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Planmetric Mapping Using Hand-held GPS

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***Abstract– Cartography* is the art and science of making maps. Until the 1960s, maps were made the time-honored, traditional way: Draw an original map by hand, based on land survey measurements and other information. Print as many copies as you need. That change with the advent of computers, satellite imagery, and Global Positioning System (GPS), made making maps much easier. Most paper maps now are generated or produced on a computer. Now a day, GPS become one of the important tools of map data collection. It preserves time, reduces cost, provides reliable accuracy, digital data transferring and manipulation, more over data can be collected at any time. Survey GPS receiver provides high accuracy compared with hand-held one. At the same time, the later is the much cheaper and is usually used for navigation purposes. This research work is oriented to practically evaluate the field horizontal accuracy that can be obtained using the hand held GPS receiver. Results obtained, showed that the hand held GPS receiver can practically provides horizontal accuracy of about 4m. This result leads to the suitability of using it for collecting data to produce planimetric maps at scale 1:7,500 and smaller.**

***Index Terms*– GPS Receiver, Digital Map, Topographic Map and Planimetric Map**

I. INTRODUCTION

THE history of surveying is a story of changing technology and methods. Throughout the years, the emergence of a new technology was quickly followed by innovation in the way surveyors made their measurements. There has been a pronounced shift in technology, beginning with manual methods, and progressing in tern through magnetic, mechanical, optical, electronical and digital technologies [9].

Now a day, GPS, total station, smart station and laser scan etc. represent quick modern technology of land survey data collection.

II. MAPPING

Maps are visual expression of portion of the earth's surface. Features are depicted using various combinations of points, lines and standard symbols. Maps have traditionally been produced in graphic, or "hard-copy", form that is printed on paper pr sable-based plastic material. Today, however, most mapping data is collected in digital form, and is then processed using Computer Aided Design and Drafting and Design (CADD) systems to develop "softcopy" maps. Softcopy maps are stored within a computer, can be analyzed, modified, enlarged or reduced in scale, and have their contour intervals changed while being viewed on the monitors of CADD systems. Different types of "layers" of information can also be extracted from digital maps to be represented and analyzed separately, and softcopy maps can be instantaneously transferred to other offices or remote locations electronically. Of course they can also be printed in hardcopy form if desired. Softcopy maps are indispensable in the development and operation of modern Geographic Information Systems (GISs) [9].

III. TOPOGRAPGIC AND PLANIMETRIC MAPS

Topographic maps show natural land features such as lakes, rivers, and mountain peaks as well as man-made features such as roads, railroad tracks, and canals. These maps also have contour lines that trace the outline of the terrain and show elevation. *Contour lines* suggest what the land looks like in three dimensions.

Planimetric maps don't provide much information about the terrain. Lakes, rivers, and mountain pass elevations may be shown, but there isn't any detailed land information. A classic example of a planimetric map is *a state highway map or a road atlas*. Planimetric maps are perfect in cities or on highways, but they're not suited for backcountry use [7].

IV. MAPPING SCALES

In nearly all cases, a census cartographic program will have to consult existing hard-copy maps for the production of a digital cartographic database or for updating an existing GIS database. The census geography staff need to obtain all up-to-date maps for the country's territory, including the following types of maps.

- National overview maps, usually at scales between 1:250,000 and 1:5,000,000, depending on the size of the country. These maps should show major civil divisions, the location of urban areas, and major physical features such as important roads, rivers, lakes, elevation, and special points of reference. These maps are used for planning purposes;

- Topographic maps at large and medium cartographic scales. The availability of maps at these scales will vary by country. While some countries have complete coverage at 1:25,000 or 1:50,000, the largest complete map series in others is only 1:100,000 or 1:250,000 scale;
- Town and city maps at large cartographic scales
- Maps of administrative units at all levels of civil division; showing roads, city blocks, parks and so on;
- Thematic maps showing population distribution for previous census dates, or any features that may be useful for census mapping.

V. MAP ACCURACY

One of the golden rules in mapping process before starting to make field observation is to estimate the accuracy required according to map scale. Then selecting the suitable instruments according to map accuracy specifications. Table 1 shows horizontal map accuracy according to national specifications of Sudan survey authority.

Table 1. Map Accuracy Specifications

Map Scale	Horizontal Accuracy RMSE (m)*
1:50	0.0125
1:100	0.025
1:200	0.050
1:250	0.063
1:500	0.125
1:1,000	0.25
1:2,000	0.50
1:2,500	0.625
1:5,000	1.25
1:10,000	2.50
1:25,000	6.25
1:50,000	12.25
1:100,000	25
1:250,000	62.5
1:500,000	125.0
1:1,000,000	250.0
1:4,000,000	1200.0

* Root Mean Square Error

VI. GLOBAL POSITIONING SYSTEM

American scientists figured out that if they knew the satellite's precise orbital position, they could accurately locate their exact position on Earth by listening to the pinging sounds and measuring the satellite's radio signal Doppler shift. Satellites offered some possibilities for navigation and positioning system, and the U.S. Department of Defense (DoD) explored the concept. This evolved into the NAVSTAR (Navigation Satellite Timing and Ranging) Global Positioning System, which is the official name for the United States' GPS program [2].

The first satellite to support the development and testing of the system was placed in orbit in 1978 and fully operated in December 1993.

The global positioning system can be arbitrarily broken into three parts; space segment, control segment, and user segment.

i. The space segment: Consists of 24 satellites operating in 6 orbital planes spaced at 60˚ interval around the equator. Four additional satellites are held in reserve as spares. The satellites travel in near-circular orbits that have a mean altitude of 20,200km above the earth and an orbital period of 12 sidereal hours. Precise atomic clocks are used in the GPS satellites to control the timing of the signal they transmit.

ii. The control segment: Consists of five monitoring ground stations at which the signals from the satellites are monitored and their orbits tracked. The tracking information is relayed to the master control station in Colorado Springs. The master control station uses this data to make precise near future predictions of the satellite orbits, and their clock correction parameters.

iii. The user segment: Consists of two categories receivers that are classified by their access to two services that the system provides; The Standard Positioning Service (SPS): Provided on the L1 broadcast frequency at no cost to the user. The Precise Positioning Service (PPS): is broadcast on both L1 and L2 and is only available to receivers having valid cryptographic keys.

VII. THE GPS SIGNALS

The GPS satellites continually broadcast a unique signal on two carrier frequencies on a number of different frequencies. But instead of having only one message on one frequency, a number of different messages can be carried on one frequency at the same time.

The carriers, which are transmitted in the L band of microwave radio frequencies, are identified as the L_1 signal with frequency of 1575.42MHz and the L_2 signal at frequency of 1227.60MHz. The L_1 band has frequency of $154 \times f_0$, and L_2 band has a frequency of $120 \times f_0$.

In order for receiver to determine the ground position of the station they occupy. It was necessary to devise a system for accurate measurement of signal travel time from satellite to receiver. This was accomplished with modulating the carrier with *Pseudo Random noise* (PRN) code.

Each satellite transmits two different PRN codes. These are: (i) Coarse/Acquisition code or (C/A) code has a frequency of 1.023MHz and a wavelength of 300m. It is accessible to all users. (ii) Precise code or P code has a frequency of 10.23MHz and a wavelength of 30m can only be read with receivers that have the proper cryptographic keys. The L_1 signal is modulated with P-code and C/A code, while L_2 is modulated only with P-code.

Navigation message is carried by both L_1 and L_2 frequencies and basically carry information about satellite position and its working status (healthy).

VIII. FUNDAMENTALS OF GPS POSITIONING

GPS receiver compute distances to four satellites and fixes a position by trilatration. Two fundamental methods are employed by the GPS receivers to determine distances to satellites: *code range* and *carrier phase-shift* measurements.

- *Code ranging:* The distance (*R*) (known as a *Pseudo Range*): is simply determined by multiplying the speed of light (*c*) by the time (*t*), ($R=c\ X\ t$). From the travel time, and the known signal velocity, the distance to the satellite can be computed.
- *Carrier phase-shift measurements:* Better accuracy in measuring rang to satellites can be obtained by observing phase shift in GPS signals. In this approach, the phase shift in the signal that occurs from the instant it is transmitted by the satellite, until it received at the ground station, is observed. This procedure yields the fractional cycle of the signal from satellite to receiver. However, it doesn't account for the number of full wavelengths or cycles that occurred as the signal traveled between the satellite and the receiver. This number is called the *integer ambiguity* (*N*) or simply *ambiguity*.

The total distance can be computed by the summation of the phase measurement, initial ambiguity at first observation, and number of full cycles counted by receiver [9].

IX. ERRORS IN GPS OBSERVATIONS

GPS electromagnetic waves can be affected by several sources of error during their transmission. These errors may include:

i. Satellite and receiver clock biases,
ii. Ionospheric and tropospheric refraction,
iii. Satellite ephemeris errors (orbit errors),
iv. Multipathing,
v. Instrument miscentring,
vi. Antenna height measurements,
vii. Satellite geometry, (Dilution of Precision DOPs) and
viii. Selective availability (before May 2000).

X. GPS RECEIVERS

GPS receivers rang in precision and capabilities. Geodetic or survey receivers provide high accuracy and have numerous capabilities of mapping. Navigation and geographic information system (GIS) receivers produce lower accuracy and have limited capabilities.

The major differences in the receivers are the number of channels available (in other words, the number of satellites that can be tacked at one time) and whether or not the receiver can observe both L1 and L2 frequencies; code phase and carrier phase may also be measured. Generally speaking, dual frequency receivers require much shorter observation times for positioning measurements than do the single- frequency receivers and can be used for real-time positioning. Some low-end, general-purpose GPS receivers track only one channel at a time (sequencing from satellite to satellite as tracking progresses); an improved low-end, general- purpose receiver tracks on two channels but still must sequence the tracking to other satellites to achieve positioning. Some low-end surveying receivers can continually observe on five channels (sequencing is not require), whereas some-end surveying receivers can observe on twenty channels. Some receivers can log data every 15 second-controlling photogrammetric camera operation- while other geodetic-quality receivers can log data every second [8].

XI. MEASUREMNTS AND RSULTS

This research work is oriented to estimate the field accuracy that can be obtained using hand held GPS receiver. Accordingly, evaluating its suitability to meet a particular mapping scales.

Number of 16 well distributed points were selected first in Khartoum state (Sudan). Field observations were carried out using Trimple500 geodetic GPS receives applying real time kinametic (RTK) observation technique. These points are observed on World Geodetic System (WGS1984) reference system and projected on Universal Transverse Marketer System (UTM).

The same points were then observed using Garmin eTrex hand held GPS receiver on the same reference. Results of the two sets of field observations are rounded and listed in Table 2.

In order to estimate the error in the hand held GPS receiver, geodetic GPS receiver observations were assumed to be correct. Differences between the two sets of the observed coordinates are computed in both easting (E) and northing (N) for each point as listed in Table 3.

Table 2. Observed Coordinates

Point	Observed Coordinates (m)			
	Hand held GPS		Geodetic GPS	
	E	N	E	N
1	452806	1723177	452806	1723182
2	449054	1721064	449055	1721065
3	452145	1720245	452143	1720242
4	451159	1719712	451158	1719713
5	449552	1721841	449555	1721839
6	450728	1721448	450733	1721449
7	449810	1719957	449811	1719955
8	450030	1720962	450032	1720961
9	451510	1722396	451510	1722399
10	451262	1723539	451265	1723544
11	448945	1722849	448949	1722851
12	450539	1723091	450537	1723087
13	453211	1720494	453214	1720498
14	451013	1721033	451015	1721030
15	452832	1721758	452837	1721762
16	449943	1719281	449944	1719281

Table 3. Differences between the two sets of observed coordinates

Point	Differences (Errors) m	
	E	N
1	0	-5
2	-1	-1
3	2	3
4	1	-1
5	-3	2
6	-5	-1
7	-1	2
8	-2	1
9	0	-3
10	-3	-5
11	-4	-2
12	2	4
13	-3	-4
14	-2	3
15	-5	-4
16	-1	0

By analyzing results obtained in Table 3 using simple statistical values, it can be extracted that:

- Errors in easting varied between 2m and -5 m with -1.56m average. On the other hand errors in northing varied between 4 m and -5 m with average of -0.69m.
- The root mean square errors in both easting and northing were found to be 2.65m and 2.98m respectively.
- The linear accuracy of the hand held GPS receiver was computed to be 3.98m ≈ 4m. Table 4 demonstrates statistical analysis of the results obtained.

Table 4. Analysis of the results

Statistics	Differences (m)	
	E	N
Maximum	2	4
Minimum	-5	-5
Average	-1.56	-0.69
RMSE (m)	2.65	2.98
Linear Accuracy (m)	3.98 ≈ 4	

XII. CONCLUSION

This research work is directed to evaluate the suitability of using the hand held GPS receiver - Navigator GPS - to collect planinetric data to meet a particular mapping scale. Garmin eTeix hand held GPS receiver was subject to this study. From the result obtained above, and by referring to the map Accuracy specifications, it can be concluded with the following:

- The planimetric accuracy of the hand held GPS receiver was found to be 4m.
- Planimetric maps at scale 1:7,500 and smaller can be produced utilizing these data collected by the hand held GPS receiver.
- Hand held GPS receivers can successfully be used for collecting data for mapping in different fields including national, and town maps.
- Moreover, Ground control points for adjusting satellite images of 5m resolution and less, can be established using hand held GPS receivers.

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