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Benchmarking GPS Real Time Kinematic

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Abstract

RTK technique is widely becoming a popular method in many land surveying works. The advantage of having real time position at sufficient level of accuracy and precision has encourage surveyors to utilise the technique in engineering, topographical and cadastral surveying. This paper present early result from the tests designed to examine GPS RTK capability, accuracy and precision, in relation to factors such as percentages of canopy blocking, daily satellite configuration and base-rover distances. In the 1st test, investigation was done on the precision of the RTK systems by the effect of variation of distances between base and rover. At the 2nd test; a 24-hour observation was conducted to examine the coordinate variation during that period. Lastly during the 3rd test; observation under palm oil trees were done to obtain the relationship between .accuracy and or precision with the percentage of canopy coverages deduced by digital imaging

Key words: Real Time Kinematic, precision, benchmarking

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1. Introduction

Real Time Kinematic (RTK) method in GPS has attracted many professionals especially the land surveyors to utilise this technique in their daily operation. The advantage of having real time data facilitates many tasks such as setting out, topographical surveying and cadastral works.

In most cases the instrument manufacturers do present their instrument specification in their brochures. Yet, there are circumstances that instruments capabilities need to be verified and tested under prevailing condition of the relevance surveying. Among the capability that needs to be checked are time taken to resolve the ambiguity, duration to regain the signal after interruption, distance factor, degradation due to blockage or multipath effects.

This paper explains early results in RTK benchmarking namely on three factors;

a) Precision vs. Distances
b) 24 hour RTK observation at one point in order to see the variation, and
c) Degradation of coordinates due to palm oil canopy coverages.

2. Precision vs. Distances Test

2.1 Purpose, Site and Instrument

The purpose of this test is;

- To study the performance of RTK positioning with respect to the distances between the base station and the roving receiver.
- To compare this performance with the precision specification given by the instrument manufacturer.

The test was conducted in Invermay, along Dukes

Rd., Route 87 and Outram. This location is within 30 km. south of Dunedin city centre, New Zealand. All the observations were carried out in the month of April 1999.

The instruments used in this test were;

a) One set of Trimble SSE 4000 used as base station, Invermay; and,
b) One set of Trimble SSE 4000 with RTK facilities for the roving unit.

2.2 Field Methodology

Five points were established for the test. There were A1, Wool, School Road, North Taieri, and Outram. The points lie roughly on an East-West line spanning about 13 km. from the base to Outram. They were selected on the basis of good sky visibility and easy accessibility. This is the reason for different distances spacing between them; while realising almost equal spacing would be advantageous.

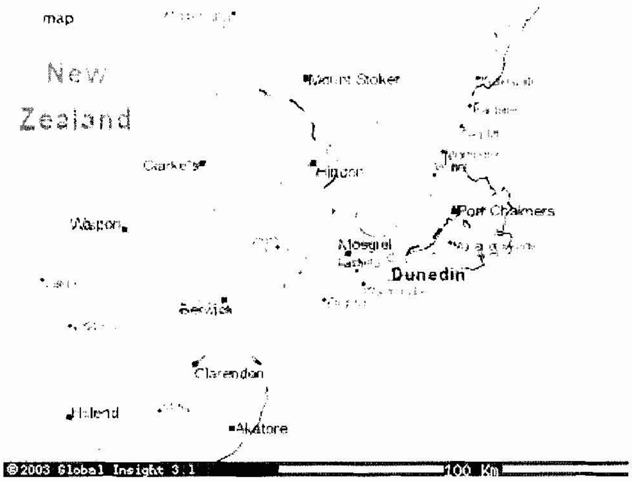

Figure 1: Location of the test site at Mosgiel, Dunedin of South Island, New Zealand.

The base station receiver was set up using the TDC1 data collector at the Point Inverdung; situated within the perimeter of Invermay Agricultural Research Station, Mosgiel, Dunedin (Figure 1). The main reason of choosing this point as a base station was because of it's high elevation (altitude 99.51 m) and clear visibility to the other lower elevation observation points with exception to Point A1 which is located 100 metres from the base station and has approximately the same elevation.

RTK observations were done on the test points starting from Point A1. At least five single observations were attempted at each station. The antenna was removed and repositioned on the point after each observation, to trigger the receiver to reinitialise before any new measurement commences.

The sequence of observation was then carried out at the next adjacent point. The points were observed in the following sequence, A1→Wool→ School Road→ North Taieri→ Outram.

On the first day, at least 5 sets of observation per station were carried out starting from A1 forwards to Outram; and then another 5 sets backward. As safety measure, extra one or two measurement per station was observed. The same operation was followed on the second day of the test. All together there were about 20 sets of raw data for every point were collected.

The observations were smooth when the optimum number of satellites was available. As usual when the number of satellites falls below 5, the observations were put on hold and restarted when signal from more than 5 satellites were regained.

2.3 Office Procedures

The main purpose of the computation is to perform these tasks:

a) determination of the standard error of the Northing, Easting and Height component (see Table 1)
b) determination of the root mean square (RMS) of horizontal and vertical component; and,
c) carrying out statistical tests of the horizontal and the vertical precision.

Points	Distance From base (km)	Standard Error (mm)		
		N	E	H
A1	0.1	8	6	10
Wool	2.7	7	8	13
Sch. Rd	6.5	11	7	15
N.Taieri	9.2	14	9	21
Outram	2.9	18	12	32

Table 1: Standard Error for N, E and H

All the raw RTK data were downloaded into SDRmap software for processing. Coordinates produced were then transferred into Excel for further analysis.

The horizontal and vertical precision was computed in the following steps:

- the mean of the Northing, Easting and Height for every point.

- the difference of each reading from the mean. (dN, dE and dH). Eg.,

$$dN_i = N_i - \overline{N};$$

- the squares of horizontal difference of the sample;

$$dhz^2 = dN^2 + dE^2$$

- the sum of squares of the vertical difference of the sample;

$$\sum dV^2 = \sum dH^2 = \sum (dH - \overline{H})^2$$

- the RMS of the horizontal component ; rh =sqrt ($\Sigma dhz^2/n$), where n is the number of observation.

- the RMS of the vertical component ; rv =sqrt ($\Sigma dV^2/n$)

- the standard error of the horizontal and vertical component; Sh and Sv

The RMS values have been used to estimate the precision of the horizontal component and the vertical component. These are shown in Table 2 and Table 3 respectively.

Points	Instrument Precision (mm) σ_0	Sample RTK precision (mm)
A1	10	10
Wools	11	10
School Rd.	16	13
North Taiery	21	16
Outram	28	21

Table 2: Horizontal Precision

	Instrument Precision (mm) $\sigma 0$	Sample precision (mm)
A1	20	10
Wools	20	13
School Rd.	21	15
North Taieri	22	21
Outram	24	31

Table 3: Vertical Precision

It was mentioned in the instrument specification, that the horizontal and vertical precision are 1cm + 2ppm, and 2cm + 1ppm respectively. A statistical test of the horizontal and vertical precision was carried out to agree with the precision given by the manufacturer. This is shown in Table 4 and Table 5. The statistical test should be able to verify the manufacturer's claim, based on the results of the standard error of the horizontal and vertical of the observed coordinates.

	D.o.Fre	**Test Statisti**	**90%**	**95%**	**99%**
1) A1	17	4.3	24.8 Accept	27.6 Accept	33.4 Accept
2) Wool	18	7.6	26.0 Accept	28.9 Accept	34.8 Accept
3) Schl Rd.	18	9.2	26.0 Accept	28.9 Accept	34.8 Accept
4) N Taieri	21	19.1	29.6 Accept	32.7 Accept	38.9 Accept
5) Outram	17	28.4	24.8 *Reject*	27.6 Reject	36.2 Accept

Table 4: Statistical Testing for Horizontal Position

	D.o.Freedm	Test Statistic	90%	95%	99%
1) A1	17	4.3	24.8 Accept	27.6 Accept	33.4 Accept
2) Woo	18	7.6	26.0 Accept	28.9 Accept	34.8 Accept
3) Schl Rd.	18	9.2	26.0 Accept	28.9 Accept	34.8 Accept
4) N Taieri	21	19.1	29.6 Accept	32.7 Accept	38.9 Accept
5) Out ram	17	28.4	24.8 *Reject*	27.6 Reject	36.2 Accept

Table 5: Statistical testing for the Vertical Precision.

2.4 Analysis

Figures from Table 1 indicate that, in general, the greater the distances, the more the accuracy decreases. Similar to the previous tests; the vertical component seems to suffer the most, with the range of standard error from 10mm to 32mm. Since all points have good sky visibility and unobstructed path to the base, most likely the distances factor that plays the dominant role here.

Precision of the horizontal from the samples (Table 2) also indicates similar behaviour (i.e., precision deteriorated once the distance is longer); from 10mm to 21 mm.. The precision of the vertical as shown in Table 3 gives slightly worse figure; from 10mm to 21mm And the most affected point is Outram, obviously, the furthest point.

The Chi-Square statistical test (Table 4 and Table 5) strongly shows that the precision of instrument given by the manufacturer at confidence level of 90%, 95% and 99% are mostly valid for all distances (up to 13 km in this test). The hypothesis H0 : $\sigma^2 = \sigma_0^2$ is rejected for the vertical at 90% and 95% confidence level for Point Outram; which indicate that the precision of vertical in that distances is worse than the manufacturer's specification.

This test was not conducted for observation beyond 13 km. from the base. Nevertheless the above results shows that RTK surveying are good within 10 km range if precision of less than 30 mm is needed.

3. 24 Hours Test

3.1 Objective, Test Site, Instrument and Observation date:

The objective of this test is to determine the variation of coordinates for 24 hours RTK observation at a selected point.

The test was done on an open and unobstructed ground, near Sultan Ismail Mosque, UTM, Skudai, Johor in August 2002.

Two sets of Trimble 4800 receiver with Trimble Survey Controller were used.

3.2 Methodology

RTK observation was observed for 24 hour at a selected point. The instrument was set to record data continuously at the rate of one minute for the first thirty minutes of the hour. The remaining thirty minutes were utilised for activities such as changing battery, downloading data and checking the equipment.

3.3 Results

The Standard Error of Northing, Easting and Height for all observation (about 720 readings) are tabulated in Table 6.

	N	E	Height
Stdev (mm)	14	37	8
Mean (m)	171854.591	626900.991	34.229
Max (m)	171854.608	626901.01	34.289
Min (m)	171854.574	626900.97	34.193
Range (mm)	34	40	96

Table 6: Result of 24 hour RTK observation at one point (720 readings)

Five readings per hour were then chosen to show variation in coordinates (actual observation minus the mean). It was found that the readings are mostly consistent within ± 20mm in all three components, as shown in Figure 2.

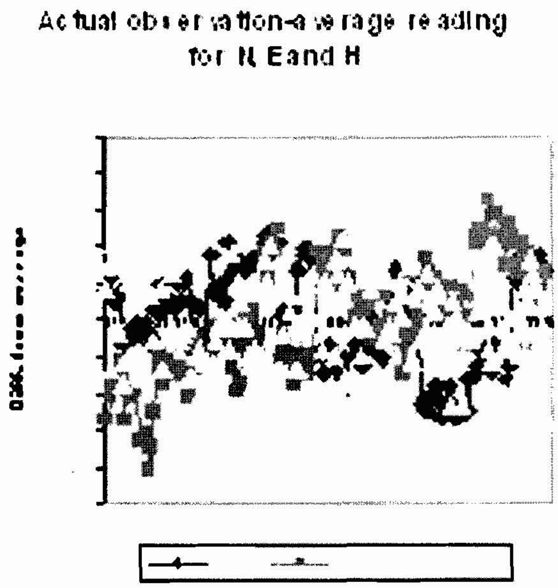

Figure 2: Actual observation minus average reading for Northing, Easting and Height

4. Palm Oil Trees Canopy Test

4.1 Objective, Instrument, Test Site and Observation Date

The purpose of this test is to obtain a relationship between canopy coverages and precision of the measurement.Two sets of Trimble 4800 receiver with Trimble Survey Controller were used. The test was done near Sport Complex, UTM, Skudai, Johor, Malaysia in July 2002.

4.2 Methodology

a) Several points were selected along roughly a straight line. The first point is situated on an open and unobstructed area. The line was designed in such a way that it approaches a palm oil plantation nearby with the assumption that the percentage of canopy coverage is increased as the selected points are closer to the trees or inside the trees ground area.

b) RTK observation was then carried out on every point. About 25 observations are recorded per point, along with the S/N ratio and the time taken to complete these 25 observation (a set of observations). Once completed the roving receiver was then proceed to the next point where similar routine was undertaken.

c) Apart from RTK data, digital images of the trees canopy was taken using Kodak Digital Camera, equipped with tiger eye lenses (very wide angles) to ensure maximum coverage. See Figure 3 for a sample of the image.

Figure 3: Sample digital Image at Point KS3 of Palm Oil trees area near Sport Complex UTM

d) About 5 sets of observation per points (125 readings) were recorded. The data was downloaded into Trimble Geomatic office for processing.

4.3 Analyses

Once downloaded, the standard error of the coordinates at every point were calculated.
At the same time, digital image of the canopy are downloaded into the computer for the calculation of the percentage of canopy coverages using Matrox Inspector software The standard error of the coordinates and the percentage of canopy coverages are shown on Table 7.

Point and % of cover	Std error Northing (mm)	Std error Easting (mm)	Std Error Heighting (mm)
KS1(unobstructed) 0%	7	8	59
KS2 (15%)	11	19	75
KS3(70%)	183	704	695
KS4 (80%)	No data recorded	No data recorded	No data recorded

Table 7: Standard Error for Northing,Easting and

heighting under different % of canopy coverages of palm oil trees.

It was clearly shown from the results that the canopy plays important role in degradation of the precision of the position produced by RTK. Not only it worsens the coordinates, the time taken to complete the observation was also longer once the canopy percentage is higher. At the deepest end, RTK observation was not feasible at all, especially when a canopy percentage is higher than 60%.

5. Conclusion

In order to optimise RTK, some benchmarking test have to be established to ensure that the users really have a good understanding of the instruments capability in relation to their works.

Some of the tests were not conducted by the manufacturer due to limitation to assimilate the actual situation faced by the surveyors on the ground (e.g., different terrain, different rule, and different obstruction set up). This paper has present early results from three of the tests undertaken. Among the findings are:

a) Precision of RTK is acceptable within 10km from the base. The precision deteriorated once the distances is greater than 10km.

b) In near Equator area like Malaysia, RTK readings remain consistent throughout 24 hours observation. This is mainly due to the fact that most of the time, the receiver managed to get the signal from more than 5 satellites. In addition, varied satellite geometry does not effect the reading significantly.

c) Observation under trees canopy seems to produce less favourable results especially when the canopy is more than 60% of total coverages.

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