The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX5571/MEX5271 Machine Vision**
Academic Year	: 2019/20
Date	: 4th October 2020
Time	: 1330-1630hrs
Duration	**: 3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Eight (8)** questions in **Six (6)** pages.
3. Answer any **Five (5)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. This is a Closed Book Test (CBT).
6. Answers should be in clear hand writing.
7. Do not use Red colour pen.

Question 01

a) Describe the Canny edge detector. What are the steps involved in edge detection using this detector? Use diagrams where necessary in your explanation. [*7 marks*]

b) Explain what camera calibration is. What are the steps involved? What do we attempt to recover in camera calibration? [*7 marks*]

c) When would it be suitable to use histogram equalization? Briefly outline the steps to histogram-equalize a given image. [*6 marks*]

Question 02

a) Briefly describe the difference between diffuse reflection and specular reflection. Use diagrams where necessary in your description. [6 *marks*]

b) A greyscale transformation can be applied directly onto a greyscale image to manipulate its pixel values (assuming the range is [0,255]). Draw the diagrams for the following greyscale transformations:

   i. thresholding the image at pixel value 100. [7 *marks*]

   ii. linearly stretch the intensity in the interval [100,200] to [0,255]. [7 *marks*]

Question 03

The speed of an object is to be measured using an image processing technique, which uses a camera and a flash that exposes the scene for $\boldsymbol{K}$ seconds. The object is $2.5cm$ long, $1cm$ wide, and its speed is $750 \pm 250\ m/s$. The camera produces an image in which the object occupies 10% of the horizontal resolution of a 256×256 digital image.

a) Determine the maximum value of $\boldsymbol{K}$ that will guarantee that the blur from motion does not exceed $1\ pixel$. [10 *marks*]

b) Determine the minimum number of frames per second that would have to be taken in order to guarantee that at least two complete images of the object are obtained during its path through the field of view of the camera. [10 *marks*]

Question 04

a) A drone is designed to transmit images as it approaches for landing. Due to a rotor failure, the drone experiences a rapid rotation about its vertical axis. As a result of the sudden rotation, the images which were sent during the last two seconds of landing were blurred by a uniform rotational motion. The camera is located at the bottom of the drone along its vertical axis and pointing downwards. During the acquisition time of each image, the drone rotation was limited to $\pi/8$ radians. The image acquisition process can be modeled as an ideal shutter that is open only during the time which drone rotates the $\pi/8$ radians. Assuming that the vertical motion during the image acquisition was negligible, formulate a solution for restoring the images. [10 *marks*]

b) Figure Q4 represents a gray-level probability density function of an image $P_1(Z)$ Corresponds to objects and $P_2(Z)$ corresponds to the background. Find the optimal threshold between object and background pixels. Note that $P_1 = P_2$. [10 *marks*]

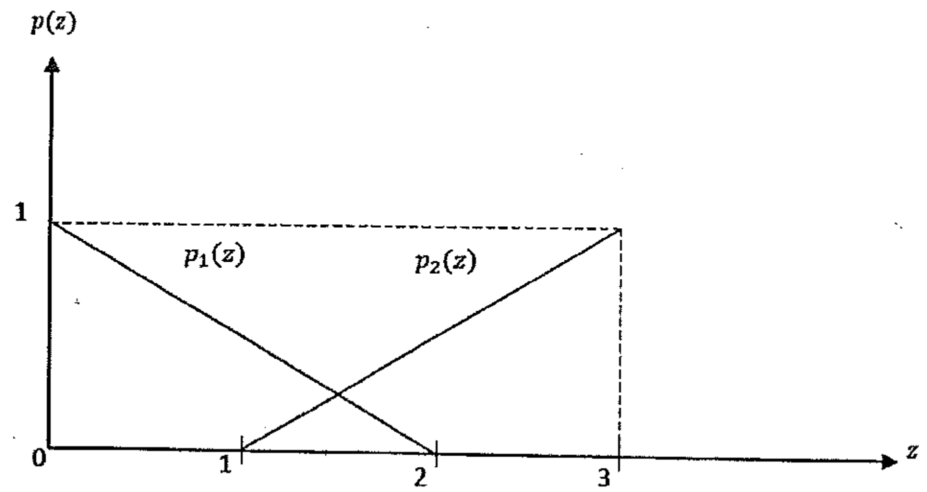

Figure Q4

Question 05

3D reconstruction from multiple images is the creation of 3D models from a set of images. It is the reverse process of obtaining 2D images from 3D scenes. The essence of an image is a projection from a 3D scene onto a 2D plane, during which process the depth is lost. The 3D point corresponding to a specific image point is constrained to be on the line of sight. From a single image, it is impossible to determine which point on this line corresponds to the image point. If two images are available, then the position of a 3D point can be found as the intersection of the two projection rays. This process is referred to as triangulation. The key for this process is the relations between multiple views, which convey the information that corresponding sets of points must contain some structure and that this structure is related to the poses and the calibration of the camera. The following system setup has two stereoscopic cameras, one placed at the right and the other placed at the left as a human-like visual system, as shown in Figure Q5.

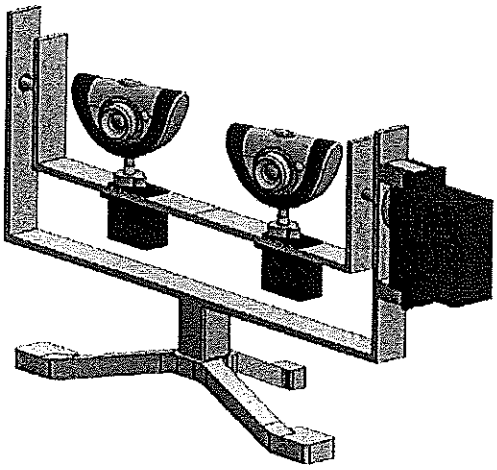

Figure Q5

a) Describe the steps of converting multiple 2D images into a 3D model. [10 *marks*]

b) Design the distance mapping algorithm that two cameras the position of the object relative to the frame. [10 *marks*]

Question 06

A CCD TV camera is used to perform a long-term study by observing the same area 24 hours a day, for 30 days. Digital images are captured and transmitted to a central location every 5 minutes. The illumination of the scene changes from natural daylight to artificial lighting. At no time is the scene without illumination, so it is always possible to obtain an image. Because the range of illumination is such that it is always in the linear operating range of the camera, it is decided not to employ any compensating mechanisms on the camera itself. Rather, it is decided to use image processing techniques to post-process and thus normalize the images to the equivalent of constant illumination.

Propose a method to do this. You are free to use any method you wish, but state clearly all the assumptions you made in arriving at your design. [20 *marks*]

Question 07

You have been asked to design a process control for a bottling plant. Your task is to design a vision system that rejects contaminated bottles. The contamination appears as a brightly colored precipitate inside the bottle. Several sample images are shown in Table Q7.

Image	Image name	Contamination status
	Image#1	Uncontaminated
	Image#2	
	Image#3	
	Image#4	Contaminated
	Image#5	
	Image#6	
	Image#7	

Table Q7

You have proposed a four-step algorithm for identifying contaminated bottles:

a) Determine the average image intensity, I_{av}.

b) Apply an intensity threshold to the image, $T_I = I_{av} + \Delta$.

c) Count the number of pixels in the largest segmented blob, $N_{largest}$.

d) Reject bottle as contaminated if $N_{largest}$ is greater than a pixel threshold, T_N.

Using the images provided, choose suitable values for the threshold parameters Δ and T_N that reject only the contaminated bottles.

Question 08

a) Sketch a block diagram model for the image degradation/restoration process and give the equations describing the model in both the spatial and frequency domain. Given two images, one is degraded by Gaussian noise and one degraded by impulse noise, name two filters (one for each image) that can be used to remove the noise. [7 *marks*]

b) Describe how inverse filtering can be used to restore a degraded image and how the degradation can be estimated if unknown. Under what assumption can you perfectly restore the image (given knowledge of the exact degradation function), and how can you avoid erratic behavior when the assumption is not met. [6 *marks*]

c) One category of image segmentation is referred to as edge-based segmentation. Describe how the first and second-order derivatives can be used to detect edges, how they differ from each other, how they are affected by noise, and which filter masks can be used. [7 *marks*]

END