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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

Fourth Year Undergraduate/Postgraduate

06-25024

LM Robot Vision

Main Summer Examinations 2025

Time allowed: 2 hours

[Answer all questions]

Turn Over

Note

Answer ALL questions.

Question 1

(a) Give the equations for calculating the image coordinates for orthogonal projection and weak perspective. What approximations do they make and when are they appropriate to use? **[5 marks]**

(b) What is AWB? Briefly explain three approaches to AWB. **[5 marks]**

(c) Explain diffuse reflection and state how the observed intensity varies with respect to: (i) the angle between the direction of the incident light and the normal vector of the surface; (ii) the angle between the direction of the reflected light and the normal vector of the surface. **[5 marks]**

(d) Briefly compare and contrast hand-designed features (e.g., SIFT) and features created through machine learning methods such as deep learning. **[5 marks]**

(e) Briefly describe photometric stereo and provide a sketch. Specify the inputs and outputs. **[5 marks]**

Question 2

For a visual inspection task, we aim to obtain images with both high resolution and a global view; therefore, we consider using image stitching. Provide short and concise answers to the following questions:

(a) What conditions need to be fulfilled to apply homography for image stitching? **[3 marks]**

(b) Define the dimensions of the homography matrix. **[3 marks]**

(c) Explain the degrees of freedom of homography. **[3 marks]**

(d) How many features are needed for matching? **[3 marks]**

(e) What should be the ideal properties of these features? **[4 marks]**

(f) If several matches are incorrect, what method should we employ to estimate the mappings correctly? Provide a pseudocode for the algorithm. **[5 marks]**

(g) How can we exploit the information that the probability of an incorrect feature match is p? **[4 marks]**

Question 3

A company developing mobile robots for monitoring warehouses has tasked their engineers with designing a simple stereo rig to monitor a room and report the positions of objects within the stereo rig's view. The engineers were given two identical high-quality RGB cameras. Assume that the high-quality cameras have no optical distortions; however, their internal parameters are not known. Consider a pinhole camera model and provide short and concise answers to the following questions:

(a) Specify the projective matrix that maps 3D points onto a 2D image (dimensions, number of parameters, describe the parameters). **[5 marks]**

(b) Explain the process of recovering the camera parameters. **[6 marks]**

(c) Which parameters are relevant for the given task? Specify their units. **[4 marks]**

(d) Design a simple stereo rig where the camera axes are parallel and draw a sketch. Determine the minimum baseline of the system that would enable distinguishing distances closer than D_{Max}, assuming that a minimum detectable disparity is 1 pixel. **[6 marks]**

(e) Describe how a laser could be added to improve measurement robustness and how it would affect performance when measuring distances for objects with reflective and non-reflective surfaces. **[4 marks]**

Question 4

A company developing autonomous cars has tasked their research and development team to design a system for monocular depth estimation using unsupervised learning techniques. Provide answers to the following questions:

(a) Explain the concept of unsupervised learning in the context of monocular depth estimation. How does it differ from supervised learning? **[5 marks]**

(b) Describe the architecture of a typical neural network used for unsupervised monocular depth estimation. Include key components and their functions. **[5 marks]**

(c) What is the role of the photometric loss in unsupervised monocular depth estimation? How is it computed? **[5 marks]**

(d) Design an experiment to evaluate the performance of your unsupervised monocular depth estimation model. What metrics would you use and why? **[5 marks]**

(e) Discuss the challenges associated with unsupervised monocular depth estimation and propose potential solutions to address these challenges (also considering other approaches and sensors). **[5 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.