Some GPS Guidelines and Recommendations for Large-Scale Applications

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ABSTRACT

In Algeria Today, GPS technique is used in various applications such as cadastre, conducting road project, auscultation, bathymetry survey, and deformation monitoring. Algerian surveyors confront a major problem about transformation from GPS co-ordinates to national one, and seek about GPS guidelines to help them in their GPS operation field and processing. Generally, they used instructions given by GPS receiver manufacturer as guidelines to start and perform their own project.

In this context, a need to develop a set of specifications and recommendations to use GPS for the above specific applications is considered an urgent task. In this paper is discussed some guidelines and recommendations limited only on large-scale applications such as cadastre, and based essentially on our GPS experience.

This experience is based on several projects developed at the Geodetic Laboratory of the National Center of Spatial Techniques, about the use of GPS in cadastre, networks engineering, auscultation, road survey, and in the south of Algeria (lack of geodetic information).

These guidelines concern the following subjects: planning and conducting a GPS project for cadastral survey; conception of a new cadastral network and how to update and densify an existing cadastral network; adequate positioning mode; testing and calibration of GPS receivers; field and office procedures; results checking and presentation.

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1. INTRODUCTION

GPS is changing the face of geodesy and all surveying applications. Currently, surveyors and researchers use GPS techniques to increase their efficiency, productivity, and to produce more accurate results. However, GPS can be used for many surveying tasks ranging from horizontal and vertical control network, cadastral surveying, airborne photogrammetry, dynamic positioning, hydraugraphic survey, road and rail survey to navigation.
For large-scale applications such as cadastral mapping or engineering surveying, GPS is used firstly to establish a homogeneous and precise geodetic control network which serve as the basis for subordinate surveys and undertaking various types of projects. and secondly for making a cadastral or topographical map for specific use.
Establishing a cadastral or engineering project using conventional survey methods or modern technique (GPS) need guidelines specifications to start and performing a new project.

2. GENERAL GUIDELINES FOR CONDUCTING A GPS PROJECT

The guidelines and recommendations described in this paper are generalized only for large scales applications such cadastral surveying, engineering, topographical and detail surveying. To accomplish these surveys in the most efficient and cost effective manner, and to ensure that the required accuracy criteria are obtained, a detailed survey-planning phase is essential. It is emphasised that the project planning is one of the most important aspects of GPS surveying, as careful planning maximises the chances of the survey achieving the desired accuracy, within a reasonable time and low cost.
Before commencing the planning of a GPS survey for large-scale applications, the following preliminary questions must be established first:

- What is the purpose of the survey
- What are the accuracy and reliability requirements?
- What resources are available?
- What previous surveys have been carried out?
- And, are there any special (or unusual) characteristics of the project?

In the second step of GPS planning survey for large-scale applications, surveyor try to answer the following questions:

1. Which satellites must be observed?
2. During how much time and at what moment of the day must be observed?
3. Which observations modes must be applied for the network conception?
4. Which precautions must be taken during the GPS mission?
5. And how to assure the existing network connection by GPS?

Before answering the previous questions, it will be necessary to do various phases of preparations, which require the execution of the following tasks:

1. Calibration and system tests
2. Reconnaissance and definition of the project.
3. Demarcation of points
4. Field operations and GPS observations
5. All GPS processing and analysis (planimetric, levelling, adjustment and adequate method of transformation)
6. Final report (GPS and transformed coordinates, stations descriptions of all new GPS points, and historic of GPS project).

2.1 GPS Equipment and Systems Tests

In order to verify receiver hardware, field procedures and processing, a system test may be required. The test will consist of the measurement of a small test network using geodetic control points with mark spacing reflecting the size of the project (minimum 4 points polygon). This will be designed to evaluate the performance of a multiple receiver system used simultaneously.

Another test consists of measurement of a zero baseline. A zero baseline test is performed in order to ensure the correct of a pair GPS receivers, associated antennas and cabling, and data software. The test is carried out by connecting two GPS receivers to a single antenna, using an antenna splitter appropriate for the brand of receiver/antenna (as recommended by GPS manufacturer). This comparatively simple test can verify the precision of the receiver measurements, as well as validate the data processing software.

2.2 Reconnaissance Guidelines

The aim of the reconnaissance is searching the maximal possibilities offered by the project area so that the network conception is more economical and homogeneous. This conditions is satisfied if the number of points and the number of necessary observations is reduced to the minimum number that satisfied configuration constraints of a cadastral network (number of connection, redundancy, geometry ,....). This notion of economy will have a repercussion on the quality of GPS survey and on times of GPS cadastral network conception.

The field reconnaissance must be always preceded by working on map that will specify the shape and definition of the future control network. The project will only be fruitful if the documents used are recent and precise, it doesn't exclude the use of old documents with different scales, because their contribution is more exhaustive for the GPS project.

While performing the initial reconnaissance, the following criteria must be evaluated and included in the description of the project.

- Road travel times between all stations,
- the best itinerary possible and the necessary vehicle,
- Walking time,
- GPS receiver breakdown and setup time.
- Recording the azimuth and vertical angle of all sites obstructions.
- Assure that all stations have an unobstructed view of 15° above the horizon, and satellites below of 10° should not be observed.

2.3 OPERATIONS FIELD GUIDELINES

The manipulation of GPS receiver on the field is relatively simple. In order to assure a high rate of success and progress of GPS project, it must be indispensable to schedule for each day the number of observations sessions. However, the receivers organisation for each observation day is vital to ensure that the survey proceeds smoothly. The followings requirements must be considered:

- The demarcation of points must be well defined and appropriate, secure and stable.
- The old and new points to be surveyed.
- The availability in the field of approximates coordinates of points to introduce into receiver.
- The strategy to be used for propagating the survey (a logistical problem).
- Prudent survey practice, requiring redundancy and check measurements to be incorporated into the network design.
- The antenna height must be measured twice (at the beginning and at the end of observation session).
- Verify sufficient common data collected at all sites operating simultaneously.
- Verify quality of data to ensure that acceptable results will be obtained.
- Where station has not collected sufficient data, reoccupation may be necessary.
- For high precision surveys, all antennas should be oriented to true north to remove potential antenna phase offsets.
- Field observation recording sheets should be completed for each session. The receiver type, serial number and software used for reductions must be recorded on these sheets.
- It is not necessary to take meteorological observations readings. However it is recommended that on field sheets a general note be made of abnormal meteorological conditions.

2.4 GPS OBSERVATIONS GUIDELINES

There are four survey techniques that may be suitable for use for any particular application. They are the Static, rapid static, stop and go kinematic and continuous kinematic survey techniques. Surveyors must decide which technique is most suitable the specific application. In most cases, a combination between these techniques is desirable. For example, static survey procedures may be used to connect the survey to control points. Kinematic techniques can then used in the local survey region and a total station used to complete the obstruction portions of the survey. The important observational requirements for each survey technique is presented in the following:

2.4.1 Observational requirements for static baselines

The following guidelines must be applied when performing the **static** survey technique:

- The observation period for shorter lines (less than10 km) should be between 15 minutes to 30 minutes.

- The epoch recording rate is recommended to be 15 or 30 seconds for all observations static sessions.
- The satellite geometry should change significantly during the observation period.
- Single frequency receivers may be used for short lines (less than 10km) for non high precision application.
- Sufficient data to resolve ambiguities (for lines not greater than 20 km) should be collected to increase the accuracy of the solution. It is essential that ambiguities be resolved for all lines less than 15 km.

2.4.2 Observational requirements for fast static baselines

The following guidelines must be applied when performing the fast **static** survey technique:

- Baseline lengths should be limited to a maximum of 10km.
- Operators should refer to the manufacturer's specifications concerning the length of observing periods. Enough data must be collected to resolve ambiguities. It is recommended to collect at least 5 minutes of "clean" data, and more as required by the baseline length and number of satellites available.
- Dual frequency receivers are needed, as they allow various data combinations in estimating the solution.
- Preferably five or more satellites should be common to all survey sites simultaneously occupied.
- The epoch recording rate may vary between 5 and 10 seconds.

2.4.3 Observational requirements for kinematic baselines

The following guidelines must be applied when performing the **Kinematic** and **Pseudo-Kinematic** survey technique:

- Preferably, five or more common satellites are required due to the possibility of signal loss during motion between rover stations.
- When starting each kinematic chain, and in order to solve ambiguities resolution, receivers should be initialised as described in the manufacturer's instruction. (This is not necessary with receivers with ambiguity resolution on-the-fly capability.) The chain should close off on a known point. For completely independent results and for quality control purposes, each point should be re-occupied in a different session with different satellite geometry.
- The epoch recording rate should normally be between 1 to 5 seconds.
- Minimum station occupation should be between 5 to 10 epochs.
- Single frequency receivers may be used, although dual frequency capability is an advantage for cycle slip repair during processing.
- It is recommended to use two reference (set at known points) receivers and at least one rover receiver.

The use of kinematic GPS observations will increase productively by a factor of 5 to 10 over static method, while still providing adequate accuracy levels. On many projects, a combination between both static and kinematic GPS observations may prove to be most cost-effective.

2.5 Processing Guidelines

If more than two receivers are deployed to performing a GPS project for large scale application, there are two main methods of processing to use:

1. Baseline processing where the data from a single pair of receivers is processed independently of other such pairs. The result is a single baseline between the points.
2. Multi-station processing where the complete data set from all receivers is processed together in a simultaneous adjustment of all the data. The result is a set of coordinates or baselines together with full covariance information between points.

For each particular GPS project, is defined a strategy of processing, essentially it based on:

- After downloading GPS data from receiver to personal computer, a preliminary process is executed after data checking.
- Choice of calculation parameters.
- The preliminary process is done baseline by baseline, session by session, day by day in order to detect the bad measure and to choose (n-1) independent baseline (n is number of points which will be used into the final adjustment of GPS project). GPS survey results should be "quality controlled" at each step of survey and data processing
- Adjustment of all baselines to verify that the survey meets the required standard and to obtain the final coordinates of project. It is suggested that in the constrained adjustment only one control point in the network be held fixed and the other control points be tightly constrained with appropriate standard.
- Verify the accuracy and reliability of the GPS survey.
- Analysis of internal and external consistence of the entire network of project and verify the loop closure process.
- Transformation of GPS coordinates into national coordinates using the adequate method of transformation for the project.

It is emphasised that data collected in the same day should be processed as soon as possible in order to assure the progress and the quality of the survey at each stage.

3.GUIDELINES FOR CONCEPTION OF A CADASTRAL NETWORK

An entire cadastral network may be built up either from a large number of independently processed baselines, or, more efficiently, in a simulations adjustment in which the set of differenced observations is generated in a mathematically correlated fashion.
In general, a GPS survey mission involves the use of a small number of receivers to coordinates a large number of stations.
In order to achieve the desired precision for a generalized cadastral network, the methodology of conception consists to use a combination of survey technique. We used firstly the static mode to observe the reference cadastral network including at least three points, known into national system (Nord Sahara Datum for Algeria) and secondly, the fast static or kinematic mode to co-ordinate the new cadastral GPS points. GPS observation of reference cadastral

network is an important task when developing a new cadastral or engineering project by GPS. This network must have a good repartition of reference points over the project area and the distance between points must up to 10 km.
As conventional techniques, the conception by GPS of reference cadastral network requires good reliability and precision and low cost. For this conception, the following important criteria should be considered:

- Size and shape definition of the entire cadastral network
- Definition of number of points constituting the entire cadastral network
- Definition of the distance between each pairs of points
- Definition of the inter-visibility between points and the existence of old points required for future transformation
- The satellites visibility to station for each observation session must be known. It is recommended to have a shortest baselines possible in order to solve ambiguity resolution.
- Times of displacements between sites
- Number of the available receivers
- Planimetric and altimetric precision required for the project.

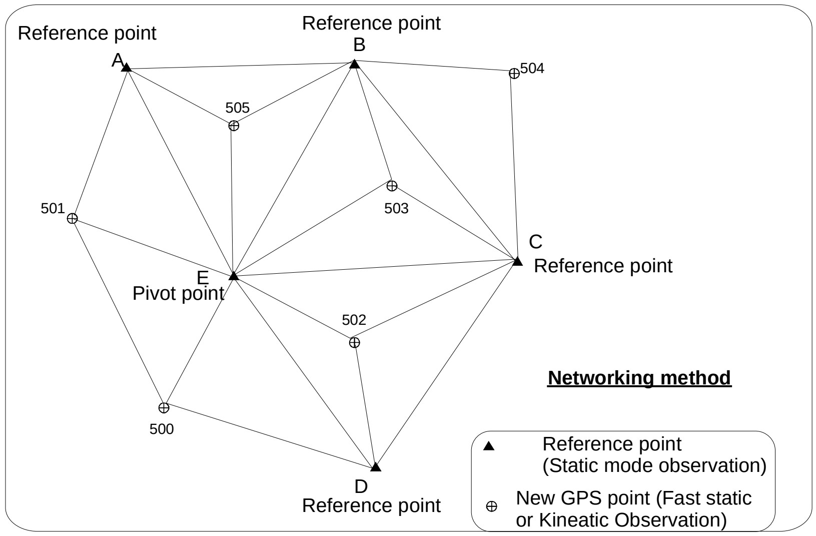
Algerian surveyors confront a major problem about transformation between WGS84 coordinates datum to national coordinates datum (Nord Sahara 1959), which require the availability of transformation parameters between both datum. To perform the transformation, a knowledge of some characteristics geographical data is necessary (system of common points, homogeneous of gravimetric data). In Algeria, this data are insufficient for most precise applications. To remedy of the lack of local geoidal heights in small region, we studied new approaches of planimetric and height transformation. In the paper (NABED, 2000) is presented a simplified transformation based on geodetic line concept called the inverse and the direct problem of geodesics, which provides an accuracy in order of centimeter and allows to transform planimetric GPS coordinates to national one for cadastral applications. About transformation of GPS ellipsoidal height to mean-sea level height, a Fortran program has been developed based on methodology described in the paper (BENAHMED DAHO, 2001).

3.1 GPS Network Design

A wide variety of survey configuration methods may be used to densify project control using GPS survey techniques. Unlike conventional triangulation, trilateration, and EDM traverse surveying, the GPS network design is not as significant. The followings two methods are generally used for conception a GPS cadastral network.

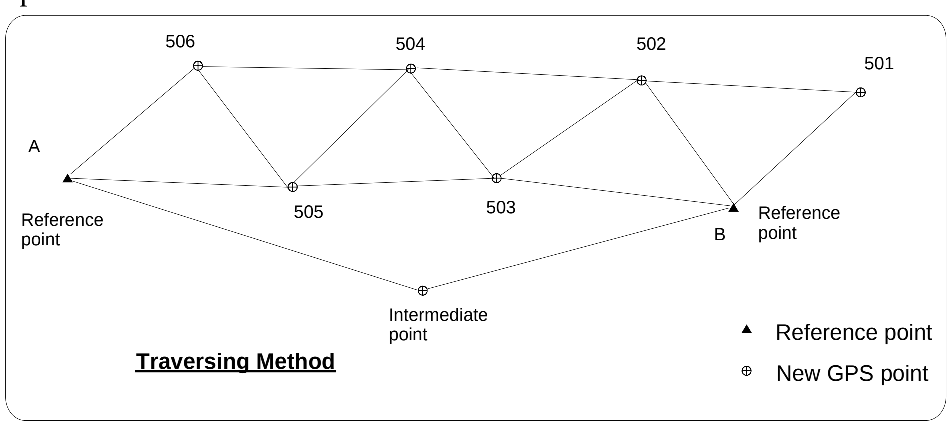
3.1.1 Networking method (Pivot method)

This method consist to cover the project area by several of reference points (called pivot), which are used to determine simultaneously with other roving receivers new GPS points. The pivot network will be controlled by multiple measures or by repeated baselines.



3.1.2 Traversing method

Traversing is the method of choice when the user has only two or three receivers and required accuracies are 1:5000 – 1:50000. Traversing with GPS is done similar to conventional methods. To achieve the accuracy required, the surveyor must have a minimum of one fixed point (or known control point), three are preferred. A loop traverse in performed by observing a baseline from start point-end point. If this baseline passes 20 km, one establishes an intermediate point.



3.2 Criteria of Cadastral Network Conception

The criteria of network conception are defined according to the type of large-scale application project. So that the conception of the cadastral network either optimal, the following conditions are valid for all the types of large scales applications:

- The reference points at least three must cover the project area.
- The baselines must be up to 10 km, because shorter baseline, more the atmospheric conditions to stations are identical.
- All GPS new points must be included in at least one loop.
- Each point of cadastral network must be connected directly with at least two other points of network.
- 65% of GPS points of cadastral network must have at least three directly connections with others points.
- 10% of GPS points of cadastral network must be reoccupied. Two occupations of the same points permit to check efficiently the antenna height.
- At least 5% of baselines must be repeated.

Loops closures provide the mechanism for performing field data validation as well final adjustment accuracy analysis. Loops should be formed every 10 to 20 baselines, preferably closing on existing control point. From our GPS experience, we have deducted other criteria and may added to the previous one:

- The inter-visibility between the new GPS points is required in order to permit a future use of conventional techniques.
- The couples of points whose inter visibility is not satisfied must be designated by the notation “NV”, which indicate not visible.
- All points of cadastral network must have a unique identification.
- All GPS observations require a verification by other independent GPS observations from other reference points. The independent measures must be executed in different sessions (at least 30 minutes after the first session), in order to permit a satellite geometry change and to detect a possible mistake caused by the multipath. In the independent measures, the receivers at each station should be turned off and the tripod elevations changed. It is important that the tripods be moved in elevation and replumbed over the control station between sessions.
- A unique standard atmospheric model is applied for all baselines processing of project.

3.3 Guidelines for Updating an Existing Cadastral Network

Updating an existing cadastral network by GPS technique is another aspect of using this new technique when performing a new GPS project. In fact, the integration of the terrestrial and GPS coordinates into a global adjustment and the setting up a methodology for the updating and densification of the existing network constitute a very interesting investigating task for all large-scale applications, particularly cadastral one. To perform this task, require the access to original data for specified region in order to compute a new adjustment. Discrepancies of order of centimeter or even some meter can emerge between old and new coordinates. In this context, it must be decided if an adjustment of the totality of the entire cadastral network including all cadastral points (old and GPS) is necessary. This decision is very important and should not be taken without an estimation of the cost and advantages that can generate the updating of the entire cadastral network.

4. REPORTING OF GPS MISSION

Once final adjustment is done and GPS coordinates transformed into national system using an adequate approach of transformation, a final report is usually derived and may include the following:

- History of the project,
- Methodology containing the conduct of all operations field procedures, data integrity checks and the quality of the measurements and processing, final adjustment and method of transformation used.
- A list of points with their identification,
- A map of the entire network (scale: 1/25000) which indicate the surveyed points and the measured baselines,
- Sheets of observations and the points description,
- A table presenting the final adjusted coordinates (WGS84 and local), and must be supplied in digital form.
- It is useful that observational data should be archived in case re-processing is required in the future.

5. CONCLUSION

The proposed GPS guidelines and recommendations described in this paper is based essentially on our GPS experience and others GPS surveying research through the world particularly in Canada, Australia and USA. Several projects were developed at the geodetic laboratory of the National Center of Spatial Techniques using GPS, concerning the use GPS in cadastre, network engineering, auscultation, road survey and in area where geodetic information is lack (south of Algeria). In the future, we hope establish a GPS guidelines for each application.

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BIOGRAPHICAL NOTES

Mr. Abdelkader Nadir NABED

He works as researcher in the geodetic laboratory of National Center of Spatial techniques (CNTS –Arzew –Algeria), has his post-graduate Magister diploma in Geodetic Sciences since 1996, he have presented his research about GPS Techniques and Cadastre. The main tasks of his actual research is articulated on positioning by GPS techniques for large scale application (cadastre, road survey, auscultation , etc…) on methods of observations (Static, Rapid Static, Kinematic, OTF technique, …), on treatments of GPS data, and on problem of transformation from GPS coordinates into national coordinates. He teach GPS courses for engineer and Magister students since 1996.

Mr. Bachir Gourine

Graduated as a geodetic engineer from the National Center of Spatial Techniques (CNTS), Arzew, Algeria, in 1994. He teach geodesy and micro-triangulation since 1995, at the CNTS. He is working as geodesist in the laboratory of Geodesy, CNTS. The main subjects of his research concern the combination of the terrestrial and spatial (GPS) observations for geodetic applications, the transformation methods of GPS coordinates to national coordinates, the modeling and evaluation of the network deformations by the Monte-Carlo method and finite element method (FEM).

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