NUI MAYNOOTH

Ollscoil na hÉireann Má Nuad

OLLSCOIL NA hÉIREANN MÁ NUAD

THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH

AUTUMN 2015 EXAMINATION

CS410

Computer Vision

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Time allowed: 2 hours

Answer ***three*** questions

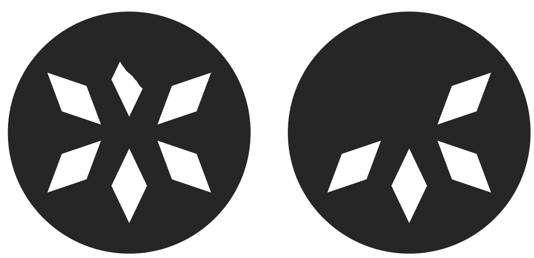
All questions carry equal marks

[25 marks]

1 (a) A manufacturer of decorative ventilation covers produces three different types of cover, each of which is shown in the first figure below. The interior shapes on each of the covers are holes through which the ventilation occurs. The covers are available in brown, red, and black.

Teardrop ***Diamond*** ***Star***

The manufacturing process results in a small number of failure cases whereby one or more of the holes on a given cover is only partially cut or is not cut through at all. Examples of these failures for the Diamond cover are shown in the figure below.



All covers are transported along a single conveyor belt from the manufacturing area to the packaging area. The manufacturer has employed you to develop and install a computer vision based inspection system at the end of the conveyor to interface with a robotic manipulator that will sort the ventilation covers. The system will include a single overhead **<u>grayscale</u>** camera that looks directly down on the conveyor belt. The computer vision system is required to (i) recognise the type of each cover in the image (i.e. Teardrop, Diamond, Star), (ii) recognise which covers have been incorrectly produced, and (iii) **<u>precisely</u>** compute the centre of each cover (in image coordinates) within a given image from the camera. Multiple covers may appear in a single frame but will not touch each other.

Detail the complete set of processing and analysis steps involved in the implementation of a computer vision system to solve the above problem.

[25 marks]

2 (a) During the course it was shown how it was possible to model the projection effected by the pin hole camera as a linear transformation from 4-dimensional homogeneous point to a 3-dimensional homogeneous point. This transformation is provided in the expression below: [10 marks]

$$\mathbf{p} = \mathbf{MP} = \begin{pmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & m_{22} & m_{23} & m_{24} \\ m_{31} & m_{32} & m_{33} & m_{34} \end{pmatrix} \mathbf{P} = \begin{pmatrix} \mathbf{m}_1^T \\ \mathbf{m}_2^T \\ \mathbf{m}_3^T \end{pmatrix} \mathbf{P} = \begin{pmatrix} \mathbf{m}_1^T \mathbf{P} \\ \mathbf{m}_2^T \mathbf{P} \\ \mathbf{m}_3^T \mathbf{P} \end{pmatrix}$$

Given details of an approach to calibrating a real-world camera, thereby estimating the values of the individual components of the camera matrix $\mathbf{M}$. In particular, explain how a set of 3D to 2D point correspondences may be used to re-cast the above expression as a homogeneous linear system of the form,

$$\mathbf{Ax} = \mathbf{0}$$

and, explain how it may be solved to compute the camera matrix.

(b) How does mathematical model of the camera simplify when one only considers the transformation between a planar target and the image plane (e.g. a checkerboard and the image plane)? Explain how the calibration procedure alters in this situation? Finally, why is it mathematically possible to invert the projection between the camera and the planar target, but not possible to invert the camera projection in general? [8 marks]

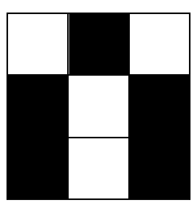
(c) In the course we saw that labeling the pixels within a 3x3 region as follows: [7 marks]

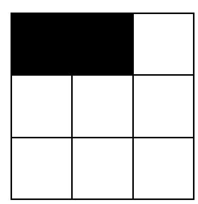
3	2	1
4	8	0
5	6	7

pixel 8 can be identified as critical connected if the following predicate evaluates to true:

$$
\begin{aligned}
8.\{ & \left[(1+2+3).(5+6+7).\overline{4}.\overline{0}\right] \\
+ & \left[(1+0+7).(3+4+5).\overline{2}.\overline{6}\right] \\
+ & \left[3.(5+6+7+0+1).\overline{2}.\overline{4}\right] \\
+ & \left[1.(3+4+5+6+7).\overline{2}.\overline{0}\right] \\
+ & \left[7.(1+2+3+4+5).\overline{0}.\overline{6}\right] \\
+ & \left[5.(7+0+1+2+3).\overline{4}.\overline{6}\right]\}
\end{aligned}
$$

Using the above expression show how it can be used to determine if the central pixels of the following neighbourhoods are critically connected.





[25 marks]

3 (a) What is Bayes rule? Provide an expression Bayes rule and define each term used within the rule. Provide an intuitive explanation of each of the terms. [15 marks]

Explain how Bayes rule can be used in the context of pattern recognition to provide a means of classification between classes of objects.

Through the use of a diagram explain how the Bayes classifier minimises the misclassification rate. Is minimising the misclassification rate always the correct objective for a classification system? Justify your answer.

(b) The two tables below show the frequency of measurement of the length of two classes of objects. As can be seen from the data Class 2 have a broader spread of [10 marks]

Class 1:

Length (cm)	12	13	14	15	16	17	18
Frequency	21	26	28	12	5	6	5

Class 2:

Length (cm)	7	8	9	10	11	12
Frequency	16	15	19	33	32	33

If an unknown object of length 12cm is detected, and the probability of an object from class 1 occurring is twice that of an object occurring from class 2, demonstrate how the Bayes classifier would classify the unknown object.

[25 marks]

4 (a) With the aid of diagrams, explain how the Hough transform may be used to locate lines in an image. Include a pseudo-code version of the algorithm in your answer. [13 marks]

One of the strengths of the Hough transform is its robustness to occlusions and noise. Give an explanation of the source of this robustness.

(b) List and explain the steps involved in computing the SIFT descriptors for an image. [12 marks]