I.\mathbf{v}$$

where I represents intensity and $\mathbf{v}$ represents velocity.

Use this formula to explain where in the image the difference signal will be low, and where it will be high: give physical reasons underlying these results. **[4]**

PART MARKS

2. (a) What are the main features of the *Hough transform* approach to object location? Consider to what extent these vary between the cases of straight line and circle detection. **[4]**

(b) What are the main advantages of the Hough transform *vis-à-vis* standard template matching procedures? **[3]**

(c) A miniature surveillance aeroplane is to be tracked and intercepted. Its appearance takes the form of a concave symmetric quadrilateral, of the form shown in Figure 2. Its *location* is to be taken as the concave corner C and its *direction* by the axis AC. Go through all the steps needed to obtain the relevant three parameters by applying the standard straight line Hough transform to the whole image. **[8]**

(d) A learned professor says that approach (c) would be silly and that the operation of the algorithm could be made far faster by detecting the corners rather than the straight sides, and then using the maximal clique approach to identify the aeroplane. Consider whether this is a valid assessment of the situation, and whether it would give (i) better, (ii) equal, or (iii) worse robustness. **[5]**

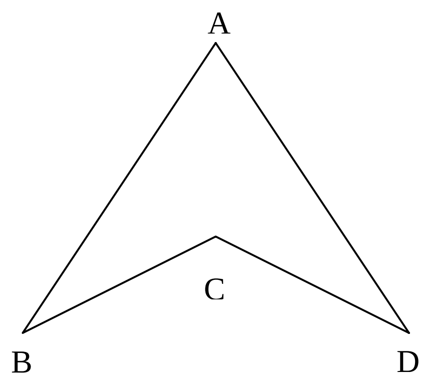

Figure 2

3. (a) Explain the value of a median filter when applied to grey-scale images. What advantages does it have relative to a mean filter, and why? **[3]**

(b) Give a basic median filter algorithm, and describe a *simple* means of speeding up its operation. **[3]**

(c) Show that it should be possible to speed up a median filter algorithm further by merely *updating* the local intensity histogram as the filter proceeds along each row of the image. *Ideally*, how much faster would such a technique work when applied in an $n \times n$ pixel window? Would this result apply for a small (e.g. 3×3) window? **[5]**

(d) *Outline* how an approximate mode filter may be designed, starting with a median filter algorithm. In what important way do its characteristics differ from those of a median filter? **[4]**

(e) The image of an obliquely viewed poster is transformed in order to eliminate perspective distortion. The algorithm that is used takes each original pixel intensity and copies it to the single most appropriate pixel location in the transformed image T. In the process, the intensities of many pixels in the new image are not decided, but an image mask M shows which locations these are.

Devise an algorithm *strategy* that takes the information from images T and M and produces a complete output image containing reasonable choices for the unfilled pixel intensities. If you wish, you may use median or mode filter algorithms as part of your new algorithm. **[5]**

PART MARKS

4. (a) What is the *correspondence problem* of binocular vision? Why is it important? Explain the extent to which it is overcome by the epipolar line technique. **[5]**

(b) By considering planes and their intersections, determine the exact location of the epipolar line E in the right image, corresponding to the point P in the left image. Show further that all points on E lead to the same epipolar line F in the left image. Finally, if there is no 'vergence', so that the two image planes lie in the same plane in space, show that lines E and F are exactly collinear. **[6]**

(c) A continuous path on a smooth convex surface is viewed by a binocular vision system. Show that the order of the points along this path appears the same to both eyes. **[2]**

(d) Assuming that *almost all* the feature points in a scene are seen by *both* eyes (a small number may appear too blurred to be discernable to one or other eye), show that moving simultaneously along the two epipolar lines E and F should permit extremely fast matching of the features along them. **[4]**

(e) In respect of (d), contrast the situation for observation of (i) print on a flat sheet of paper, and (ii) a human face in a close-up view. To what extent is the latter problem a 'worst case' situation? **[3]**

5. (a) What is the particular value of using invariants for analysing 2D perspective images of 3D scenes? **[3]**

(b) A commonly used 3D invariant is the cross ratio. State clearly under what conditions it may be applied. Explain briefly why *pairs* of cross ratios are sometimes found to be useful. **[3]**

(c) Give a formula for the cross ratio. Show that whatever the order of the points to which the formula is applied, very few cross-ratio values are possible. Why is it sometimes crucial to try all the possible values, yet on other occasions this is not necessary? **[7]**

(d) A vision sensor is to be designed to aid blind people by detecting any steps on paths composed of flagstones. Show how this may be achieved using cross ratios. Explain clearly the principles involved in your reasoning, with the aid of careful sketches of the assumed geometry. Estimate the image resolution (dimensions of the image in pixels) required to be sure of detecting any small step of height 5 cm: you should make reasonable approximations, such as viewing the region of the step when it appears 30° to 45° below the horizontal. **[7]**

END