A GPS METHODOLOGY FOR SURVEYING AND MAPPING CADASTRAL PARCELS IN ALBANIA

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ABSTRACT

This paper describes a GPS methodology for cadastral surveying and mapping at the parcel level. It was designed to take into account the particular demands and realities of Albania, but it also has relevance to other developing countries which are in the process of developing a cadastre and land registration system (CLRS). The methodology is described in terms of office planning and preparation, field procedures, post-processing, and geodetic considerations. The latter part of the paper summarizes the field tests that were undertaken in Albania in order to test and refine the methodology. The methodology makes use of a new "sub-meter" receiver (Pathfinder PRO XL) which is used in a differential mode to provide accuracies to around one meter.

BACKGROUND

Albania is a small Balkan country located between Greece (to the south), the ex-republic of Yugoslavia (to the north and east), and the Adriatic Sea (to the west). It is approximately 28,000 square kilometers in area, which is equivalent to the size of Belgium or the state of Maryland in the US. In terms of Gross Domestic Product (GDP) and other welfare indicators, Albania is the poorest country in Europe. The population of the country is around 3.3 million (World Bank 1992).

Like many countries in the region, Albania has recently moved from a centralized, command economy to one based on market principles. A fundamental part of this transformation involves the privatization of land rights and the facilitation of a land market. During the communist era most of the agricultural land was organized into state farms and cooperatives and since 1991 Albania has been redistributing this land to individual families. It is estimated that the distribution program will involve some 2.5 million land parcels and housing units (Jazoj et al 1994). The majority of the land in rural areas has already been allocated to individual families.

The challenge facing Albania is to put in place a cadastre and land registration system (CLRS) before land starts changing hands through sales, inheritances and other transactions. This means surveying and mapping individual parcels and registering a legal document which identifies the spatial dimensions of the parcel, right holders and the nature of their rights. The minute size of the land parcels (average of about 0.3 hectares), as well as the fragmented nature of land holdings, makes it extremely difficult to design and implement a CLRS within the tight time constraints. This paper describes a project which was undertaken to design a methodology that would provide a rapid and affordable means of surveying and mapping land parcels and individual buildings (in urban areas).

SURVEYING AND MAPPING IN ALBANIA

Surveying and mapping in Albania is primarily the responsibility of three government agencies. The Land Research Institute (LRI) is responsible for surveying and mapping in rural areas. The mapping is generally at a scale of 1:5000, although they do produce maps at other scales (e.g. 1:2500). The Geology and Geodesy Enterprise (GGE) deals with most of the urban surveying and mapping. Most of this mapping is done at scales of 1:500 and 1:200. The Military Topographic Institute (MTI) is responsible for the national map series (1:50 000 and smaller).

Unlike many other less developed countries, Albania has a dense network of geodetic control points (approximately 4 Km density) which in many instances are clearly demarcated by means of tall tripod signals. Provisional tests using GPS (MSI 1992) confirm that this network has been surveyed to a high degree of accuracy.

Albania is fortunate to have a relatively high number (estimated at around 300) of well educated surveyors who have graduated from the 5-year surveying program at the Polytechnic University of Tirana. The curriculum includes a strong mathematical and measurement science foundation in the first three years. The latter two years are more general than most surveying programs and deal with such diverse topics as Ecology, Urban Planning, Mining Technology, and Hydrotechnic Construction. The surveying program graduates approximately 20 students per year and has apparently maintained this level for the past 20 years. A large majority of these graduates are currently unemployed or are involved in some other line of work.

There are also a number of survey technicians who have specialized in surveying at the Middle School level (equivalent to high school in the US). The number of people with these qualifications is estimated at 500. The pool of expertise in the area of surveying and mapping appears to be adequate to support the development of a CLRS. However, given the dramatic changes in land law and the introduction of a legal cadastre, additional training and education will be required to update the skills and expertise of both the university- and middle school-trained surveyors.

The substantial set of maps that currently exist in Albania, especially at larger scales (1:500 - 1:10,000), provides a valuable base of land information on which to build an effective cadastre. In addition to this map information, LRI has a well organized and referenced archive of survey records, one set dealing with control densification (triangulation) and the other with tacheometric surveys.

Perhaps the most challenging aspect of the Albanian situation is the minute size and fragmentation of land holdings. In many instances villagers have been allocated between one to four parcels of land (up to seven parcels are allowed by law). These individual parcels may be several kilometers apart and involve agricultural land as well as pasture and land containing olive trees (defined in terms of the number of trees). From a surveying and mapping perspective this fragmentation presents a complex environment in which to identify cost-effective solutions for the creation of CLRS.

DESCRIPTION OF GPS METHODOLOGY

The GPS methodology tested and implemented in Albania utilized the technique known as 'Differential Pseudo-Range Positioning'. A minimum of two GPS receivers are required for this technique. The 'reference' or 'base' receiver occupies a known geodetic control monument and the 'remote' or 'rover' receiver is used to occupy parcel corners. The data collected at the reference receiver are used to compute corrections (?X, ?Y, ?Z) to the pseudo-range measurements. These differential corrections are then applied directly to the remote receiver during post-processing. The magnitudes of these corrections are common to both units, provided that the distance between the reference receiver and remote unit is not too great, . The technique is capable of yielding sub-meter accuracy positions for the parcel corners. The methodology was tested using a Trimble Pathfinder PRO XL as a rover receiver and a single frequency Trimble 4000 SE as the reference receiver.

The technique has the following advantages:

- Implementation is relatively simple
- Observational technique is robust, therefore requiring minimal training
- Only one base station is required to support multiple rover units (productivity can then be significantly increased at a relatively low cost)
- No coordination is required between rover units (field crews can therefore operate independently of each other)
- Occupation times are short (30 seconds)

A general description of the methodology is outlined below in terms of the following four categories: office planning and preparation, field procedures, post-processing, and geodetic considerations.

Office Planning and Preparationa) Satellite Coverage
Comprehensive planning and organization is an essential part of the GPS methodology. Therefore, prior to the survey, the satellite coverage must be evaluated in the area of interest for the given time period. Recent ephemeris data are required, which describe the most up-to-date computed orbital parameters of the satellite constellation. The ephemeris data are obtained by utilizing a GPS receiver to collect data from at least one satellite for approximately 15 minutes. This ensures that the full navigation message is obtained.

The collected data are downloaded to a personal computer (PC). The mission planning software (e.g. TRIMBLE Quick Plan), is used to generate a number of satellite visibility graphs and reports. The graphs depicting 'Number of Satellites' and 'PDOP' offer a convenient means of quickly assessing whether sufficient satellite coverage is available, i.e. a minimum of 4 satellites and low PDOP values. PDOP is an indicator of the geometric strength of the satellite constellation.

b) Creation of a Data Dictionary
A data dictionary is a catalog of information about the definition, structure and usage of the data. It is used to structure and guide the data collection process. Each dictionary consists of a list of features, a list of attributes for each feature, and a list of values for each attribute. For example in parcel mapping, a single feature 'parcel corner' was deemed adequate in the tests. Attributes such as 'parcel id', 'date' and 'time' were also included. The tests in urban areas required a more detailed dictionary (including features such as 'power pole', 'building Corner', 'cl of road', 'concrete bunker', 'fence corner', etc). Once the data dictionary has been created, it is uploaded to the datalogger for subsequent use in the field.

c) Base Receiver Configuration
Achieving sub-meter accuracy with GPS receivers such as the Pathfinder Pro XL is only possible under specific operational conditions. These parameters (e.g. logging interval, elevation mask, PDOP mask, and SNR (Signal to Noise Ratio) mask) can be configured in the receiver prior to measurement.

The logging interval specifies the regularity with which positions are stored within the receiver. The amount of data that can be collected is restricted by the size of the internal memory within the receiver. An interval of 5 seconds provides a balance between the volume of data generated, and the occupation time required by the rover at each point. The elevation mask should be set at 10 to ensure that satellites too close to the horizon are excluded, since atmospheric effects may result in signal degradation. The PDOP mask is set to a value of 8 to ensure that data are collected only when a favorable satellite constellation exists. The SNR ratio provides a measure of the strength of the signal being received. An SNR ratio below 4 should be avoided, as this low signal strength will adversely affect the positional accuracy.

d) Rover Receiver Configuration
The rover receiver should be configured in the same way as the base receiver, with the following exceptions. A requirement of the differential correction process is that the rover collect a subset of the satellites being tracked at the base station. The elevation mask (15^0), PDOP mask (6), and SNR mask (6) values are therefore set to be more stringent for the rover receiver.

Although the Pathfinder Pro XL yields sub-meter accuracy on a second-by-second basis, it is advisable to collect several positions. These positions are then averaged after differential correction to yield a more reliable position. The minimum number of positions should be 6, therefore requiring each parcel (or building) corner to be occupied for 30 seconds.

Field Procedurea) Reconnaissance

A thorough reconnaissance is an essential part of the fieldwork if efficiency and productivity are to be maximized. This applies to all surveying techniques, but is especially true for GPS surveying. Reconnaissance is required in the first instance to identify suitable existing geodetic control points in the vicinity. The selected control point should be accessible, preferably by vehicle, and should have an open horizon. Secondly, the area to be mapped must be identified and sketches of the fields should be drawn to facilitate parcel-level sketches drawn during the measurement process. These procedures enable the measurement process to be optimized and the results to be organized in a logical fashion.

b) Base Receiver Set-up

The base receiver can either be set up at a continuously operated central base station or at a recovered control point in the vicinity of the survey. The height of the antenna must be measured and recorded in a field book, together with other relevant data (e.g. the station name, the date, the time, weather conditions). Care should be taken to ensure that the base station is collecting data prior to any rover receivers, since only simultaneous data between base and rover receivers may subsequently be differentially corrected.

Ideally base receivers should be set up at both a central base station and at a control point in the vicinity of the survey (or at a second centralized base station). This provides a valuable check on the measurements taken and also acts as a back-up should one of the receivers develop problems or lose power. In the event that a second base receiver is regarded as too costly, it is important to introduce other mean of checking the GPS results (e.g. checking against large scale maps showing some of the measured features)

c) Data Collection with Rover Receiver

The rover receiver (Pathfinder Pro XL) is enclosed in a backpack, the antenna is mounted on a range pole, and the data collector held by the operator. This arrangement is well-suited to the mobility required for cadastral surveying. The measurement process then involves the identification of each parcel corner by the village community leader/elder, the collection of GPS data at each point (30 seconds), and the annotation of a field sketch.

d) Field Sketches

Field sketches are an essential part of the data collection procedure and constitute valuable boundary evidence. Since GPS measures point positions, it is necessary in the post-processing stage to connect these points to delineate the boundary lines to be shown on the cadastral map. It is therefore imperative that good notes be maintained in the field to allow the reliable generation of the cadastral map, preferably by a party not involved in the data collection process. The sketch should depict as clearly as possible the point name, monument descriptions, the boundary lines as determined in the field, any parcel identification numbers, and other relevant field features. In the tests conducted (see next section) this often proved to be the most challenging part of the fieldwork.

Post-processing

At the end of each days' work, the data should be downloaded to the PC and archived on a removable diskette prior to any processing. This ensures that a back-up copy of all raw data is maintained for security reasons.

The differential correction process may be divided into the following steps:

- Specify and prepare the base data file(s)
- Enter the reference coordinates of the base station
- Specify and prepare the rover data file(s)
- Differentially correct the data
- Transform the results to local datum.

These steps are executed as functions within the PFINDER software.

All data collected and stored in the receiver relate to the WGS 84 reference ellipsoid. The data should be processed on WGS 84 and converted to the local datum once processing has been completed (see section Geodetic Considerations for more details). The reference coordinates entered for the base station should relate to the WGS 84 ellipsoid. It may be necessary to obtain these coordinates by transforming the position from the local datum to WGS 84. Extreme care should be exercised in the transformation and subsequent entering of these coordinates, since any error in the base reference position will be reflected in similar magnitude in the coordinates of the parcel corners.

The differentially corrected rover positions and the attribute data compiled in the datalogger must be converted to a format that conforms with the mapping software. Generally AUTOCAD or one of the more popular GIS' (e.g. ArcInfo) will be used to map and manage the parcel database. PFINDER allows for conversion into a number of common formats for exporting the data to different mapping and GIS packages.

Map Production

In order to provide a clear description of the land parcels for registration and cadastral purposes, it is necessary to generate a cadastral map showing all parcels in a jurisdiction. This cadastral map serves as a legal description for all registered parcels. Metes and bounds descriptions are not regarded as an adequate method of describing land parcels. The cadastral map or cadastral overlay also represents the property layer in a multipurpose LIS/GIS and as such must be capable of being integrated with other layers of information such as natural resources, infrastructure and socio-economic themes.

The computer-aided drawing software (AUTOCAD version 11) was utilized during tests conducted in Albania for the production of the cadastral map. It should be noted that the production of a reliable representation of the data is highly dependent upon the compilation of comprehensive sketches during the data collection process.

Geodetic Considerations in Albania

The use of GPS techniques within Albania raises some important geodetic issues. As was mentioned before, all GPS data are related by definition to the World Geodetic System of 1984 (WGS 84). This system is an earth-centered, earth-fixed 3-dimensional coordinate system, with an ellipsoid which best approximates the surface of the earth as a whole. The local geodetic datum presently in use in Albania is based upon the Krassowsky ellipsoid. The Albanian datum is therefore based upon a locally best- fitting ellipsoid. The relationship between the local ellipsoid and global geocentric reference systems, such as WGS 84, is therefore not easily determinable, making accurate transformations between these systems difficult to achieve. Final corrected positions may be transformed onto the local datum in Albania using the appropriate transformation routines. This approach also requires that the reference station coordinates be known in the WGS 84 system.

The datum transformation parameters may be approximated in several ways. Firstly, ties may be made to global reference stations which are known in the WGS 84 system, such as stations comprising the Cooperative International Geodetic Network (CIGNET). These continuously operating stations track GPS satellites and store the data, which is then available through a number of agencies over the Internet. Such stations exist within relatively close proximity to Albania, e.g., Matera in Italy, and Ankara in Turkey. Baselines may be processed to known stations within Albania, and used to compute mean ?X, ?Y and ?Z translations between the systems.

An alternative means of determining the required transformation parameters utilizes the methods of satellite geodesy, which has the capability of providing high accuracy geocentric coordinates. The determination of at least three points in both coordinate systems enables the solution of a 7-parameter transformation, i.e., three translations, three rotations and a scale change. However, regional parameter variations may exist due to network inhomogeneity - it is therefore advisable to obtain as many well-distributed common points as possible to obtain increased redundancy, and more reliable determination of the parameters for the complete region of interest. This entails a reobservation of the geodetic control network, preferable using high precision GPS receivers (such as the P-code receivers used by DMA for this purpose).

TESTING OF GPS METHODOLOGY

Controlled Testing at UF Test Site

Before departure for Albania, testing of the most promising GPS methodologies was undertaken at the University of Florida in Gainesville. The primary focus was on the effect of baseline distance (i.e. distance between reference base station and rover receiver) on the accuracy of the GPS positions and the establishment of efficient field procedures. Tests were carried out on a test site specifically created for this project on the University of Florida campus and baseline distances of up to 235 kilometers were included.

Field Tests in Albania

Tests were carried out at sites where there was perceived to be a high demand for surveying and mapping to support land registration. Although the earlier focus of the

PRS project had been on rural areas, it has become apparent that in the near future the highest frequency of land transactions is likely to be in the urban fringe around the larger cities, particularly Tirana. As a result of these changing needs, tests were conducted in both rural and urban areas.

a) Rural Tests The village of Zhurje is located approximately 20 kilometers west of Tirana and is part of the ex-cooperative of Ndroq. This village was selected because it was currently in the process of being surveyed by traditional methods and a direct comparison of the GPS and traditional approaches could therefore be made. Approximately three quarters of the 100 hectares of the village had already been surveyed. Zhurje is a typical example of non-mountainous farmland and had the further advantage of being easily accessible from Tirana. The average parcel size in the village is approximately 0.25 hectares (2,500 square meters).

An existing control point in Tirana was used as one reference point for the GPS survey and an additional one was located in the vicinity of Zhurje. Once the two reference or base stations receivers (both geodetic receivers) had been set up, the survey of the parcel corners was commenced. This was done using the procedure described earlier in this paper.

It is essential in the process of cadastral surveying in Albania to include a village representative in the survey team in order to identify the location of the parcel corners. Parcel corners are generally not monumented, but are identified by the edge of a field of crops or a small irrigation furrow. In Zhurje we were fortunate to have the services of both a village elder, who had been involved with the original allocation of individual parcels, and the surveyor who was undertaking the survey of the village. A total of 29 parcels were surveyed over a period of 4 hours and 35 minutes (excluding 40 minutes to set up the base station) using GPS.

b) Urban Sites

Selita is located on the urban fringe of Tirana just outside the "yellow line" which designates the urban boundary of Tirana. It consists of a mix of old buildings (mainly around the periphery), recently completed buildings, and houses in different stages of construction . The buildings are substantial and solidly built from brick, a testament to the building skills developed during the communist era when apartment blocks were built using communal labor.

The only boundaries that could be construed as property boundaries were the walls built around several of the houses. There does not seem to be any preconceived subdivision plan and development was occurring in a random fashion. The corners of 30 buildings in different stages of development as well as road centerlines and power poles were surveyed using the method describes earlier.

The satellite coverage was such that on only a small number of occasions were we unable to obtain sufficient satellites for a position fix. These problems were experienced primarily where buildings of two or more stories were situated close together. A tape was used to establish the position of the corners that could not be measured by GPS. A total of 124 points were measured over a period of 3 hours (excluding the time for base station set-up). Details on further tests are contained in Barnes et al (1994).

RESULTS

Results of the controlled testing on the effect of baseline distance showed that in general an accuracy of around 1 meter can be achieved up to distances of 135 kilometers. At a distance of 135 kilometers 1 position fell more than 1.4 meters from the true value, while 6 positions fell between 1 and 1.4 meters. While most of the measurements fall within the required accuracy limit, these outliers are grounds for some concern and their elimination will be part of the research goal in the next phase. Figure 1 summarizes the mean, minimum and maximum errors for the five baseline distances that were tested.

The results indicate that minimal densification in geodetic control will be required to support the recommended GPS methodology. As can be seen on the map of Albania in Figure 2, a single base station in Tirana (e.g. on the roof of the LRI building) could serve almost the entire country. This implies a significant saving in resources and time and allows greater control over the base station.

The results of the field tests were very encouraging and showed that this methodology can be employed very effectively. Table 1 below demonstrates the productivity levels achieved in the urban and rural tests conducted in Albania. This time reflects measurement time only and does not take into account time spent on adjudicating parcel boundaries.

TABLE 1. Productivity of GPS Methodology in Field Tests

One of the central questions that was faced in this research was whether or not this methodology was faster or more productive than the traditional taping techniques that are currently being used in Albania. This approach typically involves taping along the boundaries of each parcel and plotting the results on an existing 1:2,500 scale map. While not much data has been systematically collected on the productivity of this approach under different conditions in Albania, we were able to obtain general figures from the managers of this work. A comparison of the GPS and traditional approaches is given below in Table 2.

TABLE 2. Comparison of Productivity (Daily) between GPS and Traditional Approaches

a. taking into account estimated adjudication time

The data for the GPS productivity was based on the levels achieved in the field tests. Since this work was done in an experimental mode, one should only draw general conclusions from the above comparative data.

CONCLUSIONS

The tests conducted at the University of Florida showed that meter level accuracy is achievable even when the baseline distance between reference station and rover is as long as 135 kilometers (see Figure 1). This means that for most cadastral surveying purposes it is not necessary to invest in an expensive and time consuming control densification exercise prior to parcel surveying and mapping.

Preliminary comparisons with the traditional surveying and mapping approach show that the GPS methodology can be significantly more productive both in the office and field. Furthermore, it does not depend on existing maps being available and provides data in a digital format which can easily be transferred to a computerized mapping system or GIS. Given the lack of monumentation and the temporary nature of the individual parcel boundaries, the authors recommend that the traditional approach be continued for small parcels within larger fields (blocks of parcels), but that the fields, or some other aggregated unit, be defined by means of the GPS methodology.

Finally, it should be re-emphasized that speed and not accuracy is the critical criterion for surveying and mapping in Albania and many other developing countries. Based on this and other priorities in Albania, we feel that the GPS methodology described in this paper offers a viable and extremely attractive alternative to other approaches that are currently being used.

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