Chapter 5
3D Shape Recovery from Endoscope Image Based on Both Photometric and Geometric Constraints

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Abstract. An endoscope is a medical instrument that acquires images inside the human body. Sometimes, diagnosis requires assessment of the 3-D shape of observed tissue. For example, the pathology of a polyp often is related its geometrical shape. This chapter proposes a new approach for the 3-D shape recovery under the conditions of both point light illumination and perspective projection. The purpose of the proposed approach is to recover the direct shape of an object from an endoscope image using shape-from-shading approach. Observation model is assumed under the condition that both of a camera view point and a point light source are located at the origin and the goal is to recover the (X,Y,Z) coordinates at each point on the object. The previous approaches recover the shape based on Fast Marching...
Method (FMM) under the condition of parallel light source and orthographic projection, while proposed approach uses optimization technique based on the constraints of image irradiance equation and geometrical constraint. Photometric constraints are derived from the relation of observed image intensity and the surface gradient parameters and the depth parameter at each point, while the geometrical constraints use the geometrical relation between the depth at a point and the surface gradient parameters at the neighboring points. Optimization is used to determine the unique depth parameter at any point using both constraints from an initial point at the local brightest point. Proposed approach is evaluated via simulation and demonstrated through experiment. It is confirmed that the recovered shape improves the better performance than that by the previous approaches.

**Keywords:** Shape from Shading, Endoscope, Fast Marching Method, Point Light Source, Perspective Projection.

### 5.1 Introduction

Medicine is an important area of application of computer vision technology. Endoscopy allows medical practitioners to observe the interior of hollow organs and other body cavities in a minimally invasive way. Sometimes, diagnosis requires assessment of 3-D shape of observed tissue. For example, the pathological condition of a polyp often is related to its geometrical shape.

Specialized endoscopes with a laser light beam head [1]. Alternative method use two cameras mounted in parallel in the head [2]. The problem considered is the recovery of the 3-D shape of tissue in view. Stereo based endoscopy is one approach [3]. The challenge with stereo endoscopy is to determine corresponding features in the two images while the shape of internal organs itself is changing.

Here, a general purpose endoscope is considered, of the sort still most widely used in medical practice. This is because endoscope with some special hardware devise may limit the wider popularization of the application. With a single camera endoscope, shape from shading can be applied with the new assumption based approach.

Shape from Shading (SfS) uses the image intensity to recover the surface orientation of a target object from a single image. Horn [4] pioneered the shape from shading in computer vision, and many approaches have been proposed. In many studies, Lambertian model and orthographic projection is assumed with a known lighting direction to recover the surface orientation. Horn’s SfS solved the surface gradient parameters along the characteristic strip based on the initial point which can determine the surface gradient initially. An approach of extension of SfS is Photometric Stereo proposed by Woodham [5], which uses three different light source conditions of illumination instead of using a fixed camera. Photometric stereo can determine the surface gradients locally and solved the problem of the original SfS which cannot recover the surface gradients at whole points on the object.