Optimised Data Acquisition Processes and Tools for Land Administration

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Key words: Land Survey, Demarcation, GPS, Land Administration, Database

SUMMARY

Novel tools and procedures for use in land administration are among enabling technologies in efforts to reduce poverty through land policy reforms. Working with the ministry of Lands Water and the Environment in Uganda, DataGrid, Inc., has developed an integrated but flexible system of hardware, software and operating procedures that may be adapted and optimized for broader use. The system includes survey instruments and software with recommended procedures for systematic demarcation, adjudication, surveying and data capturing. Land data is stored in an on-the-spot field accessible database and can automatically generate a land document with property sketch and key survey data. The document and database can be augmented with demographic, social, as well as geo-referenced GIS data that may be used for a wide range of planning purposes. Since there are now programs in place to promote systematic land reform on national scales there is an opportunity to enhance the return by extending the scope to national resource management in a broader sense than land management. The proposed system is designed to be expandable and compatible with other database formats.

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1. INTRODUCTION

A case has been made for the strong link between land policies and poverty indicating a possible venue for poverty reduction (e.g., Deininger, 2003). However, national land administration resources are often insufficient to effectively implement land policies. Many governments depend on paper records whose upkeep and management are taxing on human resources and susceptible to human error. Slow and expensive to operate, these may ultimately fail to deliver the reliability and low cost needed to generate the expected benefits from new land policies. In addition, vulnerability to natural or man-made disasters may eventually negate any progress. This article describes optimized data acquisition processes and tools integrated into a land administration system tailored to this need and adaptable to local conditions.

2. OBJECTIVE

Land reform in a region where most land has not been previously surveyed is an opportunity to introduce a consistent system of land data collection and management. Uganda for example has embarked on a systematic demarcation and survey that will eventually very nearly cover the entire country. Among the requirements are compatibility with previously used paper records, accuracy of better than 1 meter accounting for all errors and a desired survey accuracy of 1 dm. While the need for any specific survey accuracy usually can be debated it depends on the size of the smallest plots, future requirements and the need to maintain a professional level that might enhance rather than reduce the reputation of the project. The latter led van der Molen and Lemmen (2004) to considers the accuracy requirement to be basically a social issue. Set by an independent study, the accuracy requirement is usually of this order and we might anticipate a trend toward more stringent limits in the future. A large systematic error in the coordinates might enter through the transformation to the local or national datum. The first step was therefore to establish adequate accuracy seven set transformation parameters. DataGrid also provided a provision to store all coordinates in the Earth Centered Earth inertial reference frame to allow reconversion to any map datum without loss in accuracy should improved or differently defined datum parameters be developed in the future. A cost analysis (Gustafson, 2005) indicates that requirements in the decimeter range do not increase total project costs significantly through the increased instrument costs. Also, manpower costs are hardly affected provided that the DataGrid recommended procedures be followed.

The need for paper records initially caused a “bottleneck” that in the data acquisition rate. Hand drafted property sketches took longer time to make on average than the demarcation and actual data collection using especially made single frequency carrier phase GPS receivers/datacollectors and postprocessing software when two roving GPSs were used simultaneously serviced by a single draftsman. It was soon realized that limited availability of skilled draftsmen would translate to a bigger delay should this procedure be used on the national scale. This was the original motivation for development of computer software to automatically generate the required form. Since management of the paper records also can cause delays or even loss, DataGrid ventured to also develop computer database software.

Another optimization was the development of procedures that reduce the number of certified surveyors needed and to simplify all procedures to reduce the need for other skilled or highly trained labor. This was accomplished through a teams approach described below.

3. Implementation procedures

The process of developing a modern land administration system that is expandable into a management tool of a broad range of national resources following DataGrid's method starts with planning and scheduling. Specific needs that depend on applicable law, traditions, and customer wishes are assessed, as are the extent of existing records, known conflicts, and available infrastructure. A set of operating procedures is developed accordingly and the corresponding software modules are customized. New software routines may have to be developed. The solution may be tested in a pilot project before it is implemented in full scale. DataGrid uses a teams approach and in most cases this approach can be either fully tested or simulated using DataGrid human resources to supplement the customer's personnel. DataGrid can then assist in the hiring process and can provide training either directly or through its affiliates. Assessing and processing of existing records is typically the customer's expertise. Key legal documents might be retrieved and scanned into electronic form for entry in the GeoData database. This is one of the responsibilities of the office team.
An information and scheduling team divides the region to be administered into sets that can be demarcated and surveyed by a demarcation and survey team in a single one day visit (typically 50 properties) and schedules the visit. This team meets with the stakeholders to gather information on local issues, identify remaining conflicts, and prepare the community for the demarcation and survey process. For example, some boundaries may traditionally be defined by the run of a stream that may have shifted its course or whose bed may otherwise be poorly defined. There may be other previously unidentified land ownership or rights disputes. The office team needs to be notified of such issues so that it can gather all relevant information and help develop a strategy to deal with the issues. This preparation is paramount since the failure to complete demarcation and survey and to resolve all issues that can be negotiated in the field during a single visit by the demarcation and survey team can rapidly drive up costs.

A representative of the stakeholders may be offered to be trained and to participate in the actual demarcation and survey process as an operator. This requires one to two days training with the first day consisting of a brief introduction and instructions from the chief surveyor who leads the team followed by "on the job shadowing" of a seasoned operator. The first day training culminates in a 30-minute competency test and an opportunity for the trainee to ask questions, observed by the chief surveyor. (It might be advisable to pay trainees only once they pass the test.) The optional second day would be as a fifth operator, performing control measurements that can be used as additional integrity checking. In this scheme, a new operator would typically observe the demarcation and survey process in three to four sites before they start surveying. These operators could serve as valuable sensitization officers and informants facilitating the communication between stakeholders and the teams. This aspect of sensitization may work well and even be essential in some areas but fail in other regions. It is an example of the importance of adapting procedures to local conditions.

Each demarcation and survey team is lead by a chief surveyor who has overall responsibility for the team of operators and for dispute adjudication. The operators normally follow a quick static high-precision measurement procedure developed by DataGrid that typically yields GPS coordinates with 10-centimeter accuracy and includes data integrity checking to practically eliminate the effects of multipath and human errors. GPS position determination and integrity checking is tightly integrated with the process of locating boundaries in the presence of stakeholders and with the demarcation or monument making. Every measurement point is visited by two GPS operators at least 20 minutes apart to make sure that the GPS satellite configuration has shifted sufficiently for any degradation due to multipath or other error in a GPS measurement to have changed. Disagreement between the two determinations beyond tolerances triggers additional measurements, until results agree. In particularly difficult situations, the surveyor may revert to the use of relative positioning from a nearby point using a total station.

The key instruments are GPS receivers/dataloggers specially made by DataGrid that use carrierphase differential GPS measurements to achieve high-precision position determination. It is often advantageous to use two base stations. One is on a legally acceptable reference point in the vicinity that ideally has known coordinates in some standard datum system. Such points may need to be established which usually also can be accomplished with the same equipment as used for the survey. The second, more centrally located reference point does not need to be on previously determined coordinates and can therefore be selected for good sky visibility. Its position will be determined relative the first base station as part of standard procedures. While positions relative the legal reference point (base-station one) sometimes satisfy legal demands, a local, national, or international datum is often used and has frequent advantages. DataGrid can assist in selection or determination of a suitable datum.

4 Equipment

DataGrid custom develops GPS/ datacollector combinations (Figure 1) that can collect and store one day to several months' worth of field data in non-volatile flash memory depending on settings and options. These collectors can merge data from diverse sources such as data controllers, digital cameras or voice recorders. They can be used to photograph or collect biometric data for identification of for example stakeholders or other persons who cannot present adequate identification. This allows swift collection of data and recording of

Figure 1. DataGrid Mk-1 Crane, GPS receiver and data collector.

testimony on the spot. Biometrics that can be added through customization includes fingerprint and iris scan as well as any number of card, tag or barcode readers. The collectors can capture data on soil conditions (moisture, pH-levels, Nitrogen levels, etc…), air quality (Radon levels, etc…), or can interface to other instruments or sensors that can communicate over Bluetooth, serial or analogue ports. All GPS/datacollectors can merge data from internal and external instruments with the GPS data stream so the time and location of data collection is saved. Collected data can thus be shown in context on a map using DataGrid GeoMapper software.

Single frequency band (L1) carrierphase GPSs position determinations using DataGrid's Mk 1 Crane GPS and on-the-spot automated postprocessing are suitable and cost effective as long as both base stations are within approximately 15 kilometers. Establishment of intermediate reference points may effectively extend the range. This is economical in systematic surveys. Longer range can also be achieved directly using DataGrid's dual frequency band (L1 and L2) version, the Toughman. Both the Crane and Toughman are small and rugged GPS receivers that can merge and/or synchronize data arriving via external ports with the GPS data stream (analogue, RS-232 or Bluetooth wireless). This allows great efficiency in collecting data during field visits using any number of devices including sensors that monitor soil or other environmental conditions such as Radon levels. Photographs and notes taken on Pockets PCs or Personal Digital Assistants can also be automatically synchronized with the GPS data for merger into a common GeoData database using the DataGrid GeoID software suit. Figure 2 shows a typical field configuration on a pole with the especially developed low weight high precision antenna, solar panels and a Personal Digital Assistant field computer. The low antenna weight enables use with extremely tall survey poles extendable 7.5 or 8 meters to reach above the dense canopy of banana plantations and the like. Extremely low power consumption and integrated battery controller/charger allows solar power to keep the GPS receiver's internal batteries charged. This is an important feature under field conditions, where power can be difficult to come by. The equipment is always ready for use. It eliminates the need to schedule time for charging the GPS receivers and eliminates the risk that equipment is taken to the field discharged. Internal Lithium ion polymer batteries allow operation for an entire workday (over 10 hours) without sunlight. The particular type of ion polymer used allows operation in extreme temperatures.

Figure 2. DataGrid Mk-1 Crane or Toughman GPS/Data collectors in typical field configuration. Shown on a pole with low weight antenna, solar panels and a PDA.

The Mk-1 has operated in extreme environments from the heat of the equator to the cold and darkness of the polar regions. DataGrid has recently augmented the system with a dual frequency GPSs using the same simple processing and simplified data collection for higher productivity.

5 Software

The GeoID software suite, running on Desktop and Notebook computers under Windows, consists of a postprocessing module, a database and mapping software in addition to setup and maintenance tools. There is also software that runs on a Palm-OS, Pocket PC, or Windows CE field computers.

Postprocessing can yield high accuracy GPS solutions but is often considered to be cumbersome and normally requires considerable training. Many who like to see the GPS solutions while they are still in the field tend to rule it out. Others rule it out because of the cost of processing. DataGrid's has therefore developed a highly automated mode for its postprocessing. This mode requires no special training and can be run on-the-spot on a field computer while still delivering decimeter level accuracy as long as instructions for the data collection developed by DataGrid are followed. The measurement sequence involves three to five minutes occupation of every measurement point. A reoccupancy procedure eliminates most effects of multipath and other errors and can be used to estimate the typical accuracy of a survey.

The results of the postprocessing appear in the GeoData database where some human intervention is still required to associate a measured coordinate set with a specific land parcel. This process might be automated in the future, based on adherence to a numbering system for the surveyed points. The organization of the database can be hard-keyed with standard entries to promote consistency and simplicity as demographic and other data is entered in the field. Besides land titles, forms that may be generated include a broad range of claims such as deeds, zoning restrictions, seasonal rights given to nomadic peoples, mining claims, fishing and hunting rights (see example in Figure 3). While the rights as entered in the database are for the most part restricted by two-dimensional geographic coordinates the database can also operate on entries that are less strictly defined spatially (exemplified by rights of migrating peoples) or that are defined in three dimensions (such as tunnels, mining rights, and high-rise buildings). Operation can thus be optimized for the task; yet the software is powerful and sufficiently advanced to encompass for example the set of recommendations outlined by van der Molen and Lemmen (2004). An important advantage with this comprehensive data structure is the ability to handle all aspects of the data in digital format which in turn allows affordable data preservation and affordable upgrades as needs change. The database format and structure is made to allow data export to other software packages and is compatible with PostgreSQL. Most of the data can for example be exported to ESRI's ArcGIS and other land administration software, including ArcCadastre by ESRI and Lantmäteriet. However, since GeoData uses a flexible structure to be compatible with recommendations by van der Molen and Lemmen (2004), data organization and some attributes may be lost or may not work properly in other databases.

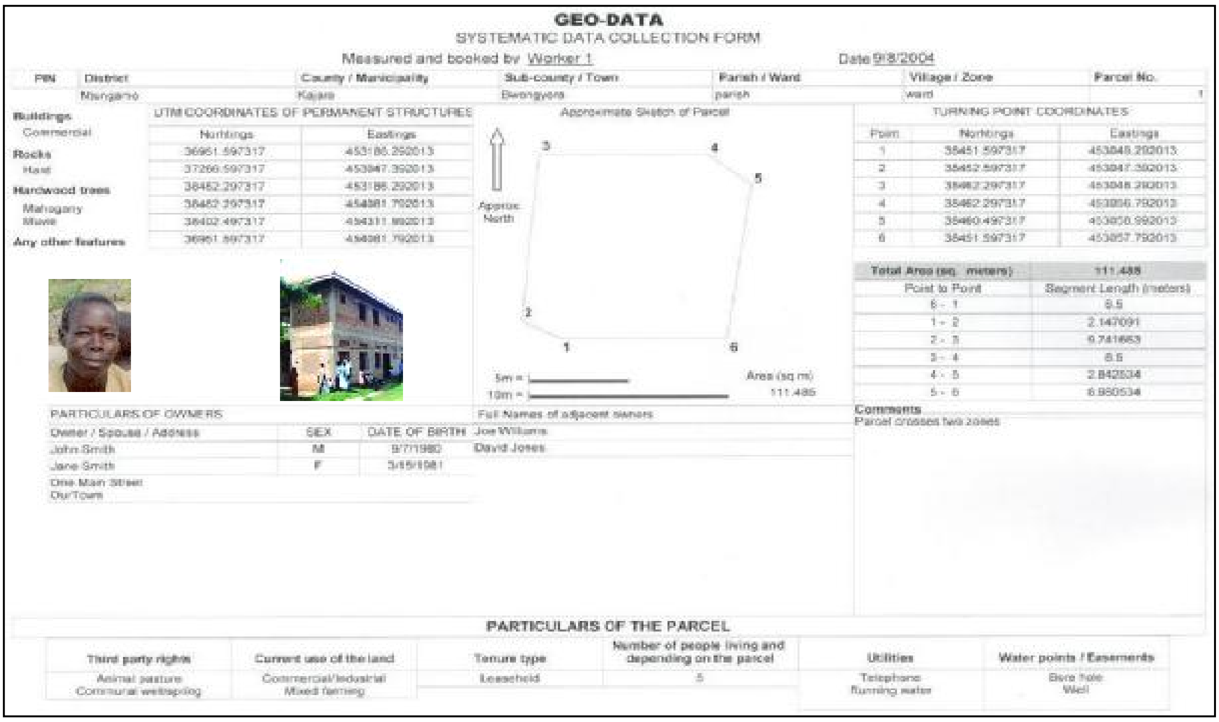

Figure 5. Sample land survey form generated by the GeoData database.

The GeoMapper software is a datum transformation and visualization tool where field data such as photographs and for example soil properties may be shown associated with the coordinates of the location where they were collected. Data generated by GeoData such as land certificates or database entries on land use or demographic information may also be displayed with the coordinates of the corresponding parcel. GeoData supports ESRI's shapefile format and can export data to for example AutoCad by AutoDesk. Coordinates may be transformed into a comprehensive array of preset standard datums. These may be edited by the user who may also add new datum definitions. DataGrid can lock the datum during customization to remove the risk for human error and datum ambiguity.

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BIOGRAPHICAL NOTES

Bo Gustafson earned a Ph.D. in Astronomy from Lund University in Sweden in 1981. His activities in theoretical and experimental astrophysics earned him awards and recognition from NASA and the International Astronomical Union (IAU) who named an asteroid in his honor. Gustafson is President of DataGrid Inc., 1022 NW 2nd Street, Gainesville, Florida, 32601, USA, a company that he founded to bring the technology of space science to bear on the plight of developing countries and for overall improved efficiency and reliability in land administration and other large scale human endeavors. Gustafson is also a Professor of Astronomy at the University of Florida and Director for its Laboratory for Astrophysics where his team has developed and built instrumentation for NASA, ESA and other space agencies in addition to performing fundamental research on radiation and its interaction with matter, a topic of great relevance to GPS technology.

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