CE316-6-AU

UNIVERSITY OF ESSEX

Undergraduate Examinations 2016

COMPUTER VISION

Time allowed: **TWO** hours

Candidates are permitted to bring into the examination room:

Calculator — Casio FX–83GT PLUS or Casio FX–85GT PLUS **only**

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.

Please do not leave your seat unless you are given permission by an invigilator.
Do not communicate in any way with any other candidate in the examination room.
Do not open the question paper until told to do so.
All answers must be written in the answer book(s) provided.
All rough work must be written in the answer book(s) provided. A line should be drawn through any rough work to indicate to the examiner that it is not part of the work to be marked.
At the end of the examination, remain seated until your answer book(s) have been collected and you have been told you may leave.

SECTION A

Candidates must answer ALL questions in Section A.

Question 1

(a) Sketch a histogram of the 4-bit image shown in Figure A1.1. From it, determine whether it is under-exposed, over-exposed, or well-exposed. **[5%]**

7	11	9	4	10	6	10	7	7	9
7	6	6	10	10	7	9	8	7	5
6	8	8	7	7	7	5	9	12	8
9	7	10	8	5	13	6	10	9	9
7	7	10	6	9	6	4	8	5	5
11	5	6	9	9	7	7	9	9	9
10	6	7	7	7	8	9	3	5	8
8	7	9	8	4	9	8	6	5	5
9	9	8	7	9	6	7	8	6	11
4	9	6	7	7	8	5	8	5	6

Figure A1.1

(b) What kind of feature is the following convolution mask good at detecting? **[5%]**

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

(c) A sphere of known diameter is placed in a scene and imaged by a vision system. Discuss briefly whether one can determine the distance to the sphere from a single image, or whether one must have a stereo vision system in order to determine its distance. If a single image is enough, state what ancillary data would be needed. **[5%]**

(d) Outline briefly the major stages in John Canny's edge detector. **[5%]**

(e) A computer vision application involves tracking objects that are moving in straight lines. It is found that an object moves from $(216, 51)$ to $(7, 390)$ in 14 frames. At what speed (in pixels/frame) is the object moving? **[5%]**

END OF SECTION A

SECTION B

Candidates must answer THREE questions in Section B.

Question 2

(a) What is the *integral image* representation of an image? What is the advantage of using the representation? **[8%]**

(b) Write in pseudo-code a routine that takes an image indexed by (x, y), $f(x, y)$, and returns the corresponding integral image I. You may use the expression below to help you. **[10%]**

$$I(x, y) = f(x, y) + I(x - 1, y) + I(x, y - 1) - I(x - 1, y - 1)$$

(c) Using the following image as input, work out the corresponding integral image. **[7%]**

4	1	2	2
0	4	1	3
3	1	0	4
2	1	3	2

Question 3

(a) A software developer is developing a security system for laptops which uses face recognition to authenticate the user. Describe briefly how face recognition systems work. **[7%]**

(b) Two candidate face recognition algorithms are evaluated on the same face dataset and the false and true positive rates shown in Table B3.1 are obtained as a threshold is varied. Draw the receiver operating characteristic (ROC) curves for the two algorithms on the same axes. **[10%]**

false positive rate	true positive rate (algorithm A)	true positive rate (algorithm B)
0.17	0.47	0.58
0.33	0.61	0.72
0.50	0.82	0.74
0.67	0.92	0.80
0.83	0.97	0.82
0.95	0.98	0.86

Table B3.1

Hence explain which algorithm would be the more appropriate for the task.

(c) Describe any shortcomings of this security system. **[8%]**

Question 4

(a) Explain how the process of convolution with a mask is performed. **[5%]**

(b) What are the advantages of using the median instead of the mean when performing convolution? **[5%]**

(c) The grid of numbers in Figure B4.1 represents an image. **[10%]**

1	1	1	1	1	1
1	1	1	5	1	1
1	1	1	5	5	1
1	5	1	1	1	1
1	1	1	1	1	1

Figure B4.1

Calculate the result of applying a 3×3 blur to this image using both the mean and the median. Interpret your result in light of the advantages you presented in (b).

(d) If the median were replaced by the minimum value, what would be the result of the convolution operation? (You do not have to calculate the result, just indicate what the effect will be.) **[5%]**

Question 5

An autonomous spacecraft is being developed to deliver supplies from the ground to the International Space Station. The spacecraft is equipped with a pair of cameras to help the docking process, using a target consisting of concentric circles to help the incoming spacecraft.

(a) Describe briefly a way that allows the centre of the docking target to be located. **[5%]**

(b) If the positions of the centre of the docking target in the image from the left- and right-hand cameras are x_L and x_R, derive an expression that allows the distance Z to the target to be determined. State any assumptions you have made. **[12%]**

(c) The focal length of the cameras is (400 ± 0.4) mm and they are separated by (500 ± 2) mm. At some point during the approach, the target is at $x_L = 100$ mm and $x_R = 88$ mm. Determine the distance to the target and its error. **[8%]**

END OF PAPER CE316-6-AU