1 Acquisition

We present a high quality facial capture system that employs unpolarized binary spherical gradient illumination. Our capture setup consists of the Imperial Multispectral LED sphere with 168 LED lighting nodes and a multiview facial capture setup consisting of 9 DSLR cameras (Canon 800D) (Figure 1, top). For acquisition, we employ only the white LEDs on the LED sphere (Philips Color Kinetics iW MR gen3) to illuminate a subject with 6 binary spherical gradient illumination conditions (along principal X, Y and Z directions and their complements) as proposed by Kamprouris et al. [1] (Figure 1, bottom). We rapidly acquire a face under these 6 binary illumination conditions from our 9 cameras operating in burst mode to minimize any subject motion during capture. The data acquired is then employed for both multiview facial geometry reconstruction and for high quality reflectance separation and estimation of separated diffuse and specular photometric normals for rendering.

2 Reflectance Separation

We now present our main contribution of this work which is further improvement in the quality of diffuse-specular separation of the mixed albedo acquired using binary spherical gradient illumination. Our baseline here is the diffuse-specular separation obtained by Kamprouris et al. [1] using their proposed analytic solution obtained from HSV color transformation analysis (see Figure 3 b, c). As can be seen, the quality of separation is quite good at the sides of the face but suffers from poor signal-to-noise (SNR) of the separated specular component near the frontal areas of the face. This results in sub-optimal separation and some specular pollution near the frontal areas of the face in the separated diffuse albedo.

Instead, we employ a linear system to solve for the specular component based on the observation that under the binary gradient and complement pairs, the brightly lit condition consists of diffuse+specular while the darker condition consists of pure diffuse component. Without loss of generality, assuming a surface appears brighter under gradient G and darker under complement C, we can formulate the linear system solution as follows:

\[
\begin{bmatrix}
G \\
C
\end{bmatrix} = \begin{bmatrix}
N_d & 1 \\
1 - N_d & 0
\end{bmatrix} \begin{bmatrix}
D \\
S
\end{bmatrix}
\]

Here, D is the diffuse component and S the specular component of the signal in a color channel, and \(N_d\) is the corresponding component of the diffuse normal (shifted to [0, 1]) for that principal direction. We solve this linear system for the green channel since it has the best SNR. The diffuse normal \(N_d\) is obtained using \(SUV\) transformation of the acquired data and employing only the chroma components \(U, V\) to compute the photometric normal [1]. We separately solve Equation 1 twice, once each for the X and Y gradient-complement pairs, to obtain two different estimates of D and S. Assuming monochromatic specular reflection, we just compute the final estimate of specular reflectance as the mean of the two solutions for S (Figure 3, d). Finally, we simply subtract the monochromatic specular component S from the mixed albedo to obtain the separated diffuse albedo (Figure 3, e). As can be seen, we obtain a much higher quality of reflectance separation when using the linear system solution.

3 Results

We present rendering results for faces of a dark-skin subject and a light-skin subject acquired using our facial capture process (see Figure 4). Here, the facial geometry is rendered using the separated diffuse and specular reflectance (albedo) described in Section 3, in conjunction with high quality diffuse and specular normals obtained using binary spherical gradients [1]. As can be seen, we achieve very high quality photorealistic facial renderings with the acquired data.
