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Progressive 3D reconstruction of infrastructure with videogrammetry

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ABSTRACT

A number of methods are commonly used today to collect infrastructure's spatial data (time-of-flight, visual triangulation, etc.). However, current practice lacks a solution that is accurate, automatic, and cost-efficient at the same time. This paper presents a videogrammetric framework for acquiring spatial data of infrastructure which holds the promise to address this limitation. It uses a calibrated set of low-cost high resolution video cameras that is progressively traversed around the scene and aims to produce a dense 3D point cloud which is updated in each frame. It allows for progressive reconstruction as opposed to point-and-shoot followed by point cloud stitching. The feasibility of the framework is studied in this paper. Required steps through this process are presented and the unique challenges of each step are identified. Results specific to each step are also presented.

1. Introduction

3D reconstruction is the process of capturing the shape and structure of an object. The structure (i.e., spatial coordinates of the object points) can be sensed either directly (i.e., active sensors) or indirectly (i.e., passive sensors). 3D reconstruction of infrastructure represents its geometry in the form of a point cloud. It can be used both for visualization and measurements. However, it is most useful for infrastructure as-built documentation. In the current practice, terrain and underground as-built data can assist architects and structural/geotechnical engineers in designing infrastructure projects. Worksite spatial data can assist constructors, inspectors, and owners to administer their operations, control/verify several quality aspects of an infrastructure project [1,2], design the layout more efficiently [3], and monitor the project's progress in a more proactive manner [4]. As-built information of completed projects can assist designers in identifying the deviations from their design and maintainers in monitoring its deflection/deterioration [5] and assessing the damage caused by disasters [6].

Existing 3D reconstruction methodologies utilize technologies such as laser scanning and photogrammetry. Laser scanning is a terrestrial laser imaging system that creates a highly accurate 3D image of a surface for use mainly in Computer-Aided Design (CAD) and reverse engineering applications [7]. It operates with the time-of-flight principle. Highly accurate images can be acquired by using laser scanners such as Light Detection and Ranging (LiDAR). However, at spatial discontinuities (i.e., object edges), the scanned data contains inaccurate data points, known as mixed-pixels [8]. These scanners have limited use in infrastructure mapping activities as the equipment costs are prohibitive. Moreover, several control points have to be set up in order to stitch different laser scans together [9]. On the other hand, photogrammetry is the technique of measuring objects (2D or 3D) from visual data, such as photographs, imagery, CCD cameras, and radiation sensors/scanners [10]. Site engineers have to photograph multiple images and later manually stitch them to create a 3D representation of the scene. This approach is therefore tediously time consuming and necessary human intervention affects the resolution of the collected data.

Videogrammetry can be used to acquire spatial data using a camera set. It seeks to provide information and related tools to reduce the decision making time and complexity by the process of infrastructure spatial data collection. Videogrammetry based methods face challenges related to its time sensitive nature and level of automation involved. The goal of time-dependent imaging is to allow the user to move the cameras while scanning of infrastructure scene is in progress.

The framework proposed in this paper addresses the feasibility and challenges to the application of videogrammetry in geometric 3D reconstruction of infrastructure. It holds the promise to overcome the limitations of the existing techniques in order to effectively apply videogrammetric spatial data collection. The purpose of this paper is to show the flow of the whole process. The framework explores necessary steps for 3D reconstruction from video sequences and discusses about the most suitable methods that are potentially able to

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