A36890

Calculators may be used in this examination provided they are not capable of being used to store alphabetical information other than hexadecimal numbers

UNIVERSITY OF BIRMINGHAM

School of Computer Science

Third Year Undergraduate

06-30213

LH Computer Vision and Imaging

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Turn Over

Note

Answer ALL questions, based on what you learned from the module.

Question 1

Autonomous vehicles are an area where Computer Vision Techniques are heavily used, where the road segment (including the outline and the road markings) and other important features such as road signs, pedestrians, and vehicles have to be detected. One such view is given below in figure 1. Answer the following questions using traditional computer vision techniques.



Figure 1: View from an autonomous vehicle *Lane Estimation for Autonomous Vehicles using Vision and LIDAR, Albert S. Huang*

(a) Close visual inspection revealed that some random noise is present in these images. Propose a noise removal technique, mentioning all the parameters. **[4 marks]**

(b) With illustrations, briefly explain how the proposed kernel removes or reduces noise. **[3 marks]**

(c) Considering the fact that the steering output of the car is not overly sensitive to the detection accuracy of the road segment boundaries in the image and that fast calculations are important, propose an edge detection algorithm, explaining all the parameters involved in the process. **[4 marks]**

(d) "Canny edge detection would be a bad selection for the given scene considering the visible texture on the road surface". Do you agree or disagree with this statement? Explain your answer in detail. **[4 marks]**

(e) Hough transform was proposed for detecting the lines demarcating the lanes on the road. Briefly explain the process involved in finding such lines using the Hough transform. **[6 marks]**

(f) After collecting more data, it was proposed to use Deep Learning approaches to detect obstacles such as other vehicles, pedestrians as well as to detect various road signs. Taking into account the need to process this information in real time, propose an algorithm to this task, briefly explaining how the algorithm achieve this speed. **[4 marks]**

Question 2

(a) Please explain why understanding (computer) vision is difficult (list at least three points you learned from the lectures). **[6 marks]**

(b) Colour can be represented in different spaces (channels). Please select ALL the commonly used correct colour spaces (in computer vision) from the below options:

A. BBC

B. RGB

C. HSV

D. HSX

E. HSL

And describe what your selected colour space(s) mean, i.e. what does each letter indicate? **[6 marks]**

(c) A computational graph is a structured way to represent mathematical operations as a directed graph. Each node represents a variable or an operation, and the edges define dependencies between them. It provides an efficient way for computation and allows modularity. In machine/deep learning, we use gradients to iteratively update model parameters to train a model. Given the equation $f(x, y, z) = (x - 2y)z$, and $x = 1.5, y = -2, z = 5$, draw the computational graph, and explain how to use this computational graph to do the backpropagation to get the final gradients, in detail. **[13 marks]**

Question 3

(a) What is principal component analysis (PCA)? and what can it be used for in image processing? **[4 marks]**

(b) Given matrix with two dimensions, $\mathbf{X}$ and $\mathbf{Y}$, each dimension has n values ($\mathbf{X} = \{X_1, X_2, ...X_n\}$, $\mathbf{Y} = \{Y_1, Y_2, ...Y_n\}$), the covariance matrix of these two dimensions is:

$$C = \begin{bmatrix} \text{Var}(\mathbf{X}) & \text{Cov}(\mathbf{X}, \mathbf{Y}) \\ \text{Cov}(\mathbf{Y}, \mathbf{X}) & \text{Var}(\mathbf{Y}) \end{bmatrix}.$$

Please give the definition (i.e. equation) of $\text{Var}(\mathbf{X})$, $\text{Cov}(\mathbf{X}, \mathbf{Y})$, $\text{Cov}(\mathbf{Y}, \mathbf{X})$ and $\text{Var}(\mathbf{Y})$ in the above matrix. **[8 marks]**

(c) If a covariance has a positive value, *e.g.,* $\text{cov}(\mathbf{X}, \mathbf{Y}) > 0$, what is the relationship between the two dimensions? What if the covariance has a negative value or zero? Please write your answer in the following table.

Value	The relationship between $\mathbf{X}$ and $\mathbf{Y}$ dimensions
Positive value	
Negative value	
zero	

[3 marks]

(d) With the covariance matrix C, we can compute the eigenvalues λ and eigenvectors $\mathbf{e}$ of the data. Please outline the main steps involved in determining these eigenvalues λ and eigenvectors eigenvectors $\mathbf{e}$. **[10 marks]**

Question 4

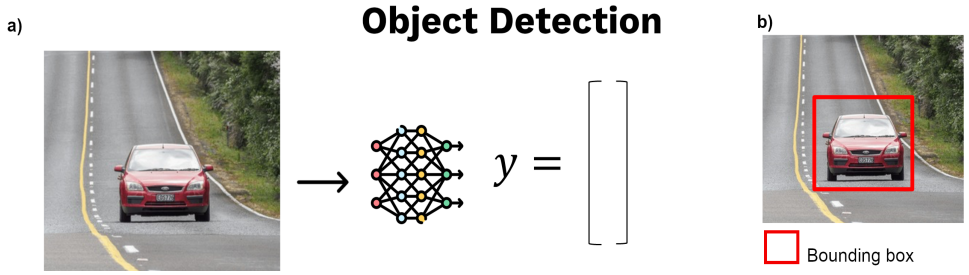


Figure 2: Graphical representation of a single-object detection and localisation task and the output vector y (a), and encoded output (b) obtained with an artificial neural network.

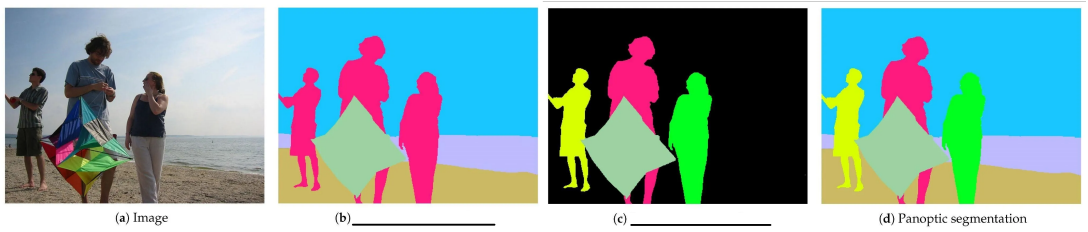


Figure 3: High-level segmentation of a natural scene. Input image (a), technique 1 (b), technique 2 (c), and panoptic segmentation (d). Note: the three people in b have the same colour/label, while in c and d are with different colours/labels.

(a) Consider a traditional artificial neural network (ANN) used to tackle an object detection task to recognise and localise cars, pedestrians, or trucks. The ANN takes an input image (Fig.2 a) and it generates an output vector y containing six elements. Based on Figure 2 b, list all the elements in the output vector y, and describe their meaning. **[4 marks]**

(b) Identify and explain three high-level computer vision (CV) tasks that can be addressed by building on fundamental CV techniques. **[5 marks]**

(c) Provide a general description of how local binary patterns (LBP) perform feature extraction and specify the types of features they operate on. **[3 marks]**

(d) Considering the high-level segmentation techniques you learned in lectures, provide the correct technique names for *technique 1* and *technique 2* shown in Figure 3 (b) and (c), and describe the main differences between them. **[9 marks]**

(e) Provide the definition of *optical flow*, and mention how it is represented. **[4 marks]**

Do not complete the attendance slip, fill in the front of the answer book or turn over the question paper until you are told to do so

Important Reminders

- Coats/outwear should be placed in the designated area.
- Unauthorised materials (e.g. notes or Tippex) must be placed in the designated area.
- Check that you do not have any unauthorised materials with you (e.g. in your pockets, pencil case).
- Mobile phones and smart watches **must** be switched off and placed in the designated area or under your desk. They must not be left on your person or in your pockets.
- You are not permitted to use a mobile phone as a clock. If you have difficulty seeing a clock, please alert an Invigilator.
- You are not permitted to have writing on your hand, arm or other body part.
- Check that you do not have writing on your hand, arm or other body part – if you do, you must inform an Invigilator immediately
- Alert an Invigilator immediately if you find any unauthorised item upon you during the examination.

Any students found with non-permitted items upon their person during the examination, or who fail to comply with Examination rules may be subject to Student Conduct procedures.