UNIVERSITY OF LIMERICK

OILLSCOIL LUIMNIGH
FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRONIC & COMPUTER ENGINEERING

MODULE CODE:	**CE6021**
MODULE TITLE:	**MACHINE VISION**
SEMESTER:	**AUTUMN 2022**
DURATION OF EXAM:	**2 ½ HOURS**
LECTURER:	**DR. TONY SCANLAN**

INSTRUCTION TO CANDIDATES:

ANSWER 4 OF 5 QUESTIONS.

EACH QUESTION CARRIES 20 MARKS. YOU WILL BE MARKED OUT OF 80.

THIS EXAM PAPER IS WORTH 45% OF THE FINAL MODULE RESULT.

READ EACH PROBLEM COMPLETELY AND THOROUGHLY BEFORE BEGINNING TO WORK ON IT.

INCLUDE ANY GRAPH PAPER OR ADDITIONAL SHEETS WITH YOUR SCRIPT.

CLEARLY MARK YOUR FINAL ANSWERS TO QUESTIONS.

Q1

(a) A simple pinhole camera has a distance of 0.2m from the aperture to the rear surface of the camera where the image is formed. What is the optimum aperture diameter d when the wavelength of light is $\lambda = 700nm$?

[5 marks]

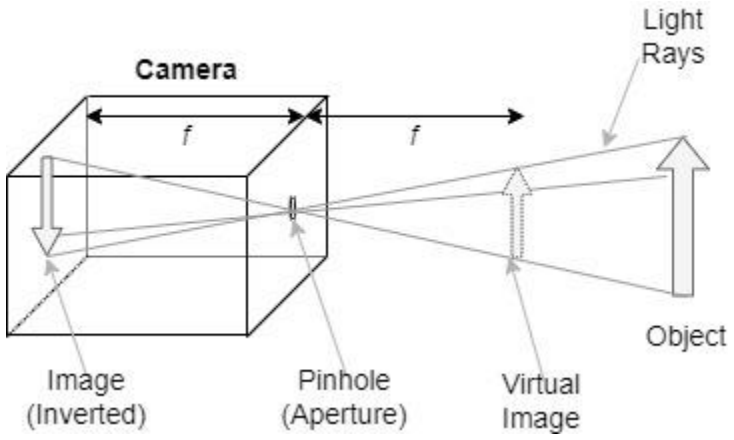

Figure 1.

(b) Give brief answers to the following questions.

i. What effect is typically seen in images captured by camera with a slow shutter speed?

ii. Calculate the approximate depth of field for a camera with F-number 1.8, allowable circle of confusion 1μm, focal length 13.5mm and a subject distance of 15m (Given the formula $D \approx \frac{2NCU^2}{f^2}$).

iii. What physical principle do digital cameras use to convert incident light into electrical current?

iv. Briefly explain how alising occurs in digital images.

v. Briefly explain how a rolling shutter in a digital image sensor can cause distortion in the image of a high speed object in motion (e.g. helicopter blades).

[8 marks]

(c) Given a wide angle camera with a 90^0 field of view how many pixels are needed to be able to resolve a 5cm wide feature at a distance of 30m?

[7 marks]

Q2

(a)

i. What is the fundamental difference between the convolution and cross correlation operations?

ii. Determine the result of convolving the 3x3 kernel **A** with the 4x4 image B shown in Figure 2. You must demonstrate how the convolution can be carried efficiently using Separable convolution.

[4 Marks]

B

1	1	2	0
2	0	1	1
3	0	1	0
2	1	0	1

$*$

A

1	2	1
2	4	2
1	2	1

Figure 2.

(b)

i. How is an edge in an image defined?
ii. What is the general principle used to find edges in images?
iii. What effect can image noise have on an edge detector and how can the effect of noise be mitigated?
iv. List the four main steps in the Canny algorithm.

[4 Marks]

(c) Describe the Harris Corner algorithm. Write your answer as pseudo code showing the key steps to detect corners in an image.

[12 Marks]

Q3

(a) Give brief answers to the following questions:

i. List some qualities (four) of a good feature detector.

ii. Give some applications (two) that keypoints obtained using feature detection can be used for.

iii. What does it mean when a feature detector is described as scale invariant?

iv. Which function is commonly used as the canonical function for generating scale spaces?

v. What is the key principle that enables scale invariant feature detectors reliably detect features at one scale only?

vi. How is the Laplacian scale space formed (List the components or give your answer in the form of an equation)?

vii. How can the Laplacian scale space be formed in a computationally efficient manner?

viii. What simple algorithm can be used to find local maxima across a scale space?

ix. What advantage does the Harris Laplacian detector have over the basic Laplacian detector?

x. Explain how the difference of Gaussians scale invariant detector is more computationally efficient than the Laplacian scale space detector?

[14 marks]

(b) In the SIFT algorithm a pixel with a calculated magnitude of $\boldsymbol{\mu}$ =15 is to be divided between the 4 nearest histograms (centres as shown in figure 3). Calculate the contribution to the histogram with centre (2,0) using bilinear interpolation.

[6 marks]

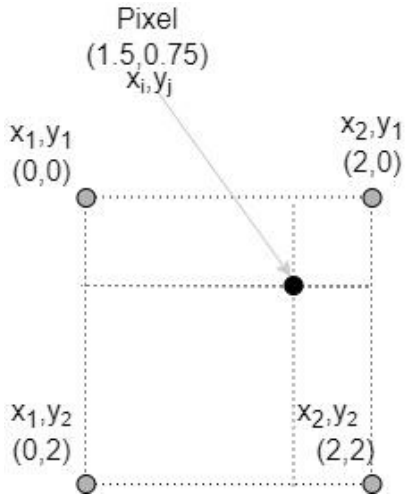

Figure 3.

Q4

(a) Give Brief answers to the following questions:

i. Define the term supervised learning.
ii. What are the three key components in a supervised learning system?
iii. What is the difference between Classification and Regression?
iv. Briefly define what the term "Generalisation" means for classifiers?

[4 marks]

(b) Give brief answers to the following questions about the K Nearest Neighbours (KNN) classifier.

i. What computation takes place during prediction with KNN?
ii. How does the value of K affect the overfitting behaviour of the classifier?

[4 marks]

(c) Give brief answers to the questions below.

i. Briefly explain the curse of dimensionality?
ii. What is the implication for image classification (using pixels as features) due to the curse of dimensionality?

[4 marks]

(d) Given a data matrix $X = \begin{bmatrix} \vdots & \dots & \vdots \\ x_1 & \dots & x_n \\ \vdots & \dots & \vdots \end{bmatrix}$ with n data sample vectors x_i of dimension d.

i. Briefly outline the steps necessary to obtain the principal components for the matrix of samples X. (You can give your answer in the form of pseudo code and/or mathematical equations)
ii. Briefly explain how images can be compressed and uncompressed using the principal component analysis.

[8 marks]

Q5

(a) Briefly describe how the Histogram of Orientated Gradients descriptor can be used to build a pedestrian detector.

[4 marks]

(b) Given the gradient information (Magnitude and Angle) for a 4 x 4 pixel cell (as shown in Figure 3) and assuming that the magnitude is to be interpolated between the two nearest neighbouring histogram bins.

i. Determine which bin centres will have some magnitude assigned by the pixel in the red square.

ii. Calculate the individual magnitudes that will be assigned to each of the bins

[6 marks]

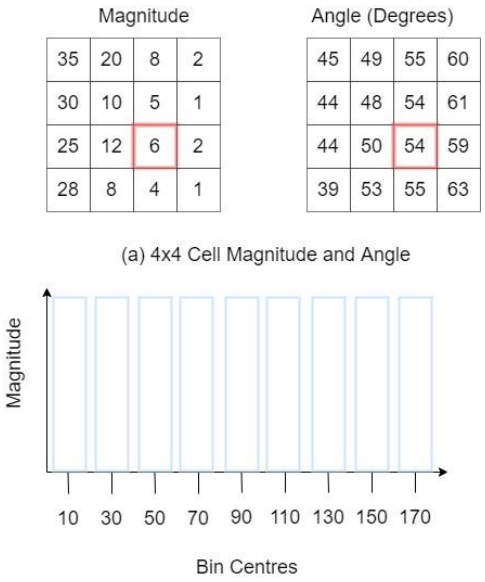

Figure 3.

(c) If a Histograms of Orientated Gradients (HOG) based detector is comprised of: cells of size 8 x 8 pixels, blocks of 2 x 2 cells, histograms with 9 orientations in each cell and an image patch size of 176 x 64 pixels.

i. Calculate how many blocks does the detector window contain (assuming the blocks overlap by 1 cell)?

ii. Calculate the length of the HOG descriptor?

[6 marks]

(d) Briefly describe how the Bag of features representation is generated for an image.

[4 marks]

Additional Information for Q5:

Convolution Formula: For any size image i, kernel of size k and stride s the output size o is given by

$$o = \left\lfloor \frac{i-k}{s} \right\rfloor + 1 \quad \text{(all values } (i, k, o, s) \text{ are in pixels)}$$