UNIVERSITY OF ESSEX

Undergraduate Examinations 2012

Computer Vision

Time allowed: **TWO** hours

Candidates are permitted to bring into the examination room:

Calculators (hand-held, containing no textual information)

The following items are provided:

Graph paper (available on the invigilator's desk)

The paper consists of **FIVE** questions.

Candidates must answer **Question 1** in **Section A** and **three** questions in **Section B**.

All questions are of equal weight.

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

SECTION A

Candidates must answer ALL questions in Section A.

Question 1

(a) A common image processing technique is histogram equalisation. Describe briefly how the technique works and what it is good for. **[5%]**

(b) You have been asked to advise on the development of an application that centres around the accurate detection of corners in images. The developers are considering supporting the BMP, JPEG, PNG and TIFF image formats. Discuss which of these should be supported, and explain why any of them should not. **[5%]**

(c) The correlation coefficient is one way of assessing the similarity of a pair of images. Why is it a better measure than the difference between the two images? **[5%]**

(d) The grid of numbers in Figure 1.1 represents part of an image.

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

Figure 1.1

What mask could be used to emphasise the feature in the middle of the region in Figure 1.1? Justify your answer. **[5%]**

(e) What is a good definition for the signal-to-noise ratio of an image? Explain how this leads to a practical way of measuring the signal-to-noise ratio in terms of the correlation coefficient between two images of the same scene. **[5%]**

END OF SECTION A

SECTION B

Candidates must answer THREE questions from Section B.

Question 2

(a) What is edge detection in computer vision? Why is it so widely used? **[5%]**

(b) The operator due to John Canny is widely used for detecting edges. Describe the major stages of this operator. **[10%]**

(c) The Sobel edge detector involves calculating the responses with two 3×3 masks

$$H = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \quad \text{and} \quad V = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ 11 & 0 & 1 \end{pmatrix}$$

and then calculating $|H| + |V|$ as the overall response of a pixel. A particular computer performs arithmetic and logical operations at the same speed, 200 million operations per second.

If an implementation of the Canny operator on this computer involves 45 operations per pixel, will it be possible to use Sobel or Canny at 10 frames/second on images containing 720×576 pixels? **[10%]**

Question 3

A mobile robot is equipped with cameras at its front two corners; a schematic plan view is shown in Figure 3.1. Two identical cameras of focal length f are arranged so that their optical axes are perfectly parallel and separated by a distance B.

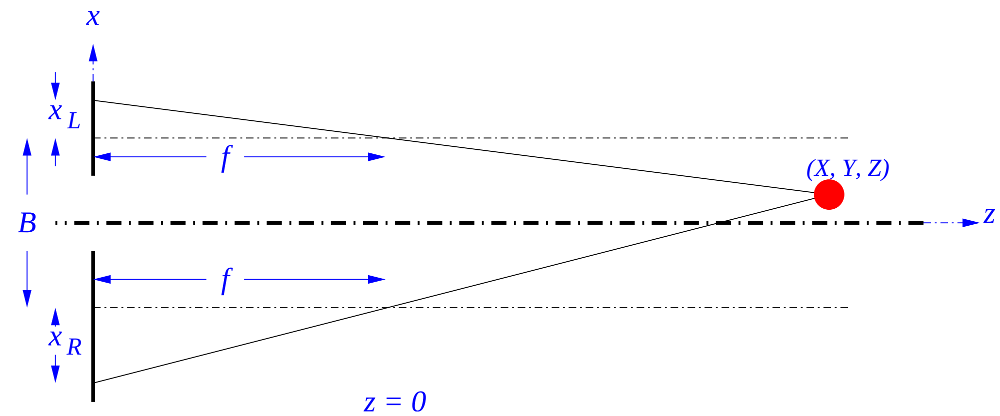

Figure 3.1

(a) Show that the distance Z to an object visible in both camera images is given by:

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

where x_L and x_R are the x-locations of the object in the left and right images respectively. **[10%]**

(b) In the case where $B = (95 \pm 1)$ mm, $f = (50 \pm 0.1)$ mm, $x_L = (10 \pm 0.5)$ mm and $x_R = (-10 \pm 0.5)$ mm, Calculate the distance Z to the object and its error. **[10%]**

(c) If a second pair of images were taken and it was found that $x_L = (8 \pm 0.5)$ mm and $x_R = (-8 \pm 0.5)$ mm, what can you infer about the motion of the object? **[5%]**

Question 4

(a) What is the histogram of an image? Explain how the histogram can be used to assess how well an image has been captured. **[5%]**

(b) Figure 4.1 shows an image captured from an infra-red sensor capable of detecting only 16×16 pixels with only 16 grey levels. From the image, determine the values that would be used to produce a histogram and plot it.

1	5	10	10	9	8	9	7	4	3
2	4	10	11	10	6	5	4	3	3
4	2	12	13	11	5	7	5	2	0
5	5	8	6	7	6	9	8	3	0
8	6	10	10	7	9	11	8	5	0
10	15	12	11	10	9	8	7	4	3
12	15	14	12	9	8	9	7	4	3
13	13	12	10	10	10	9	8	7	6
10	11	10	9	7	5	9	6	2	1

Figure 4.1

[10%]

(c) Explain briefly how histograms could be used to identify images in an image database similar to a user-provided example image. How effective is this likely to be? Can you suggest a better approach than using histograms? **[10%]**

Question 5

(a) A downward-looking video camera is attached to an autonomous aerial vehicle. Given that rotation $\mathbf{R}$, scaling $\mathbf{S}$ and translation T are given by

$$\mathbf{R} = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}, \mathbf{S} = \begin{pmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{pmatrix}, \mathbf{T} = \begin{pmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{pmatrix}$$

show that the result of a rotation of θ around (x_c, y_c) followed by a scaling of (S_x, S_y) followed by a translation through (t_x, t_y) is given by

$$s(x - x_c)\cos\theta - s(y - y_c)\sin\theta + t_x$$
$$s(x - x_c)\sin\theta + s(y - y_c)\cos\theta + t_y$$

[13%]

(b) Explain how these equations can be used in a practical system for aligning successive frames in a video sequence captured by the unmanned autonomous aircraft. **[12%]**

END OF SECTION B

END OF PAPER CE316-6-AU