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Comparison of MyRTKnet Performance with Various Real-Time Corrections Based on Different Time

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Abstract. Virtual Reference Station (VRS), Master-Auxiliary Corrections (MAX), Individualised Master-Auxiliary Corrections (IMAX), Nearest Base, and Network D-GNSS are among the Network Real-Time Kinematic (NRTK) techniques supported by the Malaysia Real-Time Kinematic GNSS Network (MyRTKnet) in providing network-based solutions to users. However, different network corrections have different limits due to different characters, thus offering a variety of position accuracy. Therefore, this study evaluated the accuracy of real-time corrections, VRS, MAX, IMAX, D-GNSS, and Nearest Base, for the coordinates at two different times, morning and evening. The study was conducted at two different times to make it easier for users to choose a suitable and quality time to conduct observations. This research was implemented on the pillars at the calibration site of Politeknik Sultan Haji Ahmad Shah (POLISAS) in Kuantan, Pahang. The coordinates in the pillar become a benchmark to differentiate with real-time correction coordinates. The result of that difference can be used to analyse the level of accuracy for real-time corrections. The study's findings show that the real-time correction accuracy of the VRS type is the most stable and has the highest accuracy. Nearest Base and MAX corrections also give relatively good accuracy and can be improved by increasing observation time and depending on the area. IMAX produces inconsistent results with relatively low accuracy, but some techniques can be applied to obtain good accuracy. D-GNSS type corrections give inconsistent results and low position accuracy as it utilises code measurement only. The research concludes that the best correction is VRS. The Nearest Base and MAX produce acceptable accuracy and can be safely chosen over IMAX and D-GNSS.

1. Introduction

The technologies of the Global Navigation Satellite System (GNSS) are now widely used in daily life, built into our electronic gadgets, and frequently employed by the general public, surveyors, and geosci entists. Various surveying and mapping tasks, including establishing control points for aerial

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photography, fixing boundary marks for cadastral survey, and monitoring real-time deformation for a geodetic survey. [1] The range of prices from low-cost systems with positioning accuracy of tens of meters to high-cost geodetic survey systems capable of positioning to the sub-centimetre level. Various methods can be applied using this GNSS tool. The simple and efficient concepts that originated in the mid-1990s are the Real Time Kinematic (RTK) and Network Real Time Kinematic (N-RTK) methods. NRTK has grown more and more accessible to Continuously Operating Reference Station (CORS) users in Malaysia.NRTK services were previously exclusively accessible in large urban areas, but they are now quickly spreading to rural areas [2].

By establishing surveying infrastructure across the nation, the Department of Survey and Mapping Malaysia (JUPEM) is the appropriate governing body for providing horizontal and vertical survey control to the surveying community in Malaysia for national development, security, and defence. JUPEM has taken a number of actions in support of the government's efforts to enhance its delivery system. Registered users can get corrections produced by the central processing facility using Network Real-Time Kinematic (NRTK) techniques through the Malaysian CORS service, also known as the Malaysia Real-Time Kinematic GNSS Network (MyRTKnet) [3].

The MyRTKnet service, developed in 2003, consists of 27 GNSS reference stations. In order to provide better services to users, JUPEM added 51 more GNSS reference stations from 2006 to 2008. With this increase, the MyRTKnet network now consists of 96 active GNSS stations located at a distance of 30 to 150 km, of which 65 stations are in the Peninsular Malaysia while 31 stations in Sabah and Sarawak. These stations are specially built to continuously record GNSS data, transmitted to the MyRTKnet Control Center at the Geodetic Survey Division, JUPEM, via broadband telecommunications lines. The MyRTKnet Control Center is responsible for publishing and disseminating GNSS correction data to mobile users in real-time. A high-precision, centimeter-level satellite location service is offered using numerous reference station networks with real-time kinematic (RTK) positioning, which is very dependable and widely available [4]. The MyRTKnet system typically offers GNSS data and correction at various levels. Users can select from eight (8) different categories of services offered by MyRTKnet based on Table 1.

Table 1 MyRTKnet services

Num.	Corrections Type	Data Character
1	Master Auxiliary Correction	Real-Time
2	Individualized Master Auxiliary Correction (IMAX)	Real-Time
3	Virtual Reference Station (VRS)	Real-Time
4	Single Base	Real-Time
5	Nearest Base	Real-Time
6	Differential GNSS (D-GNSS) based network (Network Base D-GNSS)	Real-Time
7	Virtual RINEX Data	Post-Process
8	RINEX CORS Data (RINEX Data)	Post-Process

This study investigated the performance of five real-time corrections, except for the single-base correction available in the MyRTKnet service. The test was carried out by observing two times (morning and evening) to analyse the discrepancy coordinate accuracy between two different times. This study hopes to help the users of the MyRTKnet system choose a type of correction that is highly accurate and suitable for observation times.

2. Network-RTK

As a result of putting this theory into practise and making use of the knowledge gained, the idea of real-time GNSS networks (N-RTK) was born. The reliance on a single reference station vanished in the N-RTK system. It also became possible to carry out local atmospheric modelling using information from

different reference stations [5]. Because of this modelling, inaccuracies in the ionosphere and troposphere, two of the most notable sources of error that effect GNSS data, are minimised in positioning applications [6]. These networks' advantages are listed below [7]:
a) While GPS measurements, it is not necessary to have equipment and employees at reference stations.
b) The measurements and findings fall squarely within the parameters of the national reference systems.
c) There is no necessity to squander resources by first conducting research at locations with known coordinates before beginning fieldwork.
d) The chosen datum is used to get three-dimensional real-time sensitive coordinates.
e) Point coordinates are tracked continually and updated in the event of deformation.

2.1 MyRTKnet Services
Various GNSS corrections and data levels are offered by the MyRTKnet system. The different real-time corrections have different limitations due to different characteristics. For this study, the real-time corrections that will be applied are VRS, MAX, IMAX, Nearest Base and D-GNSS.

Table 2. Various real-time corrections

Type of Corrections	Characteristics
VRS	The approach involves communication in both directions between a network server and a minimum of three reference stations [8].
MAX	It is possible for the concept to be one- or two-way. In addition to the single differences (both correction and coordinates) of other stations in the network, the position, the coordinates, and bias of a single reference station (master station) are broadcast to the rover [9].
IMAX	The network operator must have two-way communication in order to select the proper cell and extrapolate the network adjustments for the rover's location.
Nearest Base	Given the location of the rover, the server will select the reference station that is physically nearest to the rover to serve as the base station. This single-based RTK is well known as a correction because it relied on a single CORS while disregarding all of its neighbours, unlike other N-RTK solutions that relied on multiple CORS.
D-GNSS	Applications like navigation and submeter mapping might make use of this. Real-Time RTCM corrections from D-GNSS solutions can be accessed by any receiver that supports real-time corrections and cell phone data service. Due to the variety of base station locations provided by D-GNSS, users' observations are free from distance-dependent inaccuracies.

3. Data Collection Method
In this paper, fieldwork and processing strategies have completed this study's aim to evaluate the real-time accuracy of MyRTKnet service corrections at two different times. Fieldwork was carried out for positioning where the data involved are VRS, MAX, IMAX, Nearest Base and D-GNSS real-time corrections.

3.1 Area of Study

Figure 1. The location of pillars at POLISAS site calibration

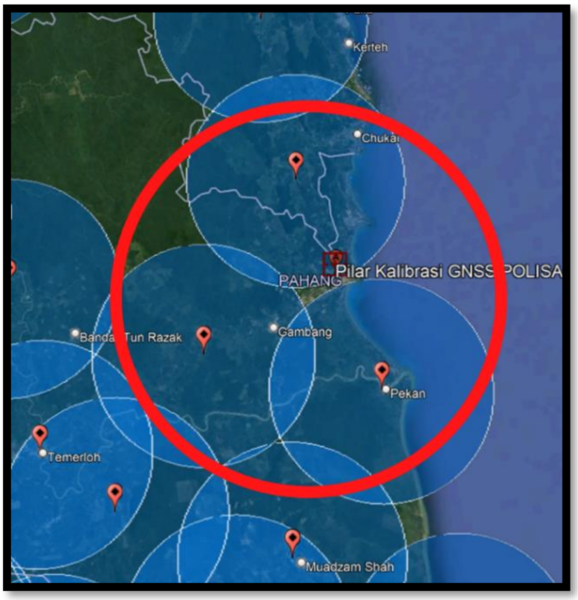

Figure 2. Radius of CORS

Referring to Figure 1, the project was implemented at the GNSS calibration site in POLISAS, Kuantan, Pahang. There are three GNSS calibration pillars (green rectangle) at the POLISAS calibration site. The coordinates in the pillar become a benchmark (known coordinate), which is distinguished from the coordinate result by observation of various real-time corrections (observed coordinate). Refer to Figure 2; the blue circle means the radius of 30km covered by a station. Stations are spaced anywhere from 30 to 100 km apart. The three active reference stations closest to the site are all 30 km away (red circle), which helps correct N-RTK observations. The baseline length between the rover and the closest CORS station affects the horizontal and vertical precision. As rover move away from the closest CORS station, precision decreases for horizontal and vertical components.

3.2 Study Workflow

Four main stages have been completed, as shown in Figure 3. The success of this project is based on a well-researched and well-planned workflow framework. Stage 1 is a critical framework in terms of planning and preparation. All selections, such as the type of tool, project location, and software used, have been made at this stage. In Stage 2, the stage where the implementation of the project in the field is based on planning, this project conducts observations in the morning and evening using five types of real-time correction. Stage 3 is the data processing stage, where data sorting is done using Excel software. Stage 4 is the last level to evaluate the data results, which is the analysis of the discrepancies between the morning and evening observations regarding accuracy. The time chosen in the morning and evening is because the surveyor typically does the surveying work in the morning or afternoon. Therefore, the selection of the timing of this time is to see which time obtains a better quality of GNSS observations.

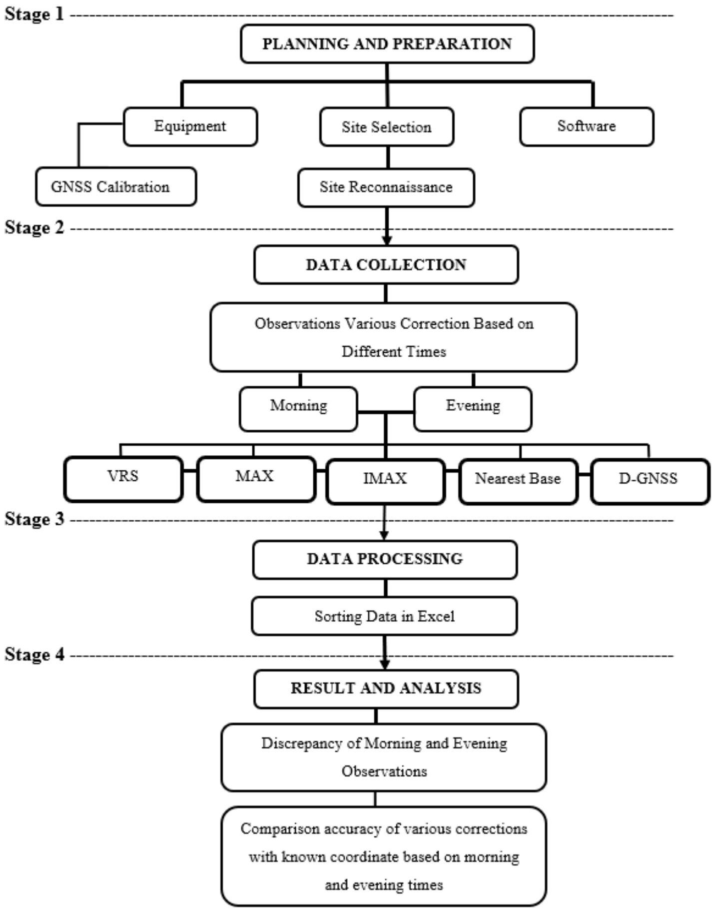

Figure 3. Detailed workflow for the study

3.3 Methodology

Referring to Figure 4, the GNSS observation of the N-RTK method is performed by mounting the GNSS on a pillar. The GNSS equipment used for this N-RTK observation brand is from South GNSS G1 Plus type. This GNSS equipment has been calibrated to ensure it is in good condition to perform in this project. Accuracy testing by observation of various types of real-time corrections is carried out for two epochs in the morning and evening.

The results of observation data from various real-time corrections are exported in ASCII format. The observation data is sorted using Excel software. The final value of each real-time correction results from averaging across all epochs. The final result is the final coordinates for each type of real-time correction made at two different times.

Figure 4. GNSS equipment mounted on pillar

4. Result and Discussion

4.1 Discrepancy of Accuracy Between Morning and Evening Observations

Table 3. Accuracy based on different times.

Pillar	Type of Corrections	Differences Error = (Actual minus Observed) (m)						Discrepancy (Morning-Evening) (m)		
		Morning			Evening					
		Δ Northing	Δ Easting	Δ Ellip. Height	Δ Northing	Δ Easting	Δ Ellip. Height	Δ Northing	Δ Easting	Δ Ellip. Height
1	VRS	0.000	-0.007	-0.007	0.006	0.005	-0.005	-0.006	-0.012	-0.002
	MAX	0.009	-0.014	-0.002	0.249	0.128	-0.024	-0.240	-0.142	0.022
	IMAX	-0.115	0.063	0.033	-0.204	0.026	0.032	0.090	0.037	0.001
	D-GNSS	-1.234	-0.660	-1.270	0.770	-0.651	-5.411	-2.004	-0.008	4.141
	Nearest Base	0.045	-0.014	0.030	-0.143	0.005	-0.124	0.188	-0.019	0.153
2	VRS	0.001	-0.004	-0.039	0.002	0.001	0.007	-0.001	-0.004	-0.047
	MAX	0.021	0.000	-0.035	-0.071	-0.077	-0.224	0.091	0.077	0.189
	IMAX	-0.014	0.026	0.085	0.080	0.064	0.318	-0.094	-0.038	-0.234
	D-GNSS	-1.277	-0.446	-1.458	-0.342	-0.519	-0.983	-0.934	0.073	-0.475
	Nearest Base	-0.014	0.023	-0.001	-0.236	-0.007	0.041	0.223	0.030	-0.042
3	VRS	-0.001	-0.004	0.027	0.000	-0.007	0.023	-0.001	0.002	0.004
	MAX	0.037	0.022	-0.007	-0.184	0.045	0.039	0.222	-0.022	-0.046
	IMAX	0.118	0.020	0.185	0.074	0.037	-0.053	0.045	-0.017	0.237
	D-GNSS	1.691	-0.675	-3.792	3.389	1.545	-3.932	-1.699	-2.220	0.140
	Nearest Base	-0.113	0.024	0.158	-0.280	0.201	0.018	0.167	-0.177	0.140

Based on the data in Table 3, there is a discrepancy between the five correction techniques observed in the three pillars in the morning and evening. VRS-type correction obtains high accuracy for observations at two different times. The coordinates obtained are within the required tolerance. The highest morning and evening discrepancy is -0.047 m (Ellipsoidal Height), but it is still classified as high accuracy. The VRS did not show a large discrepancy in the morning and evening hours and was consistent in accuracy.

For MAX-type corrections, the accuracy is slightly better in the morning than in the evening. The difference value with the reference coordinate is always within tolerance for all three pillars in the morning. The highest difference value is 0.037 m (Northing), 0.022 m (Easting), and -0.035 m (Ellipsoidal Height). In the evening, the majority of the difference exceeded the expected tolerance. The discrepancy between morning and evening is enormous, up to -0.240 m (Northing), -0.142 m (Easting), and 0.189 m (Ellipsoidal Height).

The IMAX-type correction obtained relatively low accuracy results both times. In the morning observation, the closest difference value to tolerance is in the observation in pillar 2: -0.014 m (Northing), -0.026 m (Easting), and -0.085 m (Ellipsoidal Height). In the evening, the difference value with the closest reference coordinate is the observation in pillar 3, where 0.074 m (Northing), 0.037 m (Easting) and -0.053 m (Ellipsoidal Height). This difference may be within tolerance if the observation is more extended. The discrepancy between these two times is inconsistent because there is an observation (such as the discrepancy in pillar 3) regarding Northing and Easting below the tolerance. However, the Ellipsoidal Height exceeds the proper tolerance.

The accuracy of the Nearest Base type of correction is seen to be better in the morning than in the evening. In pillar 2, there is a minimal tolerance between the reference coordinate value and the morning observation coordinate value. In the observation of pillar 1, it is also close to a reasonable accuracy value. However, the Easting value of 0.045 m has exceeded the tolerance by 15 mm. Observations in the evening have mostly exceeded tolerance. The nearest CORS cannot send a good correction because this type of correction depends on the nearest CORS to obtain the correction. Maintaining CORS as close to active as possible is vital to obtain good correction and high accuracy. The D-GNSS corrections observed in the morning and evening have significant discrepancies and low accuracy. This is a factor because this correction only works to obtain a low-precision position but can be used as navigation.

5. Conclusion

This study has effectively assessed the accuracy of the NRTK technique based on VRS, MAX, IMAX, D-GNSS, and Nearest Base type correction approaches. Due to the function, time, concept, and technique of each NRTK approach, the results produced are also diverse. The best example of a high-quality observation that can be shown is VRS. This VRS-type correction is stable for morning and evening observation tests. The character for each correction is different. Similar to VRS-type corrections, this model synthesises VRS close to the user's position and sends the wandering receiver a localization set of standard-format corrective signals. Therefore, based on the results obtained, this type of VRS character is very good if it meets the level required to obtain a high accuracy value. Based on the findings, if the server during the observation can operate well, the GNSS observations can achieve high accuracy by the requirements set for observations. However, increasing the observation time and selecting the best location for observation is essential if relying on MAX-type corrections. The observations made in this study are very accurate, but the accuracy value could be more satisfactory in the evening. It is comparable to the IMAX correction type, except the network correction is sourced from the actual reference station. The results obtained are less satisfactory because they do not achieve what they should, which is consistency and traceability. The Nearest Base type of correction also obtained good results after VRS. Nevertheless, it depends entirely on the nearest reference station. As expected in this study, the CORS station in Pekan, Pahang, is the closest and gave good results in the morning and evening. Based on the results, the D-GNSS type correction is very suitable for submeter mapping and navigation applications. Thus, by contrasting its precision, the NRTK strategy's significance can be seen. This comparison can help MyRTKnet users choose the technique that will produce the best solution with the smallest coordinate error value.

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