Cadastre Surveys with Real Time Kinematic GPS (RTK) as a Basis for Future Survey Regulations

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Key words: RTK GPS, Future Regulation, Cadastral measurements.

SUMMARY

During the last decade, many countries all over the world have adopted the FIG vision "Digital Cadastre 2014" project. Countries are preparing to transition from the analogical cadastre to the future Legal Digital Cadastre system. This transition will include upgrading the surveyor's regulations, which were based on conventional survey measurement instruments on the traditional cadastral system.

In order to build a high accuracy digital cadastre database, it is obvious that the national control network will be based on the permanent GPS station control network of the country. Additionally, achieving homogeneity in all the cadastral projects, every cadastral project must be based on GPS measurements. Hence, GPS instruments would be the main instruments for surveying.

Since the RTK GPS instrument is considered a relatively new instrument, which began serving surveyors since the middle of the last decade, several cadastral regulations have not included a procedure for RTK GPS measurement.

This paper proposes a development of an accepted procedure for reliable cadastral Surveys with Real Time GPS towards the future Survey Regulations. Such a procedure was based on experiment results of measuring 35 control points, which were measured by means of static GPS high accuracy measurements and lead to accuracy level of: 4 to 6 mm in position as well as 7 to 14 mm in Orthometric heights. The experiment area extends on about 52,000 metric dunam.

The investigation will provide a basis for an improved version of the regulations and will make a contribution to the development and updating of the digital cadastre.

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1. INTRODUCTION

Two principal objectives have to be achieved in order for GPS RTK surveys to be accepted and incorporated in official standards for cadastral applications, namely, the "High Neighboring Accuracy" and "High Positional Accuracy" relative to the geodetic network control.
These considerations have been described by Hansen (1998). In many countries, in which legal cadastre exists; the original land settlement surveys have undergone a transition from chain surveys to total station surveys. The location of the original staked out parcel boundary points is considered conclusive and inviolable.

Parallel to the transitions in cadastral surveys technology, transitions took place in geodetic control network surveys. From classical triangulation densified by traverses, through a combined triangulation-trilateration, onto purely GPS networks, which often include permanently active stations to facilitate connection, and sometime overlap the traditionally surveyed control.

The trend is to rely on licensed surveyors to perform survey operations professionally, and limit regulation/legislation to standards only.

2. GPS APPLIED IN CADASTRAL SURVEYS

One of the Survey's Regulations main tasks is to direct surveyors keeping on the cadastral measurements basics. The main cadastral measurements basics are (Williamson, 1997), (Londe, 2002):

- Homogeneity in measurements accuracy.
- Sufficient measurements accuracy that meets the regulation criteria for the cadastral accuracy.
- Reliable measurements.
-

Another cadastral measurement basic which looks common is the ability of checking the computing or process results.

Israeli Surveyor's Regulations (ISR) permit working with GPS technology in every post processing technique, since they are able to check the reliability of vector solution as well as meeting all the measurements basics.

However, despite that the RTKGPS fulfills the most of the cadastral measurement basics; it works by On-The- Fly ambiguity resolution technique that does not provide instruments for post-processing (Langley, 1998), (Abidin, 1994) and (Curry et al., 1993). So, it could not be able to check the reliability of the vector solution. Hence many survey agencies still have a reservation for the RTK GPS solution.

In Israel, the prevailing Survey Regulations (1998) recognize GPS as one of the methods applicable in cadastral surveys for the measurement of boundary points and state that the differences between two measured distances L along the boundary shall not exceed 0.03 meters. This criterion might not be suitable for checking the GPS observation methods accuracy level (Boey, 1996).
The three top order of geodetic control can be surveyed only by GPS methods and the minimum relative accuracy of neighboring points is 1:1,000,000 for the first order, 1:250,000 for the second order and 1:150,000 for the third order.
GPS surveys supply coordinates of the points surveyed related to a specified datum. The future Surveyed Standards will have to include criteria for:

- The estimated accuracy of the surveyed points.
- The estimated accuracy of the transformation from the satellite datum (such as WGS'84) to the National Datum.

3. EXPERIMENTATION NECESSARY TO FORMULATE DRAFT OF REGULATIONS

3.1 High Accuracy Local Control Network

A basic condition for modern legal cadastre is a high quality local control network (Stienberg and Even-Tzur, 2004). Accordingly, in order to find suitable criteria for making decisions regarding the RTK GPS observables precision level and reliability in the future survey regulations, it is necessary to establish a precise and inflexible local control network.

For this purpose thirty five points has been established inside 52 km square area which is bounded by polygon consists of five licensed control points. The 52 km square area is a suitable area for RTK GPS radio link and accuracy limitations.

The 35 point positions were planned is such way that permits about 400 to 500 meters distance between every two points.

Four new Topcon GPS receivers have cooperated in order to measure the network. One of the control points, which name is 504U is also a vertical control point with first order degree. The network has been built in three stages: The first stage contained linking every point in the net to the five control points (see figure 1).

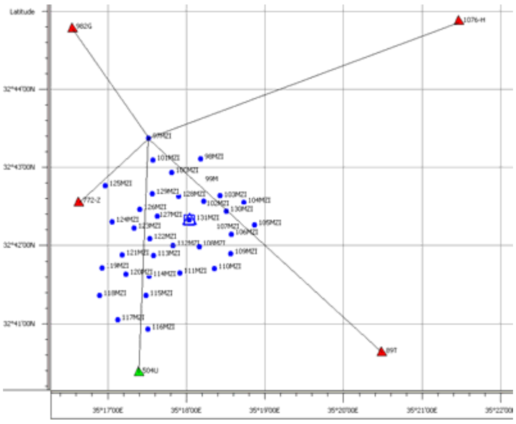

Figure 1: The 35 control points control network and an example for linking every point to the national control grids.

The second stage was done in order to establish high accuracy between all the 35 points by measuring vectors between them (see figure 2).

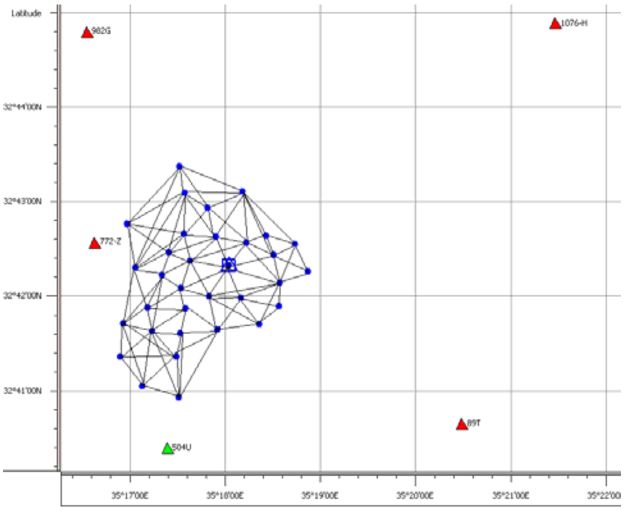

Figure 2: One loop vectors description of the first measurements part
The middle point in the little square was set up as a fix point for the least square computation of the net.

Finally, during the third stage, three different vertical control points (Benchmarks - BM), in the first degree, have been linked to the network by means of static GPS observations (see figure 3).

The Static GPS vectors were measured in 5 seconds interval for 15 to 40 minutes according to the DOP values. However, vectors between control points and vertical control points were measured for several hours up to 5 to 7 hours in different days, according to the four GPS receiver constellation. Finally, there were 651 vectors that were solved in 100% Fix solution. After minimum constraint, least square adjustment (one point was set as a fix point.), the covariance matrix had exaggerated values because of the dependent measurements of the four

GPS receivers. So, an algorithm developed by Ovstedal, 2000, for estimated the correct covariance matrix was used.
The network point's position accuracies in the *plane* were between *4 to 6 mm* and in the *vertical d*imension were between *7 to 14 mm.*

3.2 RTK GPS Measurements

Two RTK companions' measurements were done in order to provide suitable answers for:

- How reliable are the RTK GPS measurements?
- What are the accuracy levels that could be achieved by RTK GPS, in order to define obvious instruction, for surveyors, to measure and link national control points and boundary points?
- What are the limitations of the RTK GPS methods in linking the measurements to the national control network either by:

Given 7-parameter transformation (Similarity transformation).

Localization process of the RTK software which is based on measuring at least 3 control points with known and published coordinate values in the national control network.

Three experiments were done:

- In the first experiment, all the 35 network points were measured by RTK when the base receiver was placed on one of the 35 points. This point located on a roof of a building in the centre of the network, in a low place. The receiver environment is not well open, it was inside an urban place that we had expected to a cycle slip and multi-path problems. The average vector length was about 1.7 km and the maximum was about 3.5 km. Cellular communication link was uses because of the low place of the base receiver. Base point 1 called 131MZI. Every point was measured in two sessions. The difference in time between every two sessions was at least 3 hours, in order to have different constellation of the satellites, but with the same base receiver. In every session, the points were measured between three to 8 epoch measurements, as fast as it could be done. During communication difficulties, at least 6 epochs have been measured.
- In the second experiment, all the 35 points were measured exactly in the same conditions of the first experiment, but the base receiver located on a high point which is not one of the 35 points. The base point was a Benchmark which was used for checking the heights accuracy.

The base point is clearly open to the sky with an open environment that we had not except any cycle slips or multi-path problems. The average vector length was about 3.5 km. The maximum vector length was about 5.5 km. Base point 2 called 505U.

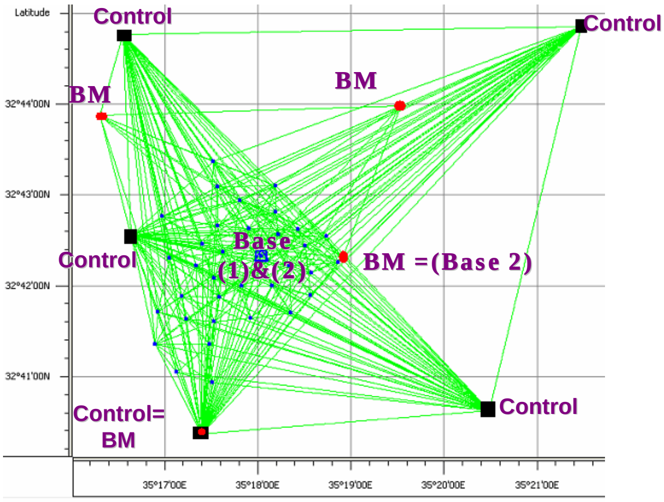

Figure 3: The whole measured vector's picture including the description of the two RTK bases location points. The BM indicates a licensed vertical Control network with high grid 1, and the control is a control point with licensed coordinates in high order level (3).

– The third experiment concentrated in evaluating the RTK localization ability. The base was set on the central point of the network. All the control points (5 controls) were measured in two sessions with minimum 8 consequence epochs (see figure 3).

During all RTK measurements, the FIX solution in 95% was set up under 0.03 m in the position and under the 0.05 in the vertical. The measurement staff was asked to save all the possible data during the RTK measurements by means of the RAW file.

4. RESULTS & DISCUSSION

4.1 Unstable Condition in the RTK GPS Solution

All the RTK results have been compared with the static control network coordinates.
The first aspect that was checked is the reliability of the RTK results. Reliable solution is defined by showing correct accuracies in the plane and the vertical dimension by the RTK results. It means that if all the accuracies that have been shown by the RTK GPS software are suitable with the correct accuracy there is no reason for suspect the RTK reliability measurements ability.

Unfortunately, in such situations there was mismatching between the shown accuracies that were saved in the RAW file and between the correct accuracies derived from the static solution. In table 1, DN (delta northing), DE (delta easting), DH (delta height) and DL (delta positioning) are the differences between the north, east , height and the position derived from the static GPS measurements and between those which were derived from the RTK solution. It could be noticed that in the second row (point name 128MZIb) the difference was 6.7 cm whereas the computed accuracy is 9 mm in the position.

Table 1: An example for unstable situation in the RTK solution.

Unstable situation Example

Name	DN	DE	DH	DL	HRMS	VRMS	HDOP	VDOP	Time	FIX/Float	Difference	
128MZIa	-0.015	-0.021	0.011	0.025	0.007	0.130	0.698	1.241	12:47:11	Fix		
128MZIb	**-0.006**	**-0.066**	**0.011**	**0.067**	**0.009**	**0.016**	**0.699**	**1.241**	**12:47:23**	**Fix**	0:00:12	
128MZIc	-0.015	0.007	0.011	0.016	0.009	0.014	0.892	1.244	12:48:51	Fix	**0:01:28**	Ops
128MZId	-0.006	-0.002	0.011	0.006	0.011	0.015	0.870	1.243	12:48:59	Fix	0:00:08	
128MZIe	-0.003	-0.005	0.011	0.005	0.012	0.017	0.870	1.243	12:49:05	Fix	0:00:06	
								DT=	0:01:54	5	One every 23 sec	
		Av	0.011	0.024	0.010	0.038	0.806	1.242				
		STDR	0.000	0.025	0.002	0.051						
		Max	0.110	0.067								
		Hor Static with no max										
		m		0.010								
		Av		0.013								
		Av+2m		0.033	**<0.067**	Error						
		Av-2*m		-0.007								

At the bottom of the table we can see a statistical hypothesis test that shows a gross error in the RTK solution. During the experimentations there was more than one unstable condition.

Hence, the first conclusion was that there is a problematic condition during RTK GPS measurements process called *unstable condition*. Unstable condition is defined as a condition in which the computed accuracy levels by the RTK software is incorrect.

Unstable condition could be noticed during RTK working, by big fluctuation coordinate values on the screen of the RTK palm computer, even when the RTK rover antenna pole is stable.
Unstable condition may be caused by a problem of cycle slip or multi-path in such way that the validation algorithm failed to catch it because of very small delay period (Rizos, 2001).

4.2 Three Methods for Dealing with an Unstable Condition

Unstable condition as we have seen in chapter (4.1) is a measurement gross error. Hence, firstly we can easily recognize it by one of the three principles:

- Measuring the same points in more that three epochs in every session.
- Measuring in two sessions. Every session must be measured in minimum 1 hour difference from the other.
- Independent measurements to the same point.
- Since we are deal with cadastral measurements, it is better to integrate a solution from the three principles above. Hence, three methods could be proposed:
- **R**TK **O**ne **B**ase – **ROB**. Two sessions with minimum 60 minutes difference interval. Every session include at least four epochs or the maximum epochs that could be measured in 30 sec, the maximum of them.

- **R**TK **M**ulti **B**ases – **RMB**. Every point must be measured from two bases independently. The difference interval between the two sessions must be at least 60 minutes.
- **R**TK **V**ector **N**et – **RVN**. When the RTK vector is a part of a whole net. However, every point in the net must be measured in independent session.

In all the three methods one licensed control point must be measured as a *checker point* in order to check the antenna heights and the transformations quality process from the GPS datum to the national control grid datum (Hansen, 1998).

4.2.1 RTK One Base – ROB

An algorithm has been developed (see figure 4 in the appendix), using the RTK RAW file, in order to recognize and set of unstable condition:

- Record all the parameters of the RTK measurements in RAW file and submit for the survey agency.
- Measure every point at least 4 epochs in two sessions in different interval time of 60 minutes.
- Write the name of the points in sequence such like: 45u-1, 45u-2 45u-3, in order to read the measurements automatically.
- For every vector that was measured in n epochs (in one session) calculate the average of E (and N).
- For every session calculate the variance of the E (or N) from the average value (VE, VN).
- Highlight the maximum variance value as a suspected measurement - $E^{suspected}$.
- Calculate the average of the coordinates without the suspected measurement - $\overline{E}$.
- Find out the calculated tolerance by the RTK software (in the RAW file) in 95% confident level around the $\overline{E}$.
- If the suspected measurement is in the declared tolerance then it is not a unstable condition, else it is an unstable condition, set it of then return to step (4). (See set of formulas 1)

$$
\begin{aligned}
&VE_i = E_i - \frac{\sum_{j=1}^{n} E_j}{n} \\
&E^{suspicious} \Rightarrow Max(VE_i|_{i=1}^{n}) \\
&\overline{E} = \frac{\sum_{i}^{n-1} E_i}{n-1} \\
&if \;\; (E^{suspicious} - \overline{E}) > \overline{E} + 2 \times \sqrt{(Hrms_i^2 + Hconst^2)} \\
(1) \quad &Or \\
&if \;\; (E^{suspicious} - \overline{E}) < \overline{E} + 2 \times \sqrt{(Hrms_i^2 + Hconst^2)} \\
&Then \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \; E^{suspicious} \text{ is an Unstable Measurement} \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \; \text{Ommit this measurement and check the others} \\
&Else \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \; E^{suspicious} \text{ is a Stable Measurement, Stop checking} \\
&\text{The Hconst is related to the centralization process of the RTK pole}
\end{aligned}
$$

4.2.2 RMB & the RVN

The second two methods are much easier because we have extra independent measurements. According to RMB we can compare the results of the number independent bases according to formula (2):

$$
\begin{aligned}
&\overline{E} = \frac{\sum_{j=1}^{n} E_j}{n} \\
&\overline{N} = \frac{\sum_{j=1}^{n} N_j}{n} \\
&\Delta l_i = \sqrt{\left(E_i - \overline{E}\right)^2 + \left(N_i - \overline{N}\right)^2} \\
(2) \quad &\Delta l_{suspected} = Max(\Delta l_i|_{i=1}^{n}) \\
&\text{Omitting the suspected measurement:} \\
&Then \\
&If \;\; \Delta l_{suspected} > 2 \cdot \sqrt{(Hrms_{suspected}^2 + Hconst^2)} \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \; \Delta l_{suspected} \text{ is an Unstable Measurement} \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \; \text{Omit this measurement and check the others} \\
&Else \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \; \Delta l_{suspected} \text{ is a Stable Measurement, Stop checking}
\end{aligned}
$$

While, if there are just two independent bases we shall use formula set (3):

$$
\begin{aligned}
&\Delta l = \sqrt{\left(E_1 - E_2\right)^2 + \left(N_1 - N_2\right)^2} \\
&Then \\
(3) \quad &If \;\; \Delta l > \sqrt{(Hrms_1^2 + Hrms_2^2 + Hconst^2)} \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \;\; It\ is\ an\ Unstable\ Measurement \\
&Else \\
&\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow \;\; It\ is\ a\ Stable\ Measurement,\ Stop\ checking
\end{aligned}
$$

The RVN method is exactly like any other nets that are measured by post processing static vectors. In our experiment, we added a static vector between the two bases then we can use another set of formulas (4):

$$
\begin{aligned}
&V = Ax - L \\
(4) \quad &V = \begin{bmatrix} v_N^1 \\ v_E^1 \\ v_U^1 \\ \vdots \\ v_N^n \\ v_E^n \\ v_U^n \end{bmatrix} \\
&if \;\; \sqrt{[(v_N^1) + (v_E^1)]^2} > 2 \cdot \sqrt{(Hrms^2 + Hconst^2)} \;\; \rightarrow \;\; Fatal\ Error\ in\ Position \\
&if \;\; v_U^n > 2 \cdot Vrms \rightarrow \;\; Fatal\ Error\ in\ Height
\end{aligned}
$$

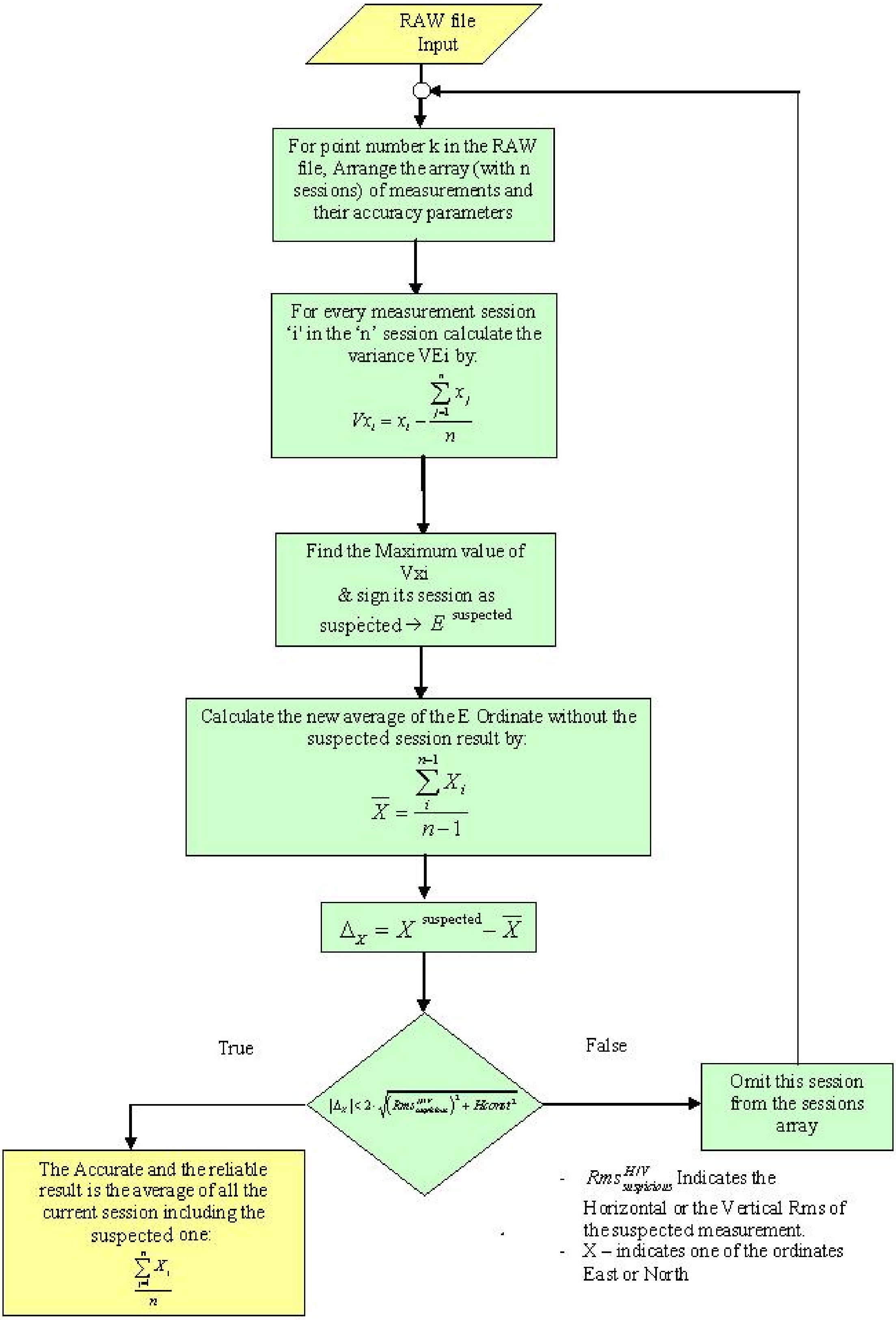

Figure 4: An algorithm Dealing with unstable condition in ROB method

4.3 Results

4.3.1 Measuring Accuracy

In Table 2 there are summary results for all three methodologies before activating the three method algorithms. All the coordinates were computed by free net adjustment computation, when the centre of the net was set on point 131MZI. All the RTK measurements where done in geographic coordinates in the same system of the static network. Geographic coordinates were used, in order to neutralize the human psychological factor of the measurements staff.

Table 2: Summary results for the three methods. The fist and the second block describe the results for the ROB method for every experiment. The third block describes the results for the RMB method. The fourth block describes the results of the RVN method when adding a static vector between the two bases

	DH	Segma DH	Max |DH|	DL	Segma DL	Max DL	num	Unstable	Not Measured
505U 1-2	**-0.002**	0.038	0.097	0.013	0.008	0.031	28	0	7
505U 1-static	-0.011	0.021	0.050	0.012	0.007	0.028	30	0	5
505U 2-static	-0.009	0.024	0.073	0.011	0.006	0.026	28	0	7
505U 1+2-static	-0.010	**0.014**	0.037	**0.009**	**0.006**	**0.024**	28	0	7
131MZI 1-2	0.010	0.030	0.068	0.021	0.013	0.063	24	4	7
131MZI 1-static	-0.014	0.029	0.077	0.025	0.010	0.044	31	3	1
131MZI 2-static	-0.023	0.030	0.080	0.021	0.012	0.048	24	4	7
131MZI 1+2-static	-0.018	0.027	0.067	0.020	0.010	0.039	24	4	7
505U-1& 131MZI-1	**0.003**	0.036	0.083	0.028	0.012	0.057	26	3	
505U-1& 131MZI-2	0.021	0.036	0.082	0.023	0.011	0.053	20	4	
505U-2& 131MZI-1	0.005	0.036	0.083	0.028	0.013	0.048	25	3	
505U-2& 131MZI-2	0.017	0.031	0.066	0.023	0.014	0.055	19	4	
RTK NET									
505U-1+131MZI-1& Static	-0.013	0.018	**0.045**	0.014	0.007	0.029	27	3	
505U-1+131MZI-2& Static	-0.019	0.019	0.047	0.013	0.006	0.021	20	4	
505U-2+131MZI-2& Static	-0.020	0.022	0.077	0.012	0.006	**0.020**	19	4	
505U-1+2+131MZI-1+2& Static	-0.016	**0.016**	0.051	**0.010**	**0.005**	0.021	19	4	

Every row in table 2 has a title; for example row number 6 title "131MZI 1-2" describes the differences between values of session 1 measurements and session 2.
In some points the measurements staff could not measured because of physical reasons.
It is very obvious that when the base was located on an open sky and open environment point we have no unstable conditions, since point name 505U as we have mentioned it is an open sky, high placed and with no objects beside and a radio communication was used instead of cellular.

Before using the three proposed algorithm the declared accuracy available by the RTK in 95% confident level for every experimentation, is shown in Table 3 according to the student statistical hypothesis test.

Table 3: Declared accuracy level of the RTK in every experimentation according to Student statistical test

Horizontal				
STDR/sqrt(n)	Student t	Do	Max DL	
0.001555	1.701	0.011	0.031	**505U 1-2**
0.001361	1.697	0.009	0.028	**505U 1-static**
0.001135	1.701	0.009	0.026	**505U 2-static**
0.001066	1.701	0.008	**0.024**	**505U 1+2-static**
0.002710	1.711	0.016	0.063	**131MZI 1-2**
0.001790	1.695	0.022	0.044	**131MZI 1-static**
0.002424	1.711	0.016	0.048	**131MZI 2-static**
0.002004	1.711	0.016	0.039	**131MZI 1+2-static**
0.002293	1.706	0.024	0.057	**505U-1& 131MZI-1**
0.002556	1.725	0.019	0.053	**505U-1& 131MZI-2**
0.002549	1.708	0.024	0.048	**505U-2& 131MZI-1**
0.003184	1.729	0.017	0.055	**505U-2& 131MZI-2**
Net Adjustment				
0.001346	1.703	0.012	0.029	**505U-1+131MZI-1& Static**
0.001410	1.725	0.010	0.021	**505U-1+131MZI-2& Static**
0.001450	1.729	0.009	0.020	**505U-2+131MZI-2& Static**
0.001238	1.729	0.008	0.021	**505U-1+2+131MZI-1+2& Static**

All the methods proposed by the paper manage to find out the same unstable condition points as shown in table (2) in the right column.

When setting of all the unstable condition points that all of them were in the first experimentations when the base was located on 131MZI the declared accuracy level of its results have been improved (see table 4).

Table 4: The declared accuracy results of the RTK first experimentation when setting of the unstable conditions

		אחרי קיזוז שגיאות גסות
Do	Max DL	
0.013	0.027	**131MZI 1-2**
0.018	0.025	**131MZI 1-static**
0.014	0.029	**131MZI 2-static**
0.014	0.023	**131MZI 1+2-static**

As it could be seen, the accuracy levels are improved, since there is no gross error in the measurements. Furthermore, survey agencies could rely on the declared accuracy of the RTK GPS manufactories.

4.3.2 The importance of the RTK base receiver location

In the first experimentation, the accuracy results were lower than the second one. Additionally, unstable conditions were recognized. The only two differences between the two experimentations are the RTK base receiver place and the communication style. However, according to the staff measurements experience, unstable conditions have been recognized during using cellular communication as well. Hence, the main conclusion of the experimentations is that there is a relation between the unstable conditions occurring and between the RTK base receiver locations. It is preferable to stand in high, open sky and empty environment (with no special big objects).

4.3.3 The quality of the transformation process based on the RTK GPS measurements

According to the third experiment, the five control points were measured by the RTK using the algorithm ROB method. In order to skip the national control network inaccuracies and inhomogeneity, we solve a free net adjustment for all the static vectors between all the five control points. Every static vector was measured in more than 32 hours in 5 sec interval, so we could be able to link the control network with the Permanent GPS Stations (PGS) array of Israel, in order to recalculate new coordinates values with maximum accuracy. Then, 7-parameter transformations by least square adjustment were calculated based on the RTK ROB method measurements and the new control points coordinates, the distances between the RTK base receiver and all the five controls are shown in Table (5).

Table 5: distances between the RTK base receiver and all the five controls. The third right column indicates the accuracy declared by the Topcon GPS manufacturer

Control Name	L (Distance) [m]	Manufacturer STDR in 68% [mm]
1076-H	7111.8	21
772-Z	2228.6	13
89T	4950.9	17
982G	5085.4	18
504U	3751.2	16

The transformation residual (the variance matrix) is shown in Table (6).

Table 6: transformation residuals parameters based on the ROB RTK measurements.

Control Name	VN [m]	VE [m]	VH [m] (ellipsoidal)
1076-H	0.012	-0.006	-0.003
504U	-0.002	-0.004	0.009
772-Z	-0.014	0.019	0.010
89T	0.000	0.011	-0.019
982G	0.004	-0.021	-0.003

All the accuracy levels look satisfactory in the cadastral system view. However, by means of the suggested algorithms of the ROB, 8 unstable conditions were removed.
The RTK software also could give the same results but unfortunately without the ROB algorithm. Hence unstable conditions must be removed (if existed) before calculating the transformation parameters.

In relative to the heights, according to the Israeli survey regulations, a local undulation model must be used for linking a measurement to the vertical control grid. So, external software must be used for this purpose. Such software could be the CTT software (www.geopioneers.com).

6. CONCLUSION

Using one of the three methods proposed in the paper, it is reliable and sufficiently precise to use the RTK GPS for cadastral measurements projects. However, since in the era of the future Legal Digital Cadastre, a boundary point plays a juridical role in court, it is recommended to use either the RVN or the RMB with an assistance of checkers licensed control points n order to validate the antenna heights as well as the transformation quality.

Furthermore, it was shown that the RTK is able to provide precise measurements results under the 10 km distance between the base and the rover. Additionally the only reservation after we solve the reliability problem in the RTK measurements is the unforced stationing of its rover antenna. Therefore, in Israel, for example we are still able to integrate the RTK like the total station uses. It means that we can link a new control point to the horizontal control network in low order accuracy such like 6 to 7, without forced stationing.

Finally, with the technology developments, when more than 10 km vectors could be measured by RTK in the same accuracy levels, we consider the RTK as the most common instrument for cadastral measurements uses.

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Jad Jarroush received his B.Sc. in Geodetic Engineering in 2000 with honors from the Technion – Israel Institute of Technology. In 2002 he received the B.Sc. in Civil Engineering with honors too and the M.Sc. certificate in Geodetic Engineering as well. All are at the Technion. He is currently a graduated student at the faculty of Civil and Environmental Engineering, division of Transportation and Geo-Information Engineering as a Candidate for Ph.D. degree in Mapping and Geo-Information Engineering. His main fields of interest include: Cadastre, 3D Cadastre, Dynamic Cadastre, GPS RTK and 3D infrastructure presentation models.

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Marwan Zeibak received his B.Sc. in Geodetic Engineering in 1979 from the Technion – Israel Institute of Technology Israel. In 1981 he received the licensed surveyor from the Survey of Israel (SOI).
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