

APPLICATION OF GPS RTK AND TOTAL STATION SYSTEM ON DYNAMIC MONITORING LAND USE

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ABSTRACT:

The Global Positioning System (GPS) is an all-weather, space-based navigation system. The real time kinematic (RTK) positioning is one of the most popular topics in civilian applications. Normally, RTK can be used to collect the land use change information successfully and quickly. However, RTK doesn't work in some cases, such as in urban areas or under trees. Then, those classical terrestrial methods, such as total station systems, can be used to aid RTK. Since the collected land use change information using either RTK or total station system will be entered to an existed land management system. Hence, the land use change styles of the interested region could be classified into a certain number of groups from the point view of Geographic Information System (GIS). In order to reduce the field surveying works of RTK and/or total station, as well as collect the spatial information of the interested land use change region promptly and accurately, it is necessary to design an optimized and effective field surveying procedure by means of analyzing the land use change styles and environmental characteristics of the interested region. Based on the above-mentioned concept, a study project has been undertaking at the National Cheng-Chi University (NCCU). Specifically speaking, the following issues will be addressed in this project: (1) performance comparisons between using RTK and using total station system on land use data capture and updating in terms of accuracy, speed, etc., (2) land use change styles analysis on the interested regions, (3) designing an effective land-use change spatial information collecting procedure using GPS based on the land use change styles, and (4) converting collected land use change data to GIS compatible files. The campus of NCCU was selected as a test region to test the performances of RTK and total station system on land use change data collection. The cadastral maps (on different times) of Mu-Za district of Taipei City were analyzed to find the possible land use change styles. Preliminary results indicate that: (1) the horizontal accuracies of RTK and total station system are $14\text{ mm} \pm 4\text{ mm}$ and $163\text{ mm} \pm 63\text{ mm}$ respectively (the coordinates of check points were determined using static GPS), (2) the time required for one point determination using RTK or total station system are about 15 seconds and 240 seconds respectively, (3) the land use change styles of Mu-Za district can be classified into 3 main types of polygon (each main type may have 2-3 styles), and (4) the field surveying works can be reduced significantly if the designed fielding surveying procedures were followed. The main concepts of NCCU project, test procedures and test results will be described and presented in this paper.

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1. INTRODUCTION

The Global Positioning System (GPS) is an all-weather, space-based navigation system. The real time kinematic (RTK) positioning is one of the most popular topics in civilian applications. Normally, RTK can be used to collect the land use change information successfully and quickly. However, RTK doesn't work due to the overhead obstructions, such as in urban areas or under trees. Then, all conventional terrestrial survey methods, such as total station (TS), can be used to aid RTK. Since the collected land use change information using either RTK or total station system will be entered to an existed land management system. Hence, the land use change styles of the interested region could be classified into a certain number of groups from the point view of Geographic Information System (GIS). In order to reduce the field surveying works of RTK and/or total station (TS), it is necessary to design an optimized and effective field surveying procedure by means of analyzing the land use change styles and environmental characteristics of the interested region.

The following issues will be addressed in this paper: (1) performance comparisons between using RTK and using total station system on land use data capture and updating in terms of accuracy, speed, etc., (2) land use change styles analysis on the interested regions. The campus of NCCU was selected as a test region to test the performances of applying RTK and/or total station system on land use change data collection. The cadastral maps (on different times) of Mu-Za district of Taipei City were analyzed to find the possible land use change styles. The section 2 will introduce the basic concept of integrating RTK and TS on land use change data collection. The concept of land use change style analysis will be given in section 3. The test procedures and test results will be described and presented in section 4, and some conclusions based on the tests results will be given in section 5.

2. INTEGRATING RTK AND TS FOR LAND SURVEYING

Real time kinematic (RTK) surveying, as implied by its name, enables positions of points to be determined instantaneously as the roving receiver (or receivers) occupies each point (Wolf & Ghilani, 2002). Real time kinematic surveying requires that two (or more) receivers be operated simultaneously. The unique aspect of this procedure is that radios are used to transmit corrections to the roving receiver. One receiver occupies a reference station and broadcast raw GPS observations to the roving unit (or units). At the rover, the GPS measurements from both receivers are processed in real-time by the unit's on-board computer to produce an immediate determination of its location. Because point positions with high accuracy are immediately known, real time kinematic surveying is capable for construction stakeout. It is also convenient for locating details for mapping and for many other surveying tasks.

Although it has so many advantages compared to conventional terrestrial survey methods, RTK has some limitations. For examples, in cases of failing to track sufficient amount of GPS satellites due to the overhead obstructions, RTK doesn't work. Then, those conventional terrestrial survey methods, such as total station (TS), can be use to aid RTK.

Total station (TS) instruments combine an EDM (electronic distance measurement), an electronic digital theodolite, and a computer in one unit. These devices automatically measure horizontal and vertical angles, as well as distances, and transmit

the results in real time to a built-in computer. The horizontal and vertical angles and slope distance can be displayed, and then upon keyboard commands, horizontal and vertical distance components can be instantaneously computed from theses data and displayed. If the instrument is oriented in direction and the coordinates of the occupied station are input to the system, the coordinates of any point sighted can be immediately obtained. This data can all be stored within the instrument, or in an automatic data collector, thereby eliminating manual recording.

The practical procedures of integrating RTK and TS on land surveying: (1) using RTK to determine the coordinates of the rover station; (2) using TS to determine the coordinates of the rover station in cases of RTK doesn't work.

The procedures of using TS to determine the coordinates of the rover station in cases of RTK doesn't work are as follows: (1) assumed that the rover station is point A and the RTK doesn't work at point A; (2) then choosing two points (P, Q) around A that will be used as control points in TS surveying; (3) determining the coordinates of P and Q points using RTK; (4) determining the coordinates of point A using TS.

3. ANALYSIS ON LAND USE CHANGE STYLES

Since the collected land use change information using either RTK or total station (TS) system will be entered to an existed land management system. Hence, the land use change styles of the interested region could be classified into a certain number of groups from the point view of Geographic Information System (GIS). On the other hand, in order to reduce the field surveying works of RTK and/or total station, it is necessary to design an optimized and effective field surveying procedure by means of analyzing the land use change styles and environmental characteristics of the interested region.

Basically the land use change styles consist of varied shapes of polygons. It is better to define the concepts of parent-polygon and children-polygon. For example, a polygon Y is divided into two polygons Y1 and Y2. Then, relative to Y1 and Y2, polygon Y is called the parent-polygon of Y1 and Y2 polygons, And, Y1 and Y2 are called the children-polygons of polygon Y.

Accordingly the land use change styles can be classified into two groups: (1) one parent-polygon is divided into several children-polygons, and there is no border merging relationship between parent-polygon and children-polygons; (2) one parent-polygon is divided into several children-polygons, and there is border merging relationship between parent-polygon and children-polygons (Lin, 2003).

Group 1 can be classified further into four styles: island style, biscuit style, ring style and full style (Figure 1). Group 2 can be classified further into three styles: two-way extension style, one-way extension style, and merging style (Figure 2). Letters A, B, C, etc. in Figure 1 and 2 denote the varied land use styles.

4. TEST RESULTS AND DISCUSSIONS

4.1 The Land Use Change Style Analysis of Urban Area

The general land use change styles are introduced in section 3. In order to further understand the land use change styles of urban areas of Taiwan, the cadastral maps (on different times) of Mu-Za district of Taipei City were analyzed.

After analyzing, the main land use change styles of Mu-Za district can be classified into three categories: (1) parent-polygon is divided into 2 or more children-polygons based on 1 vertical (or horizontal) principle border, such as shown in Figure 3; (2) parent-polygon is divided into several children-polygons based on 2 or more vertical (or horizontal) principle borders, such as shown in Figure 4; (3) several polygons are merged to one polygon, such as shown in Figure 5. Letters A, B, C, etc. in Figure 3, 4, and 5 denote the varied land use styles.

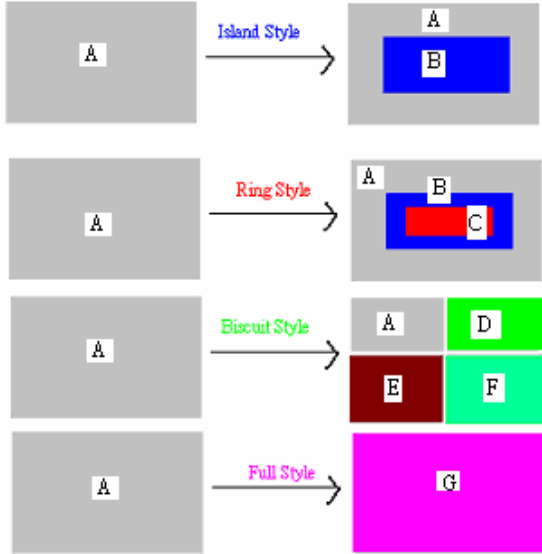


Figure 1. No border merging relationship between parent-polygon and children-polygons.

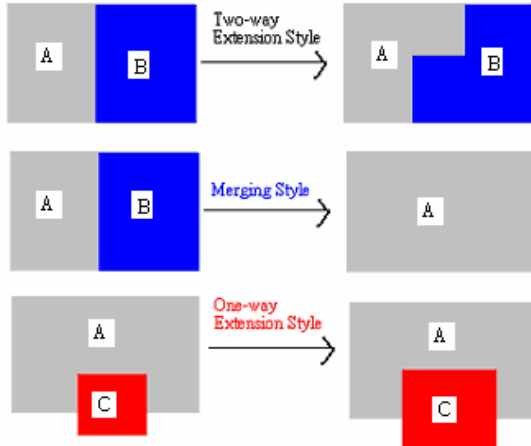


Figure 2. With border merging relationship between parent-polygon and children-polygons.

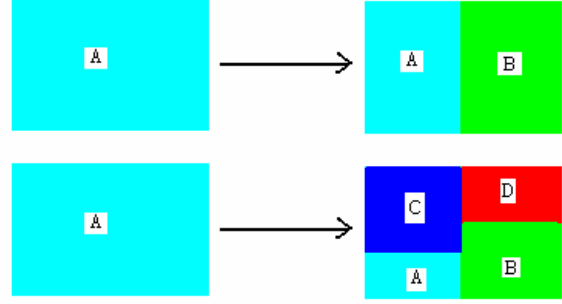


Figure 3. Category 1 of land use change styles of Mu-Za area.

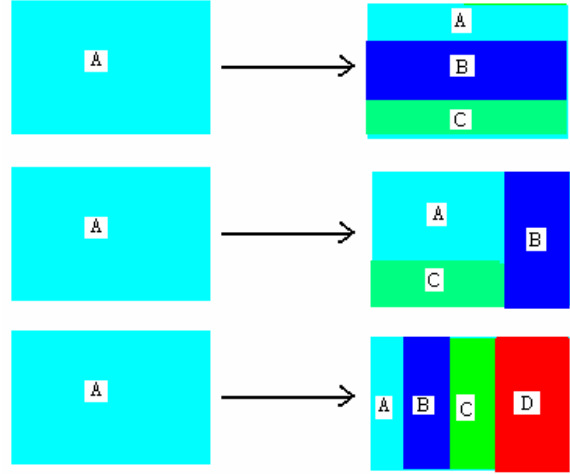


Figure 4. Category 2 of land use change styles of Mu-Za area.

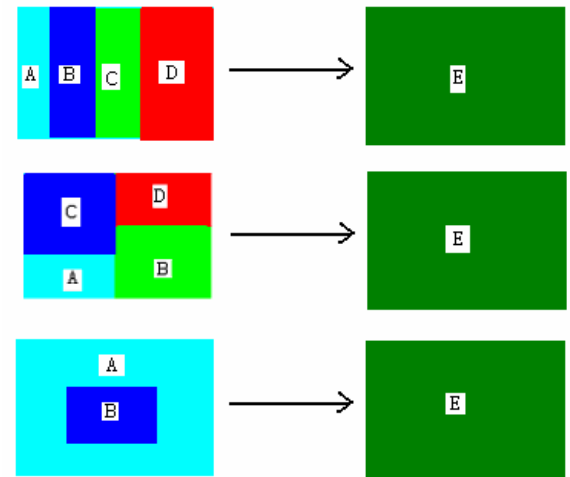


Figure 5. Category 3 of land use change styles of Mu-Za area

4.2 Land Surveying Using RTK&TS After Land Use Change Style Analysis

In order to demonstrate the advantages of integrating RTK and TS on land use data updating after land use change style analysis, the campus of National Chengchi University (NCCU) was selected as a test region. Figure 6 shows the point locations on the test region. Note that the point symbol in green color indicates that the point coordinates are determined by RTK, and the point symbol in red color indicates that the point coordinates are determined by TS. As shown in Figure 6, the parent-polygon A consists of four points A001, A002, A003 and A004.

Figure 7 shows the parent-polygon A is divided to 3 children-polygon: parcel 1, parcel 2, and parcel 3. Parcel 1 consists of points A002, A006, A007, and A005. Parcel 2 consists of points A006, A003, A004, A008, and A007. Parcel 3 consists of A005, A007, A008, and A001. According to the land use change style analysis concept introduced in section3, the test region shown in Figure 7 belongs to the biscuit style. Hence, it is necessary to determine the coordinates of points A005, A006, A007, and A008 using RTK/TS.

In order to simulate the two-way extension style, the common point of parcel 1, parcel 2, and parcel 3, was moved from A007 to A009, as shown in Figure 8. In this test, we only need to determine the coordinates of point A009.

In order to simulate the one-way extension style, the parent-polygon A was extended to include polygon B, as shown in Figure 9. The polygon B consists of points A003, A004, A010, and A011. In this test, we need to determine the coordinates of points A010, and A011 only.

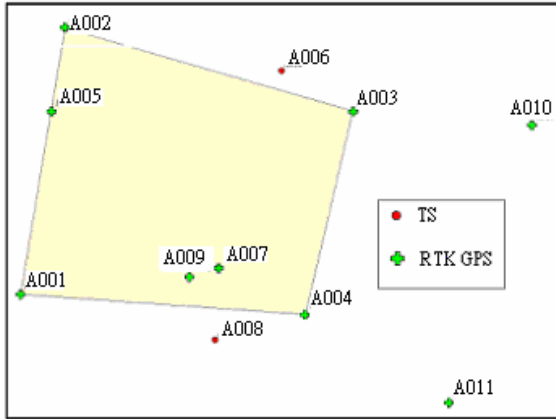


Figure 6. Land use change test region on NCCU campus.

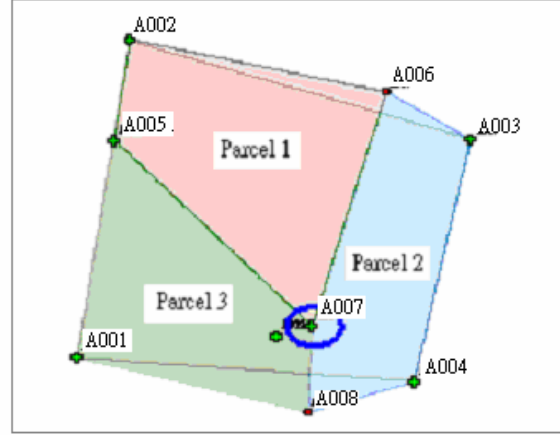


Figure 7. The parent-polygon A is divided to 3 children-polygon: parcel 1, parcel 2, and parcel 3.

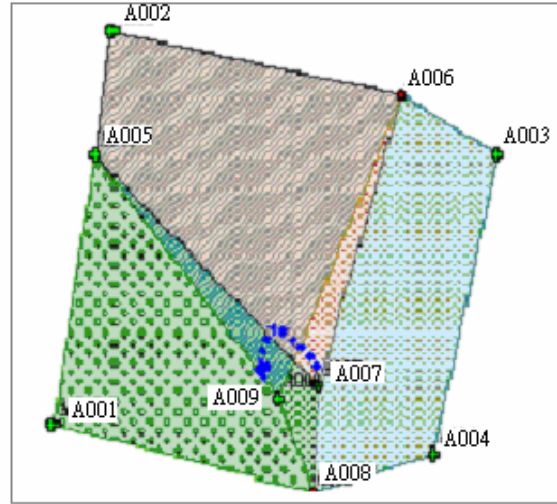


Figure 8. A simulation test of the two-way extension style.

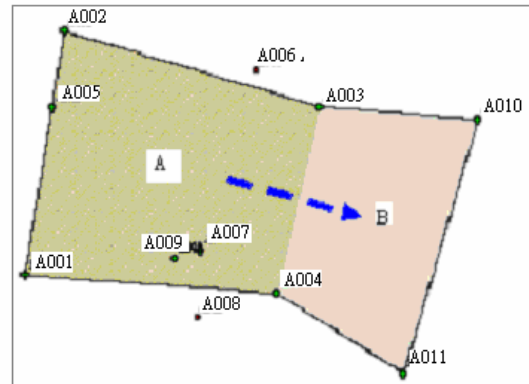


Figure 9. A simulation test of the one-way extension style.

4.3 Land Sueveying Performance Comparisons on Urban Areas Using RTK or TS

In order to compare the point accuracy, operation time required, etc. relating to RTK/TS, 12 static points located on NCCU campus were selected as control/check points as shown in Figure 10. Note that the dark triangle indicates the control point and the red circle indicates the check point.

Firstly, the coordinates of 12 points were determined by static GPS surveying method. The Ashtech Z-Surveyor GPS receivers were used to collect data at each point for 30 minutes. Those coordinates determined by static GPS surveying were assumed to be error-free. Then, those 12 points were reoccupied and observed by means of Ashtech RTK and Leica TC-605 TS respectively for 4 times.

As indicated in Figure 10, there are 2 points selected as control points for TS traversing. Therefore, there are 10 points are treated as check points in this test. For each check point, there are 3 groups of coordinates: (1) determined by static GPS, (2) determined by RTK, and (3) determined by TS traversing. In order to evaluate the accuracy achieved by means of RTK or TS, the coordinate misclosures f_E , f_N and position misclosure f_s are computed according to the following equations:

$$f_E = E - E_{\text{Static GPS}} \quad (1)$$

$$f_N = N - N_{\text{Static GPS}} \quad (2)$$

$$f_s = \sqrt{f_E^2 + f_N^2} \quad (3)$$

where $E_{\text{Static GPS}}$, $N_{\text{Static GPS}}$ indicates the easting and northing of a point respectively determined by static GPS; E , N indicates the easting and northing of a point respectively determined either by RTK or TS.

The comparisons of closure in easting (f_E), northing (f_N), and position (f_s) between applying RTK and applying TS are shown in Figure 11, 12, and 13 respectively. And Table 1 shows the statistics of accuracy comparisons between applying RTK and applying TS. It can be seen from Figure 11 to Figure 13 and Table 1 that the point accuracies using RTK are usually higher than that using TS. The position misclosure achieved by RTK and by TS are $14\text{mm} \pm 4\text{mm}$ and $163\text{mm} \pm 63\text{mm}$ respectively.

In addition to the point accuracy comparisons, the comparisons are also made on the following factors, such as: the required man-power to run RTK or TS, the required observation time per siteto run RTK or TS, etc. The comparison results are summarized in Table 2.

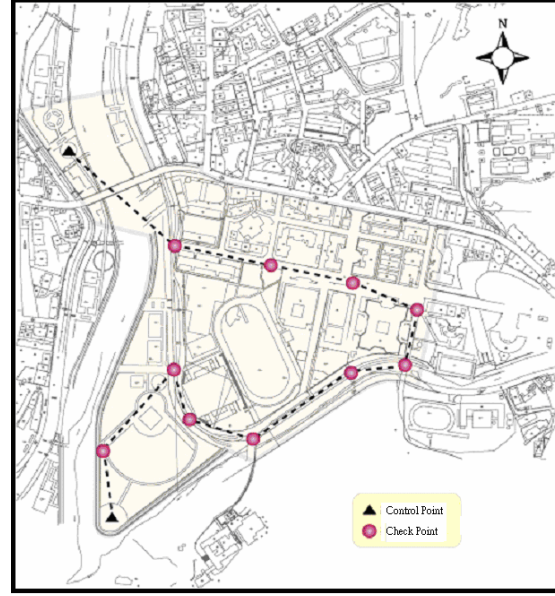


Figure 10. The selected control/check points for RTK/TS test on NCCU campus.

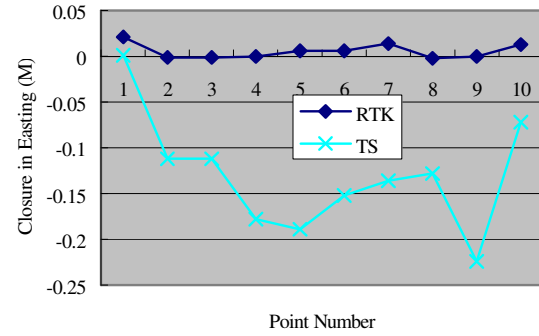


Figure 11. Comparisons of E-coordinate misclosure between applying RTK and applying TS.

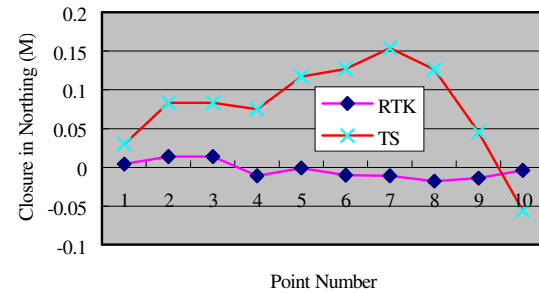


Figure 12. Comparisons of N-coordinate misclosure between applying RTK and applying TS.

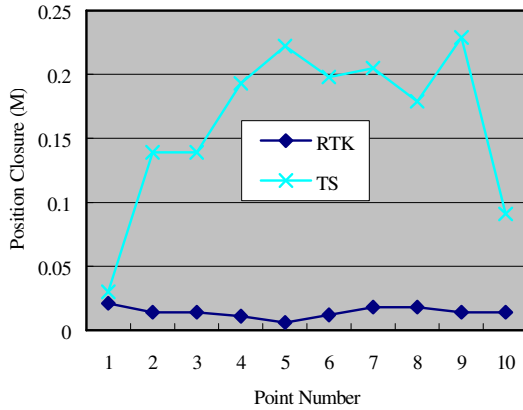


Figure 13. Comparisons of position misclosure between applying RTK and applying TS.

Table 1. Statistics of accuracy comparisons (in units of mm) between applying RTK and applying TS.

	RTK			TS		
	f_E	f_N	f_s	f_E	f_N	f_s
Max.	21	14	21	1	154	229
Min.	-2	-18	6	-224	-56	30
Mean	6	-4	14	-130	78	163
σ	8	11	4	64	61	63

Table 2. Performance comparisons between applying RTK and applying TS.

Surveying Method	Point Accuracy	Required Man-Power	Required Observation Time per Site
RTK	14mm $\pm$ 4mm	1 man	0.5 $\rightarrow$ 2.5 minutes
TS	163mm $\pm$ 63mm	3 men or more	4 $\rightarrow$ 8 minutes

5. CONCLUSION

According to the test results introduced in section 4, some remarks can be concluded: (1) RTK is one of the best choices to collect coordinates of the land use change region. However, in cases of signal blockages, such as in urban area, RTK needs to be aided by TS. (2) The position misclosures achieved by applying RTK and by applying TS are 14mm $\pm$ 4mm and 163mm $\pm$ 63mm respectively. (3) Each land parcel corresponds to a polygon from the point view of GIS. And, the land use change styles of the interested region can be analysed beforehand using the concepts introduced in section 3. Then, the point amounts required to be surveyed can be determined based on the land use change style analysis.

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