Study on High Accuracy Topographic Mapping via UAV-based Images

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Abstract. Unmanned aerial vehicle (UAV) provides a promising tool for the acquisition of such multi-temporal aerial stereo photos and high-resolution digital surface models. Recently, the flight of UAVs operates with high degrees of autonomy by the global position system and onboard digit camera and computer. The UAV-based mapping can be obtained faster and cheaper, but its accuracy is anxious. This paper aims to identify the integration ability of high accuracy topographic map via the image of quad-rotors UAV and ground control points (GCPs). The living survey data is collected in the Ern river basins area in Tainan, Taiwan. The high accuracy UAV-based topographic in the study area is calibrated by the local coordinate of GCPs using the total station with the accuracy less than 1/2000. The comparison results show the accuracy of UAV-based topographic is accepted by overlapping. The results can be a reference for the practice works of mapping survey in earth.

1. Introduction

Recently, spatial database place emphasis on renewability and instantaneously in applications of land surveys, hazard mitigation, sources investigations, land-use, and 3D reconstruction. It is one of important issues to develop a lower cost data collection platform in aerial remote sensing for spatial data collection. Much of current land, engineering and survey work via global position system (GPS) and total station are often labour intensive and the completeness of the data captured often depends on the time and cost allotted to the survey project. Traditional GPS and total station geographic data collection technical are accurate enough to design civil engineering and architectural plans. This style of data collection is often time consuming and by natural expensive. Unmanned aerial vehicle (UAV), an important way of aerial remote sensing, has been widely used in various fields with the unique technological advantages such as flexibility, convenience and low cost. UAV provides a promising tool for the acquisition of such multi-temporal aerial stereo photos and high-resolution digital surface models. Recently, the flight of UAVs operates with high degrees of autonomy by the global position system and onboard digit camera and computer. However, compared to traditional aerial photography, the flight attitude of UAV is not ideal, and the aerial coverage is small. UAV mainly comes to rapid puzzles; little involves the high accuracy topographic mapping tasks. As engineers and planners, we need to see if UAV-based photogrammetry would be accurate enough to map high accuracy topographic to replace current GPS and total station.
2. Reviews

Applications of unmanned aerial vehicle (UAV) have been increased considerably in recent years due to their greater availability and the miniaturization of sensors, GPS, inertial measurement units, and other hardware [1, 2] has demonstrated the UAV’s ability to revisit permanent plot locations and obtain high quality, high resolution images. The UAV-based imaging which could take very-high resolution images economically in restricted areas as polar regions compared to satellite and aerial photography will be used to various fields of study [3].

Both multi-rotors and fixed-wing aircrafts types of light-weight UAVs are currently commercially available. Fixed-wing UAV, equipped with light-weight digital cameras is more suitable for capturing stereographic images of larger areas. Multi-rotors can often carry more payload, resulting in the possibility of installing more advanced remote sensing systems, but their relatively low flight speed and high battery drain are limited [4]. Mancini, et al. [5] shows using the structure from motion technique to a low-altitude hexa-rotors produced a point cloud and derived digit surface model representing with high topographic quality, comparable with GPS survey data.

Walter et al. [6] shows UAV-based ortho-images allow for a detailed large scaled analysis of landslide materials and fissure structures. Such fissure structures have been clearly detected and could be related to fracture processes in the landslide material. Additionally, high-resolution textural information in UAV-based images could possibly permit a soil moisture analysis of the surface of landslides. [7].

3. Equipment

3.1. Quad-rotor UAV

Comparing to conventional helicopters, quad-rotor systems are more stable in flight with reduced vibration and have the mechanical advantage of not requiring a large, variable pitch rotor-unit. A quad-rotor open source project [8] has been used and improved by modifications of the software and the electronic circuit in order to comply with the requirements for this study.

Figure 1 shows the quad-rotor UAV equipment used in this paper. The fly height of UAVs is about equal to 60m above ground surface.

3.2. Total Station

Total station is a combination of electromagnetic distance measuring instrument and electronic theodolite. The total station can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument. Microprocessor unit processes the data collected to compute: (1) average of multiple angles measured, (2) average of multiple distance measured, (3) horizontal distance, (4) distance between any two points, (5) elevation of objects, and (6) all the three coordinates of the observed points. In this study, one such instrument is used by type OS-101 manufactured TOPCON Co. Ltd. Tokyo, Japan.
4. Study Area
Figure 2 shows the study area is located in the Ern river basins in Tainan, Taiwan. The living survey data is collected in the study area. Outstanding building corners are set as both the ground control points for UAV-based photographic and the ground control points for the closed traverse surveying works. The accuracy of the closed traverse surveying is less than 1/2000 according to Taiwan surveying codes.

5. Results and discussions
5.1. Ground Control Points
In Taiwan, Satellite Survey Center, Department of Land Administration, M.O.I. (SSC) is the governing organization for national survey. For sound national fundamental control measurement system, the SSC planning covers both the continuity and development of a series of fundamental control measurement plans since 1999 to 2007. Most of the survey point corrections are within 0.4 mm/m. This means the good survey quality. In this paper, these ground control points (GCP) constructed by SSC hear the study area are corrected and located as the basic points (BP) for ground survey and UAV-based image. Figure 3 shows some GCP located at the campus of Chang Jung University in study area.

5.2. Ground Survey
The traverse points are surveyed by the closed traverse surveying technical based on the basic points (BP). Figure 4(a) shows five BPs (C1, D1, F1, G1, H1) and three GCPs (RQ884, RQ843, and RQ846). Table 1 shows the results of the closed traverse surveying. The ratio of closure is equal to 0.00047 less than 0.0005 (1/2000). This accuracy means the good survey quality. The works are repeated at other sites, as showed in Figure 4(b)–(d) in the study area and all survey quality is good steady.
Table 1. The results of the closed traverse surveying

| point     | X(m)   | Y(m)   | point     | X(m)   | Y(m)   | Error of X | Error of Y |
|-----------|--------|--------|-----------|--------|--------|------------|------------|
| RQ846     | 175262.5562 | 2533897.176 | C1        | 175262.5562 | 2533897.176 | 0          | 0          |
| 175252.0815 | 2533976.455  | 175253.3854 | 2534038.673 | 175252.0815 | 2533976.455 | 0          | 0          |
| 175425.1473 | 2534058.185  | A         | 175429.835 | 2533914.356 | 175427.0458 | 2533900.341 | 0          | 0          |
| RQ843     | 175429.835 | 2533914.356 | A         | 175429.8118 | 2533914.478 | 0.0232270   | 0.1218626  |
| 175427.0458 | 2533900.341  | H1        | 175427.0458 | 2533900.341 | 175427.0458 | 2533900.341 | 0          | 0          |
| RQ844     | 175278.866 | 2533880.319 | B1        | 175278.866 | 2533880.319 | 0          | 0          |

Total error = \( 0.2899659 \) \( \pm 0.1450082 \)

Total Distance = 687.192

Error of closure = 0.3242031

Ratio of closure = 0.0004718

Figure 4. The results of ground survey

5.3. UAV-based Topographic

The high resolution photographic can be obtained by the quad-rotor UAV equipment (e.g. Figure 5). Figure 5 shows the overlap of UAV-based ortho-photographic and topographic. Figure 6 shows the
reconstructed topographic via the UAV-based ortho-photographic. The points of outstanding building comers, list in Table 2, are used to check the accuracy of the UAV-based topographic. Table 2 shows both the average absolute error of X-coordinate and Y-coordinate for ground survey and UAV-based topographic are less than 0.02% mm. The accuracy of UAV-based topographic is less than 0.0005 (1/2000) similar to the accuracy of the closure ratio of ground survey. This accuracy means the good UAV-based topographic quality. The result shows that UAV-based photogrammetry would be accurate enough to map high accuracy topographic. The UAV-based surveying may be to replace current GPS and total station in the future.

![Figure 5. The overlap of UAV-based image and topographic](image1)

![Figure 6. The UAV-based topographic with high accuracy](image2)

Table 2. The coordination of points of outstanding building comers

| No. of point | Ground survey(GS) | UAV-based | UAV-based vs GS |
|--------------|-------------------|-----------|-----------------|
|              | X(m)              | Y(m)      | X(m)            | Y(m)          | Error of X(mm) | Error of Y(mm) |
| L1           | 175420.71890000   | 2533973.10100000 | 175420.71889930 | 2533973.10100005 | 0.070% | 0.005% |
| L2           | 175410.19990000   | 2533950.60800000 | 175410.19989990 | 2533950.60799982 | 0.010% | 0.018% |
| L3           | 175372.42970000   | 2533947.06500000 | 175372.42970000 | 2533947.06499950 | 0.000% | 0.050% |
| L4           | 175303.99140000   | 2533923.37200000 | 175303.99139997 | 2533923.3719999 | 0.001% | 0.002% |
| L5           | 175278.28330000   | 2533926.75500000 | 175278.28329990 | 2533926.75499991 | 0.010% | 0.009% |
| L6           | 175274.25630000   | 2533957.10400000 | 175274.25619998 | 2533957.10399988 | 0.002% | 0.012% |
| L7           | 175277.26840000   | 2533970.88700000 | 175277.26839999 | 2533970.88699991 | 0.001% | 0.009% |
| L8           | 175372.24540000   | 2533985.23000000 | 175372.24539998 | 2533985.22999988 | 0.002% | 0.012% |
| L9           | 175266.31370000   | 2534006.63800000 | 175266.31369999 | 2534006.63799980 | 0.001% | 0.120% |
| L10          | 175263.90190000   | 2534025.15400000 | 175263.90190000 | 2534025.15399998 | 0.000% | 0.002% |
| L11          | 175372.16620000   | 2534039.53700000 | 175372.16619994 | 2534039.53699980 | 0.006% | 0.020% |
| L12          | 175383.48370000   | 2534037.08500000 | 175383.48370000 | 2534037.08499998 | 0.000% | 0.002% |
| L13          | 175419.97640000   | 2534015.99500000 | 175419.97639997 | 2534015.99499988 | 0.003% | 0.012% |
| L14          | 175421.82380000   | 2534001.73300000 | 175421.82379999 | 2534001.73299998 | 0.001% | 0.002% |

Average of absolute error = 0.008% 0.020%

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6. Conclusions
The UAV which could take very-high resolution UAV-based photographic economically in restricted areas as polar regions compared to satellite and aerial photography will be used to various fields. In this paper, the living survey data is collected in the study area in Tainan, Taiwan. The high accuracy UAV-based topographic in the study area is calibrated by the local coordinate of GCPs using the total station survey with the accuracy less than 1/2000. The comparison results show the accuracy of UAV-based topographic is good. The UAV-based surveying may be to replace current GPS and total station in the future.

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