Maynooth University
National University of Ireland Maynooth

OLLSCOIL NA hÉIREANN MÁ NUAD

THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH

JANUARY 2016 EXAMINATION

CS410

Computer Vision

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Time allowed: 2 hours

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

All questions carry equal marks

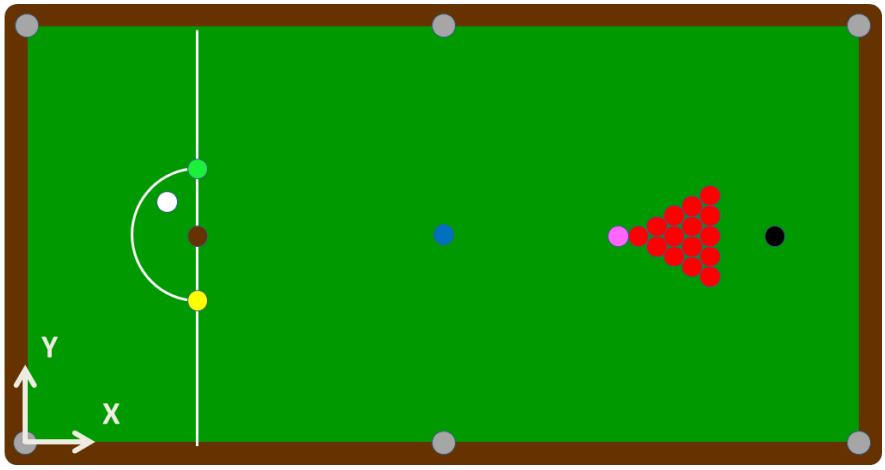
[25 marks]

1 RedBlack Ltd. are a nationwide chain of snooker halls who have recently appointed a Director of Technology tasked with identifying potential opportunities for integrating technology into their locations to improve the overall customer experience. She has approached you with an idea for developing a new computer vision system for automatically visualising and analysing game play, and suggesting strategy to players during games.

In order to enable the above applications RedBlack Ltd. have asked you to design a computer vision system to compute the location of each ball relative to the table surface. An example of the camera setup relative to the table is shown in the figure below.

A typical frame produced by this setup is shown below:

(a) You are provided with a library that will detect the pixel location of the point of contact of each ball with the table. Your first task is to use these pixel locations to compute the corresponding location of the ball relative to the two dimensional coordinate system of the table. The output of this step will be used to create a simplified top-down view of the table as shown below where the coordinate system is also shown for clarity. [13 marks]

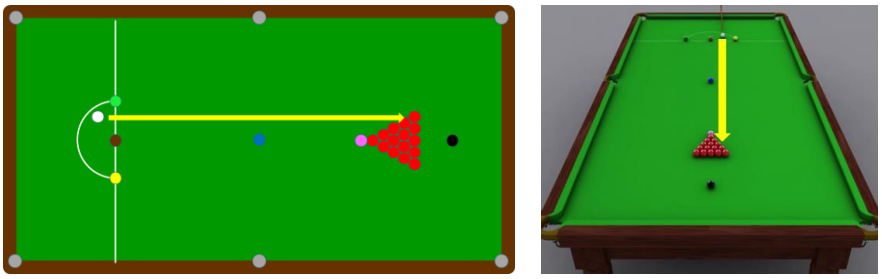


Detail the full set of steps required to create a system capable of computing the necessary ball coordinates relative to the table coordinate system shown in the figure.

(b) Using the output of the system from part (a), RedBlack Ltd. have developed a game analysis system which suggests shots to the player by overlaying them on the simplified top-down view. [12 marks]

The director of technology wants to extend the system so that it displays a side-by-side view of the top-down view with the frame from the camera. In the proposed system when a shot is being suggested it should be overlaid both on the top down view and in the frame such that the arrow appears correctly relative to the table.

An example side-by-side view of a suggested shot is shown in the figure below, where the suggested shot is displayed using the overlaid yellow arrow.



Give details of how you would extend the system developed in part (a) to provide this new functionality.

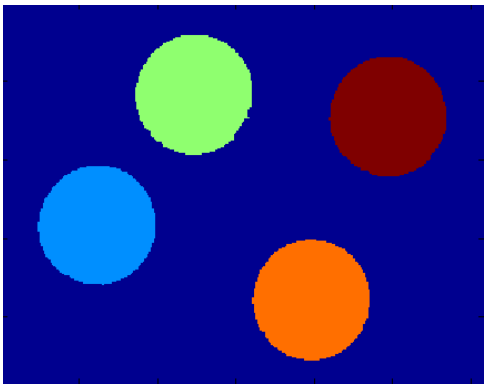
[25 marks]

2 (a) The image below shows a four US 25¢ coins taken by a camera directly overhead. The coins are ~24.3mm in diameter, and the pixel dimensions of the sensor are square with a side length of 6μm. The center of the camera's lens is 50cm above the table and looking perpendicularly at the table. The focal length of the camera used was 30mm. [8 marks]

Given the above information, what will the diameter of the coins be in the image in units of pixels?

(b) Given the image in part 2 (a) details the full set of steps required to produce the labelled image shown below, where the value of each pixel corresponds to the object label to which that pixel belongs. [10 marks]

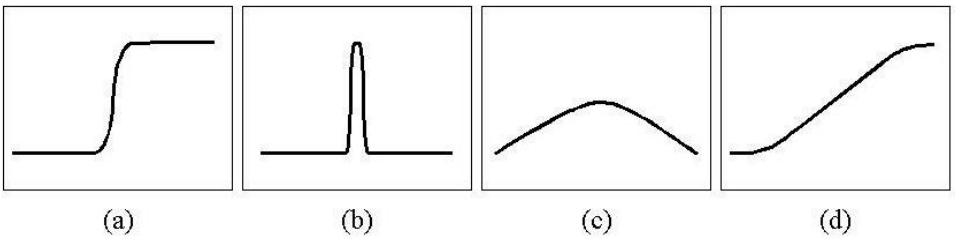
In your answer you should (i) explain the steps involved in producing binary segmented image (paying particular attention to the steps required to ensure that each coin region does not contain any holes), and, (ii) provide details of a sequential labelling algorithm that computes the labelled image from the binary segmented image.



(c) Given the labelled image shown in part 2 (b), provide details of how the position of each of the coins in the original image can be computed. [7 marks]

[25 marks]

3 (a) The figure below shows a selection of one-dimensional cross-sections of signals that might appear in a given grayscale image. Illustrate the response that a one-dimensional gradient would have to each of these signal types. [6 marks]

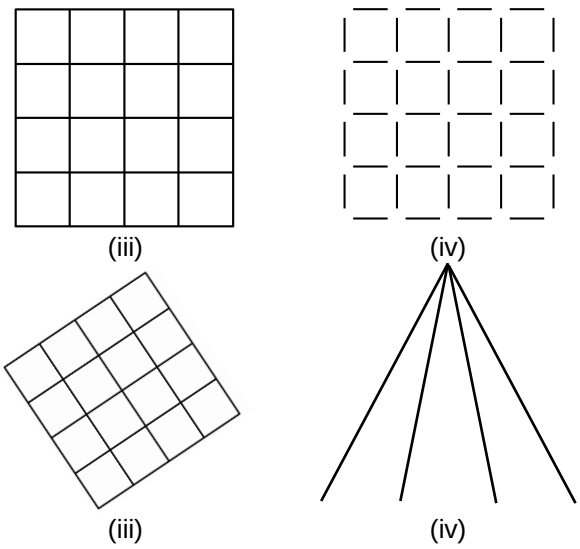


(b) Typically in image processing a gradient filter combines the first derivatives of the image in two orthogonal directions using a *root-mean-square* (*RMS*) operation. This provides us with the magnitude of the gradient. This is then thresholded at an appropriate value to provide an *edge-map* of the image. In one dimension this can be thought of as taking the absolute value of the gradient, with a similar thresholding operation applied afterwards. [6 marks]

Using this approach, and setting the threshold to be 75% of the maximum gradient value, show approximately the *regions* of the example signals that would be identified as edges.

(c) Using your answer to part (a) outline the inherent problems in applying first-derivative operators to signals of type (*c*) and (*d*). Through the use of diagrams, briefly describe how the Laplacian operator overcomes these problems. [5 marks]

(d) For each of the four images shown below, describe the configuration of peaks that would occur in Hough space if they were processed by the Hough transform. [8 marks]



[25 marks]

4 (a) Give an expression for Bayes rule and provide an explanation for each of the terms involved in the expression. [10 marks]

Explain how Bayes rule provides a general framework for pattern recognition. In particular, explain how the Bayes classifier can be used to classify between objects of different classes.

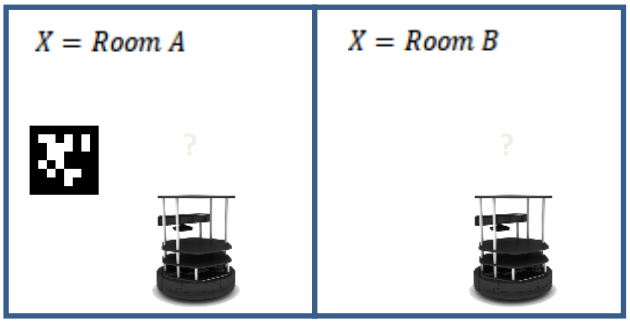
(b) The figure below shows a mobile robot equipped with a camera sensor. The robot runs software that allows it to detect the AprilTag on the right. At any point in time the robot has a measurement variable Z which can take on the value $Tag\ Detected$ or $Tag\ Not\ Detected$. [15 marks]

The AprilTag detection software has following true positive and false positive detection probabilities:

$P(Z = Tag\ Detected | Tag) = \mathbf{0.9}$

$P(Z = Tag\ Detected | No\ Tag) = \mathbf{0.2}$

Given the above, consider the scenario illustrated below in which a robot can be in one of two rooms. In Room A the Tag will always be in the field of view of the sensor, whereas Room B contains no tag.



Assume the robot initially has equal probability of being in either room. If the robot now detects the tag, demonstrate how the robot can use Bayes rule to update its belief of which room it is in.