UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Final Exam 2013

Prescription Number: COSC428

Paper Title: *Computer Vision*

Time allowed: TWO hours

Number of pages: 5

- This exam is worth a total of 100 marks
- Contribution to final grade: 40%
- Length: 11 questions
- Answer *all* questions.
- Calculators are *not* allowed.
- *This is a closed book test*.
- Use the separate *Answer Booklet* for answering *all* questions.

1 (6 marks)

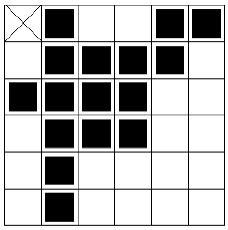
In order for a natural feature registration algorithm to work well it must be robust to common image transformations and distortions. List six such image transformations and distortions.

2 (8 marks)

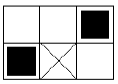
Assume that you already have a reliable model of the camera's intrinsic parameters, have removed any radial distortion and now wish to perform natural feature registration.
List the five steps of the natural feature registration algorithm [5 marks]
Name three natural feature algorithms [3 marks]

3 (8 marks)

The *opening* of an image X is called a "homogeneous opening" when the same structuring element B (similar to a filter) is used for both the erosion and dilation operations. (Note that the crossed pixel in B indicates where B is centred on each successive pixel in A.)
Show the *homogeneous opening* of X with respect to B for the X and B shown below. Show your answer in two figures (similar to the figure for X) representing the two morphological steps which support opening.



X



B

4 (12 marks)

Describe how pixels in a camera differ from the photoreceptors in the human retina in terms of colour space and the distribution of colour, sensitivity, and resolution. (Use diagrams in your answer.)

5 (4 marks)

Write the equations for finding the
(a) gradient direction (angle) of an edge [2 marks]
(b) gradient strength (absolute value) of an edge in an image [2 marks]

6 (8 marks)

Name each pair of filters labelled (a) to (d) below and describe what each filter accomplishes.

Δ_1 Δ_2

$$\begin{matrix} 0 & 1 \\ -1 & 0 \end{matrix} \qquad \begin{matrix} 1 & 0 \\ 0 & -1 \end{matrix}$$

(a)

Δ_1 Δ_2

$$\begin{matrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{matrix} \qquad \begin{matrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{matrix}$$

(b)

Δ_1 Δ_2

$$\begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix} \qquad \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix}$$

(c)

Δ_1 Δ_2

$$\begin{matrix} -3 & -1 & 1 & 3 \\ -3 & -1 & 1 & 3 \\ -3 & -1 & 1 & 3 \\ -3 & -1 & 1 & 3 \end{matrix} \qquad \begin{matrix} 3 & 3 & 3 & 3 \\ 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 \\ -3 & -3 & -3 & -3 \end{matrix}$$

(d)

7 (10 marks)

A good edge detector should have:

- Good Detection: filter responds to edge, not noise.
- Good Localization: detect edge near true edge.
- Single Response: one per edge.

(a) Describe how the Canny edge detection algorithm accomplishes the above attributes of a good edge detector. [8 marks]

(b) Explain how the choice of Gaussian kernel size affects the desired behavior of the Canny edge detector. [2 marks]

8 (10 marks)

A good local image feature to track should:

- satisfy brightness constancy
- have sufficient texture variation
- not have too much texture variation
- correspond to a "real" surface patch
- not deform too much over time

Taking into account the above features, describe and compare the following two algorithms:

(a) Harris detector [5 marks]

(b) Scale-Invariant Feature Transform (SIFT) [5 marks]

9 (12 marks)

Describe how correctly matched points in two images enable finding:

(a) depth values in a stereo pair of images [4 marks]

(b) optical flow points in two successive frames of video using the Lukas Kanade algorithm [4 marks]

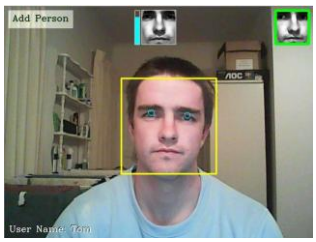
(c) Describe how depth can be calculated from optical flow. [4 marks]

10 (6 marks)

If a virtual 3D model of a body can be kept aligned with a person moving in a 2D image, then it is possible to find all the joint angles for each frame of video, from that 3D model. So describe how three chained homogeneous transformation matrices can project a point b on the ith body part of a virtual 3D model onto a pixel p in a 2D image.

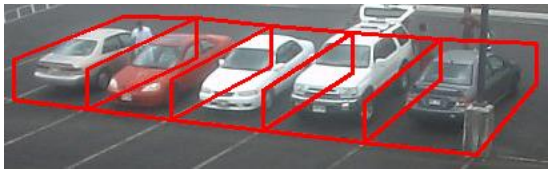
11 (16 marks)

You are to briefly describe **only four** of the following 2013 class projects [for 4 marks each] by just listing (one per line) at least four algorithmic steps, naming the algorithms used in the order they were used.
Do not select your own or similar project (e.g. face recognition projects do not select other face recognition projects, etc).

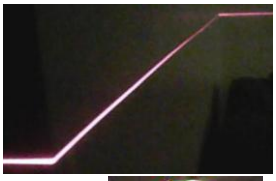


(i) Recognises users to enable "Access control for a mobile device".

(ii) "Estimation of Vehicle Velocity by Measurement of Optical Flow from a Front Facing Camera"



(iii) "Analysing a Stable Low Frame Rate Camera Stream to Identify the Occupancy State of Car Parks"



(iv) "Laser Scanning Technology as a means of indoor Unmanned Aerial Vehicle navigation" using a laser line to measure distance

(v) "Estimation of Shoulder Width to Height" as a biometric

(vi) "Real Time Static Hand Gesture-to-Speech Engine" using a Kinect camera

(vii) "Robot Soccer Referee Platform for Small, Mono-coloured Robots" using a birds-eye camera view of sphero balls hitting ping-pong balls.

(viii) "A Webcam-Based Virtual Piano Teacher"

END OF PAPER