Digital Topographic Mapping in Urban Obstructed Environment Based on Multi-GNSS Network RTK Technology

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Abstract. Digital topographic mapping experiments were carried out based on network RTK technology using GPS/BEIDOU/GLONASS multi-constellation compatible GNSS receivers in urban obstructed environment. Operation scheme and technique flow were discussed. Experimental results show that the horizontal position and elevation of the points measured by RTK can reach 2cm and 3cm precision level respectively in open environment. RTK initialization time needs about 3-5s. While in obstructed environment, such as high building and tree shading, the RTK initialization time needs about dozens of seconds or tens of seconds, and sometimes floating solutions or even differential solutions were obtained. The impact of dense and tall building on RTK measurement is more seriously. It is more likely to get RTK fixed solution in the south side of high building than the north side of the building.

1. Introduction
Digital City is the development trend of modern cities. Obtaining and updating urban spatial data is the foundation of Digital City. GNSS Continuously Operating Reference Station (CORS) is one of the urban spatial data infrastructure and is the foundation of building a modern digital city. CORS system has been developed into a network integrated service system and will play an important role in the construction of Digital City. With the development and improvement of multi-constellation GNSS, especially rapid development of BEIDOU, the horizontal position and elevation of the points can be measured quickly by network RTK technology with 2-3cm precision level using only one GNSS receiver. In order to test the performance of network RTK in urban obstructed region, the experiment and analysis of the digital topographic mapping using SDCORS network RTK service were carried out in various environment.

2. Experiment environment of network RTK
In order to test the performance of digital topographic mapping based on network RTK technology in urban obstructed environment. We selected two representative experimental areas in our university, which are Zone 1, Zone 2. Figure 1 gives the plan of each zone. Zone 1 is around the Yifu Building. Zone 2 is around the Yingxue Lake. From Figure 1, we can see that: There are buildings, trees and roads in the Zone 1. There is a large area of calm water, woods, grass, roads in the Zone 2.
3. Network RTK experiments and result analysis

The instrument used in the digital topographic mapping experiment is GPS/BEIDOU/GLONASS three-constellation compatible receiver. The use of network RTK technology in mapping needs to meet the corresponding technical specifications and follows certain operating methods. According to RTK surveying technical specifications, each detail point needs to be observed one round and each round needs to collect five epochs for mapping. The final results of the observation point is the average value of each epoch. In RTK surveying, we should also follow the following operation procedure to avoid obtaining wrong integer ambiguity. First, all the observations are performed after the RTK fixed solution is stable and convergent. Secondly, the operation scheme “first fixed not recorded, second fixed recorded” is performed.

After the RTK point correction, the topographic detail points can be collected. One person is responsible for holding the RTK mobile station for data acquisition, and another person follows to draw the sketch and record the attribute information of detail points.

In the field operation process, the RTK initialization time needs about 3-5 seconds and the horizontal position and elevation of the topographic points can reach 2 cm and 3 cm precision level respectively in the open environment or in not seriously sheltered environment (see Figure.2). While in the seriously obstructed environment (see Figure.3), the RTK initialization time needs about dozens of seconds or even a few minutes and sometimes ambiguity fixed solutions can not be obtained.
For those points which cannot obtain ambiguity fixed solutions, we use RTK technology combining with distance measurement method to obtain positions of seriously obstructed detail points. As shown in Figure 4, P is a point in seriously obstructed environment (see Figure 5) where RTK cannot obtain ambiguity fixed solutions. A and B are points in not seriously obstructed environment where RTK can obtain ambiguity fixed solutions. The distance of AP(S1) and BP(S2) can be measured by an electromagnetic distance measuring instrument or a tape. The coordinates of point P can be calculated according to the linear intersection method. The calculation method is as follows:

\[
S_{AB} = \sqrt{(x_B - x_A)^2 + (y_B - y_A)^2}
\]

\[\alpha_{AB} = \arctan \left( \frac{y_B - y_A}{x_B - x_A} \right)\]

\[\angle A = \arccos \left( \frac{S_A^2 + S_{AB}^2 - S_B^2}{2S_A \cdot S_{AB}} \right)\]

\[\alpha_{AP} = \alpha_{AB} - \angle A\]

\[x_P = x_A + S_A \cos \alpha_{AP}\]

\[y_P = y_A + S_A \sin \alpha_{AP}\]

In order to validate the performance of the above-mentioned linear intersection method, we compared the coordinates of point P calculated by formula (1)-(5) with the coordinates of point P measured by traditional method using a total station. The differences of x and y component are 0.5cm and 1.3cm, respectively. The bias of horizontal position is 1.4cm. Therefore this method can meet the needs of mapping in seriously obstructed environment.

After the completion of RTK field data acquisition, the exported data files from RTK field electric handbook are stored in the computer. Finally, the topographic mapping software CASS 7.0 is used to draw the maps. Figure 6-7 give the digital topographic maps corresponding to Zone 1 and Zone 2 as shown in Figure 1.
4. Conclusions
The experimental results of digital topographic mapping in various urban environment based on GPS/BEIDOU/GLONASS Multi-GNSS RTK technology showed that: (1) In open environment or in not seriously sheltered environment, the horizontal position and elevation of the topographic points can reach 2cm and 3cm precision level respectively using RTK technology. The observed number of satellites is about 20(the cut-off elevation angle is 10 degree) and PDOP is less than 2. The RTK initialization time is only 3-5 seconds. (2)While in obstructed environment, the RTK initialization time needs about dozens of seconds or even a few minutes and sometimes ambiguity fixed solutions cannot be obtained. For the seriously obstructed topographic points, using RTK technology combining with distance measurement method can also obtain the positions of detail points with the 2-3cm precision level.

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