THE TECHNIQUES OF TERRAIN MAPPING AND MODELING USING UAVS

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Abstract: This paper is focused on the techniques of terrain mapping and modeling using small Unmanned Aerial Vehicles (UAV). The main advantages of these systems are their price and ability to perform a quick survey and data acquisition on small unknown area. Low altitude aerial photographs can be used for calibrated orthophoto maps or as an input for topographic maps. There are also techniques to obtain a 3D data of terrain or objects and generate Digital Surface/Terrain Model (DSM/DTM). One approach uses laser scanner mounted to a UAV to obtaining point clouds of terrain and photographic data from digital camera to create textures. Very similar technique uses terrestrial laser scanner data in combination with aerial photography. DSM can be also created from aerial photographic data only using a passive triangulation method. The paper further briefly presents an UAV system which is being developed on the Department of Control and Automatization.

Keywords: UAV, quadrotor, mapping, terrain modeling, photogrammetry

1 INTRODUCTION

Nowadays it is hard to find a place on the Earth which has not been mapped yet. Using satellites any place on the Earht or other planet can be photographed from the space with the resolution up to 0,5 m^2 per pixel. Higher resolution is reached using aerial photography, which is more expensive per square meter therefore it is used only for populated and interesting areas. This is done by special manned aircrafts flying in low altitudes (hundreds of meters up to kilometers).

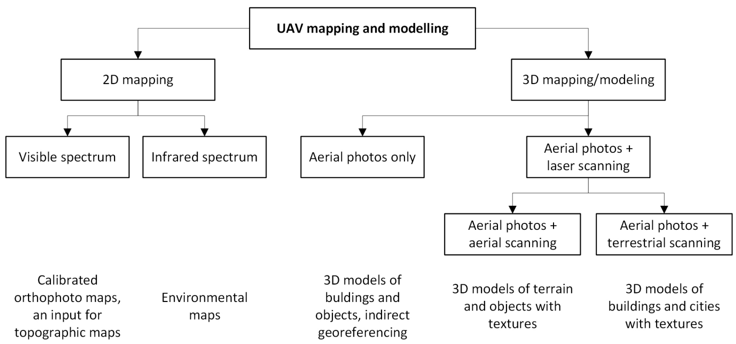

Figure 1: The ways of aerial mapping and terrain modeling.

UAV platforms are being used for commercial aerial imagery in recent years. Small digital camera is typically attached to the body of a UAV platform, such as helicopters, airplanes or multirotors, which can be remotely controlled or which can fly autonomously using any global position system. The biggest advantage of these platforms is their low price and ability to perform a quick data acquisition on small areas from low altitude.

Sometimes it is also useful to know information about terrain elevation. UAVs can be equipped by laser scanners to measure altitude and 3D digital terrain model can be created. These models are used in various sectors, e.g. in agriculture, archeology, in environmental sector or in construction industry. Also 3D orthophoto maps of cities containing models of buildings are very popular. Figure 1 shows different techniques of mapping and modeling and their field of use.

The paper starts with a section describing aerial photography acquisition and 2D mapping technique. Second section is focused on various methods of obtaining 3D terrain data using aerial/terrestrial laser scanning in combination with aerial photography and DSM creation. The last part introduces UAV system which is being developed on the Department of Control and Automatization and which can be used for photogrammetry purposes in the future.

Figure 2: Three differen UAV platforms: plane [1], multirotor [2] and helicopter [3].

2 2D MAPPING

Small size UAVs can be effectively used for high resolution aerial photography acquisition of small areas. There are three main UAV platforms, which are used in practice. At first there are planes, which are suitable for mapping larger areas (e.g. city districts, agricultural areas) because they are effective for long distance flights at an altitude about hundreds of meters [1]. Another two platforms, multirotors and helicopters, have a different construction, but they have very similar flying characteristics. Compared to planes, they are not suitable for long distance flights, but their main advantage is ability to hover. They can take photos at altitudes of meters up to hundreds of meters and they can take off from anywhere in a moment. Figure 2 shows examples of UAV platforms.

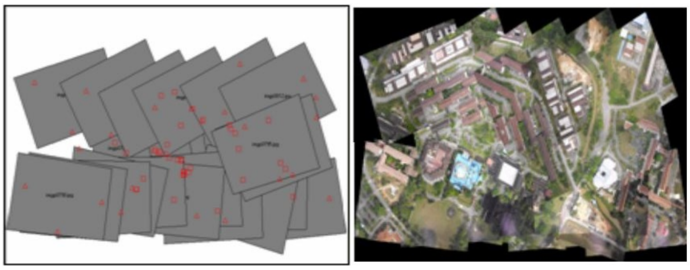

Figure 3: Every photography is calibrated in some coordinate system and then they are coupled together [4].

The UAV is usually equipped with a small commercial CCD camera, which allows taking photographs in resolution up to 20 megapixels and which weighs only hundreds of grams. Because theses commercial cameras are non-metric, the parameters of lens should be determined in laboratory [4]. Using an onboard GPS receiver, every photograph is calibrated typically into WGS-84 coordinates. Because a single photograph can cover a small area only, a series of photographs are taken from different positions. As the Figure 3 shows a suitable flight trajectory is very important to cover larger area. From this reason is used a preprogrammed autopilot which is able to navigate by waypoints and which can take photographs with required overlaps (typically 60% overlap and 30% sidelap [4] [5]). Calibrated orhophoto map can be used as a base map in Geographical Information System (GIS) and as an input for topographic map. A CCD camera can be replaced by thermocamera to use in some special applications [6], e.g. in agricultural or environmental applications.

3 3D MAPPING AND TERRAIN MODELING

This section describes some techniques how to obtain information about terrain elevation and how to generate calibrated point clouds of the area of interest. Every point in a point cloud, which is obtained e.g. from a laser scanner, is calibrated in some coordinate system and contains its 3D position information (latitude, longitude and elevation in WGS-84). From a point cloud can be generated continuous DSM and eventually DTM, which ideally contains only information about terrain elevation without objects (trees, buildings).

3.1 AERIAL PHOTOGRAPHIC DATA ONLY

The technology, which is used to obtain reliable information from image data, is called photogrammetry. An advantage of this is that no extra hardware is required compared to 2D UAV mapping, the only requirement is that every point must be visible on two or more photographs. The technique is based on the principle of a passive triangulation: the 3D position of every point of the point cloud is calculated from its 2D positions in obtained photographs. This requires an accurate calibration of camera lens and the knowledge of the GPS position from which the photography was taken. The method is also called as direct georeferencing.

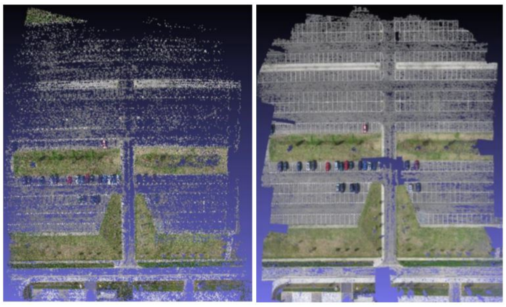

Figure 4: The number of generated points depends on the used software [7].

For the generation of the point clouds are typically used special softwares or web services. According to the software and image quality, there can be generated up to thousands points per square meter. Figure 4 presents results of two different softwares: Photosynth on the left (∼7 points/m^2) and PMVS2 on the right (∼90 points/m^2). An accuracy of the point's positions is determined by ground control points, which positions are measured by accurate GPS. Some papers present sub-meter accuracy [7], another one even a centimeter accuracy [3]. The photogrammetry technique can be also used for georeferencing in geodesy.

3.2 AERIAL PHOTOGRAPHIC DATA AND LASER SCANNING

Information about terrain elevation can be obtained from UAV directly using laser scanner. This is the technology of remote sensing that measures distance by illuminating objects with a laser and analyzing the reflected light. The technology is often called LiDAR (Light Detection And Ranging). Typical UAV is equipped with one laser scanner and one or more digital cameras, which are used for texture generation. Both the point cloud and photographs are calibrated into some coordinate system and then they are combined to obtain a textured DSM. A disadvantage of this solution are higher price and the weight of the laser scanners, therefore this solution is suitable for UAVs with bigger payload capability (typically hundreds kilograms planes and helicopters). DSMs created by laser scanners can offer under-meter accuracy, paper [8] presents point position accuracy about 10 cm.

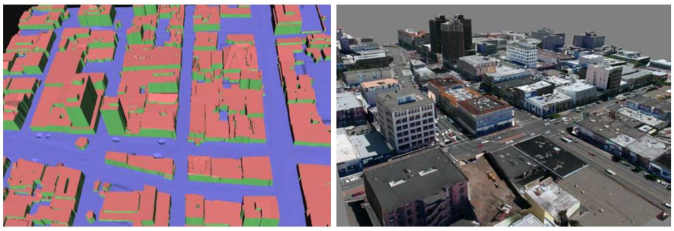

Figure 5: Untextured and textured 3D model of uraban area [9].

In urban areas, there can be used another sources of data for textured DSM creation. A 3D model of a city can be created from the combination of aerial and ground-based laser scans. Ground-based laser scans, which can be acquired from a car, provide a higher accuracy because they are closer to measured objects, but they cannot measure some places (e.g. a shape of the roof of the building). These unmeasured places can be filled with the data from aerial scanning. The same can be applied for combination of aerial and ground-based photographs used for texture generation. The biggest challenge of this multiple sources data coupling is how to achieve a precise overlap of various sources data, for example how to map an oblique aerial photographs to existing 3D city model (Figure 5) [9].

4 UAV PLATFORM DEVELOPEMENT

A small Group of robotics from the Department of Control and Automatization is focused on the developement of UAV platform, which could be used in the future for aerial mapping and DSM generation. Uranus UAV [10], which is shown in Figure 6, is equipped with our own control unit, AHRS (Attitude and Heading Reference System) Xsens MTi-G with GPS, which provide position accuracy about 2,5 meters CEP (Circular Error Probable). A payload about 300 grams allows to fly with compact digital camera for aerial photography acquirement.

Figure 6: UAV platform developed at the Department of Control and Instrumentation.

The accuracy of direct georeferencing from photographic data can be increased by using RTK (Real Time Kinematic) GPS. This GPS provides up to centimeter-level position accuracy and also very precise heading information in the case of use two antennas. The photogrammetry technique can be improved by using multiple images of the area of interest to compute multiple triangulation solutions. This accurate direct georeferencing technique may be used in construction industry or geodesy.

5 CONCLUSIONS

In this paper the basic techniques of 2D and 3D mapping using UAV was presented. A special attention was paid to the realized projects, which differ mainly in the used platform and in the technique of data acquisition. An attractive technique called photogrammetry, which uses an image data only to generate digital surface model, was described. The photogrammetry can be realized also using low payload UAVs and can achieve centimeter-level accuracy. In the future work, this technique can be improved by using high accurate RTK GPS and by using multiple images to point position calculation.

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