Multi-Flash 3D Photography: Capturing Shape and Appearance

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Input Image Surface Reconstruction Estimated Appearance

We describe a new 3D scanning system which exploits the depth discontinuity information captured by the multi-flash camera proposed by [Raskar et al. 2004]. In contrast to existing differential and global shape-from-silhouette algorithms, our method can reconstruct the position and orientation of points located deep inside concavities. Points which do not produce an observable depth discontinuity, however, cannot be reconstructed. We apply Sibley's method for fitting an implicit surface to fill the resulting sampling gaps [Crispell et al. 2006]. Extending this prior work, we model the appearance of each surface point by fitting a Phong reflectance model to the BRDF samples using the visibility information provided by the implicit surface.

Data Capture

A computer-controlled turntable and stationary 8 megapixel digital camera are used to acquire data from 670 viewpoints in a circular path around an object. For each viewpoint, we capture four images using illumination from the top, left, right, and bottom flashes, respectively. The camera is intrinsically calibrated and its pose with respect to the turntable is determined using a calibration grid. After data capture, we rectify each image to remove any radial distortion and to align the camera's vertical axis with the axis of rotation.

Shape from Depth Discontinuities

Using the algorithm described in [Raskar et al. 2004], we estimate a *depth edge confidence map* for each viewpoint – corresponding to the likelihood of a depth discontinuity at a given pixel. These confidence images are concatenated to form a space-time volume, and each *epipolar slice* (corresponding to an image scanline) is processed independently. Points on the surface are then estimated from the differential properties of space-time curves fitted at sub-pixel resolution to ridges in the epipolar slices [Crispell et al. 2006].

The reconstructed point cloud will exhibit errors near frontier points and will possess several gaps. To minimize these effects, we filter outliers by backprojecting the point cloud into a small number of foreground-segmented images. Gap-filling is accomplished by introducing samples from the implicit surface.

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Appearance Modeling

Using the implicit surface, we can determine which points are visible from each viewpoint. Despite the relatively large number of viewpoints, however, the BRDF remains sparsely-sampled since the illumination sources and camera are nearly coincident. As a result, we simply fit a Phong model to the set of reflectance observations at each point (using a subset of 67 viewpoints). Note that, unlike similar texture assignment methods (e.g., [Sadlo et al. 2005]), we can detect (or remove) shadows automatically using the *maximum composite* of the four images. When insufficient data is available to fit the Phong model, we only estimate the diffuse albedo. Experimentally, we found that the *median diffuse albedo* was a computationally-efficient and visually-plausible substitute for the diffuse component of the Phong model.

Experimental results are summarized above (from left to right: sample image, estimated oriented point cloud and implicit surface, and two views of the final model with Phong texture). In this example, the reconstructed surface was stored as a point-based representation and rendered using Pointshop3D [Sadlo et al. 2005].

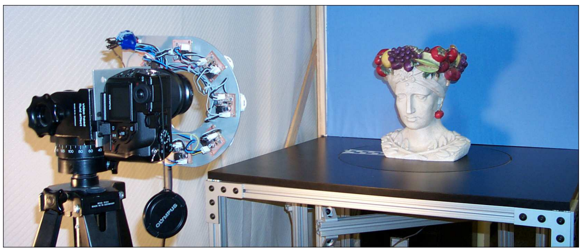

Figure 1: Multi-flash camera and computer-controlled turntable.

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