Accuracy assessment of the single CORS technology for establishing the large scale cadastral map

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Abstract - Global Navigation Satellite System (GNSS) has been widely used in the field of surveying. When applying the GNSS technology, the positioning could be done by setting up a network of continuous operation reference stations (CORS). Real Time Kinematic (RTK) method based on CORS stations, therefore, has been developed. While the accuracy of positioning by the RTK technique depends on the distance from the CORS base to the rover station, it is necessary to determine the most reasonable distance from the CORS station to the rover station to ensure the appropriate accuracy for the establishment of large-scale cadastral maps. In this study, an investigation on a variety of distances between the base and the rover was performed to their influence on the accuracy of positioning. The results showed that when producing cadastral maps with scales of 1: 200, 1: 500, 1:1000, 1:2000 and 1:5000, the maximum distances from the CORS station to the rover station are 2.2 km, 5.3 km, 10.5 km, 20.8 km and 51.7 km, respectively.

Keywords - continuously operating reference station – CORS, global navigation satellite system – GNSS, real time kinematic – RTK, CORS-N001 station, large scale cadastral map.

1. INTRODUCTION

Cadastral survey is often performed by utilizing theodolites and total stations. While the advantage of these traditional measurements is simple, they need to base on surveying control networks that are often established in the principle of working from the whole to the part to ensure the requirement of point density for detail surveying. This leads to the necessity of finding out an alternative solution of mapping without control networks. Global Positioning System is one of the latest achievements in the field of surveying and mapping. The RTK CORS technology (Real Time Kinematic Continuously Operating Reference Stations) in which surveying does not need to build a geodetic control networks.

The Global Positioning System (GPS) was developed originally as a military navigational aid. It has been used also by civilian users for various purposes, including automotive navigation, operational control of aircraft and ships and measurement of tectonic plate movements (Hofmann at al., 2001; Masaru Ozeki and Kosuke Heki, 2011). Over the last few year, By combining Europe's Galileo, the USA's NAVSTAR Global Positioning System (GPS), Russia's Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS) and China's BeiDou Navigation Satellite System, the Global Navigation Satellite System (GNSS) was formed (https://www.gsa.europa.eu/european-gnss/what-gnss). Global Navigation Satellite System has recently become a major technology in the map surveying field with many advantages such as multi-system, highly development of support systems, receivers, software and of new measurement methods. With the appearance of GNSS technology, positioning is following the trend of setting up continous operating reference station network (CORS) instead of the traditional geodetic network. (Lei Wang, Wu-sheng Hu, 2013, Pages 1707-1711). (Nguyen Viet Nghia, et al., 2016, Pages 247-253).

Continuously Operating Reference Stations (CORS) is a network of reference stations that provide a virtual base station that allows users to access long-range high-accuracy Network RTK corrections (https://www.navcomtech.com/en/landsurvey/CORS). CORS provides GPS data to support very accurate 3D positioning, meteorology, space weather, and geophysical applications (https://www.ngs.noaa.gov/CORS). With CORS technology, positioning can be done by a variety of measuring techniques, each of them has certain advantages and disadvantages. At present the application of CORS technology to measure and to establish cadastral map can use single CORS or network of CORS. However, if using CORS network, many CORS need to be built, therefore, much investment in technical and financial equipment is needed. The use of single station CORS technology to establish cadastral

ISSN 2229-5518
mapping has the advantage of less financial investment and shorter construction time. However, when using a single CORS to measure by RTK technique the accuracy of the rover decreases with increasing the distance from the CORS to the Rover base station. (Khaled Mohamed Abdel Mageed, 2013).

This article presents the results of investigation on dependence between the Rover position error and distance to the CORS in order to determine the most reasonable distance from the CORS to the rover base station for ensuring accuracy requirements for establishing a large scale cadastral map.

2. COMPONENTS AND POSITIONING SOLUTIONS OF CORS TECHNOLOGY

2.1. Components of the CORS

A CORS system consists of one or more GNSS reference stations operating continuously, permanently, incorporating the application of server technology, management software and the internet system to transmit data those will constitute a synchronous network. Based on the operation of a CORS, it is possible to use RTK technique and only need one moblie reveiver (Rover) which can connect data via GPRS to the CORS we can determine precisely and quickly the position of reveiver with distances significantly increased compared to conventional methods. There are now many different companies that design CORS, however, CORS system is composed of four parts including reference station systems, data processing center, data communications systems, and user applications among which are connected together to form a LAN via a data communication system. (Lei Wang, Wu-sheng Hu, 2013, Pages 1707-1711).

2.1.1. Reference Station System

Reference station system is composed of many reference stations. Each reference station includes the GNSS receiver, antenna, power supply (UPS), network equipment, cabinets and lightning protection systems and other equipments, and is mainly responsible for the continuous GNSS satellite positioning tracking, collecting, recording, and transmiting the data to the control and the data management center. (Lei Wang, Wu-sheng Hu, 2013, Pages 1707-1711).

2.1.2. Data processing center system

The data processing center subsystem is CORS brain and the guarantee of which the system is stable and safe operation of the continuous provision of location services. It is divided into two parts of user management center and system data center and consists of servers, workstations, network transmission equipment, power equipment (including UPS), data recording equipment, systems and safety equipment, and other equipments. System Center is mainly responsible for the analysis, calculation, processing and storage of satellite positioning data, the work done by establishing a system model to generate differential correction data and transmission, recording, management and distribution of correction data, and providing services and effective management to users (Lei Wang, Wu-sheng Hu, 2013, Pages 1707-1711).

2.1.3. Data communication system

The data communication system includes the communication between the respective reference station and the data center and between the data center and the user rover. The data transmissions are required to be reliable and stable between the data center and the reference stations and that the reaction time is kept within 1 sec. Through GPRS and CDMA wireless Internet access the data center is only connected to the World Wide Web, you can access through a wireless network to achieve customer data center. Reference station and data center communication systems using digital the circuit transmission with VPN network, reference station and data center and data management center in the same virtual network. (Lei Wang, Wu-sheng Hu, 2013, Pages 1707-1711).

2.1.4. User application system

The user application system is end user of a system. It is composed by the GNSS receiving antenna, the data receiver, and the communication module. The user accepts GNSS satellite data through the antenna, stores and processes the data with the receiver, and then via the communication module sends the data to the control and data management center and at the same time receives differential analysis data of control and data management center. (Lei Wang, Wu-sheng Hu, 2013, Pages 1707-1711).

2.2. Positioning solutions of CORS technology

Currently, many countries in the world have developed their own national CORS network operating under different techniques, suitable for use and infrastructure of that country. Based on the correction methods ranging network of CORS today can be divided into a number of models based on positioning techniques such as virtual reference station-VRS (Virtual Reference Station); Regional calibration parameters FKP (Flachen-Korrektur-Parameter; Technical editing main station for mobile stations (Individual Master-Auxiliary Corrections - IMAC); System reference station network (Net Reference Station - NRS). Each method approach has advantages and disadvantages and conditions of individual applications. (Nguyen Viet Nghia et al., 2016, Pages 247-253).

The "Virtual Reference Station" concept is based on having a network of continuously operating reference stations (CORS) connected via data links to a control center. A computer at the control center continuously gathers the information from all receivers, and creates a living database of Regional Area Corrections. These are used to create a Virtual Reference Station, situated only a few meters from where any rover is situated, together with the raw data, which would have come from it. The rover interprets and uses the data just as if it has come from real reference station. The resulting performance improvement of RTK is dramatic. The implementation of the VRS idea into a functional system solution follows the following principles. First, we need a number of continuously operating reference stations (at least three), which are connected to the network server via some communication links. The GPS rover sends its approximate position to the control center. It does this by using a mobile phone data link, such as GPRS/CDMA, to send a standard NMEA position string called GGA. This format was chosen because it is available on most receivers. The control center will accept the position, and responds by sending RTCM correction data to the rover. As soon as it is received, the rover will compute a high quality DGPS solution, and update its position. The rover then sends its new position to the control center.

The network server will now calculate new RTCM corrections so that they appear to be coming from a station right beside the rover. It sends them back out on the mobile phone data link (e.g.CDMA). The DGPS solution is accurate to cm, which is good enough to ensure that the atmospheric and ephemeris distortions, modeled for the entire reference station network, are applied correctly. The Regional Correction Parameter system FKP (Korrektur-Parameter-Flachen) was developed by Geo ++ company. (Nguyen Viet Nghia, et al., 2016, Pages 247-253).

This technique uses information from the reference station to obtain parameters that can linearly described the errors due to the influence of the orbit and atmosphere. These parameters are passed to the processing central to interpolate the errors for each different region. In addition, this technique can also be used alternatively: rover station receives the coordinates of the reference stations from the central processing station and choose the most suitable reference station. FKP has some specifications such as one-way data transmission; users can only receive but can not transmite the data so that its security is high.

Individual Master-Auxiliary Corrections (iMAC) developed by Leica and Geo ++, it operates following the principle: data processing center transmits measured value of the master station (like a RTK station), at the same time through connect protocols RTCM3.1 broadcasts auxiliary parameter station (only transmition of the changing difference of sub-station and the main station) and the difference in the coordinate position of the auxiliary and main stations to reduce load capacity of the transmission and reception of data. After receiving the signal, the mobile station begins to calculate the correction of its position, then the position of RTK is normally proceed.

Net Reference Station (NRS). The operation principle of NRS system is essentially similar to that of virtual reference station methods (VRS) while combining both the advantages of FKP and of MAC to form triangular network and utilize advantage of one or all nearby static stations to ensure the stability and quality of the data. NRS operates follow technique of DEEP-NRS when there are three or more stations the system will build all the standard sections that fits conditions, increase the coverage of regional triangular mesh. Based on the standard distance in triangle networks to choose a best triangular to provide the service for mobile measuring station.

3. MEASUREMENT PRINCIPLE OF CORS/RTK TECHNOLOGY

RTK technique is now most commonly used applying CORS technology. RTK technique is used to determine real-time coordinates using a CORS and a Rover base station. The RTK principle is similar to traditional motion metering, but the difference is that the CORS acts as a base station using the internet to transmit data and 4G telecommunication networks for transmission of correction data of CORS for the Rover station. (Nguyen Viet Nghia, et al., 2016, Pages 247-253). The principle of RTK based on CORS technology is shown in the Fig 1. (Khaled Mohamed Abdel Mageed, 2013).

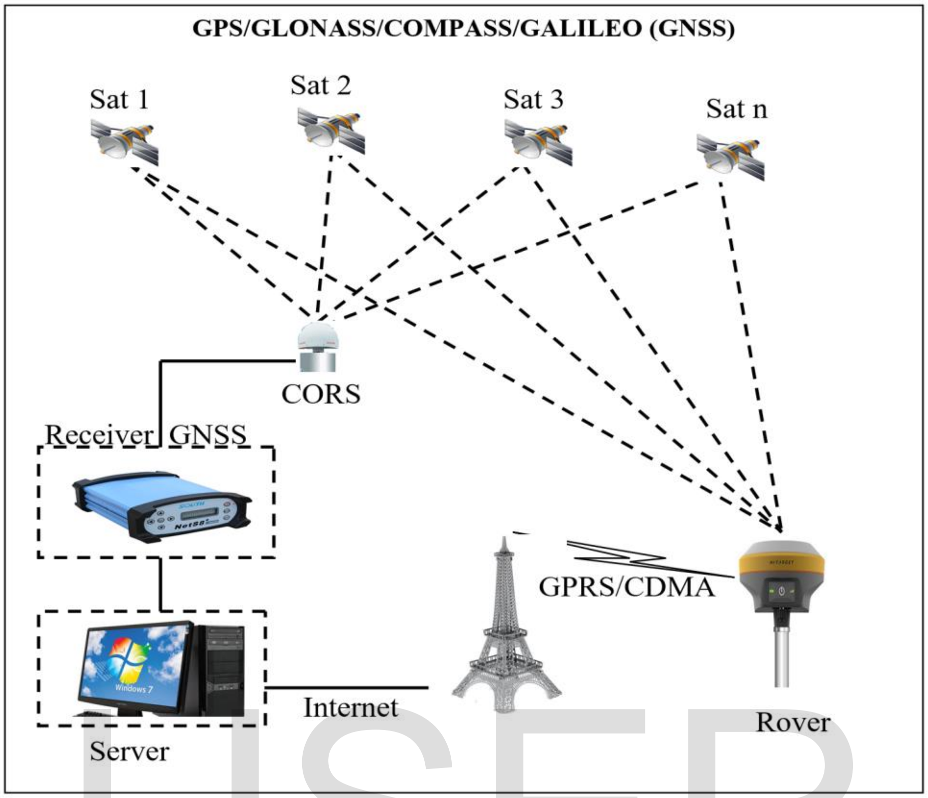

Fig 1. RTK Measurement principle of CORS technology

Rover stations are dual-frequency GNSS satellite receivers with 4G SIM card slots for receiving calibration data of coordinates from the CORS and transmitting data to the central processing station. The coordinates of rover stations are defined in the WGS-84 coordinate system and then converted to VN-2000 coordinates according to the equation (1). (Lei Wang, Wu-sheng Hu, 2013).

$$\begin{aligned} X &= \Delta X_o + k(X' + \varepsilon_o Y' - \psi_o Z') \\ Y &= \Delta Y_o + k(-\varepsilon_o X' + Y' + \omega_o Z') \\ Z &= \Delta Z_o + k(\psi_o X' - \omega_o Y' + Z') \end{aligned} \tag{1}$$

where,

X, Y, Z are the spatial coordinates in coordinates system VN-2000, (m);

X', Y', Z' are the spatial perpendicular coordinates in coordinate system WGS-84, (m);

ΔX_o, ΔY_o, ΔZ_o are the displacement parameters of origin (m);

ω_o, ψ_o, ε_o are three rotation angles of the axis (rotation angle Euler) corresponding to the axes X, Y, Z, (radian);

k is the length ratio between the two coordinate systems.

4. RESEARCH METHODOLOGY

To evaluate the accuracy of single CORS positioning technique for establishing the large scale cadastral map, in this study the coordinates of points in a test grid was compared to coordinates determined by the RTK technique using single CORS technology. The test network has 12 points, compising two base stations with numbers 116437 and 104548 and 10 new points with numbers KH-1 to KH-10 is shown in the Fig 2.

ISSN 2229-5518

The network is measured by four receivers Trimble R3 with five sections, time of a section is 90 minutes. Measurement data are processed using the software Trimble Business Center 2.4 (TBC). Results of horizontal coordinates and errors of points in test network are shown in the Table 1.

Table 1. Results of horizontal coordinates of test network points

No	X (m)	Y(m)	M_P (m)
KH-1	2331078.161	580952.520	0.003
KH-4	2328976.440	580430.385	0.003
KH-3	2330112.400	581855.510	0.004
KH-6	2326970.116	580887.986	0.004
KH-2	2333147.615	582109.681	0.004
KH-5	2327466.300	582693.099	0.004
KH-7	2326251.236	582094.451	0.004
KH-8	2324291.465	581377.192	0.004
KH-10	2323870.602	579504.400	0.007
KH-9	2323643.828	581962.164	0.004

Based on the results of the established test network, experimental measurements are made using the RTK technique, from which the accuracy of the measurement technique will be evaluated serving for the establishment of large scale cadastral maps.

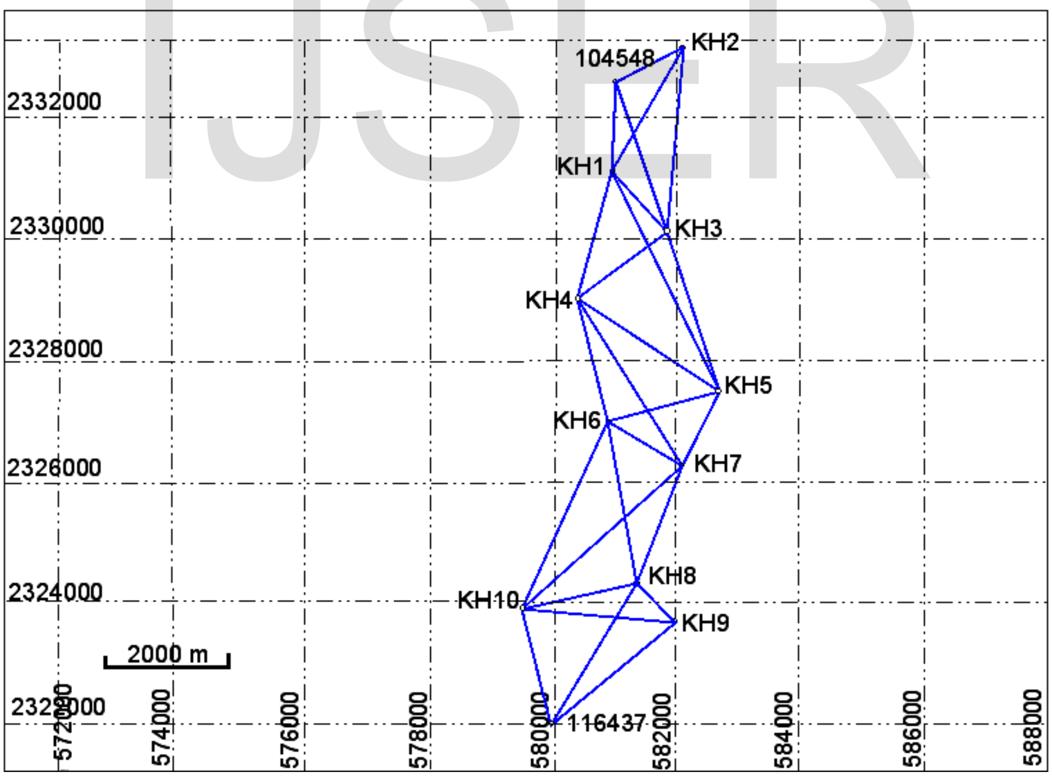

Fig 2. Network diagrams experimental measurements

4. EXPERIMENTAL RESULT

For empirical measurements, a CORS-N001 station was constructed and installed at Hanoi University of Mining and Geology by the research team (Fig 3). The receivers were connected with the CORS-N001 station by IP address 118.70.171.179. The receivers and this CORS are operated by RTK positioning technique. The telecom 4G or GPRS signal in experimental area is very good, because there were built many BTS station to enhance the quality of 4G signal to provide customer.

Fig 3. CORS-N001 system

A two-frequency TEXCEL TX10 GNSS receiver from South Company was used for the measurements. The receiver is installed parameters for calculating the transfer of coordinates, reference system, axial meridians, and for connecting to the COSR-N001 station through the IP address of the server. Based on the coordinates of the points determined by the RTK technique and the coordinates of the known points, the error in the X, Y coordinates and spot position error in the horizontal plane is calculated according to the equation (2) and (3).

The results of measuring by the two methods were compared deviation components parallel coordinates of the points by the equation (2):

$$\left.\begin{aligned}\delta X &= X_{RTK} - X_{BASE}\\ \delta Y &= Y_{RTK} - Y_{BASE}\end{aligned}\right\} \qquad (2)$$

where,

δX: error of position for axis X;

δY: error of position for axis Y.

The horizontal error of position is shown by equation (3).

$$\delta P = \sqrt{(\delta X)^2 + (\delta Y)^2} \qquad (3)$$

Calculated results of point coordinate errors of measurements using RTK technique based on CORS technology are shown in the Table 2. The tolerance horizontal error of position is calculated according to the equation (4)

$$[MP] = 0.1M \qquad (4)$$

where,

M is denominator of the map scale to be established.

Based on the regression equation (4) and formula (5), it is possible to determine the most reasonable distance when measuring according to the RTK technique using single CORS technology to establish a large-scale map.

Table 2. Calculation results of coordinate errors when measured by RTK technique

No	Point	Initial coordinates (m)		Coordinate measured by RTK technique (m)		Components of errors (m)		
		X_{BASE}	Y_{BASE}	X_{RTK}	Y_{RTK}	δX	δY	δP
1	KH-1	2331078.161	580952.520	2331078.157	580952.526	-0.004	0.006	0.007
2	KH-4	2328976.440	580430.385	2328976.432	580430.376	-0.008	-0.009	0.012
3	KH-3	2330112.400	581855.510	2330112.398	581855.524	-0.002	0.014	0.014
4	KH-6	2326970.116	580887.986	2326970.095	580888.008	-0.021	0.022	0.030
5	KH-2	2333147.615	582109.681	2333147.635	582109.702	0.020	0.021	0.029
6	KH-5	2327466.300	582693.099	2327466.278	582693.122	-0.022	0.023	0.032
7	KH-7	2326251.236	582094.451	2326251.207	582094.480	-0.029	0.029	0.041
8	KH-8	2324291.465	581377.192	2324291.425	581377.235	-0.040	0.043	0.059
9	KH-10	2323870.602	579504.400	2323870.560	579504.444	-0.042	0.044	0.061
10	KH-9	2323643.828	581962.164	2323643.786	581962.212	-0.042	0.048	0.064

Based on the data in the Table 2, a graph illustrated the relationship between the distance from the CORS to the Rover station and its location error is given in the Fig 4.

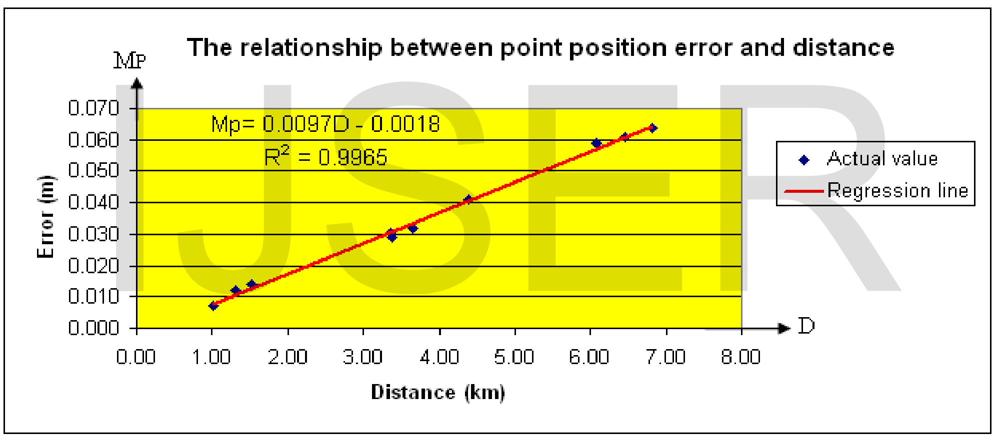

Fig 4. Relationship between horizontal error of position and distance

It was found from the Fig 4 that, when measuring by RTK technique using single CORS technology, the coordinate error of points increases with increasing the distance from the CORS to the Rover base station. The regression equation expressing the relationship between the position position error and the distance from the CORS to the Rover station is shown in Equation (6).

$$MP = 0.0097D - 0.0018 \qquad (6)$$
$$R2 = 0.9965$$

where,

MP is horizontal error of position;

D is the distance from the CORS to the rover station;

R2 is the correlation coefficient.

According to regulations, the horizontal error of detailed position depends on the scale of the map to be established. The results of calculating the distance from the CORS to the Rover base station are shown in the Table 3.

Table 3. Determined distance from the CORS to the Rover base station

Map scale	1:200	1:500	1:1000	1:2000	1:5000

Permissible error [MP] (m)	0.02	0.05	0.10	0.20	0.50
Permissible distance D (km)	2.2	5.3	10.5	20.8	51.7

Based on the calculation results in the Table 3, it is shown that when the cadastral mapping with scale of 1: 200, the allowed maximum distance from the CORS to the Rover station is 2.2 km. When the cadastral mapping with scale of 1: 500, 1:1000, 1:2000 and 1:5000 the distance allowed are 5.3 km, 10.5 km, 20.8 km and 51.7 km, respectively.

5. CONCLUSION

In this research, the investigation and evaluation of positioning accuracy by the RTK technique using single CORS technology for large-scale cadastral mapping was performed. Ten empirical points in the geodetic control network was measured and established by GPS technology and processed by TBC software. The experimetal results show that when applying RTK technique using single CORS technology, the horizontal error of position increases with inceasing the distance from the CORS to the Rover base station.

The relationship between horizontal error of position of the Rover station and the distance to the CORS was established as shown by the linear regression equation. With the established regression equation, the most reasonable distance from the CORS to the Rover base station for the establishment of large scale cadastral maps was determined. Therefore, in the cadastral survey, a single CORS and a Rover base station can be used together to perform the measurement task with the certain required precision.

ACKNOWLEDGMENT

The authors thank Department of Mine Surveying (CORS-N001 station University of Mining and Geology), NguyenKim Technology Joint Stock Company and South Limited Company for supported us this research.

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