SEMESTER 1 EXAMINATION 2018 - 2019

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.

7 page examination paper.

**Question 1.**


(A) Reference image


(B) Library image

FIGURE 1: Images of book covers

A library system is required to match an image of a book cover to a reference image (or template) stored in the library database. In the library, a user places the book face-up on a surface beneath a camera, and so the cover appears in the manner of that shown for a well-known book in Figure 1.

A computer vision system is required to match these images. **Describe** how this can be achieved, using a *selection* of computer vision approaches. **Address** whether *colour* could be used within the system, to take advantage of the delightful green and yellow colours that some books like this enjoy. **Describe** any likely *limitations* to the systems you describe.

[33 marks]

**Question 2.**

(a) In terms of core principles, **describe** the *advantages* and *disadvantages* of *edge detection* as a stage in a computer vision system.

[10 marks]

(b) **Design** an operator that can detect *circular edges* in images.

[17 marks]

(c) **Discuss** the *advantages* and *limitations* of your approach to circular edge detection.

[6 marks]

**Question 3.**

(a) **Describe** why the *Fourier transform* is important in image analysis.

[10 marks]

(b) Given a *shift* $\tau$ of an image along the $x$ axis, then the Fourier transform of an image $\mathcal{F}$ is

$$\mathcal{F}\left[P(x-\tau,y)\right] = e^{-j\omega_x\tau}P(\omega_x,\omega_y)$$

(i) **Explain** all the symbols used and **show** that the *magnitude* of the Fourier transform is shift invariant; and

(ii) **Show** by way of example how the Fourier transform of an image will *rotate* when the *image* itself is *rotated*.

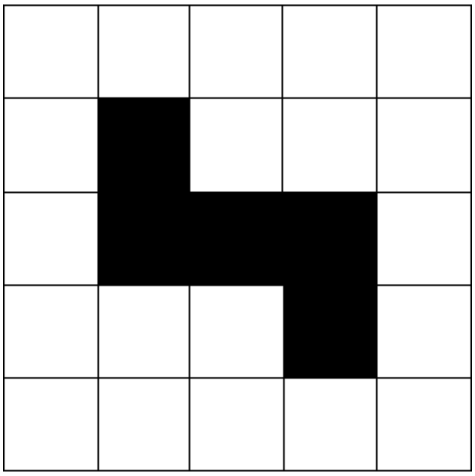
[17 marks]

(c) **Describe** the importance of the *invariance properties* of the Fourier transform, in the automated analysis of cloth and fingerprints.

[6 marks]

**Question 4.**

(a) Consider the *connected component* depicted by the solid black pixels below:



Ensuring you show all working, **compute** the *central moments* $\mu_{11}$, $\mu_{20}$ and $\mu_{02}$.

[11 marks]

(b) **Show** why the central moments $\mu_{01}$ and $\mu_{10}$ are not useful as *descriptors*.

[4 marks]

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

[12 marks]

(d) **Describe** how you would turn a *Point Distribution Model* into an *Active Appearance Model* or *Constrained Local Model*.

[6 marks]

**TURN OVER**

**Question 5.**

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

| | | | | |
|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| 0.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |

FIGURE 2: Image $I$. Numbers indicate pixel values.

(a) **State** the two *kernels* used for the $3 \times 3$ Sobel operator. **Compute** the $3 \times 3$ horizontal and vertical gradient images over the central portion of the image shown in Figure 2 by *convolving* the image with the Sobel operators.

[10 marks]

(b) **State** the formula for the *Structure Tensor* or *Second Moment Matrix*. **Compute** the *Structure Tensor* over the $3 \times 3$ window in the centre of the image in Figure 2. **Show** your working.

[8 marks]

(c) **State** the formula for the *Harris and Stephens corner response function*. Assuming $k = 0.04$, **compute** the value of the *response function* based on the Structure Tensor previously calculated. **Show** your working.

[8 marks]

(d) Briefly **describe** the rationale for the *Harris and Stephens corner response function*. **Describe** what different values of the corner function mean.

[7 marks]

**Question 6.**

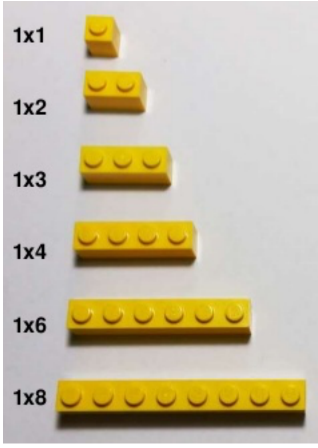



FIGURE 3: Lego bricks accepted by the sorting machine.

Consider the problem of sorting Lego bricks of different colours and lengths with a sorting machine. The sorting machine accepts mixed buckets of bricks being fed in from the top. The bricks accepted by the machine are shown in Figure 3; they each come in red, green, yellow, and blue colours.

**Describe** how you would *design* the computer vision component of this machine under the goal of achieving *maximum throughput*. Assume the bricks are released to fall through the machine with a gap between them, thus avoiding bricks touching or occluding each other as they pass in front of the vision system.

In your answer, **consider** both the design of the hardware and software with justification of the *constraints* and *invariants* required for *robustness*. 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**