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{align*}
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 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{align*}

$\ast$ $[?]$ \implies

\begin{align*}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 & 0 \\
0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 & 0 \\
0 & -1 & 1 & 0 & 0 & 1 & -1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{align*}

[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]