Two hours

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

Computer Vision

Date: Monday 20th May 2013
Time: 14:00 - 16:00

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

[PTO]
1. **This question is COMPULSORY.**

Answer any **four** (from **six**) 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) Explain how the **Hough transform** using the \((r, \theta)\) parameterisation can be used to find straight lines in edge-detected images.  
   
   **[5 marks]**

d) What is meant by the **skeleton** of an object? Explain with the aid of a diagram how the skeleton can change dramatically for a small change in the shape of an object.  
   
   **[5 marks]**

e) Explain how an **adaptive thresholding** method could be implemented using a large smoothing filter and image arithmetic. Under what circumstances might you expect the method to work well?  
   
   **[5 marks]**

f) Explain the role of **non-maximal suppression** in edge detection and describe a practical algorithm for applying it to an edge strength and orientation image.  
   
   **[5 marks]**

*End of Question 1*
2.

A COMP61342 student is designing an automatic facial recognition system. To simplify matters, she decides to consider only people facing directly into her camera system. She then lists the sources of image variation that she needs to consider when designing the system:

(I) Pose variation in the image plane (position, scale, orientation)
(II) Identity
(III) Variation of facial expression
(IV) Lighting/illumination changes

You may assume that all these sources of variation occur when the actual system is being used, and that such sources of variation are also well-represented in the database of annotated face images that are available to her during the development of the system.

a) Describe:
   i. The nature of the required annotation, and how she would build a suitable Statistical Shape Model (SSM) for faces.
   [7 marks]

   ii. The Active Shape Model (ASM) approach of Cootes et al.
   [10 marks]

   In particular, you should discuss how each of these approaches deals with the sources of variation noted above, both during the training phase, and during the identification phase, when the final system is presented with previously unseen images of both familiar and unfamiliar people.

b) With reference to the same sources of variation, explain why the Active Appearance Model (AAM) might be preferred over the ASM approach.
   [3 marks]

End of Question 2
In Computer Vision it is often useful to identify *interest points* in an image. Examples of interest point operators are the Moravec or Harris Corner detectors.

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

b) Describe two different methods that could be applied in detecting interest points. (You may choose to describe the Harris or Moravec operators, but there are others). In each case describe how the operator is applied to the image and how interest points are identified. [8 marks]

c) Describe how interest points can be used in each of

i) Correspondence matching for stereo reconstruction [5 marks]

ii) Object detection [5 marks]

End of Question 3
4.

a) Is the Harris corner detector a linear filter? Argue why or why not. [3 marks]

b) 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? [2 marks]

c) The SIFT descriptor is a popular method for describing selected feature points based on local neighborhood properties so that they can be matched reliably across images. Assuming interest points (keypoints) have been previously detected, briefly describe the main steps of creating the SIFT keypoint descriptor at a given feature point. [8 marks]

d) Explain the role of the following parameters in the SIFT algorithm: [3 marks]
   i. Contrast threshold,
   ii. Curvature threshold and,
   iii. Dimensionality of feature vector.

e) If we rotate the image, will the SIFT algorithm find the same keypoint descriptors between the original image and the rotated one? [4 marks]

End of Question 4
5. 

a) Outline at least three distinct biological and/or medical applications of non-rigid image registration. You should make clear why registration is required in each case. 

[6 marks]

b) With the aid of simple diagrams (or otherwise), explain the push-forward and pull-back mappings in the context of pairwise image registration. In particular, explain what computational issues arise that one method is usually preferred over the other when warping dense, pixelated grids. 

[6 marks]

c) Describe, using diagrams, a simple linear warping algorithm for defining a one-to-one mapping between two triangulated meshes. You need only consider one triangle of the entire mesh, and how to map to the corresponding point(s) in a second triangle of another mesh. 

[4 marks]

d) What other components are required when constructing a non-rigid image registration algorithm? 

[4 marks]

End of Question 5

END OF EXAMINATION