Identification of Feature Details in Land Extents Using Handheld GPS

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Abstract: Handheld GPS equipment are becoming affordable and vendors are presently loading them with additional features such as easy data capture, data transfer, easy tracking and analysing capabilities.

In order to ascertain the mapping capability using handheld GPS, a case study application was carried out mapping a known land extent and its features using several handheld GPS units of the same make and having same parameters.

The mapping exercise was carried out by trained GPS operator groups who surveyed the same area approximately at the same time.

GPS survey data were plotted on the served map of the project area which is a land extent of 6.6km² close to Homagama. Surveys were carried out measurements with varying spatial resolutions. Survey results indicate the issues faced by the GPS operators when maps were prepared with measured data. Results and discussion attempts to enlighten GPS users of the limitations pertaining to mapping and also the accuracies of the present paper associated. The survey used Garmin GPS 12 and Magellan 600 handheld units.

Results and accuracies of two or more units when operated parallelly are discussed in this paper. Common problems such as signal coverage in the open and under canopy, plotting capability of smaller features to an acceptable level are also discussed.

This work was limited to the measurements made in the horizontal direction and therefore no attempts were made to measure elevations.

Keywords: Land Feature Mapping, Handheld GPS, Horizontal Accuracy

1.0 Introduction

In the modern world, identification of land feature details has become more important than in the past. This has reached a high level of importance due to the advances in faster travel options; breakthroughs in telecommunication developments in data transmission over wired and wireless means etc. Feature data such as buildings, water bodies, forests, locations of tourist significance and sites which are environmentally sensitive, business centers, office locations, roads etc; are some of the land features that require identification. Requirements of feature identifications vary based on a variety of importance such as planning, design, detailed computation, management, knowledge etc. Therefore, the need to know a land feature is always linked to the identification of location and its feature attributes. In a rapidly advancing world, the

location requirements would be to identify with reference to a Global Referencing System. [1]

Fulfilment of above requirements of identifying a location can be done using many methods. Conventional surveying, satellite images, aerial photography or paper map approximations, navigational satellite systems are some of them. Global Positioning Systems (GPS) incorporate a cluster of satellites to identify the position of given feature with reference to a global referencing system. In order to identify a location using GPS, a user requires to position

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the GPS equipment at the target feature. GPS systems ranging from precise RTK (Real-Time Kinematic) to handheld, provide location coordinates with varying degrees of accuracy. The RTK-GPS provide highly accurate data comparable to Total Stations.

The differential GPS accuracies are reported as centimetre level [3]. The handheld GPS receivers have been reported as quite accurate with horizontal accuracies ranging from sub meters, a few meters, to many tens of meters but not as accurate as RTK. [4] Using four low cost handheld GPS indicated that there were significant differences in accuracy and precision in measuring coordinates. Manufacturer reporting accuracies and the rapidly decreasing prices of handheld GPS units have made them very attractive for most people to use them for position identifications. Today's handheld GPS are filled with many features such as easy data capture, data transfer, increased storage, easy tracking, capturing locational attributes in text or photographic image etc;[2]. The accuracy of GPS measurements depend on many factors such as availability of satellites, canopy, waiting time, atmospheric conditions etc, [5,6]. Data logging GPS units weighing as little as 24g are possible because of spare processing power and memory within today's GPS engine modules. GPS speed calculations have been indicated as about 10 times faster than a car odometer [8].

In this backdrop it is necessary for GPS users to understand the accuracies that are to be

expected when carrying out field data collection using GPS. With the Handheld GPS becoming affordable, there is a greater likelihood that the users would be with minimum knowledge and may not be well conversant even to correctly carry out GPS parameter settings. Therefore, it is important to identify the results and issues when collecting GPS feature data under such circumstances.

Present work carried out a Handheld GPS field survey with 5 teams of GPS users who had a brief exposure to what is a GPS, how it works, how to incorporate appropriate settings and how to carry out recording of field data. Each group was used to collect field data pertaining to a common spatial extent. The work was carried out with the use of two types of receivers namely Garmin 12 and Magellan 600. A critical comparison of data was performed to assess the methodologies to be considered during similar field work.

2.0 Objective

Objective of the study is to identify the accuracy of handheld GPS field measurements through a repeated set of measurements made by a set of average GPS users.

3.0 Study Area

The study area located in the Western Province of Sri Lanka and approximately 21 Km South East of Colombo, between 60 50' 38" and 60 50'

Figure 1 : Study Area

49" of North Latitude and between 800 0' 47" and 800 1' 2" of East Longitudes (Figure 1). Study area is the premises of a temple called the Sri Maha Bodhi Rajaramaya near the rural town of Homagama. Study area consists of sparse vegetation and is bounded by roads and a rail road. The total land extent is an approximately 66000 square meters. The land consists of approximately 37370 m² of open area, 3430 m² of Building Area, and 25200 m² of canopy area.

Table 1: Maps Used for the Study

No	Map Description
1	1:10,000 Buildings, feature data layer
2	1 chain to an inch Survey Map
3	1:50,000 Topographic Map
4	1:10,000 Land Cover Map
5	IKonos Satellite Image of Project Area

4.0 Methodology

Two types of GPS receivers were used for field work; four Garmin GPS12 and one Magellan 600 units. Nominal position accuracy is 15m (RMS) for GPS Garmin 12 and Magellan 600 has a nominal accuracy of 7 m. The 1:10,000 scale Survey Department georeferenced map was the data layer that was used to establish the reference data layer.

The study area premises plan surveyed and plotted to the scale of one chain to an inch was also available to supplement base data [7]. 1:10,000 and 1 chain to an inch maps were georeferenced and overlayed to verify features in each map and then to digitize a base map.

Figure 2: Methodology Flow Diagram

Table 2: Setting and Unit Details

GPS Settings	
Central Latitude	70 00' 1.729"N
Central Meridian	800 46' 18.160"E
Scale Factor	0.99992384
False Northing	200,000 m
False Easting	200,000 m

Survey map details were physically checked with field measurements of length and breath of buildings and it was identified that there was a maximum difference of 2.3 m and average difference was approximately 0.1 meters. The maps used for the study are in Table 1.

GPS survey of the temple premises, its boundary and buildings were assigned to five groups. Fieldwork groups consisted of a set of personnel who had very limited exposure to formal training on GPS. Groups 1-4 carried out the feature survey using Garmin 12 units and Group 5 carried out the same survey by using both Garmin 12 and Magellan 600 units at the same time.

Details of 1 chain to an inch map were verified by carrying out tape measurements of the buildings. Overall flow of the study is shown in Figure 2. GPS Field survey was conducted over a few weeks during daytime. Field data collectors were given a general instruction to pickup details of buildings, boundaries, roads and other important features pertaining to the temple premises. GPS settings used for the study are in Table 2. Data collected by the groups were entered into a GIS Database.

The present work consisted of carrying out measurements of Northings and Eastings. Therefore, the accuracy reported in this work consists of the accuracy in Northings, Easting and hence in the horizontal direction only. Accuracy value is the deviation of a measurement with reference to the base map. The accuracy definitions were taken similar to the work of [4, 8]. Horizontal accuracy was calculated as the resultant of the accuracies in the Northings and Eastings.

$$\sigma_{H}^j = \sqrt{(N_{\text{obs}}^j - N_{\text{bm}}^j)^2 + (E_{\text{obs}}^j - E_{\text{bm}}^j)^2}$$

Where σ_{H}^j is the Horizontal accuracy pertaining to the i^{th} group, N_{bm} and E_{bm} are northings and

Figure 3 : Field Measurement Mapping of Six sets of Records

Figure 4 : Average Horizontal Accuracy

Figure 7 : Positional Accuracy of Each Equipment

Figure 5 : Positional Accuracy of Each Observation

Figure 6 : Reliability of Horizontal Accuracy

Eastings measured from the base map (bm), N_{obl} and E_{obl} are the Northings and Eastings that were observed (ob) by the i th fieldwork group. j denotes a particular point under consideration. Similarly average horizontal accuracy was computed by simple averaging the measurements taken by each group. In this work positional accuracy refers to accuracy either in the Northings (σ_N) or in the Eastings (σ_E).

5.0 Results

Field measurements of five groups were plotted on base map to view and compare the features in the study area. Field measurements were compared for the positional accuracy of capturing point information both as individual groups and also as average of the sets of data from five groups. Figure 3 shows the maps prepared with the six sets of field data collected by the five groups, indicating the deviations from one another. In this study though each group had collected over 111 data points, only

40 points with reference to clearly identifiable base map points were taken for accuracy comparison shown in Figure 4. Figure 5 shows the clustering in the plot of Northings and Easting accuracies pertaining to each observation.

The entire set of data were plotted to identify the horizontal accuracy variation with percentage of the number of times the measurements were taken (Figure 6). It was noted that the horizontal accuracy was less than 14 meters for 80% of the time whereas for 90 % of the time the error was less than 20 meters. The Horizontal accuracy was less than 34 meters for the entire set of readings. The accuracy range in the Northings and Eastings when compared with the base map indicated that the Northings accuracy was between -23 and +34 meters, whereas the Eastings accuracy was between -16 and +34 meters. The points measured by Garmin 12 and Magellan 600 were plotted (Figure 7) to assess the and (Table 3)

The points that were representing building outline and perimeter of the premises were plotted and the centroids of each polygon drawn by individual groups were computed. Centroid computation done for the base map polygons was compared with group measurements. Figure 8 shows the horizontal accuracy of the centroid when compared with the polygon area. The centroid accuracy for majority of data were in though there were several instances the value reached +20 m and -50m respectively, including a significant change in the field measurement when compared with the base map Polygon areas were computed for the existing buildings and also for several moderate type polygons which were created by identifying the measurements and the survey plan coordinates. The polygon area comparison is shown in Figure 9. Percentage Accuracy is the percentage accuracy of either the measured area

Table 3: Comparison of Observation Accuracy

	Records	Observed Maximum Limits				
		σ_N (meter)		a_E (meter)		(σ_H) (meter)
		-ve	+ve	-ve	+ve	
All Records	204	-23	34	-16	34	34
Garmin 12	164	-23	34	-16	31	34
Magellan 600	40	-22	19	-14	19	26
Average	136	-23	29	-15	28	31

Figure 9: Accuracy Comparison of Polygon Area

or measured perimeter compared with the base map area or perimeter. Polygon area comparison for each group shows an accuracy range varying from -78 % to 109% with group average values showing a variation between +62% and -73%.

For the same polygons perimeter computation accuracy was carried out (Figure 10). Polygon perimeter comparisons show an accuracy variation between -51% and 187% for all groups where as the average values vary between -40% and 64%.

Several line segments clearly identified during perimeter measurements were compared to identify distance errors. Comparison of Garmin 12 and Magellan 600

field measurements carried out by Group 5 at the same time were compared with each other with clearly identified 105 No of segments shown in Figure 11.

Figure 10: Accuracy Comparison of Polygon Perimeter

The Garmin 12 and Magellan 600 measurements indicated an approximate accuracy variation from 2 meter up to 95 meter. The regression line showed a high correlation of the readings from both equipment with a gradient value of 0.9966 and an intercept of 0.5919 meters.

Land use of the study area was classified into

Figure 11 : Comparison of Length Accuracy

buildings, canopy and open area as shown in Figure 12. Comparisons were done for the identified observation points with respect to the canopy type observed at field and in combination with the satellite imagery. The accuracy plot of Eastings and Northings shown in Figure 13 indicate that as expected a greater accuracy could be noted in the case of no canopy, scattered canopy locations also showed a reasonable clustering of readings. The cluster group measurements were observed as shown in Table 4.

In order to identify a map developed with the GPS field measurements, average readings from all groups were taken after removing points which indicated very clear differences when compared with the other group measurements. The field data plot prepared with the averaged data set is shown in Figure 14. The field plot indicates the differences observed when measuring buildings, roads and boundaries.

Figure 12 : land Cover of Study Area

Figure 13: Accuracy of Measurements and Canopy Cover

6.0 Discussion

6.1 Field measurements from five groups indicated that there was a clear irregularity in identifying measurement points to capture feature details. As a result, out of about over 111 points taken by each group

Figure 14: Map of Averaged GPS Measurements

Table 4 : Cluster Group Observations of GPS Measurements

Canopy Classification	Variations of Clustered Observations			
	Latitude		Longitude	
	Max	Min	Max	Min
1 No canopy	1	-7	4	-4
2 Obstructing Canopy on Both Sides	4	-4	-11	-6
3 Obstructing Canopy on one Sides	6	-7	5	-8
4 Scattered Canopy	5	-4	11	-5

had to be reduced to 40 for comparison. This leads to difficulties in the averaging of the observations. Therefore, there is a clear need of an introductory training on the identification of points to capture field

information. GPS readings from all groups which were measured on random days and random daytimes showed capability of identifying the approximate order of positioning. Results indicated to the possibility of improving the plotting of collected positional data through additional field notes, sketches and pictures. There was a significant clarity of identification with respect to the measurement of regular features than with irregular boundary details such as of perimeter of ground or premises.

- 6.2 Positional accuracies from the field measurements showed that the values of Northings, Eastings and the resultant position consisted of errors that were on the high side when compared with the nominal position accuracy indicated by the manufacturers. This may be due to the number of points used for this comparison or due to the field performance of each equipment. The accuracy values of measurements indicated a clustering around the origin though a tendency to cluster in the all negative and all positive quadrants could be observed.

Centroid measurements were computed in order to identify the shift in position of a particular feature. Values computed showed the general shift only. Azimuth readings may have to be captured to find directional changes or rotations.

- 6.3 Area, Perimeter and length measurements indicated the accuracy level that could be achieved in case of capturing polygon or line features. Therefore according to study results, the accuracy of polygon area measurements become lower than 50 % on for polygons greater than 6000 m² in area. A similar observation can be made in case of the perimeter. Therefore, these could be used to assess the accuracy of features captured by the handheld GPS and make decisions on the field data collection.

- 6.4 Comparison of Garmin 12 and Magellan 600 did not show a significant difference in horizontal data capturing. This may require more field information for these results to be conclusive. However these data can be used as a guideline for future activities. As the study comparatively studied only the horizontal positioning, it may be necessary to study other features such as vertical accuracies, tracking, data storage, transfer, etc; prior to making final decisions on the type of an equipment.

- 6.5 Comparison of GPS performance recorded in relation to canopy cover and the attempts to identify notable behaviour lead to the observation that during this study, the no canopy had shown greater precision and accuracy. Scattered canopy measurements indicated a clustered data set with m accuracy through many outliers were also present. As it is important to identify the effects of canopy on the field measurements, a further study with more parameters such as weather, satellite coverage could be helpful for conclusions.

- 6.6 The field map produced with the use of averaged observations and screened for outliers showed a map with shape and locational disparities having accuracy values as indicated in the results. This provides a manager an opportunity to compare an averaged map with base data to assess the output with respect to the resource management requirements. Also the study through a set of group observations shows the deviations that could be expected during different measurement efforts. The comparison of 1:10,000 maps and 1:50,000 maps show that handheld GPS may be opted by resource managers who would find the scale of 1:50,000 as suitable for their work. However, managers with good careful assessment capabilities can capture better information from the plots to a scale of 1:10,000 along with possible ranges of sensitivity noted in the field measurements.

7.0 Conclusions

- 7.1 A comparison of field data capturing efforts by a set of average users indicated the need to provide adequate introductory training on the identification of feature details, canopy cover, regular shapes etc.
- 7.2 The accuracy of horizontal positioning that was identified during the study was 20m for 90% of the time and 14 m for 80% of the time. A 5 meter or better accuracy would be observed only for 35% of time.
- 7.3 The selection of features for detailed conclusions such as area or perimeter should be carefully carried out by understanding the accuracies that would be achieved from such measurements. This study results could be used as a guideline.

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9.0 References

- 1.0 EngineerManual- 2003,<http://www.onlinefreebooks.net/free-e-books-computer-programming-technology/geographical-technology/navstar-global-positioning-system-surveying-engineer-manual-pdf.html>, Visited, 27th July 2008.
- 2.0 GIM- International 2006-Product Survey GNSS Receivers,GIM International, October 2006.
- 3.0 Jeff Hum, Differential GPS Explained, Trimble Navigation Limited, 645, North Mary Avenue, Sunnyvale CA 94098-3642, USA 1993.
- 4.0 JoseR.Rodriguez-Perez;M.F.Alvarez;and Enoc Sanz - Ablanedo,Assessment of Low-Cost GPS Receiver Accuracy and Precision in Forest Environments,Univ.of Leon, ESTIA, Avda, Astorga s/n.24400 Ponferrada, Leon, Spain, 2007.
- 5.0 Kindra Serr;Thomas Windholz;Keith Weber, Comparing GPS Receivers:Field Study,ISU GIS Training and Research Center,Campus Box, Pocatello, Idaho 83209-8130, 2006. www.urisa.org/files/Serr.pdf
- 6.0 Ken Chamberlain,Forest Service 2003 Geospatial Conference, Colorado Springs, Colorado
- 7.0 Srimaha Bodhirajaramaya temple Plan, Pitipana, Homagama, ESR /3/88/99
- 8.0 T.H.Witte; A.M.Wilson, Accuracy of non-differential GPS for the determination of speed over ground, 2004.