Generalised Perspective Shape from Shading with Oren-Nayar Reflectance

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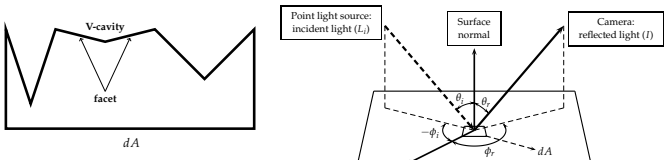
In spite of significant advances in Shape from Shading (SfS) over the last years, it is still a challenging task to design SfS approaches that are flexible enough to handle a wide range of input scenes. In this paper, we address this lack of flexibility by proposing a novel model that extends the range of possible applications. To this end, we consider the class of modern perspective SfS models formulated via partial differential equations (PDEs) [5]. In contrast to existing approaches, however, we do not restrict our model by *either* choosing an advanced reflectance model [1, 3] *or* a general setup that allows an arbitrary position of the light source different from the camera centre [2, 7]. Instead, we propose a novel general model for perspective SfS that combines the advantages of both worlds.



(a) Facet model for surface patch dA consisting of many V-shaped Lambertian cavities.

(b) Diffuse reflectance for SfS with Oren-Nayar.

Figure 1: Sketch of the Oren-Nayar surface reflection model. From [3].

On the one hand, we consider the non-Lambertian reflectance model of *Oren* and *Nayar* [4]. By modelling rough surfaces via a Gaussian distribution of V-shaped cavities with standard deviation σ, this model allows us to handle advanced materials such as concrete, plaster, clay or cloth whose properties are considerably different from those of Lambertian ones (Fig. 1). On the other hand, we make use of a *spherical* coordinate system to parametrise the resulting brightness equation [2]. By placing the centre of this coordinate system at the position of the light source, this parametrisation allows us to consider realistic scenarios where the light source is not necessarily located at the centre of the camera (Fig. 2).

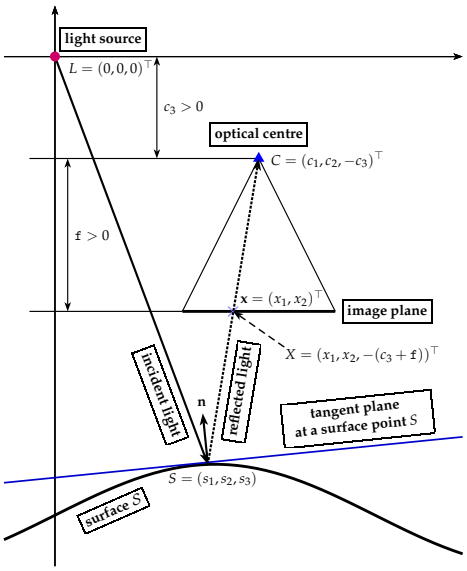
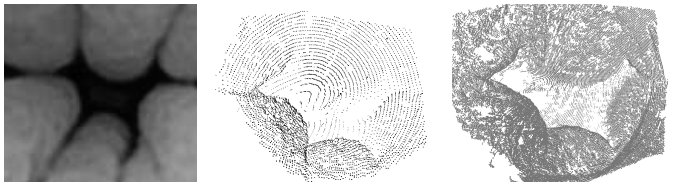


Figure 2: General SfS setup with arbitrary light source position. From [2].

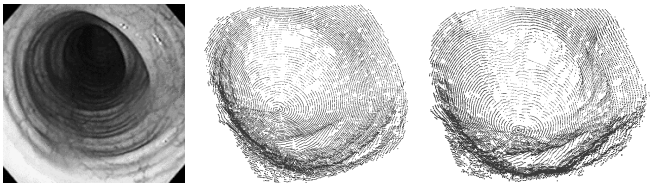
In contrast to the Lambertian case [2], the Hamilton-Jacobi equations (HJEs) that have to be solved for the Oren-Nayar model in spherical coordinates turn out to be significantly more complex. In fact, instead of solving a single HJE that is very compact, we have to distinguish *four* different cases with considerably more difficult equations. Nevertheless, following [2], we were able to derive an advanced numerical scheme of *fast marching* (FM) type [6] that allows for an efficient solution of the underlying HJEs. For the first time in the literature we thus succeed in modelling and solving an approach for perspective SfS that combines the advantage of *freely selecting* the position of the light source with the *robustness* of an advanced non-Lambertian reflectance model.

Experiments with medical real-world data demonstrate that our model offers the desired flexibility. As can be seen from Fig. 3 and Fig. 4, the quality of the reconstruction improves with finer grid sizes and the approach is stable under different choices of the roughness parameter σ.



(a) Input image. (b) $\delta_{\varphi\theta} = 0.025$. (c) $\delta_{\varphi\theta} = 0.0075$.

Figure 3: Reconstruction of gastric antrum with different grid sizes.



(a) Input image (211×208). (b) $\sigma = \frac{\pi}{6}$. (c) $\sigma = \frac{\pi}{2}$.

Figure 4: Reconstruction of duodenum with different roughnesses.

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