Two hours

Question ONE is COMPULSORY

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Computer Vision

Date:   Friday 22nd May 2015
Time:   09:45 - 11:45

Please answer Question ONE and also THREE other Questions from the FIVE Questions provided

Use a SEPARATE answerbook for each QUESTION

This is a CLOSED book examination

The use of electronic calculators is NOT permitted
1. **This question is COMPULSORY.**

Answer **any four** (from 6) of the following parts.

a) How does a *median filter* reduce random noise in an image whilst tending to preserve edges? [5 marks]

b) What is the *optical flow constraint* and why does it not uniquely determine the flow at each point in an image? [5 marks]

c) Is the Harris corner detector a linear filter? Argue why or why not. Assume that the Harris corner detector is applied to an unsmoothed image. What type of image would trigger the detector at places that clearly don’t contain a corner? [5 marks]

d) Define *disparity* in stereo vision. Given a pair of stereo images, what do we mean by the term *image rectification*? [5 marks]

e) What is the main assumption that lies behind the idea of using image smoothing for noise suppression? [5 marks]

f) Explain and contrast the region-based and edge-based approaches to extracting structure from images. [5 marks]

*End of Question 1*
2.

A graduate student is studying statistical, model-based approaches to computer vision. She considers a dataset of \( N \) vectors thus:

\[
\mathcal{X} = \{ \mathbf{x}^\alpha | \alpha = 1, \ldots, n \}, \\
\mathbf{x}^\alpha \in \mathbb{R}^d, \quad \mathbf{x}^\alpha = \{ x_{1}^\alpha, x_{2}^\alpha, \ldots, x_{d}^\alpha \}.
\]

You may consider the distribution of this dataset to be unimodal.

a) Explain in detail how Principal Component Analysis (PCA) could be applied to this dataset, and what the output would be.

[3 marks]

b) Explain how PCA is used to model shape and how it is used to model image patches in the context of computer vision (using at least one example of each). In each case, you should explain in detail how the dataset is constructed from the raw data, and how the properties and output of PCA are of use in the resultant model.

[12 marks]

A sceptical fellow student is not convinced as to the utility of the model-based approach.

c) Outline at least three disadvantages of the model-based vision approach as described above. Discuss whether or not these disadvantages can be overcome, and if so, how they might be overcome.

[5 marks]

End of Question 2
3.

a) Briefly describe the main steps of performing image segmentation using *normalised cuts*. [4 marks]

b) What are the advantages and disadvantages of
   
i. *EM clustering algorithm* [4 marks]
   
ii. *Mean-shift clustering algorithm* [4 marks]
   
iii. *Normalised cuts* [3 marks]

c) Consider an image consisting of two sets of points. One is a set of points distributed roughly uniformly on a circle of radius *r* centred at point *C1*, which is near the centre of the image. The other set of points is distributed on a circle of radius *2r*, which is centred at point *C2*, which is located inside the other circle. Assume the points in each set are distributed densely enough so that the distances between points on the same circle are smaller than the distances between points on different circles (Figure 1). Describe what segmentation the *k-means algorithm* would produce for this example, and briefly explain why. [5 marks]

![Figure 1](image-url)
4.

a) Explain what an “interest point” in an image means. [2 marks]

b) Explain what a “corner detector” means. What is the main difference in the information provided by edge and corner features? [4 marks]

c) Describe a method that could be applied to detect interest points in an image. You may choose to describe any interest point detector but you need to explain how the operator is applied to the image and how interest points are identified. [4 marks]

d) Explain how you could use the pair of images in Figure 2 to calculate the distances from the camera of the surface features that appear in the scene. In your answer you need to consider all steps in the process, from images to depth values. You may also give a diagram to illustrate your answer. [10 marks]

Figure 2

End of Question 4
5.

The following diagram is a mathematical representation of two greyscale images, in the context of non-rigid image registration.

![Diagram](image)

a) Explain the notation used in the above diagram. Hence (or otherwise), explain the concepts of the **pullback** and the **pushforward** mappings and how they are used to create warped images. Why might one mapping be preferred over the other in terms of implementations of pairwise image registration?  

[5 marks]

b) Along with a mathematical description of the warped image(s), what other basic components are required when constructing an algorithm to perform intensity-based pairwise non-rigid image registration? You should discuss both the parametric and non-parametric cases, and also the cases of unimodal and multimodal grayscale images. You should give examples for each component that you mention. 

[12 marks]

c) Discuss briefly how the pairwise framework described above could be adapted to enable registration across a population. What improvements could be made?  

[3 marks]

*End of Question 5*

END OF EXAMINATION