Determination of Target Map Coordinates using Differential Global Positioning System DGPS & Total Station Device

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Abstract: ***The determination of a target coordinates in 3-D is an important applications in remote sensing, terrestrial surveying, and civilian / military. In this paper, the DGPS, Real Time Kinematics RTK mode) and Total Station TS system have been used to estimate a target map coordinates (UTM projection, Datum WGS84), in real 3-D world. for this purpose, the field of work was prepare that the RTK of DGPS measurements consist of one base point with OPUS correction and 8 rover points. The measurements were done using the Topcon HiPer II system with total root mean square error lees then 10 mm, and Leica TPS1500+ system. Each rover point is use as TS station to shot the TS reflector in three arbitrary points. From the DGPS / RTK mode and TS measurements, the coordinates of the reflector in three positions can be determine in high accuracy lees than 10 cm. Also, the least mean square algorithms was used to evaluate the coordinates of reflector in three points from 8 TS shoots. The field work was done in the Baghdad university camp that avoiding the buildings and tress to reduce the multi path DGPS error. All criteria and results were evaluated by special written subroutine using the Matlab environment. This methods can be used successfully to find the coordinate of any faraway target or movie target.***

Keywords: Differential Global Positioning System, Total Station, & Target Coordinates.

1. Introduction

In many civilian and military remote sensing application, the calculation of a target coordinates in 3-D real world is important due to different cusses and purposes. The DGPS devices is almost use to improve the accuracy of positioning information with a limitation in civilian areas, **[1]**. In the previous image-based targeting system, the implementations have used the stereo photogrammetric techniques to determine the 3-D relative position of image features to the camera location. These methods require intensive data-processing to resolve for position and rotation angle changes between the stereo images and also rely on known reference points from a database to establish the absolute location of target features.

In modern application like this project, the target real world coordinates system are calculated using the DGPS and TS systems to improve the positioning accuracy and direct remotely results for any point and although, for a move target. In this research, the real time kinematics DGPS mode was used to calculate the coordinates of 8 rover points that were used later to find the the position of unknown target coordinates values. For this purpose, the Topcon HiPer II DGPS device was used to calculate the UTM (E,N, & Elev.) of the rover points that used in the experiment. Also, the Leica TPS1500+ system and range finder were used to estimate the distance between the rover points and unknown target coordinate. The experiment was done in the near the remote sensing unit – college of science- Baghdad university from the period 3-29-2017 to 4-10-2017.

2. The DGPS Operation Modes

The differential global positioning system operate in two main modes, the first is static mode, and the second is real time kinematics. The RTK measurements require a GPS signal correction, which was emitted from the base station to GPS rover receivers. This information is normally sent by a radio signal, which restricts the range of operational performance to 1–3 km (depending on the land use/cove characteristics), **[2]**, figure 1 show a Schematic diagram of DGPS / RTK surveys.

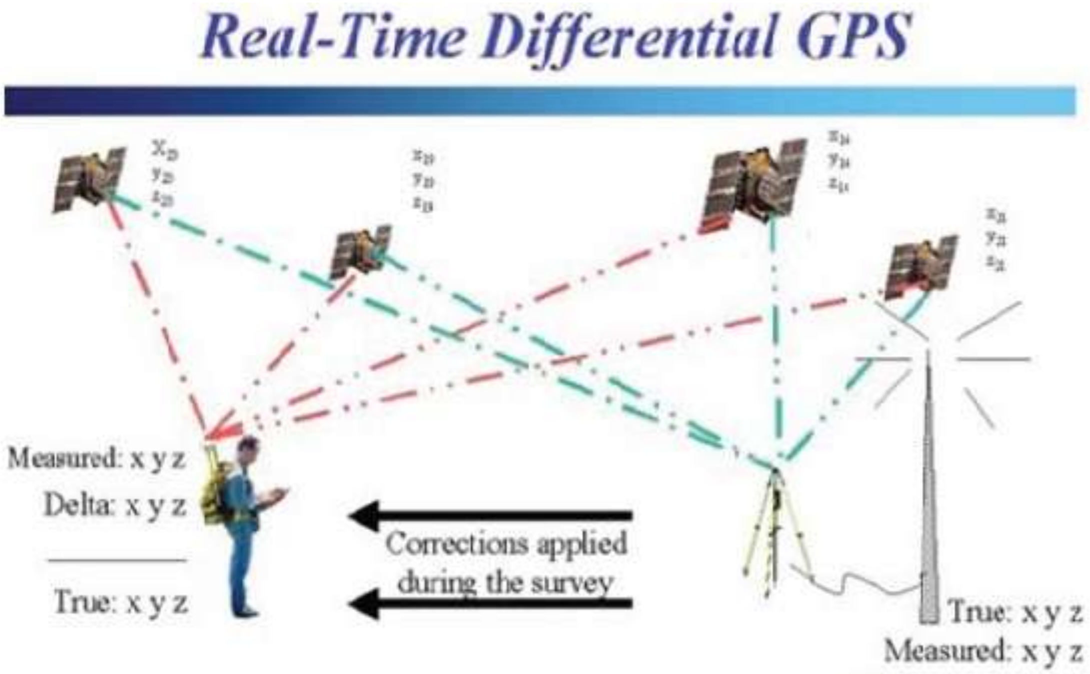

Figure 1: Schematic Diagram of DGPS / RTK Surveys, [2]

The accuracy of DGPS for one measurement is 0.5- 1.5 m, where this value can be improved using the RTK mode (with phase correction) to 0.01 m. The structure of Differential Global Positioning System can be summarize as following; In real, the DGPS use two or more GPS receiver-antenna devices to position an unknown GPS antenna or set of GPS antenna relative to a known antenna coordinates, **[3]**.

According to (**Morag, 2011**), that the theory of differential GPS, and DGPS is that any two receivers that are relatively close together will experience similar atmospheric errors. The DGPS surveys utilize GPS code phase measurements and are primarily based on the C/A code modulated on frequency L1 only. The corrected information can be applied to data from the roving receiver in real time in the field using radio signals or through post processing after data capture using special processing software. The problems of obtaining high accuracy real time positions in the field have led the surveying community to develop a DGPS-like real time method called Real Time Kinematics GPS, RTK GPS, **[3]**. During the RTK rover measurements, and for many time, the radio signal between Base station and rover was disconnected. This was due to the radio signals that distributed in surrounding area, to avoid this degradation, the radio band between the two receivers can be vary to a long wavelength to avoid the radio distortions.

3. Materials and Methods

The Topcon HiPer II GNSS Receivers

The HiPer II receiver is multi frequency GNSS (Global Navigation Satellite System) receiver, built as compact for multi surveying purpose. It receive and process the GNSS signal in both L1, and L2 frequencies for both GPS and CLONASS satellites navigation system. The reason of use these dual system is to improve the accuracy and reliability of the survey point and positions that produce by HiPer II system. The processor of system include advance multi-path mitigation. Also, the HiPer II receivers provide easy, fast, and reliable faculties, **[4].** Figure 2 show the system belong the remote sensing unit in the work filed.

Figure 2: The HiPer II receiver in the work field

The Total Station TPS1200+ System

The Surveying can be define as the technique and science of accurately determining three dimensional position of points, distances, and angles between them. The many surveying methods include (GPS, laser scanner, total station, etc.) are in use, **[5]**. In this paper, the Leica TPS1200+ instrument was used to determine the slope distance, horizontal distance and angles between two points using the laser beam option and the TS point coordinates, figure 3, show the TPS1200+ instrument. In using the TS device, the measurements dose not complete if the leveling of device not accurate, because the electronic of system is depend on the leveling case of system.

Figure 3: The TPS1200+ Instrument, (Leica TPS1200 series manual)

The Projection and Datum Systems

The projection system can be define as the projecting the real 3-D world into 2-D on the paper, the system that used in this work was Universal Transverse Mercator UTM with coordinates (E, N, Elev.) in meter unit. The zone number is 38 to north of equator, i. e. the center meridian of this hemisphere is (E, 500000 m, N, 0, and Elev. is from the sea level), **[6]**. The Datum system is the World Geodetic System 1984 WGS84 which is a wide use Datum system in many surveying and remote sensing application. So, all base and rover points can be locate on the satellite remotely images as will be shown.

4. The Research Methodology

The research methodology and the details of work can be summarize as following;

1) The first important job is to create the base station for the RTK DGPS measurements, this was done using single HiPer II receiver. The base coordinate was pickup through a duration of 3 hours in order to achieve high accuracy at 29-3-2017 near remote sensing unit / Baghdad university camp. After 36 hours the base coordinates value has been corrected using the OPUS Online Positioning User Service.
2) After few days, 8 rover points have been measured with high accuracy values, the base station, and rovers points characteristics were recorded in the data tables. Figure 4, show the base station and one rover point.

Figure 4: Base Station & Rover Point

3) In order to investigate the coordinates of real point in 3-D, three points were selected in surrounding area near the rovers point The selected point position was the position of the total station reflector, figure 5 show one of these three selected points. Also, for reliability of surveying and measurements, the base station and rover points were projected on a satellite imagery using the Goggle Earth facility. The satellite image spatial resolution is about 0.5 meter, figure 6 show this satellite image.

Figure 5: One of The Three Selected Points In The Real 3-D

Figure 5: The Satellite Image for Base Station & Rover Points

4) Each rover points will be use now as total station position to shoot the above three selected points to find the slope and horizontal distance using the LASER beam facility in the TPS1200+..

5. Results and Calculations

The Base station and Rover points coordinates and measurement details shown in the table 1. In order to leveling and unify the DGPS receiver and TPS1200+ with respect to tripod, the following measurements must be consider in calculations; such as; DGPS receiver highest from tripod= 32.25 cm, and TPS1200+ highest from tripod=24.0 cm

Table 1: The Survey By RTK DGPS For Both Base Station & Rovers Point

Station	Tripod ht. m	Antenna ht. m	E m	N m	Elev. m	Duration
Base 1	1.48	1.81	442323.804	3681911.023	33.860	3 hr.
Rover1	1.48	1.81	442316.424	3681940.669	33.849	1 min.
Rover2	1.48	1.81	442317.631	3681935.831	33.837	1 min.
Rover3	1.49	1.817	442320.625	3681923.687	33.840	1 min.
Rover4	1.50	1.825	442321.849	3681918.849	33.848	1 min.
Rover5	1.49	1.827	**442325**.435	3681904.278	33.867	1 min.
Rover6	1.51	1.835	442326.636	3681899.433	33.877	1 min.
Rover7	1.495	1.82	442329.655	3681887.320	33.845	1 min.
Rover8	1.51	1.835	442330.842	3681882.472	33.838	1 min.
Date		29/3/2017-2-4-2017				
Location		Baghdad University, near Remote Sensing unit				
Projection		UTM				
Datum		WGS84				
Device		Topcon HiPer II				
Satellite		Navstar & GLONASS				

In the tables 2 to 4, the TPS200+ distance values between the TPS in each Rover Points and selected point 1, point 2, and point three (the TPS reflector positions in real 3-D world) respectively. Also, each table content the real coordinates values measured in new Rover for the purpose of error calculation.

Table 2: The Survey By TPS1200+, Selected Point 1

TPS Station	Tripod ht. m	E m	N m	Elev. m	Slope Range m	Horizontal
Rover1	1.81	442316.424	3681940.669	33.849	36.54	35.4816
Rover2	1.81	442317.631	3681935.831	33.837	39.26	38.2741
Rover3	1.81	442320.625	3681923.687	33.840	47.70	46.8925
Rover4	1.817	442321.849	3681918.849	33.848	51.55	50.8083
Rover5	1.825	**442325**.435	3681904.278	33.867	64.03	63.4344
Rover6	1.827	442326.636	3681899.433	33.877	68.41	67.8542
Rover7	1.835	442329.655	3681887.320	33.845	79.69	79.2098
Rover8	1.82	442330.842	3681882.472	33.838	84.29	83.8354
Date		3/4/2017				
Location		Baghdad University, near Remote Sensing unit				
Projection & Datum		UTM, WGS84				
Real Coordinates of Selected Point 1		442282.459	3681950.941	42.580	-	-

Table 3: The Survey By TPS1200+, Selected Point 2

TPS Station	Tripod ht. m	E m	N m	Elev. m	Slope Range m	Horizontal
Rover1	1.81	442316.424	3681940.669	33.849	81.94	81.9399
Rover2	1.81	442317.631	3681935.831	33.837	76.95	76.9498
Rover3	1.81	442320.625	3681923.687	33.840	64.44	64.4398
Rover4	1.817	442321.849	3681918.849	33.848	59.45	59.4498
Rover5	1.825	**442325**.435	3681904.278	33.867	44.45	44.4498
Rover6	1.827	442326.636	3681899.433	33.877	39.45	39.4498
Rover7	1.835	442329.655	3681887.320	33.845	26.97	26.9696
Rover8	1.82	442330.842	3681882.472	33.838	21.98	21.9795
Date		6/4/2017				
Location		Baghdad University, near Remote Sensing unit				
Projection & Datum		UTM, WGS84				
Real Coordinates of Selected Point 2		442336.029	**3681861**.109	33.989	-	-

Table 4: The Survey By TPS1200+, Selected Point 3

TPS Station	Tripod ht. m	E m	N m	Elev. m	Slope Range m	Horizontal
Rover1	1.81	442316.424	3681940.669	33.849	140.90	140.8980
Rover2	1.81	442317.631	3681935.831	33.837	135.92	135.9179
Rover3	1.81	442320.625	3681923.687	33.840	123.41	123.4077
Rover4	1.817	442321.849	3681918.849	33.848	118.42	118.4177
Rover5	1.825	**442325**.435	3681904.278	33.867	103.42	103.4175
Rover6	1.827	442326.636	3681899.433	33.877	98.43	98.4274
Rover7	1.835	442329.655	3681887.320	33.845	85.94	85.9368
Rover8	1.82	442330.842	3681882.472	33.838	80.95	80.9465
Date		6/4/2017				
Location		Baghdad University, near Remote Sensing unit				
Projection & Datum		UTM, WGS84				
Real Coordinates of Selected Point 3		442351.681	3681804.245	34.591	-	-

In this stage, the calculation of finding the coordinates values for the three selected points in UTM projection system has been done using written program in the Matlab environment. The program input are the coordinates values of the 8 Rover points which are the same positions of the TPS1200+. The second input are the slope distance between each selected point and 8 TPS1200+ positions. For this case, the GPS positioning simulation formulas are use such as each TPS1200+ is consider as Navstar satellite, and the selected points of the reflector is the navigator antenna. For calculation purpose, the clock bias factor can ignore in this simulation, i.e. the equations is given as;

$$(x-x_1)^2+(y-y_1)^2+(z-z_1)^2=R_1{}^2$$
$$(x-x_2)^2+(y-y_2)^2+(z-z_2)^2=R_2{}^2$$
$$(x-x_3)^2+(y-y_3)^2+(z-z_3)^2=R_3{}^2 \quad \textbf{(1)}$$
$$(x-x_8)^2+(y-y_8)^2+(z-z_8)^2=R_8{}^2$$

Where, (x, y, z), are the coordinates values of selected point in 3-D world.
(x_1,y_1,z_1), are the coordinates values of Total Station 1-8.
R_1, is the slope range between selected point and total station 1-8.

In real, for solving this non-linear multivariable system, three equation can be use to find the value (x, y, z) using A Newton-Raphson method. for solving the system of linear equations requires the evaluation of a matrix, known as the Jacobian of the system, **[7]**. Equations **(1)** can be simplified into a linear system for any three Total Station positions (this is the main idea of this research, which is minimize the number of measurements as possible) such as;

$$2x(x_1-x_2)+2y(y_1-y_2)+2z(z_1-z_2)=RR_1-RR_2$$
$$2x(x_1-x_3)+2y(y_1-y_3)+2z(z_1-z_3)=RR_1-RR_3 \quad \textbf{(2)}$$
$$2x(x_2-x_3)+2y(y_2-y_3)+2z(z_2-z_3)=RR_2-RR_3$$

Where, $RR_1=x_1^2+y_1^2+z_1^2-R_1^2$

$$RR_2=x_2^2+y_2^2+z_2^2-R_2^2$$
$$RR_3=x_3^2+y_3^2+z_3^2-R_3^2$$

The above equation can be solved in matrix notion as following;

$$A*X=B \quad \textbf{(3)}$$

Where, $$A=\begin{vmatrix}(x_1-x_2) & (y_1-y_2) & (z_1-z_2)\\(x_1-x_3) & (y_1-y_3) & (z_1-z_3)\\(x_2-x_3) & (y_2-y_3) & (z_2-z_3)\end{vmatrix} \quad \textbf{(3-a)}$$

$$X=\begin{vmatrix}x\\y\\z\end{vmatrix} \quad \textbf{(3-b)}$$

$$B=\begin{vmatrix}RR_1-RR_2\\RR_1-RR_3\\RR_2-RR_3\end{vmatrix} \quad \textbf{(3-c)}$$

The value of the vector *X* are represent the coordinates of the selected reflector point in 3-D real world. this was done using the Matlab facility, the results for two sets of three combination for each selected point are given in the following tables (5-7);

Table 5: The Result of Selected Point 1, Reflector in Real 3-D

Total Station Positions	Real Coordinates UTM			Calculated Coordinates UTM		
	E m	N m	Elev. m	E m	N m	Elev. m
1, 3, &7	442282.459	3681950.941	42.580	442282.504	3681950.881	42.680
2, 5, & 8	442282.459	3681950.941	42.580	442282.399	3681950.891	42.670

Table 6: The Result of Selected Point 2, Reflector in Real 3-D

Total Station Positions	Real Coordinates UTM			Calculated Coordinates UTM		
	E m	N m	Elev. m	E m	N m	Elev. m
1, 3, &7	442336.029	**3681861**.109	33.989	442336.129	**3681861**.219	33.544
2, 5, & 8	442336.029	**3681861**.109	33.989	442336.140	**3681861**.189	33.671

Table 7: The Result of Selected Point 3, Reflector in Real 3-D

Total Station Positions	Real Coordinates UTM			Calculated Coordinates UTM		
	E m	N m	Elev. m	E m	N m	Elev. m
1, 3, &7	442351.681	3681804.245	34.591	442351.512	3681804.111	34.823
2, 5, & 8	442351.681	3681804.245	34.591	442351.554	3681804.337	34.953

The errors of all calculation are few centimeters as given in table 8.

Table 8: Error values from Direct Differences

Selected Point, Real 3-D World	Error Direct Differences		
	E m	N m	Elev. m
1	-0.045	0.06	-0.1
	0.06	0.05	-0.09
2	-0.1	-0.11	0.445
	-0.111	-0.08	0.318
3	0.169	0.134	-0.232
	0.127	-0.092	-0.362

6. Results Discussion

From above measurements and calculations, we can referee the errors values due to the Laser beam propagation interaction with atmosphere components. The Laser beam error yield the errors in the slope range distance measurements, Therefore, these errors in distance cause the error in the coordinates values of selected points of the reflector positions. The commotions for any three Total Station position does not effect the result, this is true due to the accurate measurements of the Total Station position (Rover points) by RTK DGPS mode. The errors in z direction are greater than the values in (x, y) directions, this is can be referee to the error values of RTK DGPS mode in z direction are greater than the (x, y) directions. Also, the errors in calculation may be cases by the Total Station leveling , because the device measurements are very sensitive to leveling plane. For the purpose of simplicity and time save, the three Total Station positions for any combination from 8 positions were used to calculate the coordinates of selected points in real 3-D world. So, the user can use 8 or more Total Station positions and evaluate the results using the Newton-Raphson method but in this case the measurements complexity and time consuming are present

7. Conclusion

In this paper, the coordinates of a target in real 3-D world are calculate using DGPS and TS in the Baghdad university camp, the following can be conclude;

1) The use of DGPS operate in RTK mode for accurate Rover points measurements is important in surveying, remote sensing, and geomatic project..
2) The Total Station device was used in Laser beam option to measure the slope range between the TS and selected point in 3-D world.
3) In each selected point position, the reflector of the TS is placed on it.
4) During research stage, 8 Rover points in RTK mode were recorder, and these points positions are the TS position later.
5) For the leveling process, the high of each device are consider in calculations.
6) The TS device is sensitive for leveling, which may case to prevent the measurements in some case.
7) The calculation were done using many combinations of three positions to evaluate the coordinates values of the selected point.
8) The error values are a few cm, and this error causes from different sources as discussed above.

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