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Time Influence on Observational Accuracy in Egyptian Virtual Reference Stations Network "VRS"

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Abstract: RTK positioning with a single reference station is limited to a distance of about 10 to 15 km. Beyond this distance limit, the errors at the reference and the rover receivers become less correlated (i.e. dissimilar) and would not cancel out sufficiently through the double differencing. This leads to unsuccessful fixing for the ambiguity parameters, which in turn deteriorates the positioning accuracy. The virtual reference station (VRS) concept can help to satisfy this requirement using a network of reference stations. This study represents at first the idea of using VRS, the VRS concept and then the time influence on VRS observations and how the accuracy may vary with respect to the observation time. The research represents the behavior of 5 different points' observations while they observed for 15, 30, 60, 90 and 120 minutes using Egyptian Virtual Reference Station network data.

Key words: GNSS · GPS · VRS · VRS in Post processing mode

INTRODUCTION

The Virtual Reference Station Concept: The idea behind multi-site RTK positioning is based on using a network of reference stations to create raw GPS measurements for a virtual reference station [1], which is located very close to the mobile, the rover or the receiver [2]. Then, the virtual reference station measurements are transmitted to the mobile receiver, where the normal single reference station RTK positioning can be performed. The differential errors between the reference stations within the network are determined, based on their known precise coordinates. The differential errors at any point within the network (e.g. a mobile receiver's location) can then be determined by interpolation. Once the mobile user provides his or her approximate position to the control station, the differential errors at that location are determined. The raw measurements are then created based on the differential errors and the approximate position of the mobile user [3, 4]. VRS is a developed system to provide high accuracy RTK GPS positioning, representing the network as a single based solution to the rover. Through a two-way communication, the central processing server will acquire the rovers' navigation solution in the NMEA format (National Marine Electronics Association). Once it receives this location, it selects the nearest three reference stations to calculate the corrections for the rover. This then creates a "Virtual Reference Station" in close proximity to the rover. Thus in the end the rover will receive a single baseline solution with a much shorter baseline length. Nowadays, this is one of the widely used methods for Network RTK positioning because there is no need to upgrade the user equipment software. But this method does have the drawback that there is no information on the quality of the interpolation process and thus on the quality of the VRS reference observations. For example when the rover moves too far away from the calculated virtual reference station, the rover is forced to reinitialize its position fix and a new virtual reference station needs to be calculated, therefore the efficiency of this approach is reduced [5]. The "VRS" concept is based on having a network of GPS reference stations continuously 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

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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. More details about VRS concept can be found by Restscher [6]. The implementation of the VRS technique into a functional system solution follows the following principles:

- We need a number of reference stations (at least three) are required, 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 GSM, to send a standard NMEA position string. 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. GSM) [7], see also TRIMBLE infrastructure white paper [8]. The DGPS solution is accurate to +/-1 meter, which is good enough to ensure that the atmospheric and ephemeris distortions, modeled for the entire reference station network, are applied correctly.
- This technique of creating raw reference station data for a new, invisible, unoccupied station is what gives the concept its name, "The Virtual Reference Station Concept.

Description of the Egyptian Virtual Reference Station Network: In the Egyptian virtual reference station (VRS), 40 fixed stations was located all over Egyptian delta and Nile valley with base lines varies from 20-100 km. Out of the above mentioned network, 7 stations were successfully connected to WGS-84 datum through the International GNSS Service (IGS) system stations NICO, RAMO, ORID resulting in base lines varies from 120-1900 km. In order to obtain the coordinates of the rest or the network stations the rest 33 stations were connected to the 7 stations which previously connected to IGS 2008 (Fig.1). Details of this network are found by Egyptian Survey Authority (ESA) [9].

The project prospect includes covering Nile Delta, Nile Valley and Northern cost of Mediterranean Sea according to the following boundaries: West: Western boundaries of Alexandria, Beheira, Giza, Fayoum and Nile Valley until Aswan, East: From Suez Canal to Cairo till Aswan and North: from Port Said to Alexandria and South to Aswan.

Time Influence on Observations Accuracy in the Egyptian VRS: In order to determine time influence on observations accuracy, six well-known coordinates stations were established and chosen by ESA were chosen to test its observations by post processing technique (PP) using Egyptian VRS data and compare the observed coordinates by the actual coordinates to get the coordinate difference and test the time influence on accuracy. Those points were observed on December 17th and 18th by Trimble R8 GNSS model 3 equipment. Different intervals of observations time were applied to the processing in order to compare the position of a single point. The intervals of the observations for the points under investigation will be 15, 30, 60, 90 and 120 minutes respectably on two days, 3 sites at the first day and the remaining sites on the next day. The ESA proposed a check to be done at the gaps areas to insure that there will be no differences in coordinates between observations in two different days. The whole observation and check process was planned, managed and suggested by ESA. Even the well-known coordinate's stations were chosen by ESA. The chosen points and at the same VRS cell, to test the VRS quality, 3 points are in the Nile delta and the remaining points are in Nile Valley – Cairo to Aswan – that's why the first 3 points have better accuracy perform on the first 15 minutes and the other points needed more than 15 minutes to get an acceptable accuracy, as the VRS shape is perfect and more like a triangle in the Delta while in Nile Valley it's not perfect and more like a strip than a triangle, due to Egyptian geographic nature. Six locations were selected at the gaps areas and surveyed at 17th and 18th of December 2011. Figs 2a and 2b show the number of satellites and DOP values at December 17th, while Figs 3a and 3b show the same values at December 18th. From these figures, it is clear that the number of satellite of GPS system is between 6 and 8 satellites and the maximum GDOP is less than 3.

During these days, data were collected six stations of the known coordinates. Data processing have been done for different period of observations, namely, 15 minutes, 30 minutes, 60 minutes, 90 minutes and 120 minutes to show the effect of the observation time on the accuracy

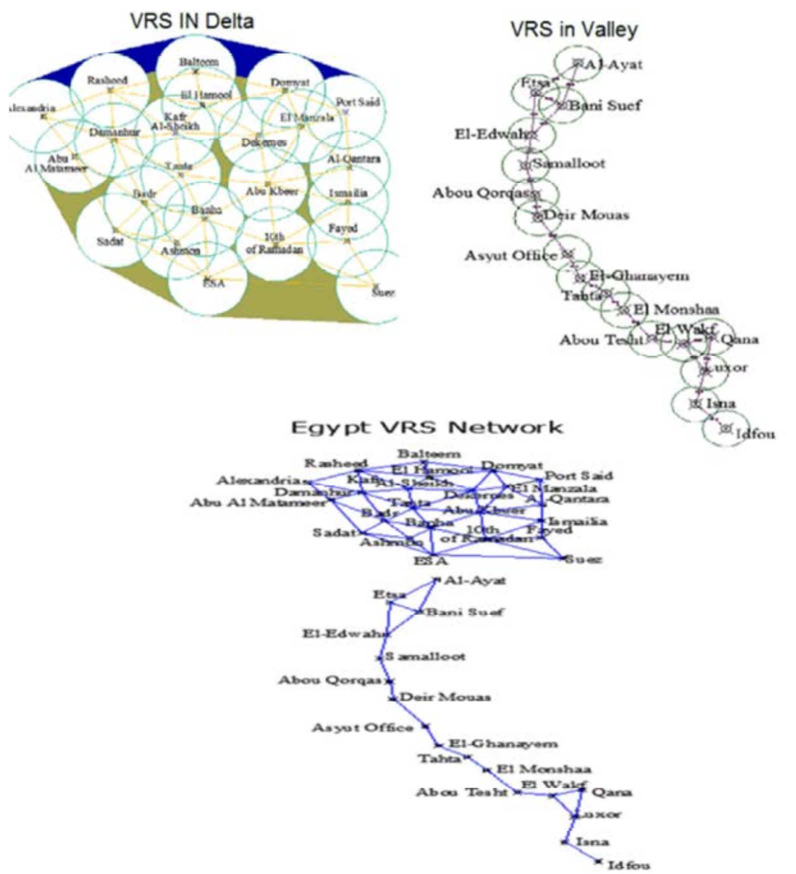

Fig. 1: Network coverage in Egypt (Nile Delta and Nile Valley).

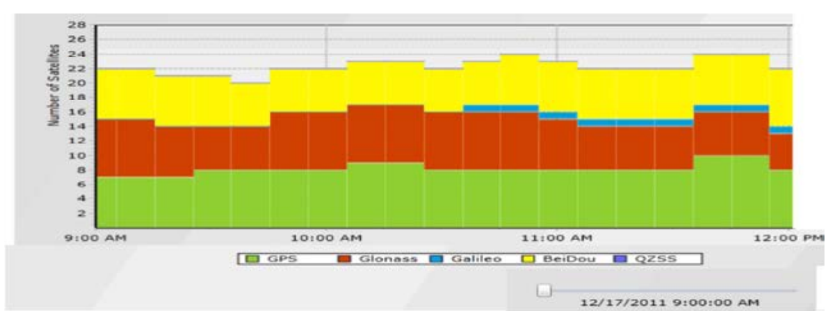

Fig. 2a: Number of satellite during the observations at December 17th 2011.

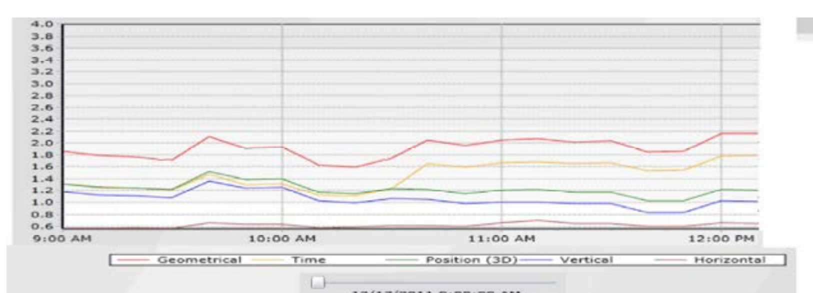

Fig. 2b: DOP values during the observations at December 17th 2011.

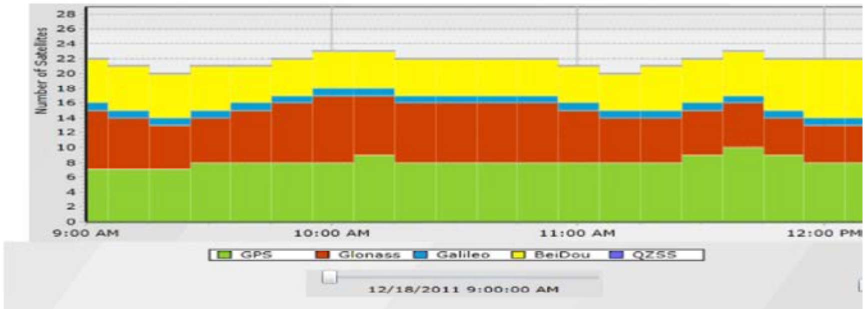

Fig. 3a: Number of satallite during the obserations at December 18th 2011.

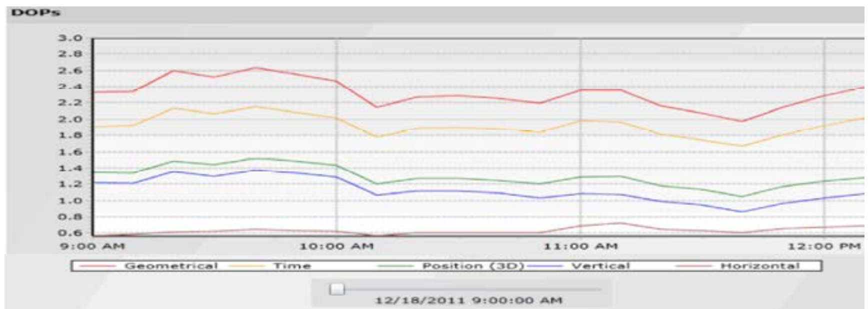

Fig. 3b: DOP values during the observations at December 18th 2011.

Table 1: Difference between real and observed coordinates for 15 minutes.

Name	dx (m)	dy (m)	dz (m)
GCP-01	-0.023	-0.005	-0.016
GCP-02	0.001	0.011	0.006
GCP-03	0.008	-0.007	-0.011
GCP-04	0.027	0.048	0.063
GCP-05	-0.006	-0.002	-0.01
GCP-06	0.149	-0.226	0.041

Table 2: Difference between real and observed coordinates for 30 minutes.

Name	dx (m)	dy (m)	dz (m)
GCP-01	0.013	-0.012	0.006
GCP-02	-0.014	0.001	-0.003
GCP-03	0.014	0.004	0.008
GCP-04	-0.006	0.012	0.014
GCP-05	-0.008	0.000	-0.009
GCP-06	0.017	0.004	-0.002

Table 3: Difference between real and observed coordinates for 60 min, units are in meters.

Name	dx (m)	dy (m)	dz (m)
GCP-01	0.005	0.002	-0.001
GCP-02	-0.021	-0.006	-0.009
GCP-03	0.027	0.008	0.015
GCP-04	0.010	0.030	0.002
GCP-05	-0.009	-0.001	-0.010
GCP-06	-0.013	-0.063	0.011

of the obtained results of the six stations. The obtained coordinates for each observation time were compared with the known coordinated of the six stations and the differences for each observation time were calculated, in

Table 4: Difference between real and observed coordinates for 90 min, units are in meters.

Name	dx (m)	dy (m)	dz (m)
GCP-01	-0.005	-0.002	-0.005
GCP-02	-0.008	0.002	0.002
GCP-03	0.018	0.007	0.01
GCP-04	-0.004	0.003	0.004
GCP-05	-0.011	-0.002	-0.011
GCP-06	-0.003	0.003	-0.014

meters, for the three axes dx, dy and dz. Also the difference in position dp = $\sqrt{(dx^2 + dy^2 + dz^2)}$ for the total error in single point coordinate.

Table 1 summarizes the differences for 15 minutes observations. From this table, it is clear that the difference in position for all points is less than 0.03 meters except for point GPC-06 reached 0.102 m. Also, it is clear that there is a mistake at point GPC-04 where its difference reached 3.448 m. Table 2 summarizes the differences for 30 minutes observations. From Table 2, it is clear that the difference in position for all points is less than 0.02 meters. Table 3 summarizes the differences for 60 minutes observations. From Table 3, it is clear that the difference in position for all points is less than 0.065 meters. It is also clear that point GPC-06 is the worse station. Table 4 summarizes the differences for 90 minutes observations. From Table 5, it is clear that the difference in position for all points is less than 0.022 meters. Table 5 illustrates the differences for

Table 5: Difference between real and observed coordinates for 120 minutes.

Name	dx (m)	dy (m)	dz (m)
GCP-01	0.001	0.004	0.001
GCP-02	-0.004	0.006	0.004
GCP-03	0.01	0.012	0.016
GCP-04	-0.006	0.003	0.004
GCP-05	-0.012	-0.001	-0.011
GCP-06	-0.001	-0.012	-0.031

120 minutes observations. From Table 5, it is clear that the difference in position for all points is less than 0.033 meters.

RESULTS AND DISCUSSION

Calculating the error tolerance after post processing using the below formula to get the coordinate error amount per point after 15, 30, 60, 90 and 120 minutes (Table 6). Figs 4a & 4b showing how the error decease and the accuracy increase as the observation time increase until they are almost fixed between 90 min to 120 min.

Changes in positions $\delta P(m) = \sqrt{\left(\delta X^2 + \delta Y^2 + \delta Z^2\right)}$

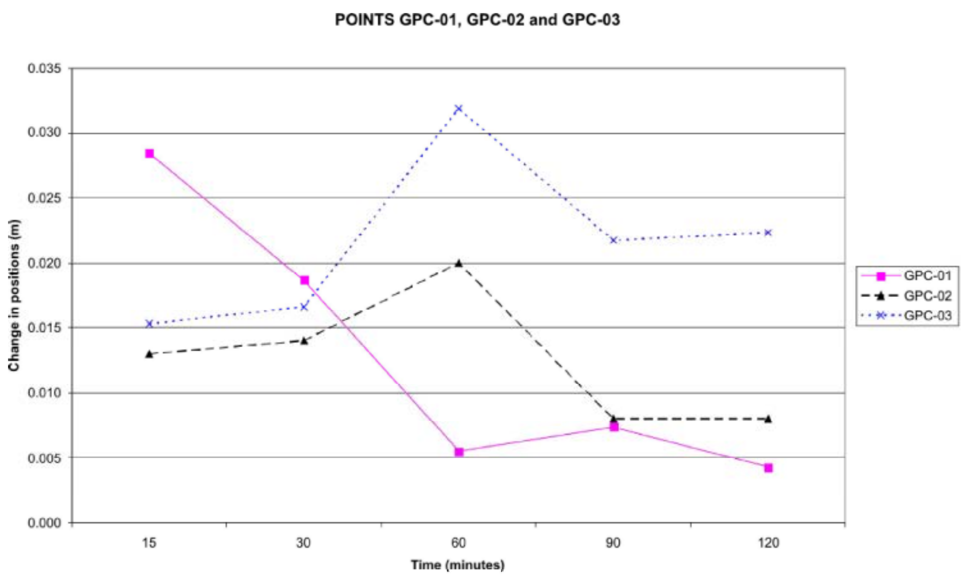

Fig. 4a: Error tolerance from 15: 120 minutes for points (GCP 01, GCP 02 and GCP 03).

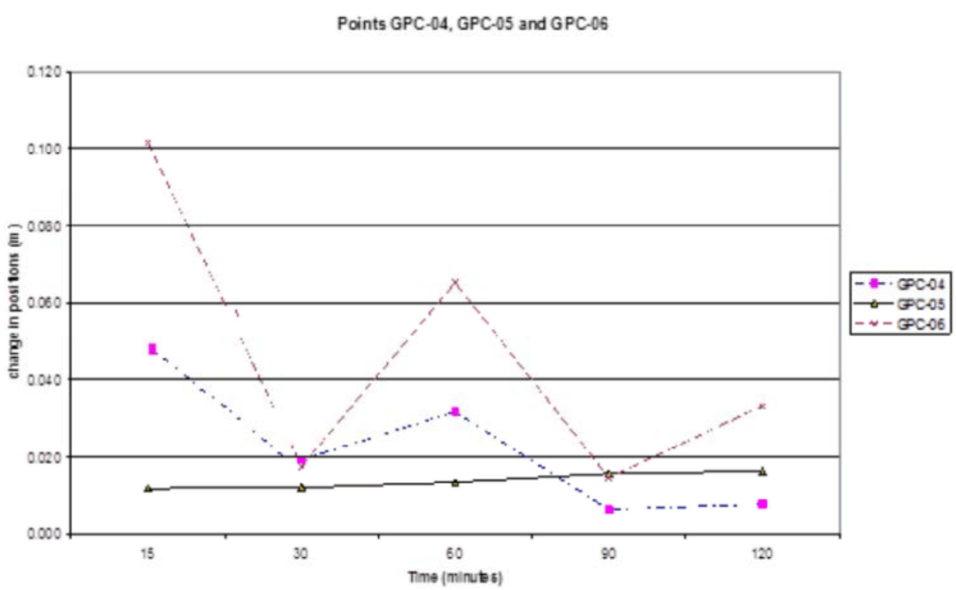

Fig. 4b: Error tolerance from 15: 120 minutes for points (GCP 04, GCP 05 and GCP 06).

Table 6: Results for variance between observed and given points coordinates.

Time (minutes)	GCP-01	GCP-02	GCP-03	GCP-04	GCP-05	GCP-06
15	0.028	0.013	0.015	0.019	0.012	0.102
30	0.019	0.014	0.017	0.019	0.012	0.018
60	0.005	0.020	0.032	0.032	0.013	0.065
90	0.007	0.008	0.022	0.006	0.016	0.015
120	0.004	0.008	0.022	0.008	0.016	0.033

CONCLUSION

The VRS network in Egypt is covering only Nile valley and Nile delta, far away of Sinai, eastern desert, western desert and not covering all the North cost. Forty stations are enough as a start to cover the most civilized regions in Egypt. The network design is typical in Nile Delta as its shape is most like a triangle, so the stations distance of each other and the network shape is good. The network design is poor in Nile Valley because its shape is close to line; making angels between stations are not equal to others. However the network users will use this network in PP mode as it's not allowed to work in RTK mode using GSM at the time of writing those lines, we recommend using the network in RTK mode as most of GPS work now use RTK mode more than PP. The RTK mode allows user to get the correction real time in the site, no need to go back to office and make processing to observed points, it's also allows user to stake out points in the site, this operation requires an internal or external radio connected to the rover, to the stations and control center to send the data between the observer and the control center, or a GSM to make the same data link between the observer and the control center, it gives better efficiency, effectively, productivity and saves time as well. For any working sessions using static technique it should collect observations not less than 30 minutes as the accuracy gets much better after 30 min as we see in points number 4 and 6 as the difference between observations and actual coordinates were reduced to sub-meters then millimeters from meters difference at 15 minutes observations.

REFERENCES

1. Dai, L., S. Han, J. Wang and C. Rizos, 2001. A Study on GPS/GLONASS Multiple Reference Station Techniques for Precise Real-Time Carrier Phase Based Positioning. ION GPS, Salt Lake City, pp: 392-403.
2. Soto Fortes, L., 2002. Optimizing the use of GPS Multi-Reference Station for Kinematic positioning. PhD. Thesis University of Calgary.
3. El-Rabbany, A., 2002. Introduction to GPS: The Global Positioning System. ARTECH House Inc, Norwood, MA 02062. USA.
4. Wasle, E., E. Lichtengger and B. Haffman-Wellenlhof, 2007. GNSS Global Navigation Satellite System: GPS, GLONASS AND GALLEO' and more" Springer, Wien, New York.
5. Euler, H.J., C.R. Keenan, B.E. Zebhauser and G. Wübbena, 2011. Study of a Simplified Approach in Utilizing Information from Permanent Reference Station Arrays. ION GPS, Salt Lake City, pp: 379-391.
6. Retscher, G., 2002.Accuracy Performance of virtual Reference Stations. Journal of Global Positioning System, 1(1): 40-47.
7. RTCM Recommended Standards for Differential GNSS Service, Version, 2.3. 1994.
8. Trimble Infrastructure white paper. Using multi reference station in VRS Mode. pp: 7
9. Egyptian Survey Authority (ESA) 2011. Hand Book of VRS Project.Fig. 2a: Number of satellite during the observations at December 17th 2011.