A Rapid and Cost-Effective Technique for Planimetric Mapping of Small Villages in Developing Countries

Ramadan H. ABDEL-MAGUID, Yasser S. El-MANADILY, Adel H. EL-SHAZLY, Egypt

Key words: Kinematic GPS positioning, Cost Effective Solutions, Small village mapping.

SUMMARY

Land development issues in developing countries impose a great emphasis on obtaining up-to-date maps in a short period of time with minimal costs. The preparation of the required planimetric maps for small villages in affordable costs, time and scale would require proposing of smart and cost effective solutions.

This paper outlines some cost-effective techniques for preparing detailed maps of small villages in Egypt. The most appropriate cost-effective technique was selected and applied for the production of a planimetric map for a small village located in Ismalia Governorate, Egypt. The proposed technique utilizes GPS kinematic positioning where one GPS receiver was set stationary over a control station while the other rover receiver was set on the back of small van. The GPS antenna was elevated using a pole to prevent blockage of GPS satellite signals by village houses while the van was moving in the narrow streets. The GPS measurements resulted into a reasonable streets centerline data that enriched with traditional tape measurements for the street widths and mapping of building houses.

The study emphasizes on the comparison between the proposed approach and the recent affordable techniques that can be used in producing of such maps. Finally, some future ideas regarding the proposed approach gained from actual practice are suggested.

A Rapid and Cost Effective Technique for Planimetric Mapping of Small Villages in Developing Countries

Ramadan H. ABDEL-MAGUID, Yasser S. El-MANADILY, Adel H. EL-SHAZLY, Egypt

1. INTRODUCTION

Land development issues emphasis the need for up to date large-scale planimetric maps. Such maps are very costly and time consuming that would require few years to be completed within the national mapping requirements.
There are many mapping specification for many countries. These specifications are for general requirements for the outcomes of the mapping process regardless of the used technique. For each specific technique, detailed guidelines are required to ensure the suitability of that technique to fulfill the required specifications (Shnurr, 2004).
For producing planimetric maps in the range of scales between 1:1,000 and 1:10,000, numerous techniques can be used. These techniques include traditional photogrammetry, satellite photogrammetry and terrestrial surveying using total station instruments.
The map scale is obviously the principle key in choosing the appropriate technology to be used. Moreover, the ground resolution of the adopted technology is becoming more important in the era of information age. The target map scale of the digital map product should be defined clearly where zooming and re-plotting functions may be encountered. Typical mapping scales and the ground resolution with their typical applications are outlined in Table (1-1).
Mapping of residential rural areas in Egypt is very difficult and it is a complicated task due to irregular pattern of street blocks. Implementing Geographic Information Systems (GIS), which optimally performs the planning, development, and management of such areas have to be based on reliable and recent geo data that needs very efficient and cost-effective surveying and mapping technique.
This paper summarizes various methods used for mapping of small villages in Egypt and concentrates on the most-suitable surveying technology that can be proposed to reach the required objectives with reasonable consumed time, money and effort.

Table (1-1) Large-scale mapping and the ground resolution (after Schnurr, 2004)

Mapping Scale	Ground Resolution*	Typical applications
1 : 1000	0.2m	Urban cadastre, detailed engineering design
1 : 2000	0.4m	Rural cadastral and boundary demarcation
1 : 5000	1m	Town planning

*Based on 0.2mm pen thickness

2. REVIEW OF SURVEYING TECHNIQUES

2.1 Field Surveying Using Total Station

Field surveying technique using total station is always adopted as a traditional method for planimetric and topographic mapping of urban and rural areas. Sometimes, this technique is utilized as a complementary method to support the common photogrammetry technique for filed compilation.

For the case of mapping of a small village that is addressed here, or the case of mapping of many scattered villages, total station technique could be used by itself as a stand alone technique. Whoever, project specifications defined by local authority for such villages are tending to tie such surveys into country mapping system using GPS technique. Hence two or more control stations must be established within the required mapping area and then field surveying using total station connecting the control stations is performed.

Such terrestrial surveying technique requires doing field works using a large number of traverse points through the irregular narrowed streets. Thus the required field surveys using such technique would be a very time consuming method. For the area shown below in figure (2.1), the area is about 100 Feddan. The main mapping activities of this area would require several days (about 5 days) to collect the data by the field crew (the crew consists of one surveyor and two prism-men). In addition, GPS control surveys required to tie the area to the national mapping system will require one-day crew (crew consists of two surveyors). The previous discussion shows that the method is a time consuming resulting into a search for another cost-effective technique to be adopted.

Figure (2.1) Case study area (Adam village, Ismalia Governorate, Egypt)

2.2 Aerial Photogrammetric and Satellite Photogrammetric Techniques

The photogrammetric based technique is the common method to produce cadastral maps for large areas. The Egyptian American project started at 1989, suggested to use GPS and photogrammetry with the aid of terrestrial total station at that time (Nassif , 2002). However the photogrammetric based solutions was recommended to be used for planning of large new areas. This technique is well defined and known that it would take a lot of time and cost utill plotting of the final maps.

Satellite photogrammetric mapping procedure is similar to photogrammetric mapping procedure in some extent but with no need for flight mission, photo laboratory processes, scanning as well as it requires less ground works (Sahin et el, 2004). Mapping using satellite images and photogrammetric procedures requires performing ground control surveys with the signalization protocol.

In terms of time and coverage, high resolution satellite image cover approximately 100 km2 on the ground. This area requires 30 photographs (aerial images) of scale 1:16,000. There are extreme difference in processing 30 aerial photographs and one satellite image. In the same time, the satellite image can be delivered very fast (two weeks after ordering) when compared to aerial photographs production process that might take 4-6 months in Egypt (Sahin et el, 2004).

The airborne methods, when compared to the adopted methods for planimetric mapping in developing countries, is usually cheaper than that based on aerial photos. However the information content of the satellite images would produce topographic maps up to scale in the range of 1:6,000 to 1:10,000 (Gianinetto et al, 2004). Table (2.1) shown below is depicted from previous research that review the effective methods based on digital imagery technique (Schnurr, 2004). The photograph size used in the table is the standard size (9x9 inch film and 6 inch lens).

Table (2-1) Types of imagery sources for large-scale mapping

Platform	Imagery/system	Resolution	Imagery control method	Typical Mapping
Satellite	IKONOS Quick bird	1.0m 0.7m	"Level 3" GPS "Level 3" GPS	1: 6,000 -1:10,000 1: 5,000 - 1: 6,000
Fixed wing aircraft	1:12,000 VAP 1:3,000 VAP	0.25m 0.06m	"Level 4" GPS "Level 4" GPS	1: 5,000 1: 1,000

Table Key: VAP: Vertical Aerial Photography (typically scanned at 20 um)
Resolution: The ground pixel size
"Level 3" GPS: carrier smoothed differential code GPS (0.4-0.8m)
"Level 4" GPS: Double differenced carrier phase GPS (0.01-0.06m)

The cost of the mapping process of villages in rural areas using high-resolution imagery is relatively high when compared with GPS based solutions. This due to many reasons such as: the need for GPS technique for control measurements, the need for field visit to delineate the separated house blocks that may be obscured due to satellite orientation, the need of additional field works for performing the level works and the high costs of the high resolution imagery especially if such images is not on the archive, and the limited area of the small villages that can not be suitable for a flight mission and can not be purchased as a sub-satellite image which leads to purchasing very un-used large image area that increases the cost dramatically. In addition of all reasons mentioned above for using GPS based solutions in front of imagery based solutions, the requirements for large scale mapping specifications (1:2,500 for current case study) can not be reached at the current time using high resolution satellite imagery technique. Therefore, the ground based technologies is recommended to be used in residential areas while image-based technique is suitable for large rural open areas (Lor and Onkalo, 2004). Also, the wide need for the GIS date is recently collected using ground based technologies due to its production nature and it's suitability to capture complex geography (Ackroyd and Dewfield, 2003). Therefore GPS-based solution is proposed to be used as being discussed in the following sections.

2.3 The proposed Technique – Kinematic GPS and Linear Measurements

In this paper, the GPS kinematic positioning technique was suggested to collect streets centerline data. Different factors were kept in mind while adopting such technique. First, the available GPS receivers and their capability to perform precise kinematic survey were to be justified. Second, the time permitted to finalize the project was addressed. Third, the required map scale and consequently the allowable accuracy required for the map was evaluated. The proposed technique depends on using two GPS receivers. It is preferred to be dual frequency receivers for fast initialization and precise positioning in partially obstructed area. The rover receiver was set on small van with its antenna held elevated by 3 m pole. Such installation was used to avoid most of satellite signal obstruction, thus reduce the possibility to encounter loss of lock on satellite signals. The van deriver was requested to try to keep GPS antenna along centerline of village streets as possible. Additional linear measurements were required for street widths to complete the required planimetric mapping as well as for separating building houses.

The time required to fix GPS carrier phase ambiguities is very essential in performing kinematic GPS surveys in such residential rural area. Kinematic GPS surveys may require observations ranges from one epoch solution to several minutes of observations based on baseline length, multipath effects, environmental effects as well as signal obstruction status. The initialization time for ideal RTK condition, where no obstructions and minimal multipath environment occurs, using Trimble 4700 GPS RTK receiver was about 50 seconds (Gibbings et al, 2001). Longer period of time may be required when using Timble 4000SST receivers that are used in this study, due to it's of older version and the encountered multipath environment.

3. EXPERIMENTAL SETUP

The case-study area shown above in figure (2.1) is a small village named "Adam" village located at Ismalia Governorate. The main characteristics of the area that reflects typical characteristics of many other villages in the country are:

- The area is flat, plain and margined by farms
- There are very dense continuous house blocks with narrow streets widths

The proposed planimetric map of the area was 1:2,500. Terrestrial surveys using total station was undertaken in the main road of the area and in some intersected street portions by collecting the data among the GPS control stations. The total station survey works held for one day.

The GPS technology was used for two different purposes, i.e. acquiring of ground control stations and collecting of centerline data of the village streets. The control survey was undertaken using traditional GPS static technique. The measurements were then adjusted and the accuracy of final results for the control points is less than 1 cm. The kinematic GPS measurements were undertaken using two receivers, one stationary and set on one of the control stations while the other receiver is moved along the street centerlines using a small van. The rover receiver antenna was elevated using a 3 m pole height to overcome satellite signal blockage due to the height of the village houses. The data storage problem was overcome by undertaken the kinematic survey for two one-hour missions. Loss of lock problem was the major challenge to be overcome. The authors prepared well-defined procedure to minimize such problem. The survey was undertaken in the natural manner while noticing the number of satellites tracked. When the number of satellites dropped below four, the van was stopped at any nearest location that has relatively open satellite view. This procedure insures fixing the loss of look problem at many locations directly in the field. Fixed solution was obtained in most of the GPS survey process that ensures results in the centimeter-level is obtained at the case-study area. Figure (3.1) below represents the kinematic GPS results with enlarged portions shown in the right frame.

4. ACCURACY OF THE PROPOSED TECHNIQUE

The kinematic GPS positioning technique is based on-the-fly solution. The precision estimate of such technique was evaluated by occupying many locations for certain period of time and it was found to be about ± 2cm.

The main source of error for GPS kinematic survey results of street centerlines comes from imprecise navigation of the van along the centerlines. Accordingly, the observations recorded by total station instrument were used to define the exact locations of street centerlines at selected locations. The comparison between the GPS kinematic navigation and total station techniques for selected street centerlines locations is shown below in Table (4.1). The discrepancies between the two techniques were ranging between 0.0 and 0.41 m with a mean of about ± 16 cm.

5. CONCLUSIONS

The research reviews the current specifications requirements and outlines the utilized methods for mapping process of residential rural areas. These methods are reviewed in accordance with the local circumstances that be encountered in rural area environments in Egypt with the emphasis on dealings with many small mapping sites that are kilometers apart.

The privileges gained from each method are discussed and compared with the current case study. These comparisons lead us to the importance of using GPS technique to be the key used technology in the mapping of such areas. Also, fully utilization of GPS technique by using it as a control unit, to gather the control stations coordinates, and a data collection unit, to gather the street centerline data, is reached.

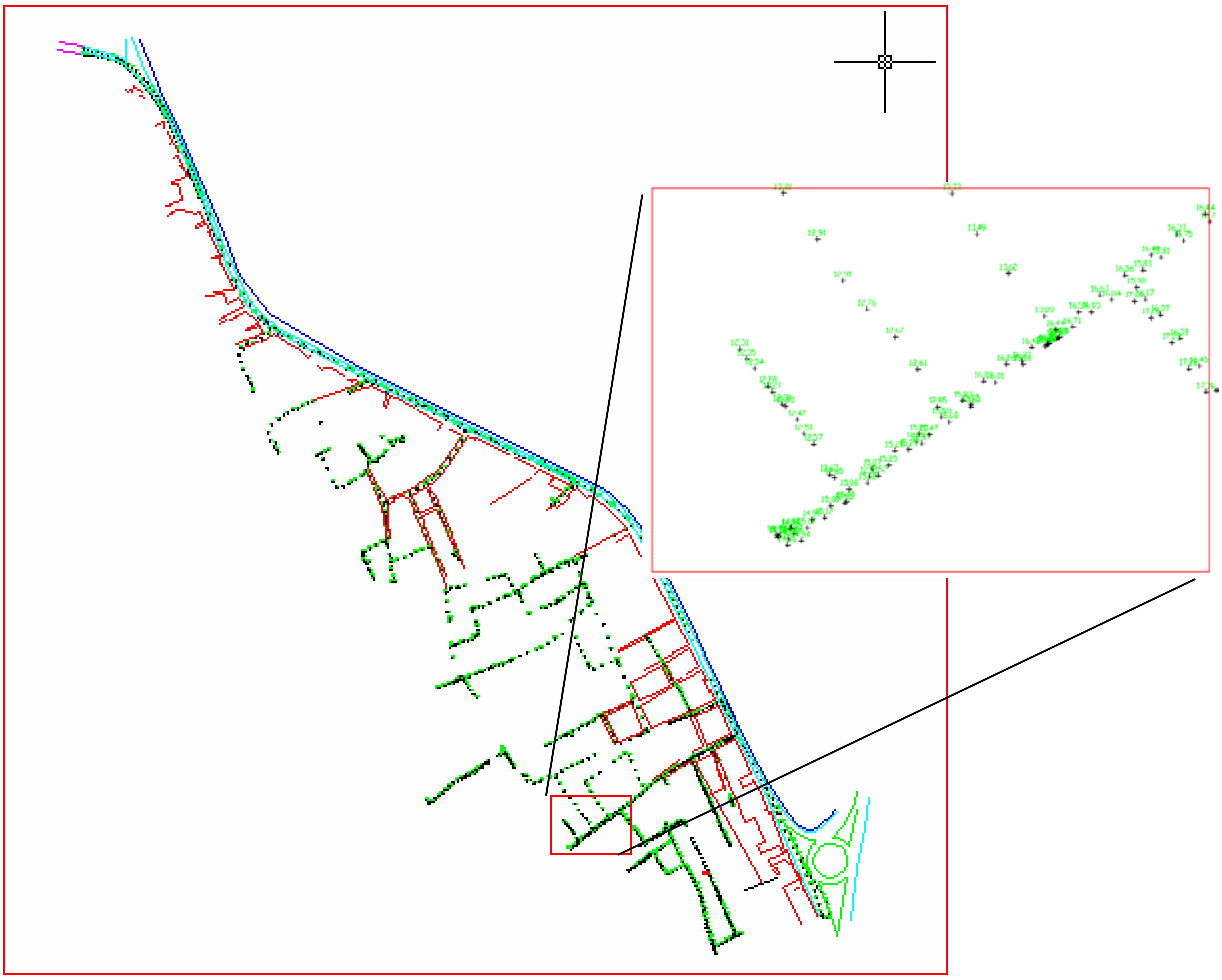

Figure (3.1) kinematic GPS survey results with enlarged portions

Table (4.1) Comparison of GPS kinematic surveys and total station results for selected street centerline locations.

Location ID	Error (m)	Location ID	Error (m)	Location ID	Error (m)
1	0	8	-0.04	15	0
2	0.17	9	0	16	-0.07
3	-0.28	10	0.07	17	-0.15
4	-0.18	12	0.41	18	-0.21
5	-0.05	12	0.19	19	0.11
6	0.06	13	0.26	20	0.2
7	0.12	14	0.09	21	0

The proposed methodology illustrates the high quality for gathering kinematic GPS data while reasonable precision (about ± 16 cm) is acquired for street centerline data measurements after detecting most of anomalous data. The adopted methodology is very important as cadastral surveys in rural open areas are currently gathered using RTK.
As expected, many problems were encountered in obstructed areas when using kinematic GPS surveys. Some of those problems were resolved using well-defined field procedure.
Interactive software modules that rely On The Fly solution are now available on the next to assess the GPS solution and provide feedback about the gained precision at different locations.
The proposed technique can be also used for producing dynamic maps and GIS database by connecting the GPS for producing the spatial database component and attach the attribute data to build the final comprehensive GIS database.

REFERENCES

Ackroyd, N. and Dewfield, N., 2003, "The Application of Real-Time GPS for National Large Scale Detail Capture", Cambridge Conference, paper 5D.3, Ordnance Survey, UK.

Gianinetto, M.; Giussani, A; and Lechi, G.M. and Scaioni, M., 2004, " "Fast Mapping" from High Resolution Satellite Images: A Sustainable Approach to Provide Maps for Developing Countries", XXth ISPRS Congress, Commission 6, 12-23 July, Istanbul, Turkey.

Gibbings, P.; Manuel, B.; Penington, R. and McDougall, K., 2001, "Assessing the Accuracy and Integrity of RTK GPS Beneath High Voltage Power Lines", A Spatial Odyssey : 42 nd Australian Surveyors Congress

Lor, D. and Onkalo, P., 2004, "Community Participation Supporting Cost Effective Surveying Methods", 3rd FIG Regional Conference, Jakarta, Indonesia, October 3-7.

Nassif, E. N., 2002, "A Radical Solution for the Cadastre Problem in Egypt Using Integrated GPS-GIS System", FIG XXII International Congress, Washington, D.C. USA, April 19-26.

Sahin, N.; Bakici, S. and Erkek, B., 2004, " An Investigation on High Resolution IKONOS Satellite Images for Cadastral Applications", XXth ISPRS Congress, Commission 7, 12-23 July , Istanbul, Turkey.

Schnurr, D. J., 2004, "A Review of Existing Cost Effective Surveying Technologies for Developing Countries", FIG Working Week 2004, Athens, Greece, May 22-27.

CONTACTS

Ramadan H. Abdel-Maguid
Department of Civil Engineering
Faculty of Engineering, Cairo University
Fayoum Branch
Fayoum
EGYPT
Tel. + 2012 3683018
Fax + 202 586 4547
Email: ramadan_maguid@yahoo.com
Web site: http://www.eng.fb.cu.edu.eg/DrRamadan.htm