Maynooth University
National University of Ireland Maynooth

OLLSCOIL NA hÉIREANN MÁ NUAD

THE NATIONAL UNIVERSITY OF IRELAND MAYNOOTH

AUTUMN 2017 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 (a) Give details of the Histogram of Oriented Gradients (HoG) image descriptor, and in particular, describe a step-by-step algorithm for computing the HoG for a given image region. [10 marks]

(b) Provide details of an approach to using the HoG representation to develop a detector for pedestrians. [5 marks]

(c) A manufacturer of autonomous surveillance systems has employed you to develop a system for estimating the approximate locations of pedestrians within an on-street surveillance system. The system will employ a HoG based detector to place a bounding box around each pedestrians and then compute the location of base of the bounding box in world coordinates i.e. in a coordinate system aligned with the plane of the street. [10 marks]

An example image from a beta prototype of the system is shown below, with a number of HoG detections overlaid as green boxes. Give details of an approach to calibrating such a system such that it is possible to compute the location of the base of each green box on the street. Furthermore, given the output of the calibration procedure and a set of bounding boxes, explain the steps involved in calculating the locations of base of the boxes in world coordinates.

[25 marks]

2 (a) A CCD camera with a square sensor of side length 4mm has a lens of 16mm fitted to it. If the camera is fitted 75 cm above an assembly line such that its principal ray (i.e. viewing direction) is perpendicular to the assembly line surface, what is the maximum size object that it can image? [8 marks]

If the above system is to be brought closer to the assembly line, would a longer or shorter focal length lens be required in order to maintain the field of view? Justify your answer.

(b) Compare and contrast CCD and CMOS imaging sensor technologies in terms of their operation, sensor organisation types, and suitability for computer vision applications. In your answer you should provide details of both the interline and frame transfer CCD organisations, and how the architecture of CMOS image sensors differs from that of CCD. [9 marks]

Modern interline sensors typically employ a microlens array to improve the performance of the camera. What is the function of the microlens array in terms of the problem it address and the solution it provides to this problem.

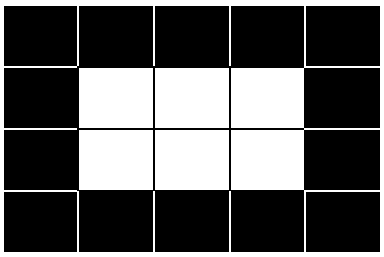
Give two approaches to sensing colour using CCD technology. What are the merits and demerits of each approach?

(c) A friend of yours sends you the picture below that they took of the propeller of a plane using their smartphone whilst on a recent flight. Knowing you to be an expert in imaging technology they ask you to explain the reason for the unusual distortion of the structure of the propeller in the resulting image. [8 marks]

Provide an explanation for the source of the distortion. What type of sensor do you think was used in the smartphone (i.e. CCD or CMOS)? Justify your answer. Finally list and explain two mechanisms for overcoming this type of distortion in machine vision type applications.

[25 marks]

3 (a) A common approach to computing the position of an object in an image is to use the first moment (also known as the centre of mass). Give an expression for the first moment of an image and demonstrate its use by showing the calculations involved in computing the first moment for the following image (where white pixels correspond to the foreground object). [6 marks]



(b) The figure below shows the Sobel filter kernels for calculating the first derivative of an image in the x and y-directions. [10 marks]

-1	0	1
-2	0	2
-1	0	1

-1	-2	-1
0	0	0
1	2	1

Compute the responses resulting from the convolution of both of these filters to the center pixel of the follow image neighbourhood:

10	182	185
12	178	182
11	180	181

Finally compute the gradient magnitude and orientation from the resulting responses.

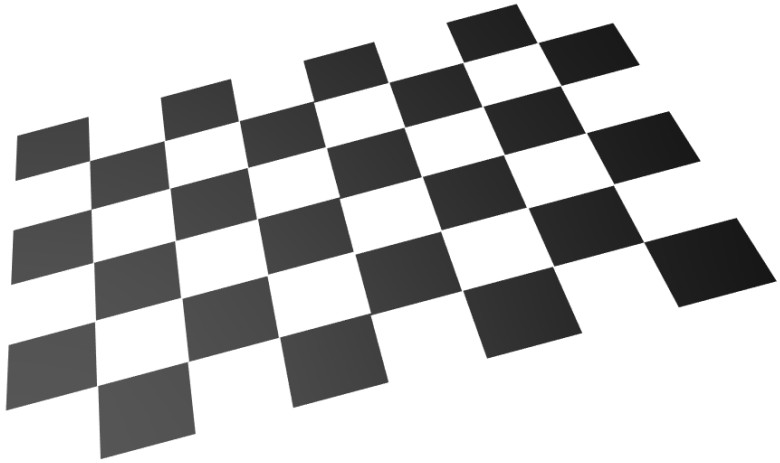
(c) Give details of the four steps involved in the Canny edge detection algorithm. What is the main strength of the Canny edge detection algorithm in comparison to, for example, Sobel or Prewitt based edge detection. [9 marks]

[25 marks]

4 (a) With the help of both diagrams and pseudo-code, give details of how the Hough transform can be used to detect lines in images? [10 marks]

(b) A common optimization in the Hough transform is to utilize the gradient orientation within the algorithm. Explain how this optimization works and show how the pseudo-code provide in your solution to question 4(a) is altered to include this optimization. [6 marks]

(c) The figure below shows and image of a checkerboard sitting on a white table imaged by a camera to the side of the table (hence the perspective distortion). [9 marks]



Give details of a Hough transform based approach to computing the locations of the checkerboard corners. Note that the output of the algorithm should be ordered such that it starts with the checkerboard corner in lower left corner of the image. The corners should then proceed with the left to right and bottom to top.