Chapter 48
3D Reconstruction of Underwater Natural Scenes and Objects Using Stereo Vision

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ABSTRACT

Over the last two decades, research community of computer vision has developed various techniques suitable for underwater applications using intensity images. This chapter will explore 3D reconstruction of underwater natural scenes and objects based on stereo vision, which will be helpful in mine detection, inspection of shipwrecks, detection of telecommunication cables and pipelines. The general steps involved in 3D reconstruction using stereo vision are provided. The brief summary of papers for 3D reconstruction of underwater environment is presented. 3D reconstruction of underwater natural scenes and objects is challenging problem due to light propagation in underwater. In contrast to light propagation in the air, the light rays are attenuated and scattered, having a great effect on image quality. We have proposed preprocessing technique to enhance degraded underwater images. At the end of the chapter, we have presented the proposed stereo vision based 3D reconstruction technique to reconstruct 3D surface of underwater objects. Ultimately, this chapter intends to give an overview of the 3D reconstruction technique using stereo vision in order to help a reader in understanding stereo vision and its benefits for underwater applications.

DOI: 10.4018/978-1-4666-3994-2.ch048

INTRODUCTION

Three dimensional (3D) reconstruction is the process of capturing the shape and appearance of real objects. Recovering 3D surface structure of an object has been a central issue in computer vision. In order to extract 3D information out of 2D images, it is useful to have a set of images showing the target object viewed from different directions. The 3D reconstruction approaches of interest for our application are the so-called optical methods, which perform reconstruction from a set of 2D images. The earliest attempt for 3D reconstruction for general applications is based on volume intersection such as Shape from Silhouette (Laurentini, 1994). The most prominent approaches in 3D reconstruction are the stereo, Voxel Coloring (Slabaugh et al., 2001) and the Space Carving (Kutulakos et al., 1998). The Voxel Coloring and the Space Carving approaches use the color consistency to distinguish surface points from other points in a scene. Cameras with an unoccluded view of a non-surface point see surfaces beyond the point, and hence inconsistent colors, in the direction of the point. Initially, the environment is represented as a discretized set of voxels, and then the algorithm is applied to color the voxels that are part of a surface in the scene. Another promising approach in 3D reconstruction is the Marching Cubes algorithm for rendering iso-surfaces from volumetric scan data (Lorenson et al., 1987). The algorithm produces a triangle mesh surface representation by connecting the patches from all cubes on the iso-surface boundary.

3D scene structures captured by a camera may be detected and acquired observing the apparent motion of brightness patterns from images. In the last fifteen years, theoretical developments in visual motion studies have established a unified framework for the treatment of the Structure from Motion (SFM) and Structure from Stereo (SFS) problems (Faugeras, 1992), also known as 3D Reconstruction from Multiple Views. 3D reconstruction from multiple views involves extracting target features from one image, matching and tracking these features across two or more images, and using triangulation to determine the position of the 3D target points relative to the camera. Visual motion methods have been well-studied, requiring densely-sampled image sequences. The primary visual motion cue useful for shape acquisition is the perceived movement of brightness patterns, known as optical flow (Horn, 1986), which is an approximation of the 3D world motion field. The 3D reconstruction from differential motion cues requires accurate optical flow computation.

Instead, stereo vision is the more accurate and robust 3D reconstruction method (Scharstein et al., 2002) and the correspondence problem is between the left and right image. A large amount of works has addressed the correspondence problem, attempting to overcome the various difficulties of the large-displacement correspondence problem like occlusions, rotations and disparities, photometric and projective distortions (Lucas et al., 1981; Tomasi et al., 1991).

STEREO VISION PARADIGM

Stereo vision refers to the ability to infer 3D information of a scene from two images taken from different viewpoints. The simplest demonstration of the essence of stereo vision is to hold an object in front of face and alternatively close the left and right eyes. Observe that the relative position of the object and background seems to change. It is exactly this difference in retinal position that is used by the brain to reconstruct a 3D scene. This is the essence of what we try to duplicate using stereo vision. The generalized stereo vision paradigm, illustrating the steps involved in the stereo vision is shown in Figure 1. These steps are described as follows:

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