Maynooth University
National University of Ireland Maynooth

OLLSCOIL NA hÉIREANN MÁ NUAD

THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH

AUTUMN 2016 EXAMINATION

CS410

Computer Vision

Dr. D. Charles, Dr. A. Winstanley, Dr. J. McDonald

Time allowed: 2 hours

Answer at least three questions
Your mark will be based on your best ***three*** answers

All questions carry equal marks

[25 marks]

1 (a) Provide an explanation of the 4 principal steps employed by the Scale Invariant Feature Transform (SIFT) in detecting a set of feature points in an image and computing the corresponding feature descriptors. [12 marks]

(b) Explain how both the Euclidean distance and the ratio test provide approaches to computing correspondences between two sets of SIFT feature vectors from two images. What is the advantage of using the ratio test over the Euclidean distance? [6 marks]

(c) A student has a collection of 100 music CD's which he has uploaded to his laptop. He would like to develop a system whereby in order to play a particular CD he would show the front cover of the CD case to the built in laptop web cam. The system should capture an image of the CD and from the image determine the correct CD to play. Outline how such an application could be developed through the use of SIFT features. [7 marks]

[25 marks]

2 (a) One of the principal differences between the thin lens camera model and the perspective projection camera model, is that in the later the focal length is taken to be the distance between the center of the lens and the imaging plane. This is equivalent to setting v = f in the thin lens equation. Why is this approximation valid? Justify your answer through the use of a numerical example. [6 marks]

(b) The 3D to 2D projection performed by a camera can be modelled as a linear system as follows: [7 marks]

$$\mathbf{p} = \mathbf{K}\begin{pmatrix}\mathbf{R} & \mathbf{t}\end{pmatrix}\mathbf{P}$$

For each term in the expression, explain the aspect of the camera projection process that it captures. Furthermore, explain the structure and dimension of each of the terms in the above expression.

(c) The matrix R in the expression in part (b) represents a 3-dimensional rotation. For each of the matrices listed below determine whether it could be the matrix R in the expression i.e. would it satisfy the constraints imposed by such a matrix: [6 marks]

$$\begin{pmatrix} 2 & 1 & 0 \\ 2 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad \begin{pmatrix} 1/\sqrt{2} & -1/\sqrt{2} & 0 \\ 1/\sqrt{2} & 1/\sqrt{2} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

(d) During the course 3 different parameterisations of rotation were discussed including, (Yaw, pitch, roll), axis-angle, and exponential coordinates For any <u>one</u> of these parameterisations, explain the parameterisation including how it relates to the corresponding 3x3 rotation matrix. [6 marks]

[25 marks]

3 (a) The 2-D convolution integral is given by the equation: [10 marks]

$$g(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(u,v)h(x-u,y-v)dudv$$

How is this operation represented in the discrete domain of a digital image? Using pseudo code, describe an algorithm for computing convolution in the discrete domain.

What is the relationship between convolution and image filtering?

(b) Provide an explanation of how edge detection is achieved using gradient based operators. In your answer you should explain how gradient based edge detection is implemented as a series of convolution operations, including providing an example set of kernels for computing the gradient. [8 marks]

How does the Laplacian operator relate to the gradient? How does it differ in terms of how it can be used for edge detection? What are the advantages of the Laplacian over gradient based approaches?

(c) The 3x3 convolution filter below provides a digital approximation of the Laplacian operator. [7 marks]

0	-1	0
-1	4	-1
0	-1	0

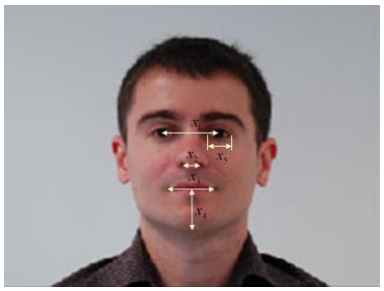
Demonstrate <u>all</u> of the steps involved in Laplacian edge detection by applying the above filter to the central three pixels of the following image.

100	100	0	0	0
100	100	0	0	0
100	100	0	0	0

[25 marks]

4 (a) Provide a mathematical definition and explanation of Bayes rule, including an explanation of the individual terms. Why is the rule useful in pattern recognition systems? In your answer you should explain how Bayes rule can be applied in classifying patterns. [9 marks]

(b) Consider a face recognition system which determines the identity of a person based on a series of measurements of facial feature as shown in the image below [8 marks]



In the context of such a system provide an intuitive explanation of what each of the individual terms in Bayes rule represents.

(c) A system designed to classify between two classes of object based on a single scalar measurement make a series of measurements of instances of each class from a training set. The resulting set of measurements are presented in the two tables of values below. [8 marks]

Object Class A

Length	7cm	8cm	9cm	10cm	11cm	12cm
Number of objects	3	5	11	13	4	2

Object Class B

Length	10cm	11cm	12cm	13cm	14cm	15cm
Number of objects	11	12	40	50	10	5

Objects from class B occur 4 times more than objects of type A.

Given the above tables and an unknown object whose length has been measured as 11cm, demonstrate how the Bayes classification rule can be used to classify the object.