UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

1997-98

For the following qualifications :-

M.Res

COURSE CODE	:	**PPP**
TITLE OF EXAMINATION	:	**Physics, Psychophysics and Physiology of Vision**
DATE	:	**26 February-1998**
TIME	:	**09.30**
TIME ALLOWED	:	**2 hours 30 minutes**

*Answer **four** questions in total, **at least one** question must be answered from section A, section B and section C. Each question is worth 25 marks. The total time allowed is two and a half hours.*

SECTION A

Attempt at least one question from this section.

Question 1: <u>Systems Design</u>

An affluent, small city in the south of England wishes to install eight video surveillance cameras so as to reduce the incidence of street crime in its central square and has decided to use a machine vision system for the detection of potentially criminal behaviour. In order to keep costs down, commercial, monochrome solid state TV cameras are to be used and the video from each fed back to a central control room in the nearby, local police station. The algorithms to be used detect criminal acts by carrying out approximately 100 numerical operations on each pixel in a 9 x 9 region of interest centred in turn at each pixel in each image over a range of three octaves of scale including the raw image data. You are asked to design the computer system to be installed, in order to meet the following requirements:

1. low cost, high reliability and availability,
2. continuous processing of all video signals and rapid response for detection of criminal actions,
3. storage of video data for 2 minutes before and 5 minutes after the triggering of a suspicious event, for use as evidence should there be a prosecution.

(a) Describe what kind of computer architecture you would propose, explaining the reasons for your choice as quantitatively as possible and discussing the alternatives that you would consider.

[12 marks]

[Question 1 cont. over page]

[TURN OVER]

[Question 1, cont.]

(b) Police experts and the developers of the processing algorithms later inform you that there are four kinds of characteristic patterns in an image that indicate imminent criminal activity and that it is important to discover as quickly as possible when any one or more of these occurs. Describe how your system proposed in (a) above would meet this additional requirement or how you would modify your design in order to meet it. Explain your reasoning.

[5 marks]

(c) Later still, the same experts tell you that the patterns observed alone or in particular combinations in the same image may be used to indicate the severity of the incident and that the complexity of the processing required to detect each of the characteristic patterns varies in the ratio of 1:2:4:5. Describe how you would modify the architecture described in (b) above in order (i) to classify the type of infringement, (ii) to maximise the throughput, and (iii) also to minimise the latency of the system. Be as quantitative as you can in your description and comment on any special condition or conditions necessary in order for your solutions to (i), (ii) and (iii) to work.

[8 marks]

[CONTINUED]

Question 2: The Statistics of Images

(a) There is a saying that "a picture is worth a thousand words". Discuss to what extent this statement is true when applied to the images obtained, for example, from a modern, digital CCD colour camera. Define quantitatively the information content of such an image and describe the qualitative characteristics of the type of images for which your measure would: (i) be large, and (ii) be small. Use your definition of the information content to explain why, in practice, it is necessary to define a controlled task or scenario when trying to develop image processing or machine vision algorithms.

[8 marks]

(b) Describe how normal (Gaussian) distributions may be used to model (i) the intensity distribution in a monochrome image, and (ii) the distribution in the RGB, red, green and blue, channels of a colour image. Discuss to what extent these models are valid and explain how, for a colour image the former is related to the latter. Describe the method you would use to estimate the parameters defining the distributions and, for the monochrome case, derive the relevant equations and comment on the results obtained.

[12 marks]

(c) Describe why these distributions need to be extended in order, for example, to describe the statistics of natural imagery and explain how the required extension relates to the empirical observation that the power spectrum of such imagery behaves like a power law. Show how such behaviour can explain the fact that such images can often be simulated on a computer by random fractal images.

[5 marks]

[TURN OVER]

SECTION B

Attempt at least one question from this section.

Question 3: Neural Adaptation

(a) What evidence supports the idea that neural adaptation contributes towards the optimisation of image processing in the human visual system.

[10 marks]

(b) Provide a detailed account of one model of visual function that exploits those benefits that may be obtained by adaptation.

[10 marks]

(c) Briefly evaluate your answer given in part (b), using the relevant empirical and theoretical evidence to support your answer.

[5 marks]

Question 4: Spatial Vision

(a) Decribe the receptive field profiles of: (i) retinal ganglion cells, and (ii) simple cells in area V1 of the visual cortex. Provide an outline of Marr's theory of edge detection indicating how this theory may be related to the receptive field profiles in the retina and area V1.

[9 marks]

(b) What evidence if any, supports Marr's theory of edge detection as a model for human visual processing?

[8 marks]

(c) Describe one model that may detect the edges of a contrast envelope.

[8 marks]

[CONTINUED]

SECTION C

Attempt at least one question from this section.

Question 5: Binocular Vision

(a) Provide a detailed synopsis of Fleet, Heeger and Wagner's model of binocular stereopsis.

[15 marks]

(b) Critically evaluate the model of binocular stereopsis proposed by Fleet et al. Your answer should draw upon the established empirical literature.

[10 marks]

Question 6: Image Motion Detection

(a) What empirical evidence supports the idea that the detection of motion by the visual system is biased?

[10 marks]

(b) Paying reference to your answer given in (a) above, describe in detail one model of visual motion detection.

[15 marks]

[END OF PAPER]