Cost and Accuracy Analysis of Detail Measurements by Real-Time Kinematic GPS (RTK-GPS)

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Key words: Detail measurement, RTK-GPS, Electronic Tacheometry.

SUMMARY

Detail measurement is one of the most important studies of the survey engineering. It can be defined as the measurement of detail points with sufficient accuracy in order to draw all the natural and artificial objects on the land.

About a 20 ha test area were established in Selcuk University Campus to compare RTK-GPS and classic methods. Detail points in the test area were measured according to polar coordinate method by using electronic tacheometry. Spatial data concerning the same area were obtained with Real Time Kinematic Global Positioning System (RTK GPS). Polar coordinate method (classical method) was accepted as a basis and compared with the spatial data obtained from RTK-GPS method in terms of accuracy and cost.

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1. INTRODUCTION

Recently, Geographical Information System (GIS) became a subject in which every section of the society is interested as parallel to the developments of computer technology. Since the properties of information about the earth whether being positional or not allows being stored in computer environment, processed, analyzed, presented as visually and etc., interests to GIS increase day by day. That's the reason of the over researches and application studies related with GIS in public institutions, local governments, private companies and universities.
The basic properties of whole information systems that are presented in different names show similarities. So, it is possible to evaluate all information system that are formed according to the position as being included in GIS system. At the implementation part of the GIS, the data collection is one of the important stages and requires highest time duration and cost between stages. Thus, more than %50 of the time and cost are required for data collection to design a system intended for GIS (Yomralıoglu, 2000).

For that reason, priority is given to choose appropriate data collection method for aim in GIS that will be formed. Positional data can be obtained from classical measurement methods, GPS methods, digitization of existing maps (cartographic), photogrammetric methods and remote sensing methods. Time, cost and accuracy of the obtained data can become different according to project aim.

Accuracy and cost analysis were done for classical measurement and RTK--GPS methods in a chosen area in Selcuk University Alaeddin Keykubat Campus with the aim of comparisons of positional data for forming a GIS. Type text here.

2. GEOGRAPHIC INFORMATION SYSTEM-(GIS)

Geographic information system is a system which implements the functions of collecting, saving, processing and presenting the user of information that can be graphic or not and obtained from observation based on position or not as a whole (Yomralıoglu, 2000).

2.1 The Components of the Geographical Information Systems

At least five main members must come together to make geographical information system implement its basic functions (Esri, 2004). These are called as hardware, software, data, human and methods and named as components of the GIS. (Figure 1).

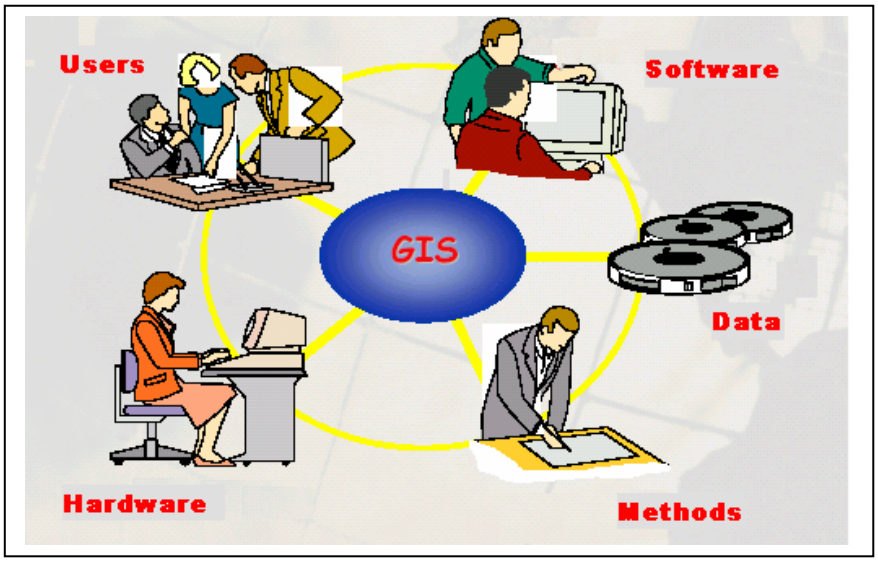


Figure 1. The components of the Geographical information System

2.2 Graphic Information and Non-Graphic Information in Geographical Information Base System

The elements are known as geographical data if they quantify the geographical assets. Geographic data is expressed as two different types regarding to their properties. These are graphic and non-graphic information. Graphic information gives information about the position, size and figure of the asset. For instance, the position of A detail in space is described in cartesian coordinates (x,y,z) or geographical coordinates (φ, λ) definitely. Non-graphic information gives information about the structural properties of the asset.

3. POSITIONAL DATA COLLECTION METHODS IN GIS

Wide varieties of approach were developed from so much different disciplines to collect the input data of the GIS that is intended for different data source. On the other hand, Most of the GIS applications requires collection and integration of the data from more than one source (Sarbanoğlu, 1991).

At the implementation part of the GIS, the data collection is one of the important stages and requires highest time duration and cost between stages. The methods followed in the collection of data in GIS can be order as below (Figure 2):

- Classical measurement methods,
- Photogrammetric methods
- GPS methods,
- Cartographic methods
- Remote sensing methods

To be consistent with the aim of this study, the only classical and RTK-GPS methods were discussed.

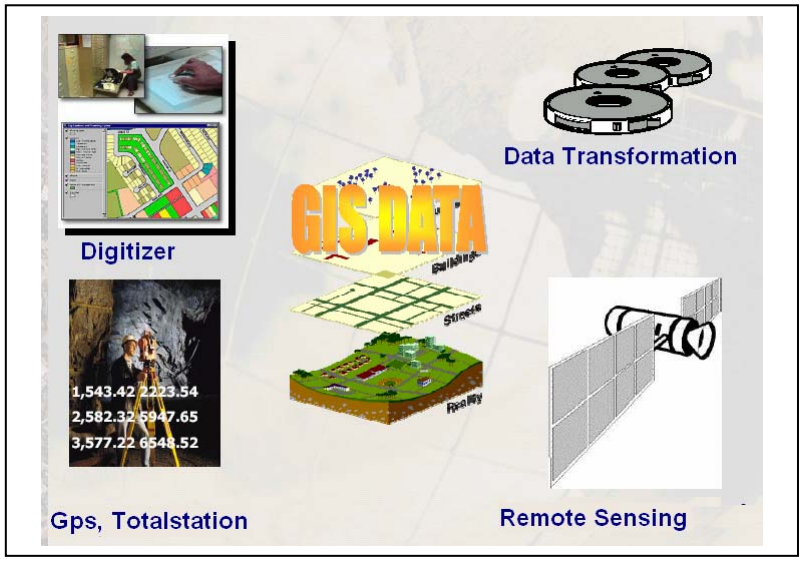


Figure 2. Positional data collection methods

3.1 Classical Methods

The basic principle of the classical method also called polar is determination of the horizontal and vertical positions of the detail points simultaneously by tachometer whose coordinates are set in determined earth control points like triangulation and polygon and use vertical angle, horizontal angle and lengths observed in detail points. In this method, electronic tachometers emerged as a production of developed technology and can make observation of vertical angle, horizontal angle and length in a high precision are used. The observations done by electronic tachometer can be saved interior or outer record unit as automatically and whenever wishes some other computations can be done by microprocessor. The accuracy of the tachometric measurements is much better than the one by classical tachometer (Inal et al, 1995)

3.2 Global Positioning Systems (GPS)

"NAVSTAR/GPS" (**N**avigation **S**atellite **T**iming **A**nd **R**anging/ **G**lobal **P**ositioning **S**ystem) system is a radio navigation system and developed by USA- DOD (Department of Defence). Since the system is developed version of transit system, it let the user determine position, speed and time in a high accuracy in anytime, any air condition and at anywhere in global position coordinate system by using satellite signals if the user have a GPS receiver (Kahveci and Yildiz, 2001).

3.3 Real Time Kinematic GPS (RTK-GPS)

In RTK GPS method, double GPS receiver with double frequency is used in both reference and mobile station. In stationary (immobile) station, radio transmitter that broadcasts calculated corrections of measurement of carrier wave phase exists whereas a radio receiver that is used to receive these corrections exists in the mobile unit (Mekik, 2001).
With RTK GPS method the coordinate of a point in the field can be determined in ±2.5 cm accuracy (Arslanoglu and Mekik, 2003). Detail measurements that take so much time and require preparation can be done in short time duration with a high accuracy. The only disadvantage of the system is being required collection of measurement at least from 5 satellites to get sensitive result (Gokalp and Gungor, 2001). A radio modem used in this system must update the data at every 0.5-2 seconds from immobile station to mobile station. The data volume increase due to narrow interval of the data update. So, the data link of the RTK GPS must be at least 2400 bps (Bit Per Second). The suggested data transmission ratio must be 9600 and even 19200 bps. The bandwidth that can support this ratio can be found in VHF or UHF band of the radio spectrum. But, according to the legal arrangement, the usage of VHF and UHF band requires utilization license. However, radio signals broadcasted in UHF band re limited with 15 km. So that, short band FM and systems with frequency change switching can be used for transmitting RTK- GPS data (Langley, 1998).

4. APPLICATION

4.1 The Description of the Application Field

Application area is chosen as Selcuk University Alaeddin Keykubat Campus. Building up is completed partially whereas environmental gardening still keeps on (Figure 3).

Figure 3. Test field

4.2 Obtaining Positional Data by Classical Method and Accuracy Analysis

In order to make detail measurements with classical methods, a polygon network is formed from 28 points as total and 5 different taxiways where both of them depend on the country triangulation. In measurements, TOPCON GTS-701 Electronic Tachometer was used. With this tool, m_s=±(2mm+2ppm) and m_φ=±2 accuracy can be obtained for length measurement and angle observation respectively. Positional data was obtained by evaluating polar intake (receipt) measurements. The drawings were implemented with NETCAD software.

Field and Office Works were completed in almost 60 hours by a measurement team includes one map engineer, one map technician and others.
Position error of detail point in classical method,

$$m_p = \pm\sqrt{m_s^2 + \frac{S^2 m_\varphi^2}{\rho^2}} \tag{1}$$

can be found upper equation. Here meanings of the denotations are as follows;
S: Horizontal length between tool setup point and measured detail point
m_φ : The tachometer angle measurement thinness
m_s : The electronic tachometer length measurement thinness used in intake of detail
The mean length between polygon point and detail point is 400m, if the positional error of the polygon point is accepted as ±5 then the total positional error in the detail point is calculated as ±5.5 cm (Inal et al., 1995).

4.3 Accuracy Analysis of Positional Data by Real time Kinematic GPS

3 items JAVAD trade mark of GPS with double frequency and equipped with RTK- GPS hardware were used in detail intake. Radio modem used in data transmission was SATEL trade mark 3AS model. Allocated frequencies were F1 channel, transmitting frequency (MHz) 443.1375 and receiving frequency (MHz) 443.1375.

After transferring the known coordinates of the reference to the reference receiver, real time position of the mobile transmitters and detail points were determined. This study was over about 3 hours.
The coordinates of the detail points by RTK- GPS were compared with coordinates by classical method. The errors in X and Y direction at the comparison;

$$\begin{aligned} V_Y &= Y_G - Y_K \\ V_X &= X_G - X_K \end{aligned} \tag{2}$$

$$m_x = \pm\sqrt{\frac{[V_X V_X]}{n}} \tag{3}$$

$$m_Y = \pm\sqrt{\frac{[V_Y V_Y]}{n}} \tag{4}$$

$$m_p = \pm\sqrt{\frac{[V_X V_X + V_Y V_Y]}{n}} \quad (5)$$

were calculated by upper equations. Here, the meanings of the denotations are as follows;

Y_K, X_K : The point coordinates by classical method that is referenced

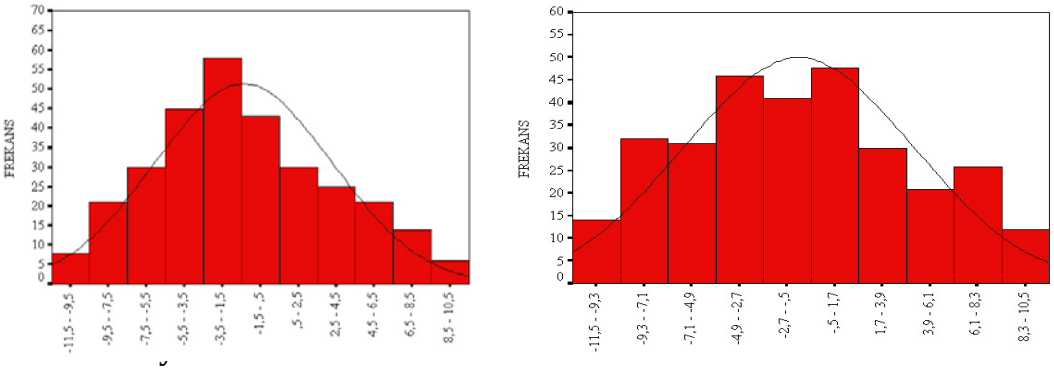
Y_G, X_G : Point coordinates by RTK- GPS

The results of the comparison are given in Table 1 (Mutluoglu, 2004).

Table 1. Comparison of the results of the classical method and RTK- GPS

Method	Mean square errors		
RTK- GPS	m_y(cm)	m_x(cm)	m_p(cm)
	±4.9	±5.4	±7.2

Histogram belongs to coordinate differences in X and Y directions are given in Figure4



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Cost analyses of the methods were done by taking care of measurement hardware (rent), measurement duration and personal expenditure for application.

Table 2. Cost analysis of classical method

Processes	**Unit**	**Cost($)**
Point plant measurements and calculations	28 items	752.57
Detail measurement		
Hardware (rent)	20 hours	169.90
Personel expenditures	5 person	621.16
Auto (rent)	10 hours	37.50
Other expenditures		336.08
Total		1917.21
Unit cost (1 ha)		95.86$/ha

Table 3. Cost analysis of RTK-GPS method

Processes	**Unit**	**Cost($)**
GPS (rent)	3 hours	123.07
Personel expenditures	5 person	140.62
Auto (rent)	3 hours	11.25
Other expenditures		68.89
Total		344.45
Unit cost (1 ha)		17.22$/ha

5. CONCLUSION AND SUGGESTION

At the implementation part of the GIS, the data collection is one of the important stages and requires highest time duration and cost between stages. In this study accuracy and cost analysis of the positional data by electronic tachometer and RTK- GPS methods were done. Positional data by RTK-GPS with mean square error of ± 7.2 cm.
The cost of the data obtained from unit (1 ha) field by RTK- GPS method is (17.22 $/ha (USA). When the cost of the data obtained from unit(1 ha) field by polar intake method considered (99.77 $/ha) RTK- GPS measurement method can be thought as an alternative to the polar intake method.

When the accuracy and cost values by RTK--GPS, it can be seen that RTK- GPS method can be used in the Geographical Information System works which need high accuracy.
But, this method offers better results in measurements in open field because of its known inconveniences. In the region with tree densities or residential, since satellite signals are interrupted no efficient results can be got. So that, in residential place and coppice, detail measurements must be supported with other classical methods.

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BIOGRAPHICAL NOTES

Dr. Ayhan CEYLAN is an assistant Professor at Selcuk University in Turkey. He has been academic staff at the university since 1987. His research interests focus on high precision surveying techniques, surveying applications, high precision levelling, mine surveying applications, and height determining techniques.

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