SEMESTER 1 EXAMINATION 2019 - 2020

COMPUTER VISION (MSC)

DURATION 120 MINS (2 Hours)

This paper contains 6 questions

Answer **THREE** questions. You are advised to spend no longer than 40 minutes per question.

An outline marking scheme is shown in brackets to the right of each question.

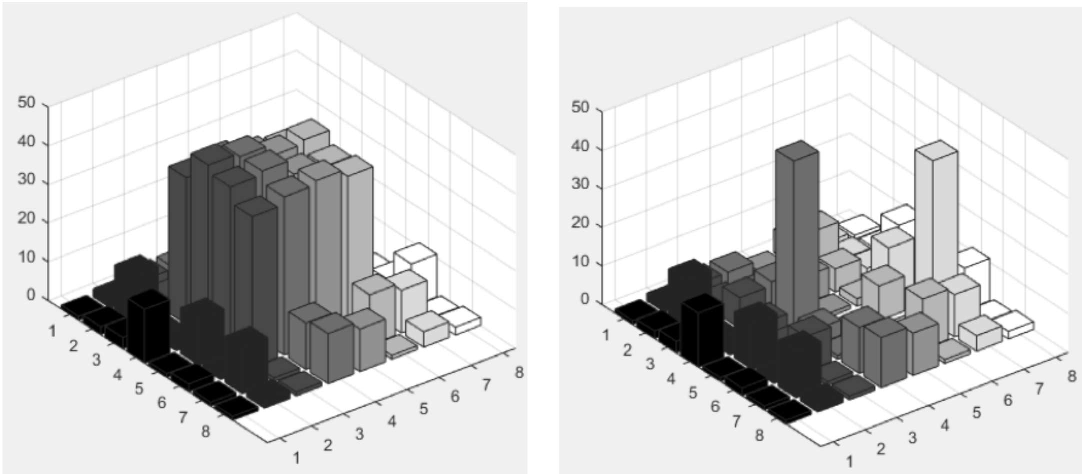
Each question is worth 33 marks. A maximum of 99 marks is available for the paper.

University approved calculators MAY be used.

A foreign language dictionary is permitted ONLY IF it is a paper version of a direct Word to Word translation dictionary AND it contains no notes, additions or annotations.

8 page examination paper.

Question 1.



(a) (b)

FIGURE 1

(a) **Describe** how *template convolution* can be used to apply group operators in image analysis. In particular describe issues concerning *borders* and *speed of operation* and how they can be solved.

[11 marks]

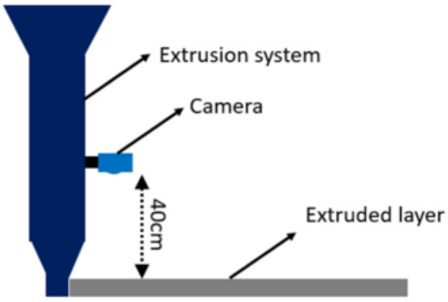
(b) For the images of Figure 1, **describe** the effects of *averaging* and *median* filtering and any differences between application of the two operators. **Describe** how each operator can be *speeded up* in implementation.

[14 marks]

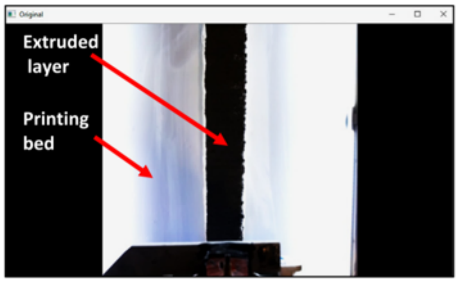
(c) For a 3×3 template, by analysing the *difference* between *direct averaging* and *Gaussian filtering*, **determine** an expression which shows the difference between the two operators. **Describe** which *components* of an image you expect this difference to affect most.

[8 marks]

Question 2.



(a) Arrangement of extrusion system



(b) Image viewed by camera showing printing bed and extruded layer

FIGURE 2: Extrusion System
(Kazemian, A., Yuan, X., Davtalab, O. and Khoshnevis, B., 2019. Computer vision for real-time extrusion quality monitoring and control in robotic construction. Automation in Construction, 101, pp. 92-98)

A manufacturer's extrusion system, illustrated in Figure 2(a), produces a layer of material of controlled width on a printing bed. The printing bed moves at a speed of 0.1 m/s. The width of the layer is to be checked by using computer vision techniques, aiming for a width that is within 99.5% of the specified width of 0.1 m. An example image viewed by the camera is shown in Figure 2(b).

Describe how this *inspection system* can be achieved using a computer vision system, providing a signal indicating that the width is within the specified tolerance. **State** any *advantages* and/or *disadvantages* of the system you propose. [33 marks]

TURN OVER

Question 3.

(a) **Provide** pseudocode for an implementation of template matching that is invariant to the position of the shape to be detected. **Outline** (i.e. describe briefly) how your approach to be extended to include *rotation*- and *scale-invariance*

[10 marks]

(b) **Provide** pseudocode for an implementation of the *Hough Transform* (HT) for lines. *Describe* how your technique could be extended to determine the *start*- and *end-points* of a detected line.

[14 marks]

(c) For an $m \times m$ template and an $N \times N$ image where N is the number of points, if the computational cost of the Fast Fourier transform is $N \log_2 N$ **determine** the *maximum* cost of

(i) template matching;

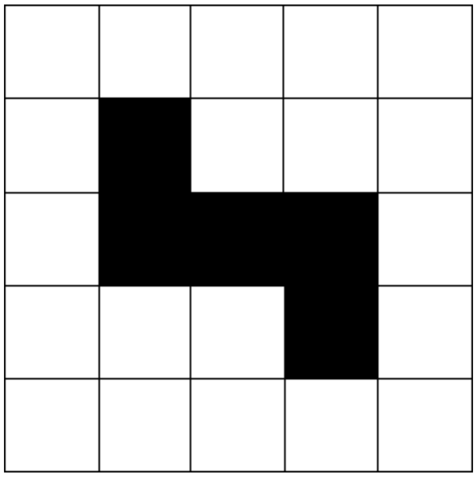
(ii) template matching implemented by using by the Fourier transform; and

(iii) the HT for lines.

[9 marks]

Question 4.

(a) Hu's first invariant moment is given by $M1 = \eta_{20} + \eta_{02}$. Considering the *connected component* depicted by the solid black pixels below, **calculate** the value of $M1$. **Ensure** you show all working.



[14 marks]

(b) **Prove** that the central moments μ_{01} and μ_{10} are not useful as descriptors.

[6 marks]

(c) **Describe** in detail the process of creating a *Point Distribution Model* to describe the shape of a human face.

[13 marks]

Question 5.

This question refers to the following representation of a black and white image.

0.0	0.0	0.0	0.0	0.0
0.0	1.0	1.0	1.0	0.0
0.0	1.0	1.0	1.0	0.0
0.0	1.0	1.0	1.0	0.0
0.0	0.0	0.0	0.0	0.0

FIGURE 3: Image I. Numbers indicate pixel values.

(a) The following is a 3x3 approximation of a Gaussian Kernel:

$$K = \frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Showing your working, **calculate** the difference-of-Gaussian response at the *centre pixel* of the image obtained by computing $((I * K) * K) - (I * K)$. *Hint:* you only need to consider values that contribute to the result when computing the convolution.

[12 marks]

(b) Briefly **explain** the notion of a Gaussian Scale Space. **State** why finding extrema in a difference of Gaussian scale space is useful.

[5 marks]

(c) Briefly **describe** how you might create Visual Words from interest points found with a *difference of Gaussian*.

[5 marks]

(d) **Describe** how you might use Visual-Word representations to create a system for searching large numbers of images. **Relate** your answer to the techniques used for efficient text indexing and search.

[11 marks]

Question 6.

FIGURE 4: An x-ray image of the Tibia Plateau in a right leg.

In medical image analysis it can often be useful to align (or 'register') different images of the same body part taken at different times. Considering the x-ray image shown in Figure 4, **describe** how you would design an algorithm to align a pair of x-ray images. You can *assume* that the images are created in such a way that they are related through a planar homography.

Be sure to **demonstrate** understanding of each part of your approach in detail, using pseudo-code and diagrams as necessary. [33 marks]

END OF PAPER

