4 Computer Vision (JGD)

(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. [4 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 coplanar with the surface normal \( N \), and \( \phi(i, e, g) = 0 \) otherwise? Name this type of surface and describe its key properties. [4 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. [4 marks]

(b) The binary pixel array on the left below was convolved with what operator to produce the result on the right? Specify the operator by numbers within an array, and identify what task this convolution accomplishes in computer vision.

\[
\begin{array}{ccccccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{array}
\times \begin{array}{ccccccccccc}
\end{array}
\Rightarrow
\begin{array}{ccccccccccc}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\
0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\
0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 1 & -1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{array}
\]

[4 marks]

(c) When visually inferring a 3D representation of a face, it is useful to extract separately both a shape model, and a texture model. Explain the purposes of these steps, their use in morphable models for pose-invariant face recognition, and how the shape and texture models are extracted and later re-combined. [4 marks]