Geo–Referenced 3D Reconstruction: Fusing Public Geographic Data and Aerial Imagery

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Abstract— **We present an image–based 3D reconstruction pipeline for acquiring geo–referenced semi–dense 3D models. Multiple overlapping images captured from a micro aerial vehicle platform provide a highly redundant source for multi-view reconstructions. Publicly available geo–spatial information sources are used to obtain an approximation to a digital surface model (DSM). Models obtained by the semi–dense reconstruction are automatically aligned to the DSM to allow the integration of highly detailed models into the original DSM and to provide geographic context.**

I. INTRODUCTION

Image–based modeling for acquiring geometric 3D object and scene reconstructions is an active field of research in photogrammetry and computer vision. The need for detailed 3D models is increasingly evident. Typical applications range from mapping and navigation, metrology for obtaining metric information and inspection tasks, or cultural heritage conservation, to photorealistic image–based rendering for the entertainment industry.

Multi-view stereo methods are able to produce precise and highly detailed 3D reconstructions, comparable to laser-based methods. Laser-based methods provide 2.5D range images and the respective 3D point cloud directly, but are on the other hand very complex for large scale outdoor scenes, especially when airborne data acquisition is required [1].

In many cases, it is desirable to link additional information to modeled objects. Especially for stationary outdoor objects, the geographic position on earth is of special interest (e.g. in Photo Tourism [2]). Additionally, geo–referenced imagery is important for creating 2D and 3D maps [3]. In this paper and the accompanying video we describe a 3D reconstruction pipeline which allows the generation of geo–referenced semi–dense models that are fused with a DSM to provide geographic context.

(a)

(b)

(c)

Fig. 1. Image acquisition and reconstruction: (a) An MAV with an attached digital camera is used to capture close–up images. (b) Sparse reconstruction of the clock tower in Graz, Austria, visualized including camera positions. (c) Semi–dense reconstruction using Patch–based Multi–View Stereo (PMVS) [6].

II. RECONSTRUCTION PIPELINE

We use a micro aerial vehicle (MAV) equipped with a Panasonic Lumix LX3 digital camera for acquiring close–up aerial imagery (see Fig. 1(a)). Our Asctec Falcon 8 Octo–Rotor helicopter MAV also provides GPS and IMU (inertial measurement unit) data which is used as prior for camera pose and orientation estimation [4], but also aids geo–referencing.

For Structure from Motion [5], features are extracted and matched across images to determine camera orientations and reconstructed feature points. Once an initial camera pose is found, aerial triangulation bundle adjustment is applied to simultaneously refine camera poses and 3D positions of the reconstructed sparse feature points (see Fig. 1(b)).

The initially sparse model can be densified using a patch-based semi-dense approach [6] (see Fig. 1(c)). The redundancy of multiple views hereby contributes to the completeness of the scene, improves depth accuracy and increases the robustness in the presence of outliers [7].

A digital surface model (DSM) helps to set 3D models into context, and can be estimated by using publicly available GIS data and geo–spatial information sources. We use terrain elevation data of the NASA Shuttle Radar Topography Mission (SRTM)[1] to generate a digital terrain model (DTM). Together with map data obtained from OpenStreetMaps[2] for extruding buildings we approximate a digital surface model by assuming a fixed building height (see Fig. 2). Geo–referencing is straight forward, as the data is indexed by GPS coordinates.

Reconstructed 3D models acquired at ground level or using MAVs can finally be roughly aligned to a digital surface model using GPS information. To improve the alignment, we first generate an orthographic projection of the estimated DSM to produce a geo–referenced height map of the surrounding terrain. Then, a refinement step based on the correlation of the DSM height map with the model height map results in precisely aligned models [8].

The result of fusing public geographic data and aerial imagery can be found in Fig. 3.

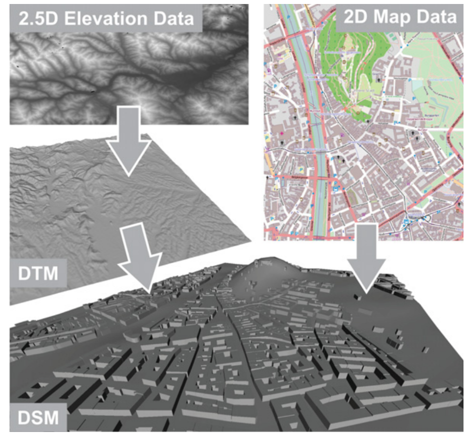

Fig. 2. DSM generation from publicly available geographic data: Terrain elevations and buildings extracted from map data are used to approximate a geo–referenced digital surface model.

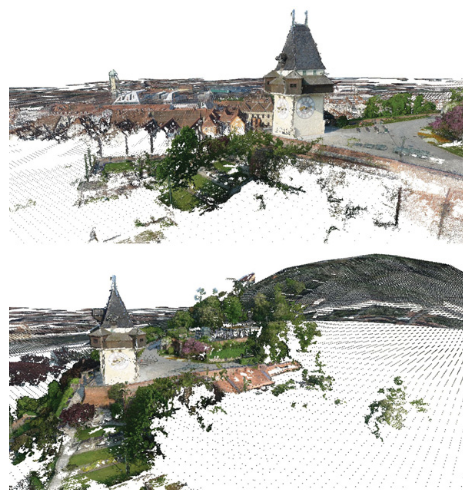

Fig. 3. Alignment of a semi–dense reconstruction with a digital surface model. The fusion of the terrain and the city in the background are achieved by the integration of geographic data.

III. CONCLUSION

We have presented an image–based reconstruction pipeline which allows to fuse publicly available geographic data and aerial imagery obtained by micro aerial vehicles. Geo–aligned, metric 3D reconstructions are valuable to a number of applications such as localization or change detection [9]. For instance, the recently proposed visual localization method for MAVs [10] could be enhanced by geo–information to visualize the flight path in context, and the alignment of construction sites for change detection [11] would be simplified.

ACKNOWLEDGMENTS

This work was supported by the Austrian Research Promotion Agency (FFG) FIT-IT projects Holistic (830044), Pegasus (825841), and Construct (830035).

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