THE NETWORKED RTK - CHANGING TECHNIQUES FOR GPS SURVEYING

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ABSTRACT

The land surveying community is about to enter a new era of control surveying. Traditional methods of Global Positioning System (GPS) static and single base Real Time Kinematic (RTK) control surveying found in most surveying and engineering projects, the recent integrated networks of reference stations interpolating corrections for the point of survey replacing the local base station. Rather than using densely spaced "permanent" or passive physical monumentation, now get the three dimensions controls from much sparser physical networks and establishing site coordinates utilizing the Continuously Operating Reference Station (CORS) system as truth.

Providing professional surveying services in support of many of New York City's major engineering department projects has provided a base of experience will be described and analyzed to demonstrate the great potential of the networked RTK as a powerful control surveying tool. The Queens's drainage system, New York State Department of Design and Construction (NYSDDC) and Rockland County's environmental study, Department of Environmental Conservations (NYSDEC) were accomplished utilizing this technique. This paper will discuss each project and provide a case study that included extensive accuracy quality control checking. This paper presents an applicable proto-type technique, considered mandatory, for the worldwide engineering projects.

The reflection of the obtained results will soon give way to launch establishing controls for similar Egyptian projects such as the Geo-digital registration of the irrigation structures and the remote sensing applications for north coast lakes.

Keywords: Networked RTK – ITRF – CORS Stations

INTRODUCTION

The Real Time Kinematic (RTK) technique has been launched originally on 1995. The system was really a big hit in land surveying technology in general and brought the GPS world from the black box GPS to what is called a GPS Total Station. The smart data collectors' production was so powerful in trusting such a system similar to the well- known traditional optical Total Station in the three dimensional coordinate computations procedures [5]. However, the sources of errors were different and mostly based upon the pre-coordinated base station of the RTK system.

The obtained accuracy of the unknown rover points is always a reflection of the accuracy at the occupied local base station. Antenna, Radio Latency, base station positional error, and modeling of ionospheric errors are commonly inherited errors from the local base stations.

Unlikely, in case of the networked RTK, the operating technique refines positional accuracy at the rover position. first of all, The part per million (PPM) error components present in single-base RTK is taken from the error budget, because errors are not linearly correlated to distance in this situation [1].Second of all, the interpolation of atmospheric errors at the survey site is another enhancement added compared to interpolation at base in single base technique.

RTK FROM INTERNET

The basic principles of RTK since several years are to have corrections from single station /multiple stations, then the rover perform the baseline processing based on the transmitted corrections at the base/bases location (s). Keeping in mind, there is no control over the quality of results computed by users. [5]

Nowadays we got an additional positive performance increases the RTK positioning accuracy and changes the error characteristics. Understanding of the new system components, comprehensive understanding of error characteristics, and of course the terrific performance of telecommunication networks paved the way for today's approach.

In the Online Positioning User Services (OPUS), instead of broadcasting corrections or data and placing the responsibility of obtaining final solution on users, advantage is taken of the existing GPS network infrastructure to compute their coordinates in the required reference system. The final coordinates for all logged users could be simply computed as a by-product of the continuous network process. The network administrator is responsible for data integrity and data quality controls, a number of web-based services are assigned for the generation of coordinates via the post-processing of data submitted by user. The implemented networked - RTK is an extension of such a real time processing system.

A client –Sever Approach (fig. 1) reverse the data flow in conventional RTK be requiring the user/rover to transmit their data to control center. This facility can select the optimal combination of stations to, for example, apply the network corrections, and compute the best possible position solution before returning to the user.

The basic principles of the Client –Server Approach are given as follows*:*

- Data from reference station network is transferred to a computing center
- The network data is used to compute models of ionosphere, troposphere, and orbit errors.
- The carrier phase ambiguities are fixed for the network baselines.
- The actual errors on the baselines are derived in centimeter accuracy using the fixed carrier phase observations.
- Linear or more sophisticated error models are used predict the errors at the user location.
- A Virtual Reference Station (VRS) is created at the user location.
- The VRS data is transmitted to the user in standard format.

The user set-up in the field follows this procedure*:*

- The field determines the user location with a navigation solution (no reference) or by DGPS (uncorrected data)
- The receiver dial into the computing center via internet modem
- The navigation solution is transferred to the computing center.
- Three Dimensional Coordinate Transformations are applied
- The computing center immediately starts to send Virtual reference station data to the field
- User.

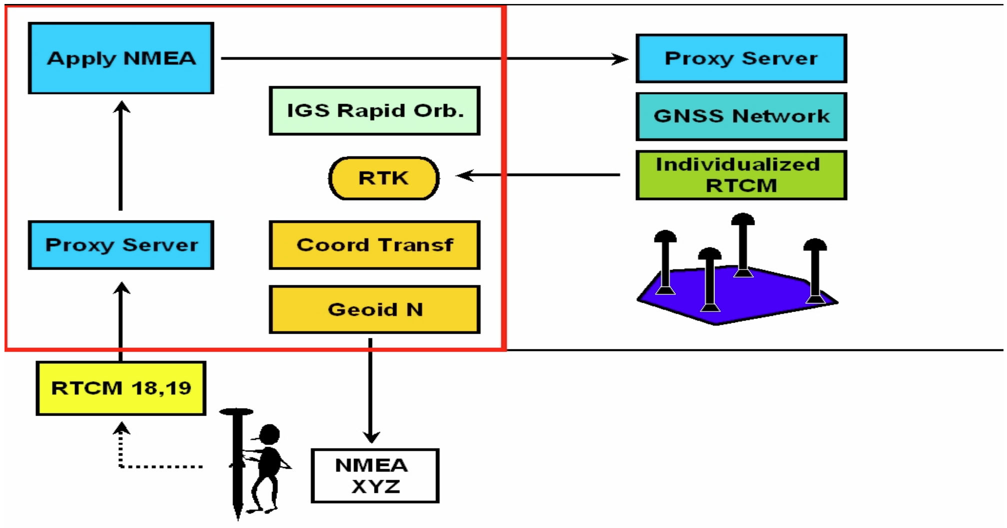

Figure 1. Client-Server GNSS-RTK model implementing transformations.

ARE THE RTK COORDINATES ITRF COMPATIBLE?

A Global Navigation Satellite System (GNSS) CORS comprises a GNSS receiver and antenna mounted on a stable monument (pillar) or structure (building) at a safe and secure location with a reliable power supply. The receiver operates continuously, logging raw data, perhaps also streaming (continuously outputting) raw data, and often outputting real time kinematic (RTK) and differential GNSS (DGNSS) data for transmission to RTK, GIS and GNSS navigation devices. The GNSS receiver is usually controlled by a computer that can be located remotely. This personal computer (PC) will usually download GNSS data files at regular intervals and pass them to a File Transfer Protocol (FTP) server for access by the GNSS user community. Reference stations and networks can vary considerably in extent size, level of service and complexity [4]. Organizations that are investigating the establishment of reference stations should consider carefully what the stations will be used for, what services they will have to provide, and what will be the appropriate levels of sophistication and cost.

Co-ordinates in an International Terrestrial Reference System (ITRS) are computed at different epochs and the solutions are called ITRF. Due to plate tectonics and tidal deformation, the co-ordinates changes for a certain point between the different ITRF. The latest version of ITRF is ITRF 2005. In simple terms the ITRF is a realization of the ITRS. WGS84 or the World Geodetic System 1984 is the geodetic reference system used by the GNSS - "GPS." WGS84 was developed for the United States Defense Mapping Agency (DMA), now called NGA (National Geospatial - Intelligence Agency). Although the name WGS84 has remained the same, it has been enhanced on several occasions to a point where it is now very closely aligned to ITRF and referenced as WGS84 (G1150). The origin of the WGS84 framework is also the earth's centre of mass. For all practical purposes, an ITRF based geodetic datum or CORS network and WGS84 are the same. The difference is of the order of centimeters. ITRF co-ordinates or positions are articulated as three dimensional geocentric or Earth Centered Cartesian co-ordinates i.e. "X, Y and Z."

Adopting an ITRF based geodetic datum allows for a single standard for collecting, storing and using geographic or survey related data. This will ensure compatibility across various geographic, land and survey systems at the local, regional, national, and global level. This is the main reason that the ITRF based CORS networks should form the basis for Spatial Data Infrastructure (SDI) which is the enabling infrastructure to manage a country's key spatial data sets i.e. it underpins or is the reference layer for the cadastre, transit, / road networks, infrastructure corridors like gas, water, power, communications etc. An ITRF based geocentric datum or CORS network will also: provide direct compatibility with GNSS measurements and mapping or geographic information system (GIS) which are also normally based on an ITRF based geodetic datum; minimize the need for casual users to understand datum transformations; allow more efficient use of an organizations' spatial data resources by reducing need for duplication and unnecessary translations; help promote wider use of spatial data through one user friendly data environment; reduce the risk of confusion as GNSS, GIS and navigation systems become more widely used and integrated into business and recreational activities.

CASE STUDIES

New York City (NYC) engineering project biddings are now recommending the use of single RTK rover unit in the scope of works and consultant Request for Proposals (RFP). The NYC project managers also adopt the system in the latest editions of the land surveying and mapping procedure manuals as one of the approved methodology in establishing of photo controls, utility surveys, highway design and construction stake out.

Study of Drainage System in Queens, NY

Digital registration of the existing and newly updated drainage networks is one of the high priorities to the NYC Department of Design and Construction (DDC) after the last year flood at major streets and main subway stations, re-design and maintenance of Santiago street (off the Grand Central Parkway) is one of the DDC projects to study and register the street profile, street intersections and drainage network to overcome the flood problem. The main concern is to measure the capacity and capability of the existing drainage system of this area.

The scope of this project mandates a complete utility survey and very detailed topographic maps with accurate street level elevation information and inverts at each individual drainage structure. For DDC to match and compile different maps the delivered default coordinate system must be the Queens Coordinate System and the elevation related to Queens Vertical Datum. Having ninety 90% percent of borough benchmarks and monuments reported as lost; these requirements are also a challenge for city project with very limited budget and tight schedule.

Now I can tell after project submission and approval that the single rover networked RTK came up with excellent results in amazing time with seamless effort. Sixty five percent 65% of the scope items were performed by the GPS observations; this percentage is 80% less in time originally spent for the rest of the project in the field and office compilation as well.

Combination between networked RTK and traditional leveling (mixing of existing benchmarks and RTK observations) showed good results consistent with DDC standards. The saving within this task was 40%, and more than expected quality have been obtained in measuring the height component.

Environmental Investigations at Industrial Areas, Rockland County, NY

New York State Department of Environment and Conservations (NYSDEC), frequently needs to establish monitoring wells and to locate environmental soil borings. Positions and elevations must be obtained at each monitoring well and related utilities of the industrial areas.

Brenner Drive, Rockland County, NY has seven factories under investigations for possible soil contaminations by DEC of which had established a sixteen monitoring wells and many soil borings. Detailed topographic mapping was requested by DEC for including the new established wells, soil borings, and utility features. Being a member of RTK network made the life easy utilizing the RTK to locate the whole topographic features and environmental structures. Such a limited budget project can not afford traditional survey techniques to transfer horizontal and vertical controls 20 kilometers away to the job site and tens of instrument setups to pick the topographic data. Actually, no surveying consultants can go for it in a state project has a strict budget and tight schedule.

The estimated field work for the job was eighty hours at the job site plus twenty hours for transferring the controls. The performed RTK field work had been done in twenty four hours, showing an average positional accuracy of ± 1 cm and average elevation accuracy of ± 2 cm. Standard Quality Control and Quality Assurance based on the Federal Geodetic Committee for mapping standards by DEC professional Engineers and Land surveyor, reported approval and consistency with the federal and New York state procedure standards.

IS IT ACCURATE ENOUGH?

The above mentioned projects have been achieved utilized mixed techniques; Total Station system and RTK networked system, the onsite controls also have been checked for the closure between the final coordinates obtained from adjusted static network versus RTK network values. The comparison between both methods is listed below; tables No. 1 and No. 2.

In the first project the analysis is based upon the obtained position calculated from traversing between two GPS Azimuth Pairs versus the same point positions located utilizing the networked RTK. The results are of maximum 0.03 ft. difference between two systems. In this case, we can statistically consider the traverse adjusted coordinate values are the most probable values and the difference between the observed RTK values and these values are the variances, which confirm the nominal published accuracy of the RTK system ±1 cm or 0.03ft.

As the elevation is of important in all engineering applications, the comparison listed below is between the results of adjusted leveling runs which started at B-Order or better NGS benchmark and terminated at different NGS benchmark to height the listed traverse points. The preformed leveling runs are consistent with the Second Order - Class II vertical control. The values of networked RTK are off the leveling values with fluctuating numbers from 0.02ft. to 0.054 ft. These elevation differences agree with the published nominal values of the system of ±0.06 ft. or 2 cm.

Table 1. Comparison between Traverse, Leveling and RTK Values within the Environment Project, Rockland County, New York

Name	Northing ft.	Easting ft.	Elevation	Code	Name	Northing ft.	Easting ft.	Elevation	Code	Δ N	Δ E	Δ e
52	847855.542	646988.084	196.622	YCIR	52	847855.5230	646988.0740	196.6000	YCIR	0.019	0.010	0.022
53	847290.563	646977.228	193.991	MAG NAIL 53	53	847290.5415	646977.2027	193.9950	MAG NAIL 53	0.021	0.025	-0.004
54	847263.730	646732.343	202.895	SPIKE 54	54	847263.7431	646732.3445	202.8753	SPIKE 54	-0.013	-0.002	0.020
55	847211.536	646444.385	197.912	SPIKE 55	55	847211.5155	646444.3960	197.9276	SPIKE 55	0.020	-0.011	-0.016
56	846969.244	646696.240	199.830	MAG NAIL 56	56	846969.2341	646696.2199	199.8801	MAG NAIL 56	0.010	0.020	-0.050
57	846797.146	646698.631	197.420	SPIKE 57	57	846797.1762	646698.6112	197.4600	SPIKE 57	-0.030	0.020	-0.040
58	846939.212	646404.567	197.155	SPIKE 58	58	846939.2021	646404.5967	197.1799	SPIKE 58	0.010	-0.030	-0.025
59	846930.024	646973.313	186.518	SPIKE 59	59	846930.0042	646973.3432	186.5579	SPIKE 59	0.020	-0.030	-0.040
60	847738.277	646715.663	204.499	MAG NAIL 60	60	847738.2671	646715.6426	204.4494	MAG NAIL 60	0.010	0.020	0.050
61	847371.150	646281.552	185.866	MAG NAIL 61	61	847371.1804	646281.5422	185.8963	MAG NAIL 61	-0.030	0.010	-0.030
62	847017.746	646313.956	189.013	SPIKE 62	62	847017.7263	646313.9764	189.0525	SPIKE 62	0.020	-0.020	-0.040

Table 2. Comparison between GPS Static Network Adjusted Values and RTK Values within the Drainage Study Project, Queens, New York

Name	Northing ft.	Easting ft.	Elevation	Code	Name	Northing ft.	Easting ft.	Elevation	Code	Δ N	Δ E	Δ e
51	200866.613	1047409.105	115.731	BL51	51	200866.615	1047409.075	115.772	BL51	-0.002	0.030	-0.041
69	200738.077	1048118.622	103.111	BL60	60	200738.047	1048118.652	103.143	BL60	0.030	-0.030	-0.032
52	200660.799	1047455.721	109.023	BL52	52	200660.839	1047455.745	109.062	BL52	-0.040	-0.024	-0.039
53	200490.983	1047590.445	98.719	BL53	53	200490.954	1047590.430	98.735	BL53	0.029	0.015	-0.016
59	200807.714	1047232.809	111.396	BL59	59	200807.748	1047232.832	111.342	BL59	-0.034	-0.023	0.054
57	200494.222	1047186.949	110.906	BL57	57	200494.262	1047186.957	110.957	BL57	-0.040	-0.008	-0.051
58	200408.408	1046797.706	114.1	BL58	58	200408.458	1046797.752	114.135	BL58	-0.050	-0.046	-0.035
55	199799.644	1047933.130	67.806	BL55	55	199799.624	1047933.162	67.843	BL55	0.020	-0.032	-0.037
54	200178.177	1047741.072	77.891	BL54	54	200178.207	1047741.092	77.872	BL54	-0.030	-0.020	0.019
56	199367.143	1048157.652	58.446	BL56	56	199367.173	1048157.664	58.475	BL56	-0.030	-0.012	-0.029
61	199653.302	1047684.971	69.576	BL61	61	199653.282	1047684.986	69.545	BL61	0.020	-0.015	0.031

CONCLUSIONS AND RECOMMENDATIONS

-The obtained results are excellent recommendation to incorporate such a system that achieves many of land surveying tasks easier, quicker, and accurate. Topographic survey, mapping accuracy check, DTM check, Hydrographic Surveying, beyond national GIS data collection, construction stake out, Photo control and Remote Sensing ground controls are the fields that have been changed radically in shorten the field operation time and rate of productivity

-The networked RTK is getting closer to the common optical techniques that used to be a solely system of establishing the third order control and traverses. The system perfection of transfer controls across rivers, lakes, tunnels, and obstacles in general is not negotiable

-An ITRF based geocentric datum or CORS provides direct compatibility with mapping and GIS which are also normally based on ITRF geodetic datum. It is highly recommended for spatial datasets and geographical information data to extend over national and regional boundaries under common reference frame. ITRF is the most accurate reference frame should be adopted for a national solution worldwide.

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