2002 Paper 8 Question 9

Neural Computing

(*a*) Sketch a neural network that implements the following three operators for image analysis by demodulation, for purposes such as finding the important features in a face:

$$g(x,y) = \int_\alpha \int_\beta e^{-\left((x-\alpha)^2+(y-\beta)^2\right)/\sigma^2} \cos(\omega(x-\alpha))\ I(\alpha,\beta)\ d\alpha\ d\beta$$

$$h(x,y) = \int_\alpha \int_\beta e^{-\left((x-\alpha)^2+(y-\beta)^2\right)/\sigma^2} \sin(\omega(x-\alpha))\ I(\alpha,\beta)\ d\alpha\ d\beta$$

$$A^2(x,y) = g^2(x,y) + h^2(x,y)$$

where $I(x,y)$ is the image, ω is a parameter determining the approximate scale of the features being extracted, and $A^2(x,y)$ is the nonlinear output of the neural network that highlights the primary features. [10 marks]

(*b*) What is accomplished when such a network acts upon an image $I(x,y)$? In the case that the image happens to be a face, why does the output $A^2(x,y)$ detect the primary facial features? [4 marks]

(*c*) Describe the effect of your neural network in terms of the two-dimensional spatial frequency domain. To what image structure is it most sensitive, as a function of frequency, and as a function of orientation? [3 marks]

(*d*) Describe the neurobiological basis of your network in terms of the known properties of cells in the mammalian visual cortex. What is the name of the neurones that are described by the operators $g(x,y)$ and $h(x,y)$? What is the name of the class of neurones whose physiology is described by $A^2(x,y)$? [3 marks]