Head-mounted Photometric Stereo for Performance Capture

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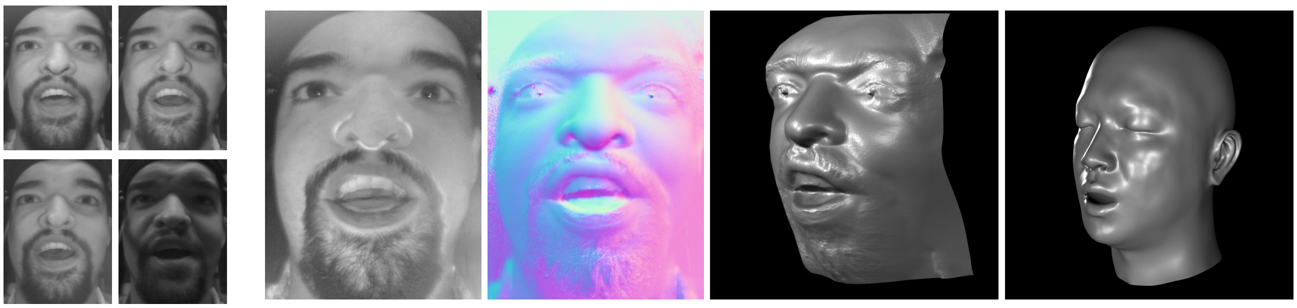

(a) (b) (c) (d) (e)

Figure 1: **(a)** *Lighting conditions (3 directions and ambient only) captured at 120fps* **(b)** *Recovered surface albedo, independent of ambient light* **(c)** *Recovered surface normals* **(d)** *Geometry recovered by integrating surface normals* **(e)** *3D facial rig driven by albedo and normals.*

Head-mounted cameras are an increasingly important tool for capturing facial performances to drive virtual characters. They provide a fixed, unoccluded view of the face, useful for observing motion capture dots or as input to video analysis. However, the 2D imagery captured with these systems is typically affected by ambient light and generally fails to record subtle 3D shape changes as the face performs. We have developed a system that augments a head-mounted camera with LED-based photometric stereo. The system allows observation of the face independent of the ambient light and records per-pixel surface normals allowing the performance to be recorded dynamically in 3D. The resulting data can be used for facial relighting or as better input to machine learning algorithms for driving an animated face.

We use a Point Grey Grasshopper camera mounted 20 cm from the face (Fig. 2). A ring of 12 individually controlled LEDs encircles the lens. The LEDs repeat a sequence of three illumination patterns, followed by an unlit frame to record and subtract ambient light (Fig. 1a); crossed linear polarizers on the lights and lens attenuate specular reflection from the face. The camera and lights run at 120 fps, yielding albedo and normal estimates (Fig. 1b,c) at 30 fps.

Figure 2: *Head-mounted camera and LED light ring*

Traditional photometric stereo [Woodham 1980] uses multiple point lights to recover surface normals by solving linear equations. More recent work (e.g. [Malzbender et al. 2006]) records surface normals in real time. Our system uses three linear gradient intensity ramps across the twelve LEDs, rotated at 0, 120, and 240 degrees. Using the full ring of lights provides more even illumination, reduces shadow artifacts, and emits light from a wider area to increase actor comfort; our video shows results using three individual LEDs for comparison. Flicker can be greatly reduced by switching patterns at 360Hz while recording at 120fps with 1/360th sec exposure, capturing every third pattern. To further eliminate distraction from the lights, we built a second lighting rig using invisible infrared LEDs, leveraging the broad spectral sensitivity of the camera. This provided similar results at the expense of some detail in the photometric normals due to increased subsurface scattering.

To correct for subject motion, we compute optical flow between similar illumination patterns to temporally align each set of patterns. Our light sources are close to the face, violating the assumption of distant illumination. To compensate, we compute per-pixel lighting directions relative to a plane approximating the face.

To estimate 3D performance geometry, we integrate the surface normals using Gaussian belief propagation. The geometry (Fig. 1d) expectedly suffers from low-frequency distortions yet reveals expressive performance detail in 3D. The results can be used as input to a machine learning algorithm to drive a facial rig with the performance after an initial training phase. For an initial test, we use an active appearance model [Cootes et al. 2001] to find blendshape weights for a given set of albedo and normal maps. Our initial results are restricted to phonemes (Fig. 1e) and we are working to extend this algorithm to animating the entire face. Initial results show that analysis of normals and albedo provides smoother animation than analysis of albedo alone. We are also working to minimize weight, which should not be significantly greater than existing rigs as the LEDs weigh just a few grams each.

References

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