Chapter 1

3D Reconstruction Algorithms Survey

Mohamed Karam Gabr
German University in Cairo, Egypt

Rimon Elias
German University in Cairo, Egypt

ABSTRACT

Over the past years, 3D reconstruction has proved to be a challenge. With augmented reality and robotics attracting more attention, the demand for efficient 3D reconstruction algorithms has increased. 3D reconstruction presents a problem in computer vision and as a result, much work has been dedicated to solving it. Different design choices were made to consider different components of the process. Examples of these differences are how the scanning process is tackled, how the 3D reconstructed world is represented, among other aspects. Therefore, an evaluation of these algorithms is necessary. This chapter focuses on the properties that facilitate the evaluation of 3D reconstruction algorithms and provides an evaluation of the various algorithms.

INTRODUCTION

Three-dimensional reconstruction, the process of building 3D models out of multiple 2D scans representing different views of some objects, has presented a challenging problem that attracted much research attention for decades in computer vision. The hardness of the 3D reconstruction problem arises from the necessity of correlating the locations, alongside colors, of some features among different 2D scans in order to decide their locations in the 3D world. Due to the variance of applications, scanners setup alongside the algorithms in use varies as well. In other words, the nature of the application enforces the scanners setup and the algorithm in use. For example, 3D reconstructing an animated real life objects that we cannot control its motion pattern (an animal for example) demands the multiple 2D scans to be taken at once to capture the same pose in all views (as having multiple scanners in use at once). On the other hand, for 3D reconstruction of other objects, a turntable and a single 2D camera can be enough.

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As mentioned above, the process of 3D reconstruction relies heavily upon the nature of the application, which directs (sometimes enforces) the scanning setup, changing the nature of the input provided by the scanning process. Thus, to fully evaluate 3D reconstruction algorithms, the nature of the scanning mechanism is to be taken into consideration. Three-dimensional scanning mechanisms (non-contact based to be more specific), can be divided into two categories: active and passive. Active scanners are those that use special light emitters as part of their setup. (Examples of active scanning methods are setups that use laser scanning.) Hence, these scanning setups demand specific components hardware, which caused these methods to attract less research attention.

Passive scanning, on the other hand, utilizes regular cameras. This approach has many advantages over the active one, which made it attract much more research interests over years. The main advantage of passive scanning over active scanning, is that no special hardware is needed, which makes it more applicable and useable. Another advantage is that cameras are easy to configure and calibrate in order to facilitate the process of correlating features among different views.

As per the provided discussion, defining a solid ground of comparison between various 3D reconstruction approaches is not straightforward. Alongside that, the aspects of improvement from one research view to another vary as well. Thus, over the past years, the process of 3D reconstruction has been subject of too many improvements. The aim of this work is to build a state-of-the-art survey on different 3D reconstruction techniques, with respect to the 3D scanning mechanisms in use, taking into consideration the range of applications of each. More specifically, this work will focus on the work committed in this field during the last decade, as older algorithms are reviewed in older surveys, as it will be presented in the background.

BACKGROUND

As mentioned above, this work will demonstrate various 3D reconstruction algorithms, and provide evaluations for them. Prior to this work, there are two surveys in this field, Slabaugh et al. (Slabaugh, Schafer, Malzbender, & Culbertson, 2001) that evaluated algorithms up to 2001, and Seitz et al. (Seitz, Curless, Diebel, Scharstein, & Szeliski, 2006) that evaluated algorithms up to 2006. Nevertheless, each of them had different perspective while evaluating the reviewed algorithms. In the rest of this section, each perspective is discussed.

Algorithms up to 2001

Slabaugh et al. (Slabaugh, Schafer, Malzbender, & Culbertson, 2001) demonstrated and reviewed work dated back to 1984 up to 2001. In their work, they presented two restrictions on the algorithms they reviewed; also they divided the algorithms into three categories. Restrictions, alongside categories are discussed in the sections below.

Restrictions

The first restriction they enforced is that they reviewed algorithms with sampled volumetric representations. Sampled volumetric representation refers to representing both real and reconstructed spaces as discrete colored points, known as pixels in 2D space and voxels in 3D space. Enforcing such restriction
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