Establishment of Coordinate Based Cadastre in Negev Desert

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SUMMARY

The Survey of Israel (SOI) has embarked upon an ambitious project to modernize its cadastre system and calculate precise coordinates for every parcel corner.

Like in many other countries, cadastre data in Israel are archived in various formats (e.g., paper and digital), diverse forms (e.g., digitized boundaries, subdivision plans, survey notes) dissimilar methods of computation (chain distances or polar measurements) and even different coordinates systems.

The new coordinate based cadastre will create uniformity and eliminate the time and labor consuming process of data integration and adjustment of dimensions and measurements. Technologically, advanced GIS tools will be used to store, manage and analyze these cadastral data system along with GPS technology which will be used to identify the coordinate based corners in the field.

From the juridical point of view, the coordinates will not be, yet, part of the chain of evidence but will aid the surveyor in quick and efficient boundary tracking. Nevertheless, work is being carried out to advance this land reform in the conservative legal system.

A few steps were set for this project including: area demarcation, assimilation of all the existing cadastral information about the allocated area (digital and paper block maps, data about international boundary monuments, subdivision plans, measurements of boundary-defining topographic features, coordinates of national control points, surveying notes, and other documents), measurement of existing authentic parcel-corner monuments, adjustment of input data and calculation of precise coordinates for each corner, integration of the adjusted data in a specifically designed cadastral database, and the development of an on-line distribution of these data to governmental agencies and citizens.

This article describes these steps and their implementation in the southern part of Israel, the Negev. This rural area with low population density constitutes about 50% of the country's area and will be the ideal test bed for the new cadastre system.

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1. INTRODUCTION

Cadastre is a system of land property registration and management that includes information about land parcels and ownership. It constitutes an important factor in modern society (Kaufmann & Steudler, 1998). Accordingly, development of modern cadastral systems provides a strong foundation of sustainable national development (Williamson, 2001).

The Israeli cadastre, as cadastral systems in various countries throughout the world, is based on ground monuments, block maps (partly handmade), field measurements books and computation files. The aforementioned materials have legal validity whenever parcel boundary restoration is needed. However, despite their legal status, the original cadastral documents suffer considerably from the lack of completeness and the boundary restoration is both complex and time consuming. Additionally, much of the data was collected with land surveying of low accuracy. As a result, the coordinates of parcel corner points are of low accuracy with great difficulty in integrating the adjoining blocks into the spatial cadastral continuity.

Historically, cadastral measurements have been carried out by reference to the national geodetic grid which has an accuracy of up to dozens of centimeters and sometimes even worse. This is in contrast to the common aspiration among cadastral experts which is to establish cadastral system that will provide the position accuracy of parcel corner points in a range of under-decimeter (according to the optimistic estimation – on the 5 cm level). In 2007 the new geodetic grid, named IG05, came into force. The new grid, based on satellite geodesy and permanent ground stations (Steinberg & Even-Tzur, 2004), enables to obtain point planar position in accuracy of a few centimeters. The latter fact allows assuming that future cadastre could be eventually declared as a legal one provided that its coordinates were determined in the IG05 grid. Certainly, such declaration should be conditioned by the change of existing cadastral legislation.

In the light of current situation, the Survey of Israel (SOI) has made a strategic decision on advancement towards the establishment of coordinate based cadastre in the IG05 geodetic grid. The main characteristic of this future system will be to optimally define parcel corner coordinates using all available information derived from original cadastral materials and considering existing physical marking of parcel corner points. Additionally, it was decided that SOI will develop a comprehensive program aiming at launching the practical implementation of the coordinate based cadastre. It was also decided to initiate the series of practical steps in the determined direction. One of these decisions was to establish a permanently functioning "Cadastre Forum" whose main goal was defined as general preparation of the SOI in the implementation of coordinate based cadastre in Israel and launching a practical project of wide extent in the southern area of the Negev Desert.

2. CADASTRE FORUM IN SOI

In 2008, the Cadastre Forum has been established in SOI, aiming at outlining the general plan of the creation of a coordinate based cadastre in Israel. The Forum included leading SOI specialists in the branches of cadastre, geodesy, GPS based measurements, ground surveying, IT technologies, and GIS/LIS. The main goals of the forum have been determined as follows:

- analysis of current experience gained during a series of pilot projects initiated and funded by SOI in the recent years
- developing general approach for the establishment of coordinate based cadastre in Israel
- adoption of a plan of activities for the next decade concentrated on realization of general approach
- launching of wide scope project aiming at achieving practical results which could benefit the whole process of establishment of coordinate based cadastre in Israel

After half a year of intensive work, the Forum has adopted a comprehensive plan which included the following action items:

- analysis and classification of original cadastral documents having legal validity for parcel boundaries restoration
- identification of original parcel corner points (authentic ground marking of points) and their measurement
- analysis of accuracies of corner points determining in existing cadastral works
- analysis of accuracies of surveying methods implemented in performing old cadastral works
- preparation of the national GIS, maintained in SOI, for checking, approval and storage of a new cadastral information
- initiation of activity on parcel boundaries restoration of existing cadastral parcellation
- intensification of R&D activity concerning cadastral routine procedures and establishment of coordinate based cadastre
- initiation of juridical activity for a new cadastral legislation supporting the process of establishment of coordinate based cadastre and professional decisions concerning determining of parcel boundaries position

One of the results achieved by the Forum was the decision to initiate the project of establishing coordinate based cadastre in the Negev Desert region, briefly called "Cadastre Negev" project. It was decided also that the project will be performed in the non-built areas spreading over 220 cadastral blocks which include most of the Negev Desert territory.

3. "CADASTRE NEGEV" PROJECT

3.1. Project Goals and Principles

Currently, there are two versions of the existing parcellation, maintained in SOI, – i) physical block maps containing graphical description of parcel boundaries and ii) national GIS database including digital cadastral data. The first version is characterized by numerous ambiguities in exterior borders of adjacent cadastral block maps, despite the fact that these maps have legal status serving as a court proof for parcel boundaries restoration. The latter version holds absolute topological compatibility of adjacent block maps but does not match block maps completely and as a result has no legal validity.

Consequently, the main goal of "Cadastre Negev" project has been determined as transformation of existing parcellation in the non-built-up areas of the southern Negev into analytical coordinate based data holding strong topological compatibility between adjacent cadastral blocks. The task is to obtain optimal corner point coordinates that eventually would be declared as those having juridical validity for parcel point's restoration.

The solution of the problem might be achieved by one of the following ways:

- digitizing of the cadastral maps and their subsequent connections into digital coordinate based data and using adjustment of exterior boundaries
- fitting GIS analytical cadastral data to physical block maps

The first solution has been rejected due to consideration that it would be too much labor consuming. Additionally, this way was actually the primary way that was implemented by SOI for establishing of national cadastral GIS. Due to numerous incompatibilities in adjacent blocks boundaries, SOI has been forced to make the decisions that resulted in distortion of originally digitized data.

Therefore, it was decided that the basic data of the project would be the existing digital data of national GIS which will be improved aiming at bringing it to maximal compatibility with the physical block maps. The digital data from the national GIS would be adjusted using auxiliary information that will be detailed in the following sections. The final product of the project will be analytical continuity based on optimally defined point coordinates. The legal status of the data will be provided by its matching to cadastral materials having juridical validity for parcel boundaries restoration.

According to the existing legislation ("metes and bounds" principle), analytical parcellation should be adjusted to fit the physical marking of boundary corner points (so-called "authentic points"). In the case of vast Negev Desert territory, corner points have not been marked on the ground during the original arrangement of parcellation. However, geodetic control points have been determined and fixed on the ground. Partly, they were positioned at the parcel corners. Accordingly, nowadays they might have been identified and measured to serve as

authentic points. Additionally, parcels containing roads that up to now did not change their route, should be measured too to be used for further boundaries adjustment.

Aiming to intensify the work, it was decided that the required geodetic measurements would be carried out by means of satellite technology – either by GPS in RTK mode or by GPS measurements that are calculated by post processing.

3.2. Why the Negev Desert?

The implementation of coordinate based cadastre project is carried out in the Negev Desert region spreading on approximately 50% of the territory of the State of Israel, (see Figure 1) and inhabited by 550,000 residents. The origin of the word "Negev" is from the Hebrew root denoting "dry". In the Bible the word Negev is also used for the direction "south". Contrary to the usual view of a "desert," the Negev is not covered with sand. Rather, it is a mélange of brown, rocky, dusty mountains interrupted by wadis (dry riverbeds that bloom briefly after rain), and deep craters.

Figure 1. Negev Desert Region.

As it was mentioned, there is a great difficulty in defining parcel corner point position based on the original cadastral documents (maps, field books, etc.) due to large ambiguities characterizing the latter. After examining the cadastral documents in the area of future project, it was found that those areas are lacking detailed information concerning corner point position, excepting cadastral block maps drawn to the scale of 1:20,000 at the stage of original arrangement of proprietary rights. Moreover, all the project area is in the State possession and most of the parcel boundaries have not been marked on the ground. In this situation, cadastral maps being the only (graphic) source of cadastral information should be digitized, according to the requirements of Surveying Regulations, aiming to obtain parcel corner point coordinates. Accordingly, the latter situation will enable determining parcel corner point position in the IG05 grid for further marking, if necessary, with analytical accuracy of modern geodetic instruments (a number of centimeters).

Notwithstanding, the task is not as simple as it could be assumed, due to a number of additional aspects. First of all, a part of the parcel corner points are the geodetic control points which have been marked on the ground. According to the existing law, they should be measured by any method permitted by the Surveying Regulations (ground surveying, satellite technology). Additionally, the road parcels in the project area should be measured. Considering the large extent of the project area, the latter task will demand great financial and human resources.

3.3. Project Tender

At the second half of 2008, the tender to perform the project has been published. The call to participate in the project has been published in press and on the SOI web site. The request for proposals (RFP) has been addressed to licensed surveyors whose professional experience, period of activity and geodetic equipment are appropriate to performing the required work. It was decided that the whole work should be finished within one year, until the end of 2009.

The tender documents, besides the RFP, included also detailed list of cadastral blocks and their materials, technical specifications for performing the job, planned schedule, contract draft, etc.

The potential contractors have been asked to submit the documents attesting their professional skills, experience in use of satellite technology, list of required equipment (with the emphasis on equipment for satellite measurements), CV of personnel in charge, and recommendation letters. Additionally, they have been obliged to apply the methodological proposal detailing a way of project realization. Those tender requirements had dual purpose – to serve as threshold conditions and as qualitative criteria to choosing contractor.

Due to exclusiveness of the project, its conceptual significance and unprecedented geographic extent, it has created a great interest among the professional community. At the end of the process of bid inspection by the special team of SOI experts, the contractor that met the pre-defined requirements has been chosen, considering the cost of his offer.

Shortly after winning the tender, the contractor obtained all the necessary materials that included:

- Scanned block maps
- Digital data of parcel boundaries from the national GIS converted from ESRI format, to CAD format for further processing by a contractor
- Orthophoto of the project area

In January 2009 the project has started.

4. PROJECT IMPLEMENTATION

As it was mentioned before, the project will be performed in the non-built areas spreading over 220 cadastral blocks in the Negev Desert territory (see Figure 2).

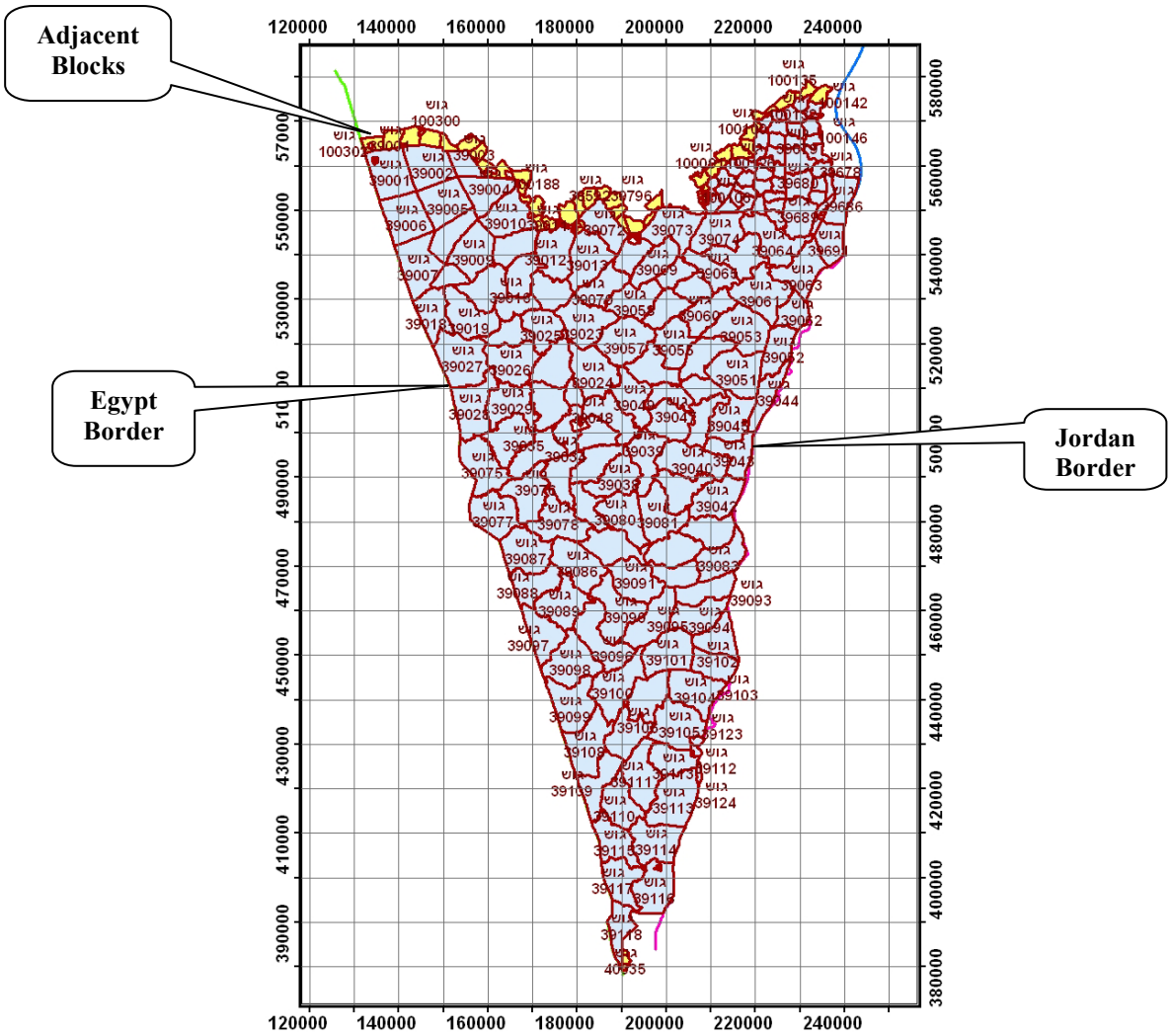

Figure 2. Project Chart

The "Cadastre Negev" project will include a number of tasks that will be performed according to the pre-defined schedule.

4.1. Authentic Points Identification

One of the important tasks of the project is to identify the original parcel corner points on the ground and to precisely measure their coordinates. The geodetic control points and the points situated on margins of road parcels (or on road axis) will serve as the original corner points in current project. They will be the basis points for parcel boundaries adjustment.

First of all, the block maps should be scrutinized aiming at finding the geodetic control points belonging to parcel boundaries. According to rough estimation, there are about 200 points like these. It might be done also by computerized means, by defining spatial query of closeness of node entities to the border lines. However, due to numerous discrepancies between parcel boundaries in GIS and on physical maps, the final check should be done using the maps.

Regarding the road parcel corner points, the check should be done whether the route of the road has not been changed, that occurs frequently in the desert region.

After that, the contractor would arrange the search of the authentic points on the ground. Considering the significant geographical scope of the project, it would be one of the most time and labor consuming tasks. Aiming to reduce required resources and to intensify the whole process, it was decided to perform the measurements by means of satellite technology.

4.2. Geodetic Measurements

The modern cadastre requires use of qualitative geodetic instruments enabling to obtain parcel point coordinates with the appropriate accuracy. Satellite technology, being used for this purpose, is one of those instruments representing advanced method of point position definition. The main advantages of GPS based technology in cadastral mapping are:

- high accuracy of point position definition
- high speed of performance and, as a result, reduction of execution terms in comparison to the conventional ground surveying methods
- reduction of required human resources
- possibility of performance under any weather conditions

Notwithstanding, there may be some difficulties in applying the GPS based technology in current project, e.g. lack of cellular covering in some remote areas of the desert region which is essential for applying the GPS-RTK method. Therefore, in real situation, cadastral surveying is being implemented as a combined method which includes both satellite technology as a principal tool and EDM measurements as a complementary one.

4.3. Connection to Adjacent Areas

In contrast with the project area, lacking detailed cadastral documents, except the block maps drawn to the scale of 1:20,000, the adjacent areas have more detailed information (e.g., mutation plans, field books, etc.), and their block maps have been drawn to larger scale. Those areas are intended to be an essential part of the project, providing the outer frame of the project region.

The adjacent areas are mainly the blocks located to the north of the project area. But, there are also the enclaves of built-up regions in interior areas which are not included in the scope of the project. The exterior boundaries of these areas would be treated as those of the adjacent ones.

The work in adjacent areas would be performed according to the requirements of the Surveying Regulations regarding restoration of parcel boundaries. That means that all the relevant cadastral documents would be gathered, checked and processed aiming at obtaining corner points coordinates. Afterwards, the field teams of the contractor would perform the examination of presence of corner points marking on the ground, checkup of their authenticity and eventually ground surveying of the found points by means of conventional EDM measurements or by satellite techniques.

In the case of ambiguities regarding restoration of parcel boundaries, the contractor will not be obliged to perform any complicated inquiry (as it was required in similar projects aiming to obtain optimal coordinates of cadastral parcellation), but to carry out the regular work according to the existing Surveying Regulations.

4.4. Connection to International Borders

The project area borders with two neighboring countries: in the west - with the Arab Republic of Egypt and in the east - with the Hashemite Kingdom of Jordan. The international borders between Israel and these countries were determined as part of the peace treaty and the international boundary points have been fixed on the ground and measured with reference to a geodetic grid.

These aforementioned borders will serve as the outer frame of the project region.

4.5. Improvement of GIS data

The cadastral layer of the national GIS will serve as an initial dataset for the project. These data that are very convenient to process were created by digitizing the original cadastral block map and subsequent fitting actions, As a result of this process the national GIS cadastral data suffer from some mismatches compared to the original maps. Notwithstanding, the cadastral block maps have legal validity for parcel boundaries restoration, even if they have been drawn to the small scale, e.g. the project blocks – 1:20,000. Consequently, it was decided that the

cadastral layer of the national GIS will pass through the improvement process and careful comparison with the original maps.

The original maps, scanned in the past, have been given to the contractor at the beginning of the project. In addition, the cadastral layer from the national GIS has been exported to CAD format and was given to the contractor. The task that the contractor would be dealing with is to geographically register the scanned original maps as a background to the cadastral layer from the national GIS, to perform the comparison between both versions and to improve the latter aiming to bring the cadastral layer as close as possible to the original map.

The main goal of the task is to fix places of large incorrectness and to make the first approximation to bringing the cadastral layer closer to their analogical source. Further procedure will be spatial adjustment based on all available information specified above.

4.6. Data Adjustment

Following the data preparation and the check of the cadastral layer from the national GIS, these data have to be integrated and properly adjusted. A data adjustment process was developed in order to achieve the required accuracy and to combine all the different factors. This process is depicted in Figure 3.

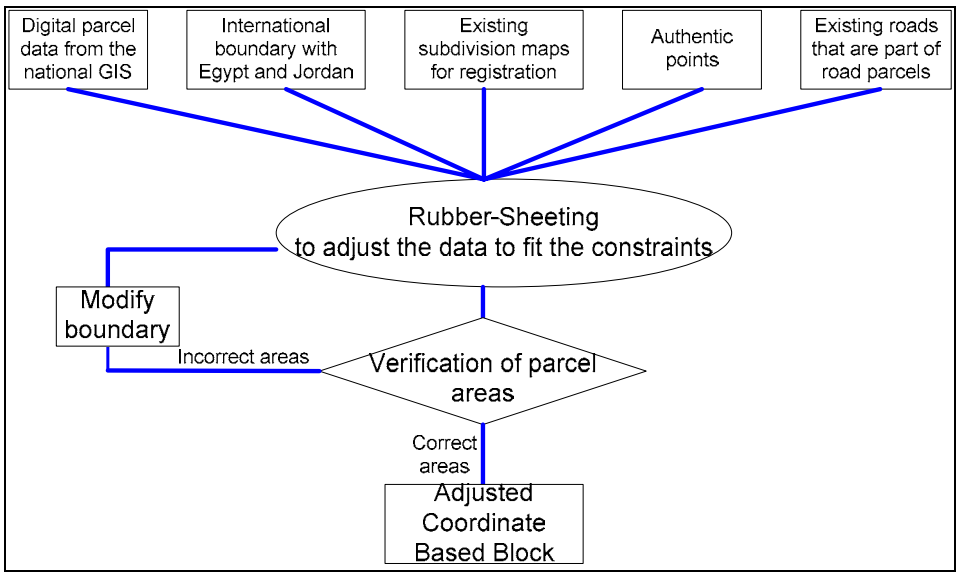

Figure 3. Fitting the data to match the constraints

The following constrains are used as the input for the process: the digital parcel data from the national GIS, the international boundary points coordinates, data from existing subdivision plans, authentic points and information about existing physical objects such as roads that exist on the ground and have to be taken into account.

These constraints are used locally modify the vector parcel maps and fit parcel corners and boundary features which were identified and surveyed on the ground. This operation, termed rubber sheeting, scales, rotates, and translates a sub-area or portion of the digital map in a non-uniform manner, such that spatial co-registration between the digital map and the surveyed points and features is accomplished. The rubber sheeting technique employs a triangulation to divide the area into small units, in each unit the transformation parameters is calculated from the constraints. A detailed mathematical description of this procedure is given in Felus 2008.

5. RESULTS AND PRODUCTS

As a result of the project, the SOI plans to obtain from the contractor the coordinate based cadastral data in CAD format and also as ASCII files formatted according to the special pattern (so-called SRV files). The latter enables to load, after computerized checking procedure, digital data to the cadastral layers of national GIS. The new data regarding parcel boundaries is intended to replace the existing data containing numerous discrepancies and mismatches.

6. CONCLUSION AND FUTURE WORK

The presented project is one of the most important projects initiated by SOI in the last decade. Its main goal is to implement coordinate based cadastre on the vast territory of southern Negev. It aims at obtaining improved digital data based on original cadastral documents (block maps) having legal validity. Project results are expected to be more complete and accurate than the existing data in national cadastral GIS.

The introduced project is the integrative component of the process initiated by SOI by means of series of projects aiming at implementing coordinate based cadastre in Israel.

The experience obtained during performing of current project undoubtedly will be used in future projects of coordinate based cadastre.

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Mr. Michael Klebanov graduated from the Technical University of Cheliabinsk, Russia, in 1985 and received his Engineer Degree (cum laude) in Civil Engineering. In 2000-2002, he completed advanced studies at the Technion - Israel Institute of Technology, Division of Geodetic Engineering, towards a Licensed Surveyor Degree. He received in 2008 a Master Degree in an M.Sc./Ph.D. direct track in Mapping and Geo-Information Engineering from the Technion and is currently a Ph.D. candidate. Since 1991, he has served with the Survey of Israel. Presently he serves as the Head of Department of Coordinate Based Cadastre and Advanced Applications.

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