UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2002/2003

September 2002

CCS504 – Computer Vision and Image Processing

Duration : 3 hours

INSTRUCTION TO CANDIDATE:

- Please ensure that this examination paper contains **SIX** questions in **SEVEN** printed pages before you start the examination.
- Answer any **FIVE (5)** questions.
- You can choose to answer either in Bahasa Malaysia or English.

ENGLISH VERSION OF THE QUESTION PAPER

1. (a) In the process of converting analog images to digital images, to eliminate loss of information due to sampling, the sampling rate needs to be chosen appropriately. Describe the concept of Shannon's theorem on sampling rate.

(5 marks)

(b) An 8x8 chess board image is to be digitized unambiguously. Show that 64 samples are insufficient. What is the minimum number of samples necessary?

(5 marks)

(c) Quadtree is a data structure for 2D image representation. It is constructed by dividing an image into four quadrants at each hierarchical level. Compute the quadtree of the image shown in Figure 1.

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

Figure 1

(7 marks)

(d) Describe one application in image processing or analysis where you think that quadtree representation is an advantage.

(3 marks)

2. (a) (i) What does histogram equalization do and what effect is it designed to have on an image?

(4 marks)

(ii) Imagine a 64x64 image with 4 grey levels. The normalized grey levels are 0, 1/3, 2/3, 1. Suppose the image distribution is as given in Table 1.

Table 1

Grey level	Number of pixels	Probability of occurrence
0	1813	0.44
1/3	1506	0.37
2/3	574	0.14
1	303	0.05

- Draw the histogram of the image, mapping the normalized grey level against the probability of occurrence.
- Apply histogram equalisation transformation to determine the equalized histogram.

  (Note: You may assume an ideal case.)
- Draw the equalized histogram.

(4 marks)

(b) The following very useful operator is often applied to an image *I(x,y)* in computer vision algorithms, to generate a related "image" *g(x,y)*:

$$g(x,y) = \int_{\alpha}\int_{\beta} \nabla^2 e^{-((x-\alpha)^2+(y-\beta)^2)/\sigma^2} I(\alpha,\beta)\, d\alpha\, d\beta$$

where

$$\nabla^2 = \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)$$

(i) Give the general name for this type of mathematical operator, and the chief purpose that it serves in computer vision.

(4 marks)

(ii) What image properties should correspond to the zeroes of the equation, i.e. those points (x, y) in the image I(x, y) where the above result g(x, y) = 0?

(4 marks)

(iii) What is the significance of the parameter σ? If you increased its value, would there be more or fewer points (x, y) at which $g(x, y) = 0$?

(4 marks)

3. (a) Explain the principles of and the differences among the three basic approaches to region growing – merging, splitting, and split and merge.

(12 marks)

(b) The image below (Figure 2) is from an MR scan through a person's head. Suggest one computational method for locating the outer boundaries of the dark central shapes (arrowed), starting from the grey-level image. You may assume that you are given an initial approximate position for the shapes.

Note: *You may describe your method conceptually. Detailed algorithmic steps are not required.*

Hint: *You may use a combination of algorithms, if necessary, to achieve the objective.*

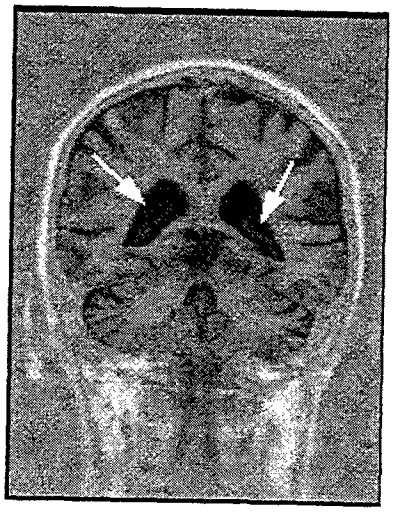

Figure 2

(8 marks)

4. (a) Describe the concept of adaptive thresholding.

(6 marks)

(b) Explain any one type of adaptive thresholding methods you are familiar with.

(6 marks)

(c) For the image and its histogram in Figure 3, suggest a suitable method of segmentation and justify why your suggestion would be the best choice.

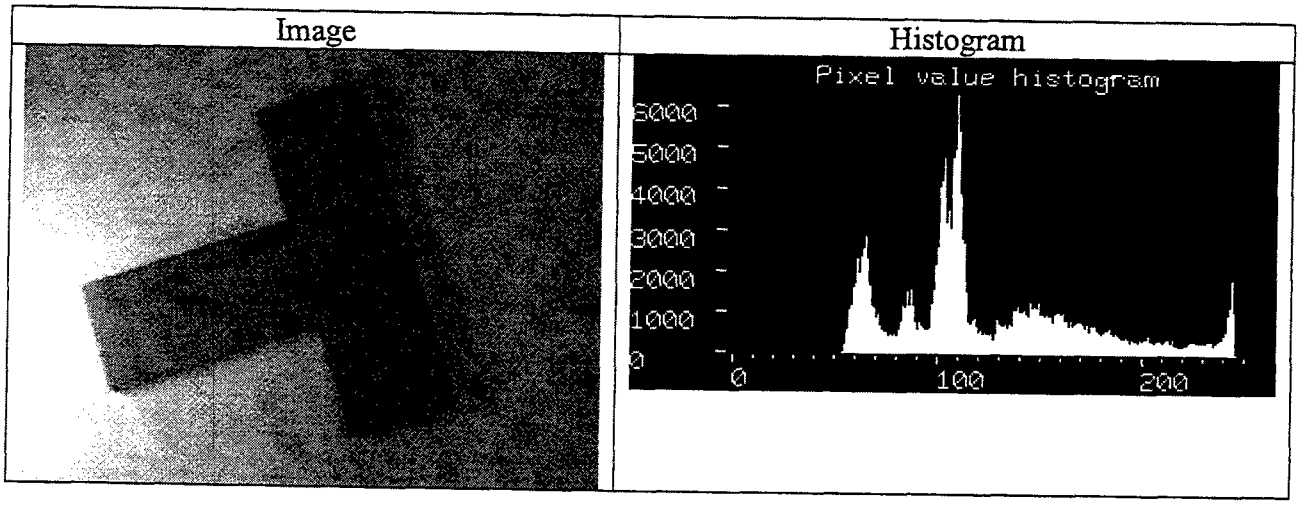

Figure 3

(8 marks)

5. (a) Define the *dilation* and *erosion* of an object A by a structuring element B.

(4 marks)

(b) Sketch the dilation and erosion of the object labelled A in the figure below, using the structuring element shown. Note that the centre of the binary structuring element B is given by the darker pixel.

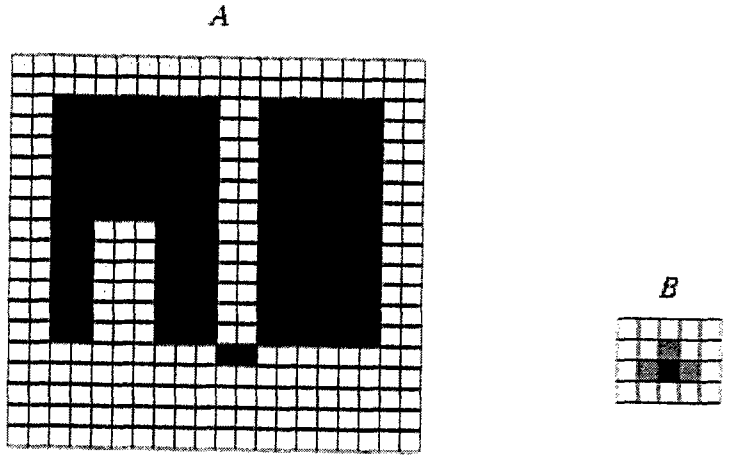

Figure 4

(8 marks)

(c) Morphological opening and closing may be explained, briefly, as follows:

Opening:

- All pixels which can be covered by the structuring element with the structuring element being entirely within the foreground region will be preserved.
- However, all foreground pixels which cannot be reached by the structuring element without parts of it moving out of the foreground region will be eroded away.

Closing:

- For any background boundary point, if the structuring element can be made to touch that point, without any part of the element being inside a foreground region, then that point remains background.
- If this is not possible, then the pixel is set to foreground.

With this understanding, consider the image shown in Figure 5. What will the morphological operations of opening followed by closing, do to this image? Sketch the results of each successive dilation/erosion steps of the opening and closing operation.

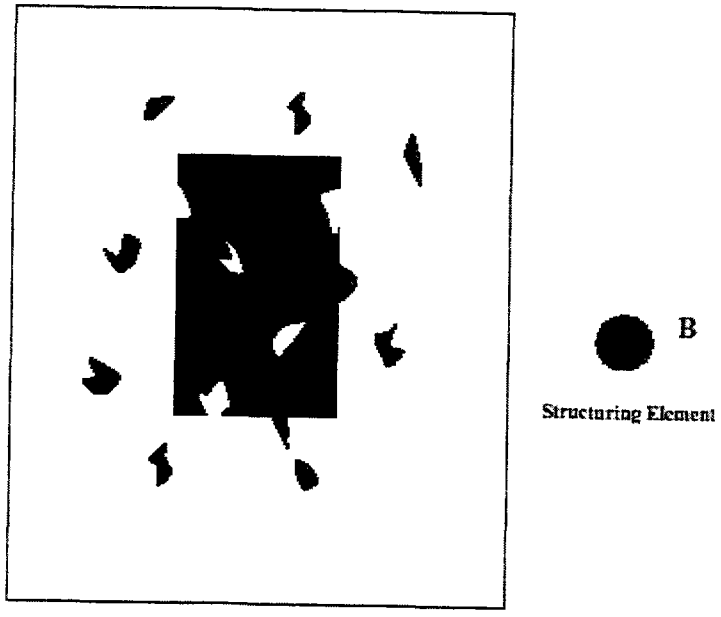

Figure 5

Note: Consider the black regions as the object regions.

(8 marks)

6. (a) Explain the following in detail:

(i) Any one type of boundary descriptor.

(ii) Any **two (2)** types of region descriptors.

(8 marks)

(b) A local hardware store wishes to install an automatic system for sorting a number of small items. Below is a typical image of all the possible items. Images may be captured from any distance, and contain only one of these items. Individual algorithms may be written each object. Describe the algorithms you would implement to recognise any four of these objects.

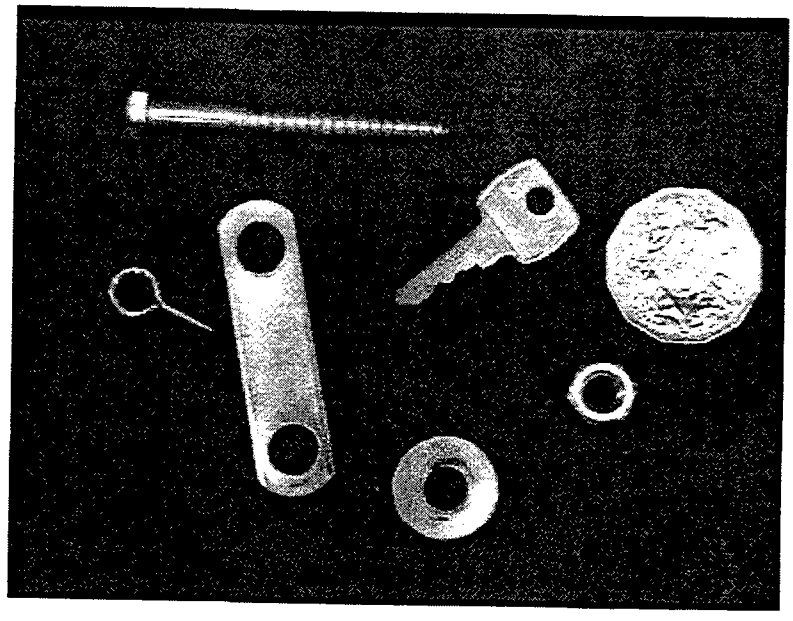

Figure 6

Note: You may write 4 independent algorithms, one for each object. Each of these algorithms may utilize suitable object descriptors. Note that you are required only to describe the algorithm briefly, and detailed codes are not necessary.

(12 marks)

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