EE322-6-AU

UNIVERSITY OF ESSEX

Undergraduate Examinations 2010

IMAGE PROCESSING

Time allowed: **TWO** hours

The following items are provided:
- Mathematical Data for Electronics
- Graph paper (available on invigilator's desk)

Candidates are permitted to bring into the examination room:
Hand-held, non-programmable calculators (containing no textual information).

Candidates must answer **QUESTION 1** in **SECTION A**
and **TWO** questions from **SECTION B.**

The paper consists of **FOUR** questions.

All questions are of equal weight.

The percentages shown in brackets provide an indication of the proportion of the total marks for a **QUESTION** which will be allocated.

SECTION A

Candidates must answer Question 1 in Section A.

Question 1

Candidates must answer any FOUR parts of Question 1.

(a) A photographer has captured a digital image but it shows very little contrast, except for a few pixels which are very bright. Explain what simple image processing technique could be used to improve the appearance of the image. [25%]

(b) Outline briefly the principles of the Moravec corner detector. [25%]

(c) What kind of feature is the convolution mask shown in Figure 1.1 good at detecting? [25%]

$$\begin{pmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

Figure 1.1

(d) The grid of numbers shown in Figure 1.2 represents part of an image. Where possible, calculate the resulting values when this part of the image is processed by a Laplacean operator. [25%]

1	1	1	1	1
1	5	1	-5	1
1	1	1	1	1

Figure 1.2

(e) An image processing system is being developed which takes into account experimental error at every stage. If the error associated with each pixel's value is ±0.5, what will be the error in each pixel after processing by a 5 × 5 blur? [25%]

(f) A computer vision application involves tracking objects which are moving in straight lines in 3D. It is found that an object moves from (86, 50) to (6, 90) in 12 frames. At what speed (in pixels/frame) is the object moving? [25%]

END OF SECTION A

SECTION B

Candidates must answer TWO questions from Section B.

Question 2

The process of following image features from frame to frame is known as *tracking*. There are several possible algorithms that can be used to perform tracking.

(a) Outline the tracking techniques known as *exhaustive search* and *gradient descent*. Discuss which is more likely to be useful for real-time processing. [30%]

(b) The performance of tracking can be improved by *prediction*. Explain what this means and how it can be used to improve tracking speed. What constraints does prediction place upon the motion of tracked objects? [20%]

(c) In a particular frame, an image feature being tracked is at (50, 100) and is moving to the right, in the $+x$ direction, at a rate of 50 pixels / frame. The top left-hand corner of the image is (0, 0). What will be its position in the next frame if its motion is assumed to be in a straight line? If the true motion of the feature is clockwise in a circle of 100 pixels radius around the point (50, 200) at a rate of 30°/frame, how accurate is this prediction? [20%]

(d) In a set of experiments, the prediction used in (c) was found to be adequate for tracking to work using gradient descent. However, when the feature was rotated at a higher speed, tracking failed. Explain why this might occur and hence identify a potential deficiency of gradient descent tracking using prediction. [30%]

Question 3

A mobile robot is constructed with a pair of identical cameras of focal length f = 50 mm mounted on the corners of the front of the vehicle. The cameras are oriented so that their optical axes are perfectly parallel, separated by a distance B = 100 mm, and point directly ahead. The robot is stationary and both cameras observe an object travelling towards the robot.

(a) With the aid of a diagram, show how one can calculate the distance of a point using the expression [50%]

$$Z = \frac{fB}{x_L - x_R}$$

where x_L and x_R are the positions of the object in the left and right images respectively.

(b) If the values of x_L and x_R in successive frames are as shown in Table 3.1, calculate using the expression derived in (a) the distance of the object in these frames. [30%]

Frame	$\boldsymbol{x_L}$	$\boldsymbol{x_R}$
0	100	88
1	68	52
2	25	-3

Table 3.1

(c) Hence, determine whether the object is moving in a straight line. [20%]

Question 4

Convolution is a common operation in computer vision.

(a) Explain how the process of convolution with a mask is performed. [20%]

(b) The grid of numbers in Figure 4.1 represents a binary image. Without performing cyclic wrap-around at the edges, convolve the image with a 3×3 blur mask, calculating the maximum at each pixel — a 'maximum' operator. Describe what has happened to the regions in this image. [20%]

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

Figure 4.1

(c) Perform a convolution on the result of (b), this time using a 3×3 mask and calculating the minimum at each pixel — a 'minimum' operator. How does this result compare with the result from (b) and the original image? [30%]

(d) Using your experience in (b) and (c), where you calculated *maximum–minimum*, predict what would happen if you were to calculate *minimum–maximum*. Note that you do not have to calculate the result. [30%]

END OF SECTION B

END OF PAPER EE322-6-AU