# Assessment of global positioning system (GPS) and imagery as database sources for surveying and mapping


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Described in this paper is an attempt to assess GPS and imagery output as database sources for surveying and mapping. The current status of GPS methods and accuracy are reviewed. A definition and some basic principles of imagery are presented. This paper considers the change that has taken place in the working procedures used in imagery data capturing. A topographic map was attained by using GPS as a data source. Also, an environmental map could be produced by the use of imagery database. Finally, attainable accuracy and merits of these techniques are presented.

خلال العقد الماضي أصبح لتقنيات الرصد الحديثة مثل المساحة الجوية بالنظام الرقمى وأنظمة التثبيت العالمى دور كبير فى تحصيل البيانات التى تخدم مجال المساحة وإنتاج الخرائط. فى هذا العمل تم تقييم هذه التقنيات كمصدر للبيانات مؤثر فى عملية إنتاج الخرائط. تم تقديم المساحة الجوية ونظام التثبيت العالمي في شكل مبسط كوسائل رفع سريعة توفر فى الوقت والجهد مع الاحتفاظ بالدقة المطلوبة فى الأعمال المساحية. التطبيق الذى أجرى بالنسبة للمساحة الجوية هو إنتاج خرائط رقمية، حيث تم تهيئة بيانات أخذت من التصويرية الجوية لجعلها مدخلات لنظام إنتاج خرائط. إذ أخذت بيانات لصورة تغطى منطقة زراعية شرق الإسكندرية تقع بين خطى عرض ٥٤ ١٢ ٣١ ، ٥١ ٠٣ ٣١ وبين خطى طول ٤٤" ٠٦ ٣٠ ، ١٠ ٥٩ ٢٩ .وقد أجرى عليها التحويل إلى الصورة الرقمية وذلك بعمل مسح ضوئى، ثم تم تناول هذا الملف بالتحليل وإنتاج الخريطة باستخدام برنامج إدريسى. والتطبيق الذى أجرى بالنسبة لنظام التثبيت العالمي هو تحليل بيانات رصدت بمستقبل ثنائى التردد وإنتاج خرائط طبوغرافية لمنطقة معينة بدولة كندا. أيضا تم عمل مقارنة بين أرصاد أخذت بهذه الوسيلة وبين بينات لنقط مثلثات مثبتة بمدينة أسوان جنوب مصر وذلك من خلال اختبار أجرى لتحديد مدى دقة هذا النظام ومدى ملاءمته لعملية إنتاج الخرائط. وفى النهاية طرحت ميزات استخدام هذه التقنيات كمصادر للبيانات والنتائج المرجوة منها.



**Keywords:** GPS, Imagery, Database, Digital photogrammetry.


## 1. Introduction

### 1.1. Definition

GPS is a satellite-based navigation and positioning system developed by U.S. department of defense. It uses a ground receiver to determine location by the triangulating between several satellites in known positions. The GPS ground receiver measures the distance between itself and each satellite by recording the amount of time it takes for a radio signal to travel from the satellite to the receiver and by knowing the speed at which the signal travels (186,000 miles per second). By knowing the exact locations of the satellites, and its exact distance from each of those satellites, the GPS receiver is able to calculate its own position precisely [1].

### 1.2. The impact of GPS on surveying

GPS was conceived primarily to serve military user requirements and cannot as such satisfy all of civilian user expectation [2]. In the beginning of the 1980's, the first civil GPS users could be found in Geodesy [3]. The NAVASTAR Global Positioning System (GPS) is revolutionizing the surveying techniques and map production. It has provided a new tool for performing very precise, homogeneous geodetic control surveys, but more importantly, it is being used in a multitude of applications to provide positioning information during the collection of geographic information system attribute data [4].

The high precision of GPS carrier phase measurements, together with appropriate adjustment algorithms, provide an adequate tool for a variety of tasks in surveying and mapping [5]. The impact of the global positioning system (GPS) on the surveying and mapping community has already become significant, while its use in geographical information systems is just beginning to be realized [6]. The GPS has already made a major impact into the field of surveying and georeferencing [7].

### 1.3. Technology review

The GPS is divided into three segments: namely, space segment, control segment, and user segment. Table 1 defines the inputs, the functions, and products of each segment.

The space segment consists of satellite vehicles, which its configuration consists of 24 satellites in six orbital planes with an inclination of 55 degrees. The satellites are approximately 20,000 km above the earth and complete each orbit of the earth in 12 hours.

The control segment is responsible for operating the global positioning systems. It consists of five control stations, spaced almost evenly around the world. All five stations track the GPS signals for use in controlling the satellites and predicting their orbits. Three stations are capable of transmitting data back to the satellites, including new ephemerides; clock corrections and other broadcast message data and command telemetry. The station located at the falcon air force station near Colorado Springs is the master control station.

The user segment consists of the receivers and associated computer software for receiving the satellite signals and computing position, velocity and time. There are many methods of survey techniques, which have been developed to take advantage of the GPS's capabilities. Some of them are static, rapid static, pseudo static, semi-kinematic, kinematic and navigation differentially corrected.

### 4. Differential global positioning system (DGPS)

GPS positioning is affected by ephemeris and satellite clock errors, atmospheric delays, receiver noise, vehicle dynamics and multipath. DGPS techniques provide measurement corrections which eliminate (or at least diminish) most of these errors and high accuracy positioning is thus feasible. The resulting accuracy of DGPS positioning depends mainly on the accuracy of the measurement corrections supplied from a reference station as well as data latency [8]. The most effective error on the accuracy of positioning was due to selective availability, but this source of error has been recently deleted. So, DGPS diminishes the rest of these errors.

## 2. Imagery definition and principles

### 2.1. Definition of photogrammetry

Photogrammetry can be defined as the method of determining the shapes, sizes and positions of objects using photographs and, therefore, it is, in the main, an indirect method of measurement since photographic images are under scrutiny rather than the objects themselves. Some linear or angular measurements in the 'object space' need to be obtained or to be known for control purposes, but primarily the photography provides the information. It is a suitable way to determine the best location for any project and to investigate the economic and technological viability of a particular site [9]. The photogrammetric approach uses two images for the reconstruction of a three dimensional stereo model, in which the cartographic features can be extracted with the XYZ ground coordinates of the map system used [10].

Photogrammetry is a combination of several scientific disciplines, but photography is the central technology. Photogrammetry is still a convenient and cost - effective way of capturing representations of the earth's surface for subsequent analysis and interpretation. And with new developments in emulsions and electronic contrast controls, photographic film remains one of the most versatile and economical ways of capturing and storing large quantities of analogue data [11].

Table 1
The space, control, and user segments of GPS

| Segment | Input | Function | Product |
|---|---|---|---|
| Space | Navigation message. | GENERATE and transmit code, carrier phases, and navigation message. | P codes, C/A codes, L1, L2 carrier, navigation message. |
| Control | P code, observations, and time (UTC). | produce GPS time, predict ephemeris, and manage space vehicles. | navigation message. |
| User | code observation, carrier phase observation and navigation message. | navigation solution and surveying solution. | position, velocity, and time. |

Photogrammetry has been used for about one hundred years to generate maps from aerial photographs and to compute highly accurate point positions in three dimensions. It is a matured technique for extracting spatial data. The advance of digital sensors has made it possible to use photogrammetry on a computer and apply its algorithms to digital imagery. Recently, the use of a computer in photogrammetry is known as digital photogrammetry [12].

*2.2. Basic principles of photogrammetry*

Aerial photogrammetry may be used for both surveying and compilation of topographical conditions. But, for the photographs to give a true plan certain conditions must be fulfilled, namely: (i) the ground on the photograph should be horizontal, (ii) the camera must not be tilted from the vertical when the exposure is made, (iii) the camera lens and photographic material should be as perfect as possible and there should be no atmospheric refraction. In addition, when flying at high altitude, the curvature of the earth is of some account. These ideal conditions rarely, if ever, are satisfied; these produce several types of distortion on the aerial photographs and associated scale variations. So, it needs some modifications to be a true plan or map. In other words, the aerial photograph is the basic source of data and unless it satisfies certain conditions, accurate measurements cannot be made [13].

For photogrammetric use, the photographs must be captured in a particular way. Not only must the area of ground be covered by strips of photographs, which have no gaps between them, but also it is essential for stereoscopic examination that every point in the object space appears on at least two photographs. When the photographic process has been completed, measurements can be taken from the photographs by a number of different methods, which are dependent upon the required end product. The most accurate methods of measurement are of a rigorous form and involve the formation of a stereo model or by the use of analytical recent way, GIS.

## 3. Transition to digital photogrammetry

Since the early stage of analytical photogrammetry, the computer has drawn the attention of the photogrammetric community as a data evaluation tool. It became the new challenge for all photogrammetrists to exploit the endless features and facilities of the computer, or in other words, to digitize the existing approaches and algorithms. Not only does digitization mean the use of a computer to perform the manual operations (automation), but also the use of digital images instead of hard-copy-film-based images; thus the computer can be utilized as a complete digital photogrammetric workstation. Nowadays, the term "Digital Photogrammetry" is considered the most recent trend in that field Digital images can be obtained by digitizing or scanning a hard-copy-film-based photograph with special devices (digitizers. and scanners), or by capturing the photograph in digital form using an array camera.

The main reason behind the push to extend analogue and analytical photogrammetry into the digital realm is for the expectations of huge cost savings in producing classical photogrammetric outputs and the new ability for using this digital output as input into other analysis systems.

The implementation of automated data input, compilation and output should lessen the time needed to produce a given quantity of photogrammetric output, like planimetric and topographic maps which will in turn have direct affect on reducing the cost of that particular output. In addition, the output of the digital photogrammetric process is already suited for direct input into corporate GIS databases and for automatic production of orthoimage base maps. GIS base map revision from aerial photographs is far more accurate than by hand digitizing or scanning out - of date hardcopy mapsheets and digital orthophoto production equipment.

Merging the full range of image processing techniques with traditional photogrammetric theory is required for the development of softcopy photogrammetry. The resulting products will include both geometric and radiometric object space descriptions, i.e. 3-D locations and grey scale values of physical features on the ground.

Generally, hardware development is faster than software and the same hold true for digital photogrammetry. But once digital photogrammetry becomes a common tool, new compilation and analysis routines will be developed to further ease the typical workflow and improve productivity [14].

## 4. Applications

### *4.1. GPS application*

Data of this application was captured using GPS as a real digitizer for a certain district in Canada. The data was obtained by Ashtech dual frequency receivers. The accuracy is indicated by the Root Mean Square (RMS) in the original file. The format of the original file is longitude, latitude and height. The original data file was converted to the format of Cartesian coordinates (x, y and z). The first line in this file should be ignored because it represents the size of the World Geodetic System (WGS84), Ellipsoid which is used in GPS. The complete data of this application is kept on a floppy disk.

The used postprocessing software is called "Prism". It is a product of the Ashtech company. The software can perform static, kinematic and pseudo-kinematic GPS Surveying. It can also perform the GPS network adjustment. A secondary part of the software is to perform all kinds of datum transformation. The Cartesian format data was analyzed by using SDR Earthwork software to get a topographic map. The final results are shown in fig. 1 and fig. 2.

### *4.2. Imagery application (a case study)*

IDRISI is the Technique that has been used in this application. It is a grid-based geographic analysis system, developed at Clark University, which is designed to provide inexpensive access to computer-assisted geographic analysis technology. It was originally intended as a research and teaching tool that could provide the focus for a collective program of system development and exchange. It has grown to become one of the largest raster-based microcomputer geographical analysis and image processing systems. It is used in over 70 countries around the world by a wide range of research institutions, government planning and resource management organizations, and educational institutions. IDRISI is not a single computer program, but a collection of almost 100 program modules that may be linked by a unified menu system.

Under study is a representative part of the agricultural land in Egypt. It is located east of Alexandria. Its latitude / longitude of the upper left corner is 31 12 54 N / 29 59 10 E. Latitude / Longitude of the lower right corner is 31 03 51 N / 30 06 44 E. It comprises a transect extending from Abu Qir in the north to Kafr El - Dawwar in the south (about 15 km by 15 km), fig. 3. The outputs were produced mainly from IDRISI technique in the Remote Sensing laboratory of the Botany Department, Faculty of Science and the Institute of Graduate Studies and Research, University of Alexandria [15]. The result is shown in fig. 4.

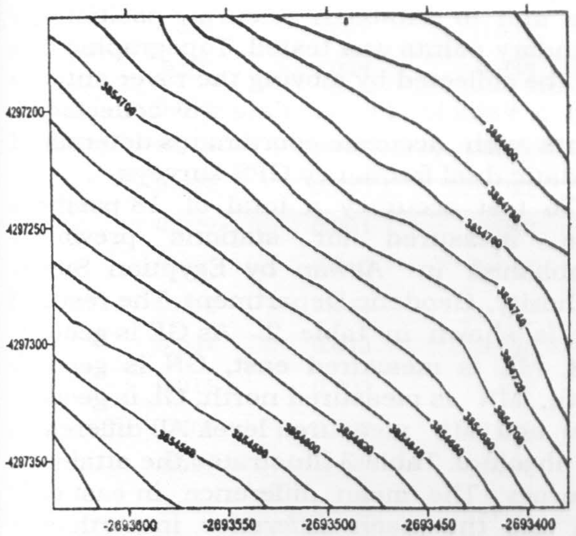


Fig. 1 Location of the study area.

## 4. Attainable accuracy

Accuracy assessment has served two primary communities: the users of maps and the producers of maps. From the production perspective, accuracy assessment is a critical dimension of the process of evaluating alternative mapping methodologies and sensors. From a user's point of view, accuracy assessment provides important information on the quality of the maps, which in turn can significantly influence the manner in which maps can be used. While the motivation for producers is typically an indication of the reliability of the map, the dominant concern remains the same – the overall accuracy of the map.

For surveying applications, where cm – level accuracy is needed a C/A Code – Carrier phase receiver is generally used. These receivers have a sophisticated user interface, which allows more flexibility in the operation of the unit and the number of channels range 12 – 24 so that all satellites in view may be tracked. Most of GPS errors are minimized using high quality antennas, DGPS and frequency receivers.

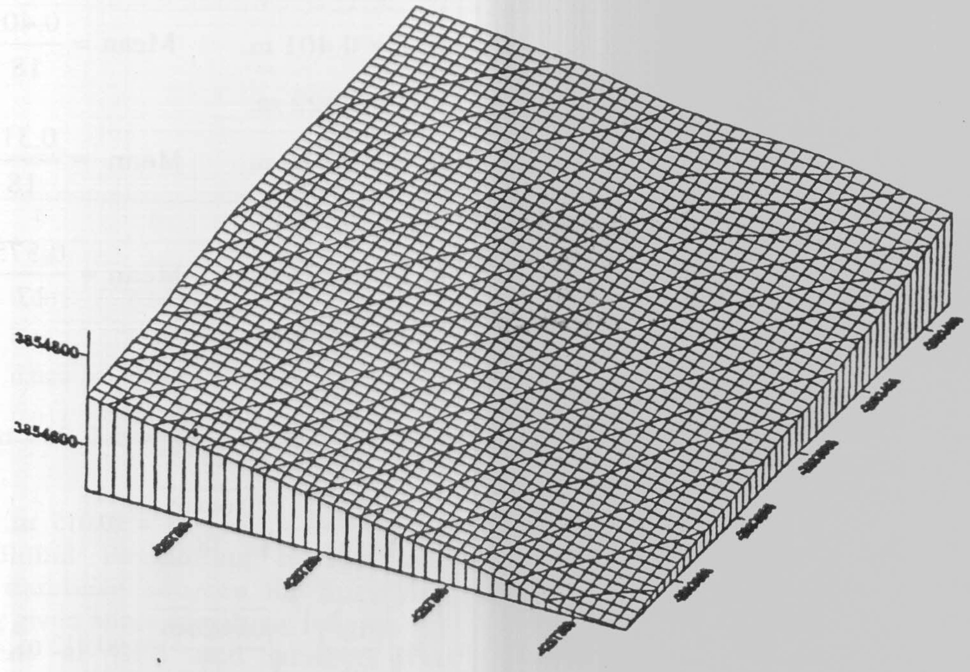


Fig. 2. Surface of the contour map.

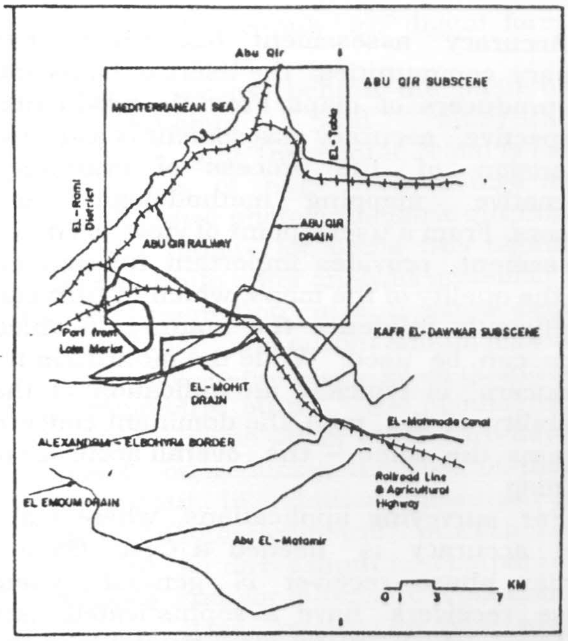


Fig. 3. Location of the study area.

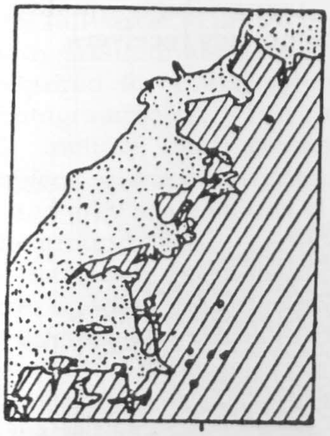

Fig. 4 The produced map.

To assess the accuracy of GPS, a test of Ashtech GG24 satellite receivers was conducted under field conditions. It is used as a real time kinematic system with an ability to process data if desired. The main components of the system as tested are: two receivers, which used both GPS and Glonass satellites. They have 12 channels for GPS and 12 channels for Glonass. The receiver antennas and the receivers can act as either the reference station or the rover. An Ashtech FS/2 controller and a Husky FX5 pen computer were used to collect data. Satel modems with an output of 0.5 watt were used at both the reference and rover receivers. The ability of the system to collect topographic data and to establish accurate positions for boundary points was tested. Topographic data can be collected by moving the rover antenna with a vehicle. Precise data was collected for points with accurate coordinates determined by static dual frequency GPS surveys.

To test accuracy a total of 18 positions were measured for stations previously established in Aswan by Egyptian Survey Authority, Geodetic Department. The result of test is shown in table 2. As GE is geodetic east, ME is measured east, GN is geodetic north, MN is measured north, GL is geodetic level and ML measured level. All differences are absolute. Table 3 illustrates the attainable accuracy. The mean difference in east of 22 mm and the mean difference in north of 18 mm while the mean difference in elevation was 34 mm. The computed standard deviation of these elements are 17 mm, 15 mm and 12 mm respectively. The attainable accuracy is represented in fig. 5.

Some data analysis is shown below.

Diff. E = 0.401 m. $\quad \text{Mean} = \dfrac{0.401}{18}$

= 0.022 m.

Diff. N = 0.315 m. $\quad \text{Mean} = \dfrac{0.315}{18}$

= 0.018 m.

Diff. L = 0.575 m. $\quad \text{Mean} = \dfrac{0.575}{17}$

= 0.034 m.

$$\sigma_E = \sqrt{\frac{[\Delta_E^2]}{n}} = \sqrt{\frac{0.0052}{18}} = \pm 0.017 \text{ m.}$$

$$\sigma_N = \sqrt{\frac{[\Delta N^2]}{n}} = \sqrt{\frac{0.00405}{18}} = \pm 0.015 \text{ m.}$$

$$\sigma_L = \sqrt{\frac{[\Delta L^2]}{n}} = \sqrt{\frac{0.002448}{17}} = \pm 0.012 \text{ m.}$$

Table 2
The result of GPS test

| # | GE-ME | GN-MN | GL-ML | Diff.E | Diff.N | Diff.L |
|---|---|---|---|---|---|---|
| 1 | 0.011 | 0.013 | | -0.011 | -0.005 | |
| 2 | 0.024 | 0.017 | 0.031 | 0.002 | -0.001 | -0.003 |
| 3 | 0.01 | 0.028 | 0.038 | -0.012 | 0.01 | 0.004 |
| 4 | 0.014 | 0.002 | 0.052 | -0.008 | -0.016 | 0.018 |
| 5 | 0.018 | 0.009 | 0.05 | -0.004 | -0.009 | 0.016 |
| 6 | 0.029 | 0.023 | 0.047 | 0.007 | 0.005 | 0.013 |
| 7 | 0.029 | 0.001 | 0.042 | 0.007 | -0.017 | 0.008 |
| 8 | 0.02 | 0.015 | 0.047 | -0.002 | -0.003 | 0.013 |
| 9 | 0.062 | 0.034 | 0.012 | 0.04 | 0.016 | -0.022 |
| 10 | 0.034 | 0.013 | 0.026 | 0.012 | -0.005 | -0.008 |
| 11 | 0.011 | 0.003 | 0.017 | -0.011 | -0.015 | -0.017 |
| 12 | 0.02 | 0.032 | 0.022 | -0.002 | 0.015 | -0.012 |
| 13 | 0.001 | 0.04 | 0.042 | -0.021 | 0.012 | 0.008 |
| 14 | 0.006 | 0.007 | 0.027 | -0.016 | -0.011 | -0.007 |
| 15 | 0.007 | 0.055 | 0.021 | -0.015 | 0.037 | -0.013 |
| 16 | 0.062 | 0.006 | 0.023 | 0.04 | -0.012 | -0.011 |
| 17 | 0.013 | 0.013 | 0.034 | -0.009 | -0.005 | 0 |
| 18 | 0.03 | 0.004 | 0.044 | 0.008 | -0.014 | 0.01 |
| Σ | 0.401 | 0.315 | 0.575 | | | |

Table 3
The attainable accuracy

| CASE | E | N | L |
|---|---|---|---|
| No of points | 18 | 18 | 17 |
| Min. | 0.001 | 0.001 | 0.012 |
| Max. | 0.062 | 0.055 | 0.052 |
| Mean | 0.022 | 0.018 | 0.034 |
| Std. dev. | 0.017 | 0.015 | 0.012 |

## 5. Merits

Using Global Positioning System and Imagery as database sources for Surveying and mapping gives some merits as follows.

1. The advent of GPS and Imagery has reduced the expense and complexity of traditional survey techniques for measuring the location of objects on the earth.
2. Using GPS and Imagery gave the ability to supply building contours with a high level of accuracy, which is very useful for planning of a cellular telephone network.
3. Using these techniques overcome the problem of disability for exchange sights between stations.
4. GPS technique is one person – operation and can be used by day or by night.
5. Surveying work can be implemented at weathers, which considered bad for traditional surveying tools.
6. These techniques give the new objects in coordinates related to a global system.
7. Using both techniques together reduces the need of ground control point or eliminates.

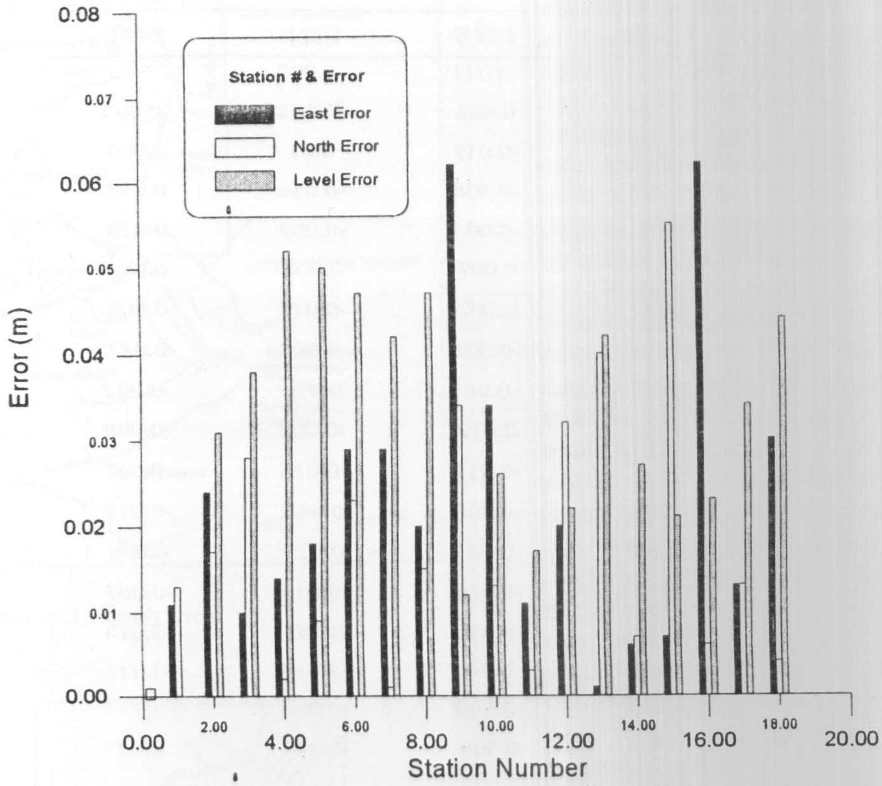


Fig. 5. The result of GPS test.

## 6. Conclusions

GPS is a rapidly maturing technology that is being used in many applications. It is moving away from a control survey tool to one that is used for positioning of surveying entities. New receivers and software systems are appearing in the market place at an exponential rate.

In conclusion, GPS techniques are currently performed to construct a digital data base for use the study area and to produce a topographic map for the same area. GPS positioning can be used to set up an overall control network. Digital land base information is preferable, since it can be input directly into a digital system, eliminating the costs and potential in accuracy of data conversion.

The use of GPS and Imagery promise better accuracy and quality for updating and will, in future, allow surveys to be based on a spatial reference system thus eliminating the need to set up a costly network. GPS is an operational system that will benefit the users of Surveying data bases in collecting accurate geographic coordinates for creating, updating or maintaining their own Surveying data bases.

Experiments using simulated and real data proved that GPS could replace ground control. As Aerial triangulation controlled by GPS observation in the aircraft has been established as a precise method of photogrammetric point determination without the need of ground control. If the GPS observations are available for blocks of aerial photos, the aerial triangulation can be carried out without any ground control points.

In addition, data needed to perform a formal accuracy assessment of map updating can be collected. Such methodology saves time and expense by combining the data collection needs for both inventory and the accuracy assessment into one project.

Finally, It can be stated that Imagery and GPS have provided reliable and accurate spatial data for Surveying and Mapping. They represent a good real – world digitizer for data retrieved and analysis, for tracking moving objects and for ground truthing.

**References**

[1] J. Hurn, "GPS, a guide to the next utility", Trimble Navigation Ltd, Sunnyvale, CA 94088 - 3642 (1989).

[2] L. Laura, "Geotechnology use Growos in California's Ag community", Earth Observation Magazine, October, pp. 16 (1996).

[3] S. Linger and M. Hudson "Using GIS and GPS to track electric utility in ventory from installation to retirement", Proceedings of the thirteenth annual ESRI user conference, Vol. 2, pp. 63 - 74 (1993).

[4] M.E. Cannon and G. Lachapelle "High accuracy C/A code GPS technology for GIS applications", The Canadian Conference on GIS Proceedings, pp. 750 (1992).

[5] Y.C. Lee, "Mapping concepts and technology II", supplementary course notes, Department of Surveying Engineering, UNB (1993).

[6] M.E. Cannon "The use of GPS for GIS georeferencing: status and applications", ISPRS commission II Symposium, Vol. 30, part 2, pp. 163 - 172 (1994).

[7] F. Arthur "Using GPS to Geo - reference and ground truth spot imagery", proceedings of the Eleventh annual ESRI user conference, Vol. 1, pp. 521 - 526 (1991).

[8] M. Abousalem, J.F. Mclellan E. Whaltey and P. Galyean "International Wide Area Differential GPS Networks", Institute of Navigation National Technical Meeting, ION95, Anaheim, California, USA (1995).

[9] W. Kilford "Elementary Air Survey", Pitman Publishing Ltd, Pitman House, 39 Parker Street, London WC2B 5PB, UK (1975).

[10] T. Toutin, "Photogrammetric stereo-restitution of digital images pair with digital image plotter", Canada Centre for Remote Sensing Applications Division, 588 Booth Street, Ottawa, Ontario, K1A 0Y7 (1993).

[11] J. Petring, "Aerial Photogrammetry", Europe's Geographic Technology Magazine, Issue 7, July, pp. 20 (1997).

[12] K. Novak, and S.L. Sperry, "Integration of Digital Photogrammetry and GIS", Proceedings of the Twelfth Annual ESRI User Conference, Vol. 2, pp. 153 - 162 (1992).

[13] A. Bannister and S., Raymond, "Surveying", Longman House, Burnt Mill, Harlow, Essex CM20 2JE, England (1984).

[14] M. Hassani and J. Cariswell, "Transition to Digital Photogrammetry", the Third European Conference Proceedings on GIS, Munich, Germany, pp. 1121 - 1128 (1992).

[15] B. Salem, A. El-Cibahy and M. El-Raey, "Detection of Land Cover Classes in Agro-Ecosystems of Northern Egypt by Remote Sensing", INT. J. Remote Sensing, Vol. 16 (14), pp. 2581-2594 (1995).

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