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ACCURACY ASSESSMENT OF SATELLITE POSITIONING DATA CASE OF ADAMA CITY, ETHIOPIA

* Roba Gemechu	Department of Geo-Engineering, College of Engineering (A), Andhra University, Visakhapatnam, India * Corresponding author
Peddada Jagadeeswara Rao	Department of Geo-Engineering, College of Engineering (A), Andhra University, Visakhapatnam, India
Sridhar Bendalam	Department of Geo-Engineering, College of Engineering (A), Andhra University, Visakhapatnam, India
Gudikandhula Narasimha Rao	Department of Geo-Engineering, College of Engineering (A), Andhra University, Visakhapatnam, India

ABSTRACT

Global positioning system (GPS) is a worldwide satellite positioning system that provides precise location. The aim of assessing the accuracy of GPS coordinate network comprises detection of errors in GPS measurements and adjusting GPS coordinate measurements to the most precise value. In this research GPS data errors were detecting by computing residual errors and root mean square errors. In the process, the precision of measured Northing and Easting coordinates wre computed using standard deviation. The adjustment of GPS coordinates starts with adjustment of reference control base station. In the study the approaches used to adjust reference base station was computing the mean coordinate value of control base station from existing digital master plan data, orthophoto, georeferenced Google earth image and SPOT satellite image. Finally the most precise value of all stations coordinate of GPS network were adjusting from the mean value of the reference control base station using spectrum survey software.

KEYWORDS : Accuracy assessment, Detecting GPS errors, GPS coordinate adjustment.

INTRODUCTION

GPS based positioning technique is a space-based satellite navigation system that provides location and time information. GPS technology has been mainly used for high precision geodetic coordinate surveying (Tamrakar, 2012). GPS coordinate networks are mandatory for a variety of disciplines such as urban management and engineering projects (Ghosh and Rao, 2001).

Accuracy assessment of GPS data starts by examining GPS errors adjustment analysis (Darius & Kristina, 2001). GPS errors can be detected through computation of residual errors and root mean square errors. In this study the precise coordinates of GPS points can be adjusting to the reference of base station. Precise reference base station was computing the mean coordinate value of control base station from existing digital master plan data, digital orthophoto, georeferenced Google earth image and SPOT satellite image. Currently Adama city land authority has not keeping precise GPS data. This study proposes to fill the gap by adjusting GPS coordinate measurements to the most precise value. The city is located in Ethiopia, at 8.55ºN, 39.27ºE and only far away 100 km south-east from the capital city of Ethiopia, Addis Ababa. Fig.1 shows location of the city.

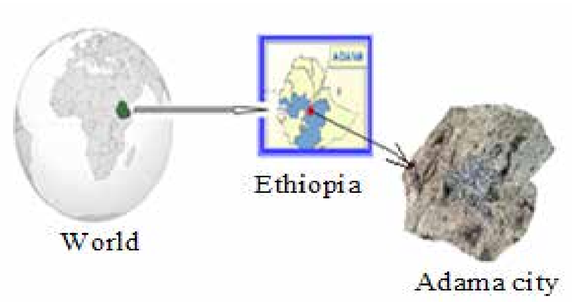

Fig.1 Geographic location of Adama city

METHODOLOGY

Work procedures

Step 1. Collecting GPS field data, SPOT and Orthophoto images

Step 2. Preprocessing GPS data, SPOT and Orthophoto images

Step3. Error detection for GPS measurement

Step 4.Comparing GPS measurements

Step 5. Adjusting control base station

Step 6. Adjustment of GPS coordinates to the reference of control station

Software used

Sokkia Spectrum survey 3.2 GPS software is used to process GPS data in this research.

Data Collection

Existing data and GPS data

For collecting GPS data Sokkia Radian IS GPS receiver is used in this research.

Existing control points values from master plan of the city (m):

GPS GCP1 Northing=948854.582

Easting=534992.663

GPS GCP2 Northing= 946886.405

Easting=534992.663

GPS GCP3 Northing= 945864.143

Easting=531327.028

GPS GCP4 Northing=945580.845

Easting=533773.889

(Source: Adama city municipality)

Unadjusted collected GPS data in m:
GPS GCP1 Northing=948854.572

Easting=534992.674

GPS GCP2 Northing= 946886.410

Easting=536128.825

GPS GCP3 Northing= 945864.111

Easting=531327.121

GPS GCP4 Northing=945580.813

Easting=533773.850

(Source: collected and processed by researcher)

SPOT and Orthophoto images
The images used for this study finding are SPOT image with 5m spatial resolution and orthophoto with 0.15m spatial resolution (Fig.2).

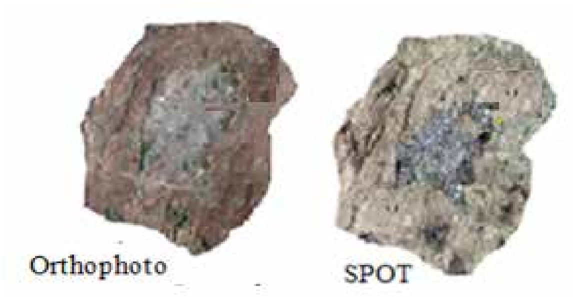

Fig.2 Georeferenced SPOT and orthophoto images Source: Ethiopian Mapping Authority, 2015)

PREPROCESSING
By using spectrum survey software the preprocessed datum and coordinate system information are:

- GPS Ellipsoid–WGS84
- Ethiopian Ellipsoid-Clarke1880
- GPS datum –WGS84
- Ethiopia local datum-Adindan
- Projection system-UTM
- GPS Coordinate system –WGS84
- Ethiopia Coordinate system-UTM

4. RESULTS AND DISCUSSION
I. Detecting GPS data errors
1. Residual errors

2. Root Mean Square Errors /RMSE/

Residual errors: Residual error = change in Easting or change in Northing

Change in Easting /ΔE / for point ID GPS GCP1= 534992.663 - 534992.674 = -0.011

Change in Northing/ ΔN/ for point ID GPS GCP1= 948854.582 - 948854.572 = 0.01

With the same formula residual errors of points GPS GCP2, GPS GCP3 and GPS GCP4 are computed (Table 1).

Mean residual Error= Dividing summation of residuals to number of observation.

Mean residual error for Easting = $\sum residuals\ \Delta E$ divided to number of observation

$$= \frac{-0.011+0.06-0.093+0.028}{4} = -0.004$$

Mean residual error for Northing = $\sum residuals\ \Delta N$ divided to number of observation

$$= \frac{0.01-0.005+0.039+0.032}{4} = 0.019$$

Root Mean Square Error /RMSE/: RMSE represents the differences between predicted values and observed values.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}}$$

Where X_{obs} is GPS observed values and X_{model} is modeled or existing values. The result from X_{obs}- X_{model} is residual error.

n is number of observation.

RMSEx =square root [(-0.011^2+ 0.060^2+-0.093^2+0.028^2)/4]

RMSEx =0.057

RMSEy = square root [(0.01^2+ -0.005^2+-0.039^2+0.032^2)/4]

RMSEy = 0.023(Table 1)

Theoretically residual errors, RMSE of Easting and Northing are zero. But in this research they are out of zero. This implies the existence of errors in the coordinate measurements.

Station name	Residuals Errors	
	ΔN Northing	ΔE Easting
GPS GCP1	0.010	-0.011
GPS GCP2	-0.005	0.060
GPS GCP3	0.032	-0.093
GPS GCP4	0.039	0.028
RMSE (m)	0.023	0.057

Table 1 Residuals Errors & RMSE
II. Comparison of GPS measurements
Standard Deviation: Standard Deviation

/ σ / is a comparison of the individual readings (measurements) to the mean of the readings.

$$\sigma = \sqrt{\frac{\sum(x-\overline{x})^2}{N-1}}$$

Where
σ = Standard Deviation
x = Each measured value
$\overline{x}$ = Mean value
N is number of observation = 4

In accuracy assessment principle of applying standard deviation, the smaller the standard deviation the higher the precision and vice versa. As observed from Table 2 Northing values (0.02) of standard deviation is more precise than Easting values (0.066) in this research (Table 2).

Point ID	Easting Residuals errors (x)	$x-\overline{x}$	$(x-\overline{x})^2$
GPS GCP1	-0.011	-0.007	0.000049
GPS GCP2	0.060	0.064	0.00409
GPS GCP3	-0.093	-0.089	0.00792
GPS GCP4	0.028	0.032	0.00102

$\sum(x-\overline{x})^2$			0.013059
Standard Deviation of Easting			0.066
GPS GCP1	0.010	-0.009	0.00008
GPS GCP2	-0.005	-0.024	0.00057
GPS GCP3	0.039	0.02	0.0004
GPS GCP4	0.032	0.013	0.00016
$\sum(x-\overline{x})^2$			0.001219
Standard Deviation of Northing			0.020

Table 2. Standard Deviation

III. Adjusted GPS coordinate networks

The goal of adjustment is to choose the most likely coordinates for points whose positions are unknown (Dawod and Abdel-Aziz, 2003). Adjustment process is starting with transforming WGS84 GPS coordinate system to the local system that is Ethiopian datum Adindan. In this research GPS GCP1 point number is base station for the others GCP and then it is the reference point or control point for the other points. This reference control point (base station) results from the mean coordinate values of existing master plan, orthophoto, georeferenced Google earth and SPOT satellite image.

Adjusted base station

$$= \frac{\text{orthophoto} + \text{Google earth} + \text{SPOT image} + \text{Master plan}}{4}$$

Adjusted base station Easting

= 535085.79m

Adjusted base station Northing=

= 949041.717m

This adjusted local (Ethiopia) reference control station adjusts the others coordinates in spectrum GPS software.

Unadjusted WGS84 GPS coordinates

GPS GCP1 Northing=948834.57

Easting=534992.27

GPS GCP2 Northing= 946866.30

Easting=536128.88

GPS GCP3 Northing= 945844.15

Easting=531327.02

GPS GCP4 Northing=945560.84

Easting=533773.81

Adjusted GPS coordinates to the reference control station

GPS GCP1 Northing=949041.717

Easting=535085.79

GPS GCP2 Northing=946886.41

Easting=536220.898

GPS GCP3 Northing= 946048.626

Easting=531418.522

GPS GCP4 Northing=945768.172

Easting=533865.786

The adjusted GPS coordinates are transforming to the local (Ethiopia) coordinate system from GPS WGS84 coordinate system. After adjusting GPS points all survey networks connected to each other are integrated into one system.Fig.3 shows the adjusted coordinates on SPOT and Orthophoto images (Fig.3).

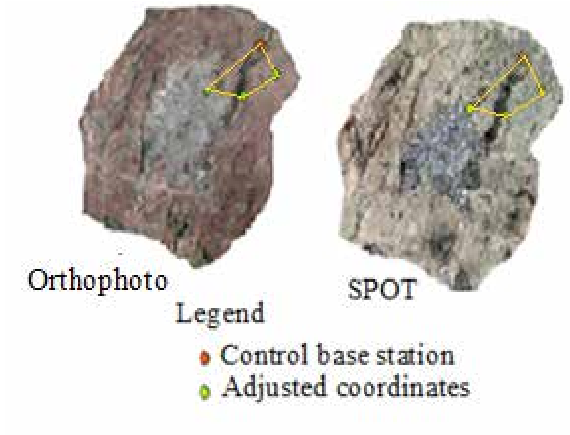

Fig.3 Position of GPS adjusted coordinates on SPOT and Orthophoto images

5. CONCLUSION

The process of accuracy assessment of GPS network to be started with detecting GPS data errors. In this research detection of errors was done using methods of computing residual errors and Root Mean Square Errors (RMSE).Theoretically for very accurate measurements residuals errors, RMSEx and RMSEy results are zero. But in this study the values are out of zero. These none zero values are errors detected. To adjust GPS coordinates the primarily adjustment of reference control point was computed. This adjusted reference control station adjusts the others networked coordinates using spectrum survey GPS software.

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