FEATURE ORIENTATION AND POSITIONAL ACCURACY ASSESSMENT OF DIGITAL ORTHOPHOTO AND LINE MAP FOR LARGE SCALE MAPPING: THE CASE STUDY ON BAHIR DAR TOWN, ETHIOPIA

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ABSTRACT:

This study used in-situ GPS data to validate the accuracy of horizontal coordinates and orientation of linear features of orthophoto and line map for Bahir Dar city. GPS data is processed using GAMIT/GLOBK and Lieca GeoOfice (LGO) in a least square sense with a tie to local and regional GPS reference stations to predict horizontal coordinates at five checkpoints. Real-Time-Kinematic GPS measurement technique is used to collect the coordinates of road centerline to test the accuracy associated with the orientation of the photogrammetric line map. The accuracy of orthophoto was evaluated by comparing with in-situ GPS coordinates and it is in a good agreement with a root mean square error (RMSE) of 12.45 cm in x- and 13.97 cm in y-coordinates, on the other hand, 6.06 cm with 95% confidence level – GPS coordinates from GAMIT/GLOBK.

Whereas, the horizontal coordinates of the orthophoto are in agreement with in-situ GPS coordinates at an accuracy of 16.71 cm and 18.98 cm in x and y-directions respectively and 11.07 cm with 95% confidence level – GPS data is processed by LGO and a tie to local GPS network. Similarly, the accuracy of linear feature is in a good fit with in-situ GPS measurement. The GPS coordinates of the road centerline deviates from the corresponding coordinates of line map by a mean value of 9.18cm in x- direction and -14.96cm in y-direction. Therefore, it can be concluded that, the accuracy of the orthophoto and line map is within the national standard of error budget (~ 25cm).

1. INTRODUCTION

With the development of technology, digital photogrametry has started to be used widely in almost all areas about mapping. Especially, digital orthophos which are photogrammetric products are being used by different sectors because of their easy interoperability. In this connection, Siriba (2009) stated that the identification of parcel boundaries using photogrammetric method has become an alternative approach to ground based surveying and has been adopted in different countries for modernizing land information registration and administration system. Photogrammetric technique provides seamless coverage of cadastral information, but the accuracy of data has to be calibrated using in-situ ground measurements to realize the production of large scale maps (ranging from 1:500 to 1:10,000) based on orthophoto and digital line map that can be reliably used for practical cadastral applications. In recent years, much technological advancement has been made in the field of photogrammetry and the process of making maps using orthophotos. However, the photogrammetric data are affected by different factors such as topographic varriations, cannopy, eath's curvature and other error sources introduced by compuational procedures such as rectification and digitaization.

The rectification process is affected by the accuracy and spatial distribution of the ground control points, the aerial triangulation process, and digital elevation, and the method/software used for rectification. These errors reduce the spatial accuracy of photogrammetric data and cause geometric distortion and misorientation of linear features. Lawali and Waziri (2014) showed that orthorectification process reduces geometric errors inherent within photography and imagery. The variables contributing to geometric errors include camera and sensor orientation, systematic error associated with camera and topographic relief displacement, and earth curvature. Greenfeld (2001) also explained that orthophotos generally offer significant benefits, but all orthophotos are not generated with equal accuracy. In general, the accuracy and quality of orthophoto varies based on the accuracy of the source data. Other contributing error factors include the characteristics and calibration of equipment used for image capture such as the camera and/or scanner.

Currently, Ethiopia is involved to develop high resolution and accurate rural and urban cadastral map. So far, promising development have been made in system development, aerial photo capturing, aerial triangulation, orthophoto generation, and feature extraction and digital line map preparation for 23 towns including Bahir Dar Town. Besides, there is an increasing demand for rural and urban cadastral mapping. For example, the Ethiopian government has planned to capture aerial photo of 92 towns during the second Growth and Transformation Plan (from 2016-2020) to further improve the cadastral and land management system.

Therefore, study aims to assess the accuracy of orthophoto and digital line map acquired over the entire area of Bahir Dar Town, by comparing coordinates of some selected points and linear features from orthophoto and digital line map against an independent accurate data more obtained from GNSS measurement. This study used orthophoto and digital line map acquired from aerial photogrammetric survey carried out over the whole area of Bahir Dar Town, accounting for a total area of 159 km^2. The photogrammetric surveying was conducted by Information Network Security Agency (INSA) in 2011/12 with standard aerial camera at 1:2,000 scale and 15cm Ground Sample Distance (GSD).

In practice, the quality of photogrammetric data can be examined by assessing the accuracy of vertical and horizontal coordinates of land parcel boundaries, point features and orientation of linear features. The positional accuracy achievable using photogrametric methods and the scale of the final map are determined based on mapping requirements and practice (Siriba, 2009). The spatial accuracy evaluation of the orthophoto and its suitability for a given application can be performed in a number of different ways. One way to do this is to overlay it onto another reference (e.g., a vector-based graphic) information layer known to have higher accuracy. Differences or errors in feature locations between the orthophoto and reference layer are observed and quantified. The results of that error quantification are used to determine the accuracy of the orthophoto. Another way to test the spatial accuracy is by using the Global Positioning System (GPS) to determine accurate positions of features that can be easily identified on the orthophoto (Greenfeld, 2001). The accuracy in the positions of photogrammetric datasets needs to be evaluated against in-situ ground-truth datasets using positional accuracy assessment technique.

Positional accuracy assessment refers to the task of evaluating the absolute relative positions of the spatial objects on aerial photo and digital line map with respect to their true locations on the surface of the Earth.

The accuracy is usually determined for both horizontal and vertical coordinates. Horizontal positional accuracy is an estimate of accuracy of the horizontal positions of the spatial objects that can be measured in terms of latitude and longitude or local easting and northing coordinates (Kapnias, 2008). Whereas, the vertical positional accuracy refers to the uncertainty with which the vertical coordinates (ellipsoidal height/geocentric radius) of spatial objects can be measured. In general, the positional accuracy of orthophoto refers to the accuracy at which the position coordinates (latitude, longitude and ellipsoidal height) of the spatial objects that are well recognized on the orthophoto are estimated in reference to their corresponding ground-truth coordinates acquired at the same locations using an independent ground based in-situ measurement such as Global Navigation Satellite System (GNSS) observations (Congalton and Green, 2009; American Society of Photogrammetry and Remote sensing (ASPRS), 2013). In theory, the accuracy of ground based reference data used to validate the accuracy of photogrammetric data shall be at least three times more accurate than the photogrammetric data being assessed (Congalton and Green, 2009), while error in positional accuracy of photogrammetric data is the difference between the coordinates of the same selected spatial objects as acquired from photogrammetric survey when compared to coordinates measured using GNSS receivers.

Regarding with the GPS data processing for reference dataset, there are two types of GPS data processing software. The first is scientific GPS data processing software and the second is commercial GPS data processing software. It is usually believed that scientific GPS data processing software is better than commercial software, in terms of accuracy of coordinate results especially in large areas. However, continual improvements in commercial GPS data processing software may enable people to achieve the same result as the scientific software for long baseline distance (Featherstone, 2004). Scientific Institutions always develop scientific software such as Bernese, GIPSY. GAMIT, SWAG. Whereas, the commercial software developed by commercial company, an example of such software; Trimble Geomatics Office (TGO), LGO and Topcon.

In addition to point wise positional accuracy assessment of the photogrammetric products (orthophoto and its digital line map), the correctness of the orientation of linear features should be evaluated (Siriba, 2009). The utilization of points remains to be convenient and photogrammetric researchers recently focused on using high level features (linear and area feature) in various photogrametric operations (Curitiba, 2003). In this connection, such features increase system redundancy and consequently show the geometric strength and robustness in terms of the ability to detect blunders and local anomalies (Atak, 2008). Siriba (2009) stated that linear feature (straight line and area) could be evaluated for their geometric, radiometric, and mosaicking accuracies. Besides, straight lines are valuable for the recovery of the interior orientation parameter (IOP) of the cameras, where object space straight lines should appear as a straight lines in the image space in the absence of distortion (Habib, 2009). Due to advancement in digital photogrammetric surveying, there is a growing interest to use linear features for various development activities and this resulted in the necessity of evaluating the accuracy of linear features orientation in space.

2. METHODOLOGY

Regarding the methodological approach, the data sources for this study are the orthophoto and digital line map acquired over the whole area of Bahir Dar city during a period of 2011/12. The ground based in-situ GNSS measurements at some selected and identified spatial objects were conducted for the checkpoints establishment. The study used the best method among positional accuracy assessment techniques. GPS data acquired at selected reference points for the observation session of 72 hours in static sense are processed using Leica Geoffice (LGO) and GAMIT/GLOBK software packages. The results from the two processing techniques were compared for internal self-accuracy assessment. The GPS post processing technique used Continuously Operating Reference Station (CORS) and International GNSS Service (IGS) as a reference stations. To improve the accuracy of the checkpoints' coordinates, the Receiver Independent Exchange Format (RINEX) file and Broadcast (BRDC) file were downloaded from those stations via Internet (http://igs.bkg.bund.de/file/rinexsearch) and imported into GAMIT/GLOBK to enable the minimization of error using double differencing principle and least square sense. Regarding checkpoint sampling design and distribution, the study used the newly endorsed ASPRS and NSSDA mapping standards and Ethiopian Mapping (EMA) standards. For comparison purpose, the coordinate transformations were made because of the GPS coordinates and the coordinates extracted from orthophoto and digital line map are defined in different coordinate reference system and the whole procedures are illustrated in the figure below (See Figure 1).
Similarly, the accuracy assessment of the orientation of linear features used statistical Mean and standard deviation of the difference between the coordinates of road centerline as extracted from digital line map or/and orthophoto and the RTK GPS surveying. Note that this study only carried out horizontal accuracy assessment due to the fact that vertical coordinates are not available for the selected checkpoints on orthophoto and digital line map.

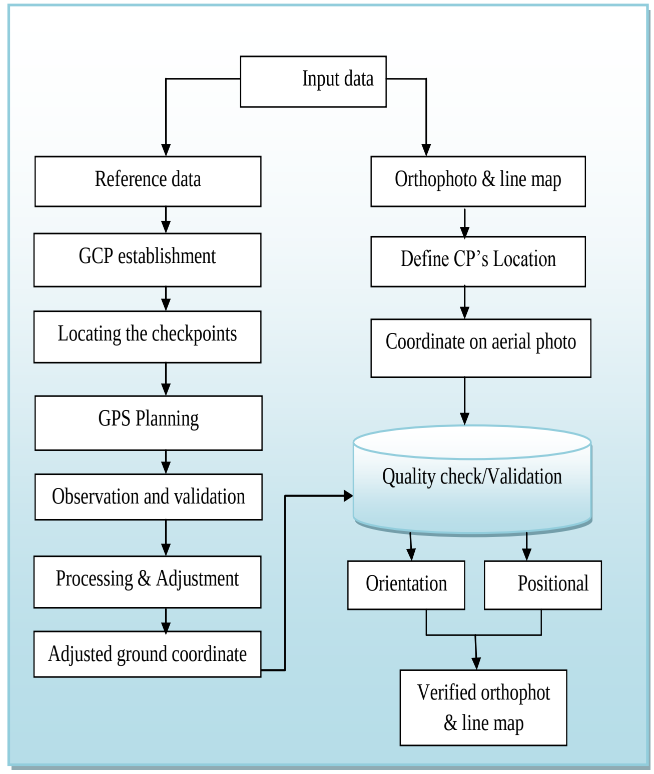

Figure 1. Positional and orientation assessment of digital orthophoto and line map schematic diagram

3. RESULT

3.1. Positional Accuracy Assessment

This study explicitly examined the accuracy of orthophoto and its digital line map in terms of horizontal position and orientation of road centreline. The GPS coordinates for the five checkpoints were determined using GAMIT/GLOBK with the RMSE values ranging from 0.61cm to 1.06 cm (Table 1).

PID	Grid Coordinate, Adindan UTM by GAMIT from regional GPS stations			Errors
	Easting (m)	Northing (m)	Ellip. Hgt (m)	RMS (mm)
GPS1	326693.6185	1282895.8886	1780.6327	10.8
GPS2	323211.6201	1282942.3193	1780.0852	6.10
GPS3	325020.2210	1280209.7277	1782.5545	9.00
GPS4	322080.5410	1282414.3735	1783.0185	6.70
GPS5	323716.1279	1281627.9210	1783.7852	6.10
Mean				7.74

Table 1. GAMIT/GLOBK derived GPS coordinates of the checkpoints with their corresponding residuals errors and GDOP values

According to the 1989 NSSDA's standard, the equation for the average horizontal error or horizontal RMSEh is calculated from the errors of the individual test sample points using equation 1.

$$RMSE_h = \sqrt{\sum_i^n((x_{ri} - x_{mi})^2 + (y_{ri} - y_{mi})^2))/n} \qquad (1)$$

The Horizontal error at the point $i = \sum_i^n((x_{ri} - x_{mi})^2 + (y_{ri} - y_{mi})^2)$
Or
The Horizontal error at the point i in x and y

$$\sigma_x^2 = \sum_i^n(x_{ri} - x_{mi})^2/n$$

$$\sigma_y^2 = \sum_i^n(y_{ri} - y_{mi})^2/n$$

Where, x_r and y_r are the reference coordinates and xm and ym are the map or image coordinates for the i[th] sample point, σ_x^2, σ_y^2 are second momentum or variance of the statistical distribution.

The second momentum or variance is the square root of the average of the set of squared differences between map coordinates and their corresponding in-situ coordinates. Errors in X and Y coordinates are computed separately because they are independent of each other. In theory, it is assumed that errors in the spatial data have random behavior and that systematic errors have been eliminated as best as possible. Assuming that errors are normally distributed and independent of each other in the X and Y component, a factor of 2.4477 is used to compute horizontal accuracy at 95 % confidence level using equation 2 (NSSDA, 1989).

$$\text{Accuracy} = \frac{2.4477\sqrt{\sum_i^n((x_{ri}-x_{mi})^2+((y_{ri}-y_{mi})^2)/n}}{2} \qquad (2)$$

or

$$Accuracy = 2.4477\frac{\sqrt{(\sigma_x^2+\sigma_y^2)}}{2} \qquad (3)$$

If $\sigma_x^2 = \sigma_y^2$, equations (2) and (3) can be reduced to a more simplified formula. Let
RMSE h = $\sqrt{2}$ *RMSE$_X$ = $\sqrt{2}$ *RMSE$_Y$
Where

$$RMSE_x = \sqrt{\sigma_x^2}$$

$$RMSE_y = \sqrt{\sigma_y^2}$$

Or equivalently, the RMSE in x- and y-directions can be given as

RMSE x = SQRT($\Sigma(x_{ri} - x_{mi})^2$)/n
RMSE y= SQRT($\Sigma\ (y_{ri} - y_{mi})^2$)/n

Therefore, the horizontal accuracy can be given by:

$$Accuracy = 2.4477\frac{RMSE_h}{2} = 1.22385 RMSE_h = 1.7308 RMSE_x = 1.7308 RMSE_y \qquad (4)$$

Note that the constants 1.7308 and 1.22385 are the standard value from the x-axis of the standard normal distribution for an interval with a probability of 95%.

The RMSE of the difference between the orthophoto coordinates and in-situ GPS coordinates of the five check points in x and y-directions are 12.45 cm and 13.97 cm, respectively. The horizontal accuracy of orthophoto is determined at 6.06 cm with 95% confidence level, which means three times less than the accuracy of reference dataset (0.774 cm) (Table 1and 2).

	GPS coordinates of the checkpoints as derived using GAMIT/GLOBK		Orthophoto-based coordinates of the checkpoints		Errors	
PID	Easting (m)	Northing (m)	Easting (m)	Northing (m)	Δ Easting (m)	Δ Northing (m)
GPS1	326693.6185	1282895.8886	326693.7970	1282895.6290	-0.1785	0.2596
GPS2	323211.6201	1282942.3193	323211.7490	1282942.1940	-0.1289	0.1253
GPS3	325020.2210	1280209.7277	325020.0660	1280209.8240	0.1550	-0.0963
GPS4	322080.5410	1282414.3735	322080.5648	1282414.3327	-0.0238	0.0408
GPS5	323716.1279	1281627.9210	323716.0620	1281627.8610	0.0659	0.0600
Number of check points				5	5	5
Sum					-0.11032	0.3894
Mean error (m)					-0.02206	0.07788
Standard deviation (m)					0.0641	0.0864
RMSE (m)					0.1245	0.1397
RMSEr (m)					0.0350	
NSSDA Horizontal Accuracy, at 95% confidence level					0.0606	

Table 2. Comparison between GPS coordinates and orthophoto-based coordinates

In addition to GAMIT/BLOBK GPS data processing software, the study used LGO software packages as well to establish checkpoints to conduct positional accuracy assessment of the given orthophoto. To do so, two scenarios were implemented regarding the use of GPS network. The first scenario was to process the GPS data of the five checkpoints with a tie to local GPS reference station (TANA CORS station was) avaliable over short baseline distance. For this scenario, the average accuracy of GPS data are 1.748 cm and 2.47 cm in x and y-directions, respectively (Table 3).

	Grid Coordinate, Adindan UTM by LGO			Errors		
PID	Easting (m)	Northing (m)	Ellip. Hgt (m)	Sx (m)	Sy (m)	Su (m)
GPS1	326693.5949	1282895.8270	1780.4128	0.0172	0.0253	0.0304
GPS2	323211.8679	1282942.4320	1780.0564	0.0109	0.0124	0.0317
GPS3	325020.1008	1280209.6530	1782.4270	0.0152	0.0252	0.0303
GPS4	322080.3765	1282414.3430	1783.4914	0.0285	0.0343	0.0879
GPS5	323715.9812	1281628.1012	1783.6153	0.0156	0.0263	0.0314
Mean				0.01748	0.0247	0.04234

Table 3. LGO-derived GPS coordinates of the checkpoints from local GPS network

The accuracy of orthophoto as compared to the GPS data acquired from LGO processing is 16.71 cm and 18.98 cm in x and y-direction, respectively in RMSE sense (Table 4). In other words, the positional accuracy of orthophoto evaluated for five checkpoints are estimated at 11.07 cm at 95 % confidence level. In this case, the baseline distance from reference station to checkpoint location was 8 km.

	LGO-derived GPS coordinates of the checkpoints		Orthophoto-derived coordinates of the checkpoints		Errors	
PID	Easting (m)	Northing (m)	Easting (m)	Northing (m)	Δ Easting (m)	Δ Northing (m)
GPS1	326693.5949	1282895.8270	326693.7970	1282895.6290	-0.2021	0.1980
GPS2	323211.8679	1282942.4320	323211.7490	1282942.1940	0.1189	0.2380
GPS3	325020.1008	1280209.6530	325020.0660	1280209.8240	0.0348	-0.1710
GPS4	322080.3765	1282414.3430	322080.5648	1282414.3327	-0.1883	0.0103
GPS5	323715.9812	1281628.1012	323716.0620	1281627.8610	-0.0808	0.2402
Number of check points				5	5	5
Sum					-0.3175	0.5155
Mean error (m)					-0.0635	0.1031
Standard deviation (m)					0.1397	0.1801
RMSE (m)					0.1671	0.1898
RMSEr (m)				0.0640		
NSSDA Horizontal Accuracy, at 95% confidence level				0.1107		

Table 4. Comparison between GPS coordinates from LGO and orthophoto-based coordinate of the checkpoints

3.2. **Comparison between LGO and GAMIT/GLOBK Solutions**

For this study, two independent GPS data processing techniques (LGO & GAMIT/GLOBK) were used to evaluate self-internal accuracy in the GPS data. The first solutions were determined by using only local GPS reference stations (TANA CORS) taken over short baseline while the solutions were for the second are derived by using regional network of GPS reference stations (ADDIS, MAL2, MBAR and NKLG) taken over long baseline. The results of the GPS data processing showed that LGO software provide more accurate coordinates when local GPS reference stations are used in the double differencing than while using regional network of GPS stations, i.e LGO solutions have less standard deviation (Table 5, Fig. 2, 3 and 4).
In this connection, the first scenario of LGO solutions were successfully computed and compared with the GAMIT/GLOBK in terms of standard deviation as residuals (Table 5). But the second scenario attempted to determine five GPS checkpoints was not successfully implemented due to receivers' type incompatibility during data processing. Thus, the position of points and other resulting parameters such as standard deviation were not computed, because the baseline vector and ambiguity status should be computed and fixed first to compute the position with corresponding accuracy.

The GAMIT/GLOBK is appropriate when using long baseline regional network of GPS stations, because in GAMIT/GLOBK, there is an opportunity to use different models which will be embedded to it to remove atmospheric effects.

	Errors from GAMIT/GLOBK using Regional network GPS station			Errors from LGO Using Local GPS reference station		
PID	Sx (m)	Sy (m)	Su (m)	Sx (m)	Sy (m)	Su (m)
GPS1	0.04487	0.04681	0.12963	0.0172	0.0253	0.0304
GPS2	0.04076	0.04032	0.11093	0.0109	0.0124	0.0317
GPS3	0.04485	0.04672	0.12923	0.0152	0.0252	0.0303
GPS4	0.04885	0.04772	0.13923	0.0285	0.0343	0.0879
GPS5	0.04079	0.04030	0.11072	0.0156	0.0263	0.0314

Table 5. Comparison between errors in position coordinates as determined from LGO and GAMIT/GLOBK

The standard deviation (Sx, Sy, and Sz) that are associated with the LGO and GAMIT/GLOBK GPS solutions as shown in Table 5 are presented in a more illustrative way using histogram. For example figure 2, 3 and 4 shows the distribution of residual errors in x, y and -components respectively as acquired from both LGO and GAMIT/GLOBK software packages.

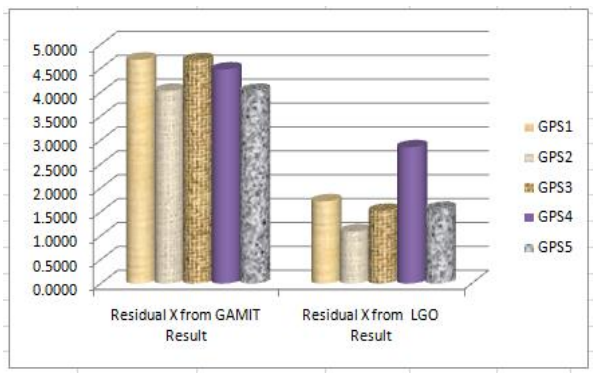

Figure 2. Plot of residual errors in x-component as computed from LGO and GAMIT (unit is in m scaled by 100)

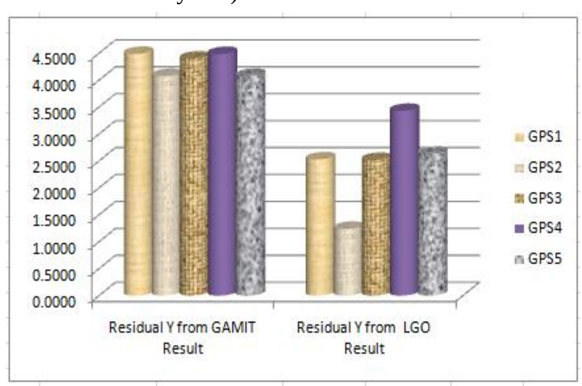

Figure 3. Plot of residual errors in y-component as determined from LGO and GAMIT (unit is in m scaled by 100)

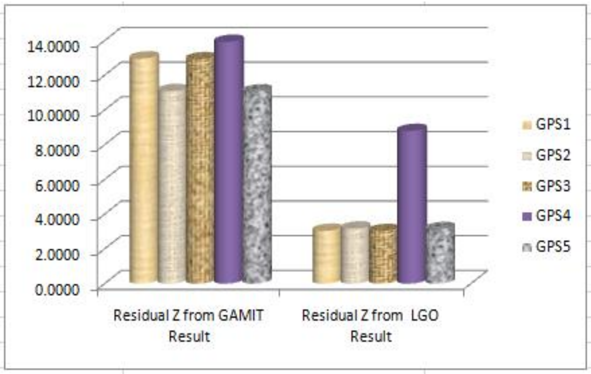

Figure 4. Plot of residual errors in Z-component as obtained from LGO and GAMIT (unit is in m scaled by 100)

3.3. Orientation of Linear Feature

The accuracy of linear features can be tested by examining variation in the orientation of the digital line map using RTK GPS surveying technique. In RTK GPS measurement, the base station (TANA CORS) sends correction for GPS error sources in real-time via radio link to the rover over 6 km on average. In this particular study, 32 coordinate values were collected along the road centerlines. The coordinate values were digitized and the digital line map (road centerline) is overlaid on top of it. The selection of digital line map (road centerline) being tested consists of straight line (A) and curved line (B) purposely, to observe how accurate the orientation change of linear features are determined from orthophoto (Fig. 6). This segment represents road centerline from Meskel square to Yetebaberut Adebabay having 800m base line length.

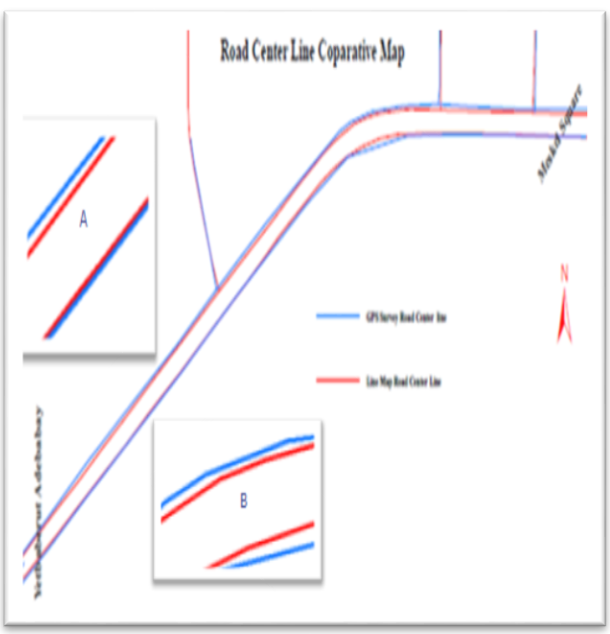

Figure 6. Comparison of orientation in road centreline as acquired from digital line map (red color) and RTK GPS surveying (blue color)

Statistically the agreement between the two datasets can be exemplified by analyzing the mean and standard deviation of the difference between the coordinates from digital line map and RTK GPS surveying for only three visible points from the two datasets. The mean of the difference is 9.18cm and -14.96cm in x- and y-components, respectively. Whereas, the standard deviation of the difference is 14.08cm and 5.90cm in x- and y- components, respectively (Table 6). It is anticipated that standard deviation is a good measure of the accuracy of orientation in linear feature and the results achieved in this study is within the national standard of error budget (~ 0.25m).

	GPS survey checkpoint values		Digital line map (road center line) values		Errors	
PID	X (m)	Y(m)	X (m)	Y(m	Δ Easting (m)	Δ Northing (m)
1	323532.9980	1281266.0790	323533.0030	1281266.3950	-0.0050	-0.3160
2	323203.9150	1281114.6500	323203.6500	1281114.8780	0.2650	-0.2280
3	323298.7320	1281166.7770	323298.5330	1281166.9810	0.1990	-0.2040
			Sum		0.4590	-0.7480
			Mean		0.0918	-0.1496
			St.dev.		0.1408	0.0590

Table 6. Point wise comparative result between digital line map (road centreline) values and GPS survey checkpoint values in road centreline

4. CONCLUSIONS AND RECOMMENDATIONS

The aim of the study was to conduct accuracy assessment of the digital orthophoto and its line map (road centerline) for large scale mapping production such as cadastral map. The two major components were positional and orientation accuracy assessment in point wise and linear feature respectively. The positional accuracy (horizontally) was evaluated mainly in terms of $RMSE_h$ and 95 % confidence level and RMSE in x, y-direction from the two datasets (GPS survey checkpoints and orthophoto derived coordinates). Whereas, the orientation of linear feature particularly the road centerline accuracy assessment was expressed in terms of mean value and the standard deviation between the digital line map and RTK GPS derived coordinates. Therefore, the accuracy of the orthophoto compared to GPS data is within the national standard of error budget (~25cm) in terms of position and orientation. From the result supported, the orthophoto and line map is considered as appropriate for cadastral mapping applications, utility mapping, infrastructural mapping, road network mapping ETC. Particularly for rural areas where parcel size are very large the acquired accuracy level are extremely beyond the expected accuracy. Both GAMIT/GLOBK and LGO software with baseline processing module can handle long baseline GPS data and short base line GPS data respectively to give millimeter level accuracy. However, there are also some weaknesses in LGO, the software needs compatible receiver types for baseline computation and it lacks to create link to precise earth rotation parameter, pole tide corrections and solid earth tide models.

5. RECOMMENDATIONS

As a way of improving beyond the scope of this study, the study recommends that future research be done in the following concepts:

- The accuracy of orthophoto can be checked by increasing the number of checkpoints and incorporating other towns having undulating topography.
- The accuracy of orthophoto can be further examined by incorporating the vertical component during line map extraction for 3D mapping applications.
- Design the best linear fitting model from linear features measured by GPS surveying and their corresponsing coordinates digitized from aerial photos.

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