2005 Paper 9 Question 11

Computer Vision

(a) Consider the following isotropic 2D filter function $f(x, y)$ incorporating the Laplacian operator $\nabla^2 = \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right)$, that is often used in computer vision:

$$f(x, y) = \nabla^2 e^{-\left(x^2 + y^2\right)/\sigma^2}$$

(i) In 2D Fourier terms, what type of filter is this? (For example, is it a lowpass, a highpass, or a bandpass filter?) [2 marks]

(ii) Are different orientations of image structure treated differently by this filter, and if so, how? [2 marks]

(iii) Approximately what is the spatial frequency bandwidth of this filter, in octaves? [Hint: the answer is independent of σ.] [1 mark]

(iv) What is meant by image operations "at a certain scale of analysis"? In this context, define a scale-space fingerprint, and explain the rôle of the scale parameter. [3 marks]

(b) What surface properties can cause a human face to form either a Lambertian image or a specular image, or an image lying anywhere on a continuum between those two extremes? In terms of geometry and angles, what defines these two extremes of image formation? What difficulties do these factors create for efforts to extract facial structure from facial images using "shape-from-shading" inference techniques? [3 marks]

(c) Why can't any computer vision operations be performed directly on `.jpeg` image formats? [1 mark]

(d) Discuss the significance of the fact that mammalian visual systems send perhaps ten times as many corticofugal neural fibres back down from the visual cortex to the thalamus, as there are ascending neural fibres bringing visual data from the retina up to the thalamus. Does this massive neural feedback projection support the thesis of "vision as graphics", and if so how? [4 marks]

(e) Explain why inferring object surface properties from image properties is, in general, an ill-posed problem. In the case of inferring the colours of objects from images of the objects, how does knowledge of the properties of the illuminant affect the status of the problem and its solubility? [4 marks]