# UNIVERSITY COLLEGE LONDON

*University of London*

# EXAMINATION FOR INTERNAL STUDENTS

## 1998-99

*For the following qualifications :-*

M.Res

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|---|---|---|
| COURSE CODE | : | **PPP** |
| TITLE OF EXAMINATION | : | **Physics, Psychophysics and Physiology of Vision** |
| DATE | : | **10 March-1999** |
| 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>Colour Representations and Colour Constancy</u>**

(a) Describe what is meant by the RGB colour cube and use it to explain how the RGB, rgb and HIS colour representations differ. Explain why these are often regarded as the three main types of colour space used in computer vision. Illustrate your answer by referring to three other colour representations of your choice.

**[9 marks]**

(b) According to a certain colour imaging model, a change in the illumination intensity or geometry, scales the $\left(R_i, G_i, B_i\right)$ values at each pixel $i = 1, \ldots. N$ by a factor $s_i$, the same for each colour channel, whilst a change in illuminant colour or spectral content causes a change to $\left(\alpha R_i, \beta G_i, \gamma B_i\right)$ with, in general, different factors $\alpha, \beta, \gamma$. Show that:

(i) rgb colour values are invariant under a change in the illumination intensity or geometry, but not invariant under a change in illuminant colour;

(ii) colours normalised over all the pixels $i = 1, \ldots. N$ are invariant under a change in illuminant colour, but not under a change in the illumination intensity or geometry.

**[4 marks]**

(c) If the pixel colours $\left(R_i, G_i, B_i\right)$ are written as an $N \text{ x } 3$ matrix, $I$, show that the transformations to the rgb representation and the pixel normalised colours used in (b) (i) and (ii) above may both be represented by matrix multiplication. Describe the precise form of the transformation matrices required.

Show how these transformations may be combined in a comprehensive scheme such as that developed by Finlayson *et al* which is invariant to both types of change. Explain why you would expect this scheme to improve the performance of a face detection system in a surveillance application and describe briefly how you would demonstrate this experimentally.

**[12 marks]**

**[TURN OVER]**

**Question 2:** **Imaging and Reflectance**

(a) The colour signal $C(\mathbf{x})$ in each of the channels of an RGB camera may be written as:

$$C(\mathbf{x}) = \int d\lambda f_C(\lambda) E(\mathbf{x}, \lambda)$$
$$= \frac{\pi D^2 \cos^4(\theta)}{4 f^2} \int d\lambda f_C(\lambda) L(\theta, \phi, \mathbf{X}, \lambda) \quad . \qquad (1)$$

Explain the meaning and physical origin of each of the terms in the above equation and describe under what condition the total intensity is given by:

$$I(\mathbf{x}) = R(\mathbf{x}) + G(\mathbf{x}) + B(\mathbf{x}) \quad . \qquad (2)$$

**[8 marks]**

(b) Describe Schafer's dichromatic model for the reflectance of light $L_0 i(\mathbf{s}, \lambda)$ from a nearby source in direction of the unit vector $\mathbf{s}$ by an object and use it to show that the colour $\mathbf{C}(\mathbf{x}) = \left(R(\mathbf{x}), G(\mathbf{x}), B(\mathbf{x})\right)$ may be expressed in the form:

$$\mathbf{C}(\mathbf{x}) = L_0 m_b \mathbf{b} + L_0 m_s c_s \mathbf{i} \quad . \qquad (3)$$

Assume that the camera described in (1) above is used, that the tiles are 20cm square and imaged at a distance of 1m with a long focal length lens so that a single tile fills the whole field of view. Show how each of the new terms appearing in (3) is defined, explain what they depend on and describe how you would expect the colour $\mathbf{C}(\mathbf{x})$ to be distributed in the RGB colour cube.

**[8 marks]**

(c) Two coloured tiles fired from different clays but with the same glaze are imaged successively under white light with a camera adjusted to the integrated white condition. Sketch what you would predict the colour distributions to be according to Shafer's dichromatic model described in (b) above. Use this prediction to indicate how you would determine quantitatively whether the same camera could be used reliably to distinguish the tiles under these conditions. Describe briefly what you might do to improve the discrimination if, under the conditions given above, the camera was not adequate, but could not be replaced. A few days later, you notice that the red channel of the camera has failed. Discuss to what extent the camera may still be used to distinguish the tiles by imaging them: (i) before they are glazed, (ii) after they are glazed.

**[9 marks]**

**[CONTINUED]**

## SECTION B

*Attempt at least one question from this section.*

**Question 3: Research Methods**

(a) Describe three different techniques that have been used to study the properties of neurons in the visual cortex.

**[9 marks]**

(b) Explain how speed discrimination thresholds may be affected by motion adaptation, and how these adaptive effects can be measured using psychophysical methods.

**[8 marks]**

Briefly discuss, using examples to illustrate your answer the relative merits of psychophysical and neurophysiological research methods.

**[8 marks]**

**Question 4: Spatial Vision**

(a) Describe briefly the mechanisms that process visual signals up to and including complex cells found in visual area V1 of the cortex. Your answer should identify the purpose of each stage of processing.

**[9 marks]**

(b) What evidence supports the idea that early visual non-linearities introduce distortion products into the visual pathways? Discuss whether these non-linearities are responsible for the detection of contrast envelopes, and hence the neural site at which the information present in contrast envelopes may be detected.

**[8 marks]**

(c) Show how the spatial gradients of amplitude, defined as the amplitude response taken from a quadrature pair of linear filters may be applied to detect the orientation of second-order signals from spatial images.

**[8 marks]**

**[TURN OVER]**

## SECTION C

*Attempt at least one question from this section.*

**Question 5: <u>Binocular Vision</u>**

(a) Describe in brief, the computational model of binocular depth perception proposed by Fleet, Heeger and Wagner (1996). Your answer should include a brief discussion of the empirical data from which this model was developed.

**[9 marks]**

(b) What is Ogle's induced effect? How might this effect be explained by the idea that the visual system exploits binocular differences in the orientation between lines and edges.

**[8 marks]**

(c) Explain why one's perception of transparency for a contrast envelope multiplied by a sinusoidal grating could be different from the perception of transparency for two added gratings of markedly different spatial frequencies.

**[8 marks]**

**Question 6: <u>Image Motion Detection.</u>**

(a) Explain the terms summative and divisive speed gain control. What empirical evidence supports the idea that these two adaptive strategies may explain static and dynamic motion after effects?

**[9 marks]**

(b) Explain how the intersection of constraints may be used to describe the magnitude and direction of a moving plaid pattern from the ambiguous velocity of the plaid's two sinusoidal gratings. Explain, using empirical evidence to support your answer, how perception departs from the predictions made by this model of motion.

**[7 marks]**

(c) Outline briefly, the computational model of motion perception proposed by Langley and Clifford (1999), and explain how this model may account for the empirical data given in your answer to 6 (a) and 6 (b).

**[9 marks]**

**[END OF PAPER**