2010 Paper 9 Question 4

Computer Vision

(*a*) Consider an object's surface reflectance map $\phi(i, e, g)$ specifying the amount of incident light reflected towards a camera from each point on the surface, where the angle of the illuminant (a point source) relative to the local surface normal N is i, the angle relative to N of a ray of light re-emitted from the surface is e, and the angle between the emitted ray and the illuminant is g.

(*i*) For what kind of surface is the reflectance map simply $\phi(i, e, g) = \cos(i)$? Name this type of surface and describe its key properties. [3 marks]

(*ii*) For what kind of surface does the reflectance map simplify to $\phi(i, e, g) = 1$ if $i = e$ and both i and e are co-planar with the surface normal N, and $\phi(i, e, g) = 0$ otherwise? Name this type of surface and describe its key properties. [3 marks]

(*iii*) For what kind of surface does the reflectance map depend only on the ratio of the cosines of the angles of incidence and emission, $\cos(i)/\cos(e)$, but not upon their relative angle g nor upon the surface normal N? Give an example of such an object, and explain the consequence of this special reflectance map for the object's appearance. [3 marks]

(*iv*) For the more general class of object surfaces described by the following reflectance map, with $0 \leq s \leq 1$,

$$\phi(i, e, g) = \frac{s(n+1)(2\cos(i)\cos(e) - \cos(g))^n}{2} + (1 - s)\cos(i)$$

which term is the specular component, and which term is the matte component? What fraction of light is emitted specularly, and what does the parameter n represent? Describe the behaviour of parameters s and n around regions of a person's face where the skin might be oily or sweaty and places where it is not, and how this impacts recognition. [4 marks]

(*b*) Using the second finite difference operator | -1 | 2 | -1 | for edge detection in an image, show how the pixel values in the top row are changed by discrete convolution with this operator: insert the output values in the bottom row.

...	0	0	0	0	5	5	5	5	5	0	0	0	0	...

[3 marks]

(*c*) Show how Bayesian inference enhances face recognition when a face contains highly distinctive features, as exploited by caricature. Suppose some facial feature x is unusual so its probability $P(x)$ is small, and that for each k^{th} face described as class C_k we know the class-conditional likelihood $P(x|C_k)$ of observing this unusual feature, but *a priori* all the classes are equiprobable. Use Bayes' Rule to show how the correct classification of face C_k given its unusual feature x acquires higher probability $P(C_k|x)$. [4 marks]