King's College London

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

Degree Programmes	BSc, MSci
Module Code	6CCS3COV
Module Title	Computer Vision
Examination Period	January 2016 (Period 1)
Time Allowed	Three hours
Rubric	ANSWER QUESTION ONE AND ANY THREE OTHER QUESTIONS. All questions carry equal marks. If more than three questions other than Question One are answered, clearly indicate which answers you would like to be marked. Write this clearly in the dedicated section on the front page of the answer booklet. If you do not indicate which questions you would like to be marked, Question One and the first three subsequent questions answered, in exam paper order, will be marked.
Calculators	Calculators may be used. The following models are permitted: Casio fx83 / Casio fx85.
Notes	Books, notes or other written material may not be brought into this examination

PLEASE DO NOT REMOVE THIS PAPER FROM THE EXAMINATION ROOM

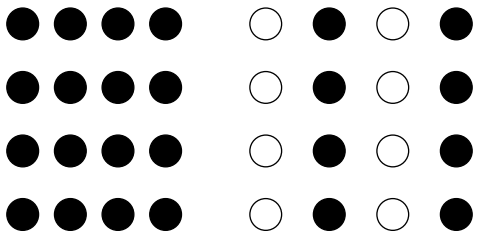
1. Compulsory question

a. What is the correspondence problem? Describe one way in which the correspondence problem is similar for stereo vision and video streams, and one way in which it is different.

[6 marks]

b. For the two following images, describe the grouping that you observe, and the Gestalt Law that leads to that grouping.

[4 marks]



(a) (b)

c. Give an example of the way in which computer vision is an "ill-posed" problem. What is the practical consequence of this issue?

[5 marks]

d. What is the result of the convolution of mask H with image I?

$$H = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad I = \begin{bmatrix} 0 & 0.5 & 0.5 & 0 & 0 \\ 0 & 1 & 0 & 0.5 & 0 \\ 0 & 1 & 1 & 0 & 0.5 \\ 0 & 0 & 1 & 1 & 0 \end{bmatrix}$$

The result should be an image that is the same size as I.

[5 marks]

QUESTION 1 CONTINUES ON NEXT PAGE

SEE NEXT PAGE

e. What is the Lateral Geniculate Nucleus, and what role does it play in the human visual system?

[5 marks]

2.

a. What is a "centre-surround receptive field" and what does it detect?

[5 marks]

b. Explain how ganglion cells in the eye and simple cells in the primary visual cortex (V1) work together to detect edges.

[10 marks]

c. Give an example of the function of complex cells in the primary visual cortex (V1).

[5 marks]

d. Describe how lateral connections in the primary visual cortex (V1) can explain some of the Gestalt laws.

[5 marks]

3.

a. One approach to image recognition is template matching. Describe briefly in words, or using pseudocode, each step required to perform template matching on an image.

[5 marks]

b. Here is a template T and an image I.

$$T = \begin{bmatrix} 250 & 200 & 250 \\ 200 & 50 & 150 \\ 200 & 150 & 100 \end{bmatrix} \qquad I = \begin{bmatrix} 50 & 150 & 150 & 200 \\ 100 & 200 & 50 & 50 \\ 50 & 100 & 100 & 150 \\ 50 & 50 & 50 & 100 \end{bmatrix}$$

Calculate the result of performing template matching on the image using sum of absolute differences (SAD) as the similarity measure.

Assuming that the image contains exactly one instance of the object in the template, suggest the location of the centre of the object in the image.

[10 marks]

c. A computer vision system uses template matching to perform object recognition.

i. The system needs to detect 20 different objects each of which can be seen from 10 different viewpoints. How many templates will be required? Why?

[4 marks]

ii. If each template is 9 pixels by 9 pixels, an image is 300 pixels by 200 pixels, and comparisons are done using sum of absolute differences, how many floating point operations are required to process one image?

[6 marks]

4.

a. Explain the effect of convolving an image with the box mask:

$$\begin{bmatrix} 0.04 & 0.04 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.04 & 0.04 \end{bmatrix}$$

[4 marks]

b. Write down a difference mask, and explain the effect of convolving an image with that mask. Contrast your answer with the your answer to Question 4.a.

[6 marks]

c. A Laplacian mask can be thought of as a combination of several difference masks.

i. Write down a 3 by 3 Laplacian mask and describe the effect of convolving an image with a Laplacian mask?

[6 marks]

ii. Write down one advantage and one disadvantage of using a Laplacian mask to process an image.

[4 marks]

iii. How can the disadvantage you gave in your answer to Question 4.c.ii be mitigated?

[5 marks]

5.

a. In mid-level vision, what do the terms "grouping" and "segmentation" mean?

[4 marks]

b. One approach to segmentation is region splitting and merging. Describe briefly in words, or using pseudocode, each step required to perform segmentation by region splitting and merging.

[7 marks]

c. The array below gives the feature vectors for each pixel in a 4×4 image:

$$\begin{bmatrix} (20,10) & (20,15) & (5,15) & (5,10) \\ (15,10) & (15,15) & (10,15) & (5,10) \\ (10,15) & (10,5) & (15,10) & (15,15) \\ (10,15) & (10,5) & (15,15) & (15,10) \end{bmatrix}$$

Use region splitting and merging to assign each pixel to a region under the assumptions that (1) Euclidian distance is used as the method to assess similarity between regions; (2) the threshold for deciding that regions are similar is 9; (3) regions have horizontal, vertical and diagonal neighbours.

[12 marks]

d. Give one weakness of region splitting and merging for segmentation.

[2 marks]

6.

a. Explain how a CCD camera forms an RGB image.

[5 marks]

b. Given an RGB image, how would you create a greyscale image from it? Your answer should explain how the computation is carried out, it should not just give the relevant MATLAB command.

[3 marks]

c. The raw output from a CCD device is the array of values below:

G11	R12	G13	R14	G15
B21	G22	B23	G24	B25
G31	R32	G33	R34	G35
B41	G42	B43	G44	B45
G51	R52	G53	R54	G55

where R12, R14 and so on are red values; G11, G13 and so on are green values; and B21, B23 and so on are blue values.

Describe how to compute red, green and blue values for each array element, and comment on how well you think the method you describe will approximate the input to the CCD.

[5 marks]

QUESTION 6 CONTINUES ON NEXT PAGE

SEE NEXT PAGE

d. A point in 3D space has coordinates [20,20,600] mm relative to the camera reference frame. If the image principal point is at coordinates [250,150] pixels, and the magnification factors in the x and y directions are 800 and 600, then determine the location of the point in the image. Assume that the camera does not suffer from skew or any other defect.

[8 marks]

e. How do the coordinates of the image change if the object moves to the location [20,20,900]?

[4 marks]