Automatic Validation of the Surveyors' Regulations Criteria – A New Challenge in the Future Legal Digital Cadastre Implementation Task

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SUMMARY

By the last decade of the last century, the worldwide cadastral community was advocating for a new modern digital method for defining the geodetic dimension of the cadastral basic layer, as an alternative for the existing measurement-based documenting method. The center of this digital concept is the maintenance of digitally acquired, high accuracy coordinates for the boundary points of the cadastral parcel, which are acquired via new surveying equipment that is based on the Active Permanent GNSS Network of the country. This modern concept is the basis for the future digital cadastral system that is the title of the digital cadastre 2014 FIG project.

In order to maximize the benefits from the digital cadastre some countries are pursuing its legalization. Implementing such a legal digital cadastre system (LDC) involves several difficulties, especially conceptual ones.

This paper attempts to highlight and discuss the need for a web-based, fully automated validation system for the future cadastral project measurements that will match the surveyors' regulations criteria and recommendations, as one of the essential technical steps towards a legal digital cadastre system implementation. A digital measurements field book (DMFB) structure and an example for a specially designed application are shown as an input for the proposed web-based automated system. This proposed structure could serve as the basis for survey agencies intending to adopt the proposed idea of such an intelligent and beneficial electronic system as a step towards the establishment of the LDC.

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1. INTRODUCTION

Cadastre is one of the oldest governmental administrative systems in any country. A major change in cadastre was done in 1858, when the Australian Robert Richard Torrens established the current system outlines, using a division of the land to blocks and parcels (Larsson, 1996). Unlike the deed registration method, which served countries before the incorporation of the Torrens method (Dale, 1976), the Torrens method describes cadastral parcel boundaries, location and dimensions, using measurements documentation relative to a national control grid.

Unfortunately, due to several reasons, during the last century this method has caused several disadvantages, especially in the area of cadastral data quality, among them non- homogeneous and low accuracy levels (Jarroush and Even-Tzur, 2006; Fradkin and Doytsher, 1997). These disadvantages have slowed down the title registration rate because of legal issues, a fact that has financial implications in any country.

2. LEGAL DIGITAL CADASTRE IMPLEMENTATION ISSUES

In Israel, the Survey of Israel (SOI) is preparing to start transforming its Torrens measurement-documentation based cadastral system, which could be titled as an analogical cadastre, to a Legal Digital Cadastre (LDC) format as soon as possible (Steinberg, 2001). The legislation process for the future cadastral database, containing the cadastral boundary points, is the main process leading to the LDC establishment.

Unfortunately, the new mathematical concepts behind the digital cadastral database may lead to several undesired implementation problems that could slow down or even block the legislation process required for the implementation of that database, which is intended to provide solutions for most of the disadvantages of the existing analogical system.

On the one hand, a citizen may have problems understanding the new mathematical evidence for the boundary point coordinates, and thus have a problem accepting it as the main proof in the court instead of the current physical evidence existing in the field. For closing this conceptual gap between the two methods, municipal and national agencies/departments should adopt special practical steps aimed at helping people understanding, accepting and working in accordance with the new concept. For example, in Israel the Ministry of Construction and Housing has been attaching an official list of coordinates of the parcel boundary points to any client buying a new department in a housing project.

On the other hand, cadastral & surveying agencies have to license every boundary point coordinates, in a manner similar to licensing new control points in the national projection control grids, before entering them into the digital cadastral database. Such a licensing process should also involve issuing some sort of an "identity card" for each point.

This process intends to assist in the legislation process of the LDC database by introducing the term "coordinates" to the public, thus reducing the rejection and other problems that may result in excess loads on the judicial system. However, in doing so, several aspects should be treated carefully in order to ensure a successful and stable cadastral system. It is suggested that the most crucial aspects are the structural, financial, technical (geodetic), judicial and zoning engineering aspects (the last two aspects will not be discussed in this paper).

2.1 Dynamic Cadastre - the Center of the Structural Aspect

The structural aspect deals with the design of the system, for example: which components will be included as part of the identity of a boundary point, defining the essential components of the system and their tasks, etc. The design of the digital system has to be able to support structural tools for solving all the problems that might occur in the future.

In the analogical measurement-based cadastre, there are mechanisms for evaluating and setting off gross error measurements that lead to eliminating these errors and fixing the result according to the new foundation. Similar mechanisms should be incorporated in the future digital system in order to permit flexibility in changing point component values such as coordinates. This need for changing coordinates may result from errors that might occur in the transformation process of the analogical measurements to digital coordinates, or from geodynamic factors, such as earth surface deformations and tectonic movement that might lead to changes in the actual point position, or both.

Jarroush and Even-Tzur (2007) suggested a full "Dynamic Cadastre" system as a suitable solution for this problematic issue based on the principle of a dynamic cadastre for dynamic nation mentioned by Blick and Grant in 1997 in New Zealand. Jarroush and Even-Tzur suggested that the accuracy parameters and time dimension should be added to the 2D or 3D coordinates in the projection grid for every boundary point. The time dimension aims to describe the epoch of time in which the cadastral point identity components values are correct. The authors also describe the vital dynamic system components that can be used for calculating the updated values of the cadastral point identity components when deformations or tectonic movements occur in the earth's surface.

2.2 Future Surveying Regulation - the Center of the Geodetic Professional Aspect

The geodetic aspect deals with the reliability and accuracy, as well as the actual licensing of the identity components values of the cadastral point. This task will be managed by the surveying and cadastral agencies.

The most important tool that may be used for fulfilling this task is the surveying regulations. The main target of the regulations is to establish the high and homogeneous accuracy level of the cadastral data, as obtained when using existing surveying methods and equipment (Craig and Wahl, 2003). In most countries, the regulations' main principle for evaluating the accuracy level of the measurements is still the "Precision Ratio", which is related to the measurements' disclosure.

The last two decades were characterized by an accelerated technological development in the field of surveying, particularly in the field of GNSS measurements. The GNSS surveying methods enable surveyors to achieve a higher accuracy in a minimal time frame (relative to the conventional surveying methods). Thus, according to Rizos et. al. (2005), the GNSS based surveying method might play a dominant role in executing cadastral surveying. These modern methods usually provide immediate coordinates for the measured point, or vector components that could be used for that purpose easily.

In addition to the new concepts of the future cadastre and the change from a measurement based to a coordinates based cadastre, the "Precision Ratio" concept must also be changed, in order to meet the standard deviations errors concept, which is more suitable for describing the coordinates' accuracy (Buckner, 1997).

In most developed countries, Continuously Operating Reference Stations (CORS) has been established for geodetic and cadastral uses. Recently, survey agencies use it as the base of the national projection datum for the country's national grids. Thus, while the ultimate goal is to describe the cadastral layer relative to the CORS, the new accuracy criteria concept should use the standard deviation error of the national projection coordinates.

While the target is to describe the error in the point's position relative to the CORS, standard deviation error is used for describing the error only in one dimension. Instead, the new criteria might incorporate the statistical error ellipse tool for estimating errors (citing a 95% confidence level) as the most appropriate method from a geodetic point of view (Jarroush and Even-Tzur, 2007). Jarroush and Adler (2006) defined two types of error ellipses essential for maintaining the quality of the LDC coordinates database. The first is the "neighbor relative error ellipse", calculated by regular computations of the minimum constraint least square adjustments relative to the fix points coordinate values, without taking into consideration their error relative to the national grid datum (Cooper, 1987). The second type of error called "absolute error ellipse", which is computed relative to the fix coordinates values while taking into consideration their error in the national grid datum (Jarroush and Even-Tzur, 2007; Papo, 1973).

This modern concept of describing errors leads the surveying regulation, in the near future, to adopt the least square (LS) computation method as the recommended method for computing the measured point coordinates and their error ellipse estimated values (Buckner, 1997).

Finally, due to the possible high accuracy measurement achieved by the new GNSS surveying methods, surveying agencies could plan for high accuracy LDC databases. For example, in Israel, Steinberg (2001) has defined a desired accuracy value of 5 cm (with a 95% confidence level) for the future LDC database.

2.3 Fully Reliable Validation Regulations - the Center of the Financial Aspect

Dealing with centimeter level of accuracy, especially with a required 95% confidence level, is not an ordinary task, more so when it is in relative to the CORS datum. In order to fulfill it surveying and cadastral agencies have to revise current surveying regulations, taking into account the new high accuracy level criteria, thus setting a new and undesired reality that the common surveyor must face. In addition, the regulations' recommendations should include a computation process which will aim to achieve homogeneity in the computation results. This requirement is a result of the differences in the results obtained from different commercial software tools when they are used for computing the same measurement data. For example, results from a GNSS vector post-process computation using the Trimble TTC software (www.trimble.com) may differ from those achieved using the Pinnacle software marketed by Topcon (www.topcon.com), despite the fact that the same two RINEX files have been used in both software tools. Although the results differences are small, up to 1 or 2 cm and sometimes even more in every vector's components, achieving the ultimate 5 cm accuracy level with a 95% confidence level is uncertain.

Another example can be seen in the different results of the adjustment computation of the measurements, which are due to the different weighting methods used by different computation software. In such a case, the surveying regulations may have to define all the relevant procedures.

When combining this fact with the requirement for licensing every boundary point's coordinate values (as described in section (2) above), surveying agencies will have to check not only the measurements' quality, but their computation methods, their results and their parameters as well, relative to those recommended by the regulations for every cadastral project. Otherwise, no one will be able to ensure the homogeneity and the accuracy level of the LDC database.
Naturally the surveying agency will have to provide sufficient manpower for executing the licensing and validation of thousands of boundary points and from a financial point of view this mission seems to be too expensive.

3. REGULATING AN AUTOMATED VALIDATION PROCESS

In order to overcome the financial burden resulting from the huge number of the boundaries and control grid points that need to be licensed in the future, a fully automated enforcement of the surveying regulations criteria will be the appropriate alternative solution.

For executing such a full, reliable and homogeneous enforcement process, cadastral and surveying agencies could use one of the two solutions: using a cadastral computations licensing software or adopting a web-based system for the automated validation of the surveying regulations.

In order to evaluate the complexity of the regulations' enforcement process, let us first specify the different processes involved in providing coordinates and their accuracy estimates:

1. Planning the structure of the measurements' network. E.g.: choosing the surveying method, selecting the control points, setting the measurement time etc.
2. Surveying equipment calibrations. It is recommended using the checker point principle for checking the quality of the equipment. The checker point principle dictates the measuring of a known licensed point as means of comparing the measured results with those of the licensed point.
3. Executing the measurements in the field.
4. Downloading the measurements data from the surveying equipment and preparing it for the computation process. For example, downloading GPS receiver measurement files and post-processing the vectors.
5. Finding out measurements blunders (gross errors).
6. Executing computations for calculating the new points' coordinates and their desired error ellipse values.
7. Verifying that the final results and their accuracy meet the regulated criteria.
8. Submitting the results as a formal report to the surveying agency.

3.1 Licensing of Computational Software

This solution requires the creation of a special unit, under the direction of the cadastral agency, for the purpose of checking and validating the commercial computing algorithms and functions of any software in comparison to those recommended by the regulations, in order to ensure homogeneous and unique results.

The main disadvantage of this solution is due to the fact that software that enables full validation of the entire procedure does not exist yet. The current commercial software available in the market supports only the computation process. Thus, the first solution may be more suitable for the validation of the computation process alone, which does not meet the requested ultimate goal of an overall automated validation.

3.2 Web-base Automatic Computerized System for Surveyors' Regulations Enforcement

Theoretically, a surveying agency could initiate a web-based computerized system for the full surveying regulations enforcement. Such an enforcement process should include the entire steps and processes detailed at the beginning of this chapter.
As an input for this system, the surveyor will be required to send a digital measurement field book in an encoded format (or an electronic report), including all the source measurements and other data that will enable the system to execute the required enforcement, as dictated in the regulations.

This solution principle has been first mentioned by Haneen and Sutherland (2002) when they described an e-cadastre automation process of the cadastral survey system. The main aim of the e-cadastre was to initiate the building of the digital cadastral main layer database by means of electronic submission of the points' coordinates. A similar procedure has been used in Israel for submitting cadastral data used to shape the main cadastral blocks and parcels layer, by submitting digital data files in a defined format, the SRV format (Steinberg, 2006). The e-cadastre system, as proposed by Haneen and Sutherland (2002) included a recommendation for the new survey to be captured in a digital form, initially using paper forms and in the future via data files, upon which the regulation validation will be executed manually, while some of the computation results are validated automatically.

Our ultimate goal is to design and build the desired web-based system. One that would be fully automated and specializing in a validation of the cadastral measurements and the coordinates' computations in adherence to the surveying regulation. Such a system might include an electronic reporting procedure that will enable a dialogue between the system and the surveyor, in order to send a direct announcement to the surveyor about problems in his measurements when there are deviations from the regulations. On-line trouble shooting reports will assist the surveyors in accelerating their point licensing process by preventing unnecessary time loss due to bureaucracy and procedures.

4. TOWARD AN OBJECT - ORIENTED REGULATION STRUCTURE

The main obstacle that should be overcome by such an automated system is the complex structure of the current surveying regulations. The complexity of the regulations has been highlighted, especially in modern cadastral systems, when they aim to achieve high accuracies (in the centimeters level, with a 95% statistical confidence) relative to the CORS.

The complex structure of the regulations, recommendations and criteria makes their translation into the computerized domain difficult. Thus, remodeling the regulations should be the next stage before implementing an automated web-based validation process.

The most suitable computer architectural model for reducing the complexity of the regulations may be the "Object-Oriented" model (Weisfeld, 2000). According to object-oriented principles, the surveying agency might consider the cadastral measurements project as an object-oriented project, with defined properties, set methods and sub-objects such as points and measurements.

This paper does not intend to deal with this issue at length but would like to highlight this as a possible structure for a future surveying regulations' structure.

5. DIGITAL MEASUREMENT FIELD BOOK (DMFB)

The DMFB will be the main input tool in the proposed electronic regulations' validation process. The measurements' data should be arranged in a specific protected format, in such way that will enable executing an automated legal and effective validation process. The protected format aims to prevent any possibility of faking the measurements entered to the system. A higher protection level will ensure the esteem and legality of the process.

Actually, a DMFB could be comprised of one digital file or a group of files compressed together. The surveying agency will have to provide the surveyors with an appropriate computer application (preferably a freeware) to create the protected data format, thus building the DMFB directly from the binary surveying equipment format files. Binary files are un-editable files, thus surveyors could not edit or change them in any way.

In order to further characterize the DMFB issue, authors prefer to separate the discussion about the measurements' data into two parts: post-processing GNSS vector measurements data and other related measurements. Two reasons are behind this division. The first is related to the different complexity between immediate measurements' data executed by total station and RTK GNSS equipment and between GNSS post-processing data. The second reason is that until now; we could not find a universal digital format for describing all the possible measurements' types, such as the RINEX format which describes the GNSS raw measurements' data. Thus, it is obvious that surveying agencies might adopt more than one file format.

5.1 Files Including Data other than Post-processing GNSS Vectors Data

There are several common binary formats characterizing surveying equipment currently available in the market, for immediate processing or on the fly processing results, for example: the TDS software format (http://www.tdsway.com) that could be convert to ASCII raw data or binary data as a JOB file format; the DC file format belonging to Trimble; the GTS5 or GTS7 or JOB files of the Survey-Link software sold by Topcon, etc. Some of them include all measurements' types except GNSS post-processing vectors data results and others include only partial measurements' types, like the GTS5 files that concentrate on total station polar measurements.

Surveying agencies could request surveying equipment manufacturers for suitable computer applications for reading these formats appropriately.

It should be noted that not all the formats are necessarily binary; they could be editable ASCII files as well. However, these files may have a reduced protection level and thus the surveying agency should not adopt them.

5.2 Post-processing GNSS Vectors Data Files

Post processing software produces the GNSS vector by getting two GNSS measurements' files that have a common measurements' time period. The result of the process is a vector composed of ($\Delta X, \Delta Y, \Delta Z$) components and their covariance values.

The authors have searched the web for a universal file format designated for saving post-processing data results. The searching process concentrated on the main website of the USA National Geodetic Survey (NGS) (www.ngs.noaa.gov) as this is the official website for all GNSS data sources.

The only GPS vector data format that has been found is called a G-file. It is the input file of the BlueBook software belonging to the NGS. The BlueBook software was designed for adjusting the GNSS vectors measured between the national and the universal permanent GPS stations all over the world (www.ngs.noaa.goc/FGCS/BlueBook/). The G-file format includes data describing the geometric vector components and their covariances, GPS post-processing vector software details, the post-processing date, the GPS satellite ephemeris source (prices or broadcast), the datum parameters for the data, the measurements' data types (L1, L2, P1 code etc.) and finally, the processing method description (Single-differences, double-differences etc.).

Unfortunately, the G-file format does not include sufficient information to evaluate whether the vectors' GNSS measurements meet the regulated methods and their quality assurance criteria. The main reason is that the G-file lacks some obligatory data relating to both end vector station points and their GNSS measurements. For example, the following critical information is invalid in a G-file: the antenna heights of both of the end vector points, the duration time of the common measurements between the two points, and the DOPS values in every point. This data enables surveying agencies to validate some important GNSS regulations' criteria, such as the criteria relating to the independent existence of station points' measurements.

Until the definition of a universal GNSS vector data file format, the authors suggest four possibilities for solving this issue:

- Attaching the RINEX files of all the points in the cadastral project along with the G-files of every vector. This solution is not recommended because the G-file is an ASCII file (alpha-numeric), a fact that might reduce the protection level of the data.
- Adopting file formats produced by the post-processing software that seem to be suitable for fulfilling the automated validation process. The result of our primary examination indicates that the common format that could be suitable is the OBEN file format of the Ashtech Office Solution (AOS) software. The OBEN format files are also known as O-files.

For evaluating the O-file's suitability for fulfilling the validation mission, the authors requested the file format definition from the Thales company which graciously provided it and we are thankful to them.

On the one hand, an assessment of the O-file format indicates that it may include GNSS post-processing data sufficient for evaluating all the regulations' criteria and methods. Unfortunately, among all the commercial software packages that have examined (including: TTC and TGO by Trimble, Pinnacle and TopconTools by Topcon, GNSS software by Thales and LGO by Leica) some of them do not support exporting the O-file format. Those that do support exporting O-file formats fail to produce the correct and complete data required. Problematic data is received especially for the end vectors' station points' measurement descriptions data, such as the measurements' source times, antenna heights, DOPS value for every epoch, as well as other data contained in the O-file.

- As a result of the incomplete data contained in the O-file format (as described above), adopting the O-file format alone will not provide a sufficient solution. Thus, using the Rinex files, as reference for assessing the data or for completing the missing data in the O-files, along with the O-file, should be an appropriate option.

- The ideal solution is to define a universal GNSS post-processing vector data format, similar to the Rinex format concept. One that all the post-processing software will be required to support for both import and export.

6. A PROPOSED DMFB APLLICATION DESIGN

Basing the DMFB on surveying equipment format files (authentic data files) entails two problems. The first one is the names of the measured points as they are saved in the authentic data files since, usually, final cadastral points' names differ from their measured names in the field. The second problem is the recognition process of the existing points' purpose, such as: controls, checker points used for evaluation of the results (Jarroush and Adler, 2006) and the new points that need to be licensed by the surveying and cadastral agencies.

For solving these two issues, the following steps are needed:

- One ASCII file should be added for each binary surveying' equipment format file and used for matching the final point names in the cadastral project and defining their purpose. Point purpose could be defined by means of an accepted universal pre-defined code.
- Two ASCII files should be added to the DMFB compressed file: one for defining the control points' coordinates and the other for matching their measured names in the commercial software binary files.

Additionally, another ASCII file is needed for general titles pertaining to the cadastral project definitions. The flowchart described in figure 1 illustrates the DMFB structure.

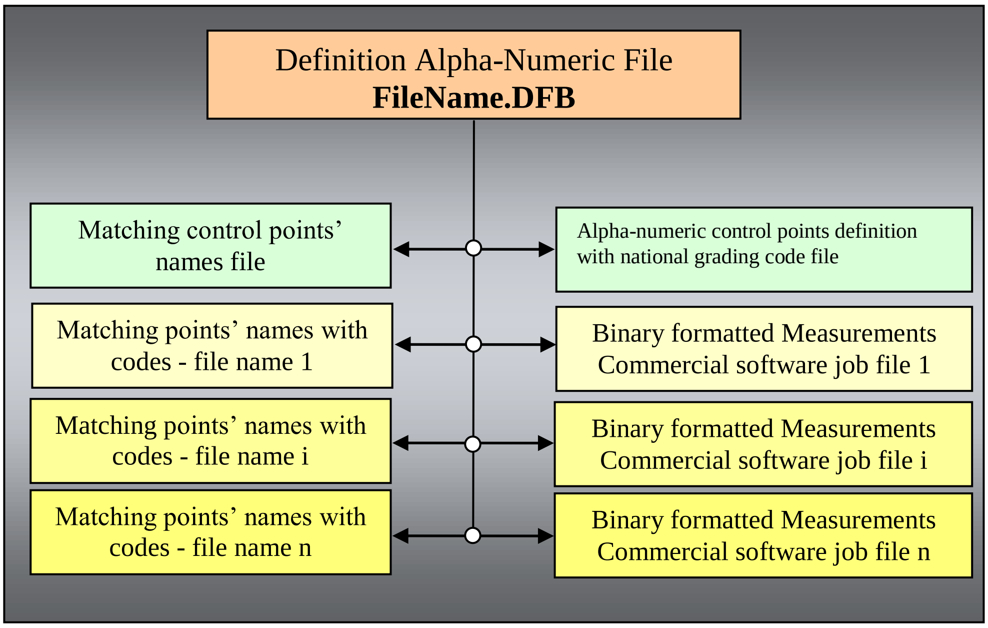

Figure 1: The digital field book structure - DMFB

A proposed format for the general ASCII format could be:
{

Project name: <20 character string >
Contract number: <long>
Contract start date: <date>
Surveyor code: <3 character string>
Surveyor license number: <long>
Surveyor name: <20 character string >
Company name: <20 character string >
START
Number measurements files: <integer>
****
Control points file name: <32 character string>.CPN
Matching control points' names file name: <32 character string>.MCP
******************** Measurements File name 1****************************
Measurements file type: <32 character string >
Measurements file name: <32 character string>.<4 character string>
Measurements boundaries' points' names file name: <32 character string>.MBP
******************** Measurements File name 2****************************
Measurements file type: <32 character string >
Measurements file name: <32 character string>.<4 character string>
Measurements boundaries' points' names file name: <32 character string>.MBP
******************** Measurements File name …****************************
******************** Measurements File name n****************************
Measurements file type: <32 character string >
Measurements file name: <32 character string>.<4 character string>
Measurements boundaries' points' names file name: <32 character string>.MBP
****
END

The suggested final DMFB compressed file suffix is DFB.

For illustrating the implementation of the DMFB, a MATLAB based application has been developed (see figure 2). Such an application can be given as freeware to all the surveyors in the country for building their cadastral project DMFB compressed file, which would be then sent via the Internet to the electronic automated system installed and maintained by the surveying agency. The application described in figure 2 asks the surveyor to enter the project and its details, a control points' definitions file as well as the measurements files that he measured in the field. It should be noted that the application enables surveyors to add several measurements data files in different formats but forces them to add an ASCII (alpha-numeric) file for every measurements' file that will be used for matching the measured points' names with the final names. The output of the described application is one compressed file that includes all the files described above.

Using the proposed DMFB structure, the automated system could build the measurement network mathematically which could be the base for evaluating the measurements and the structure of the measurement project relative to the surveying regulations and criteria.

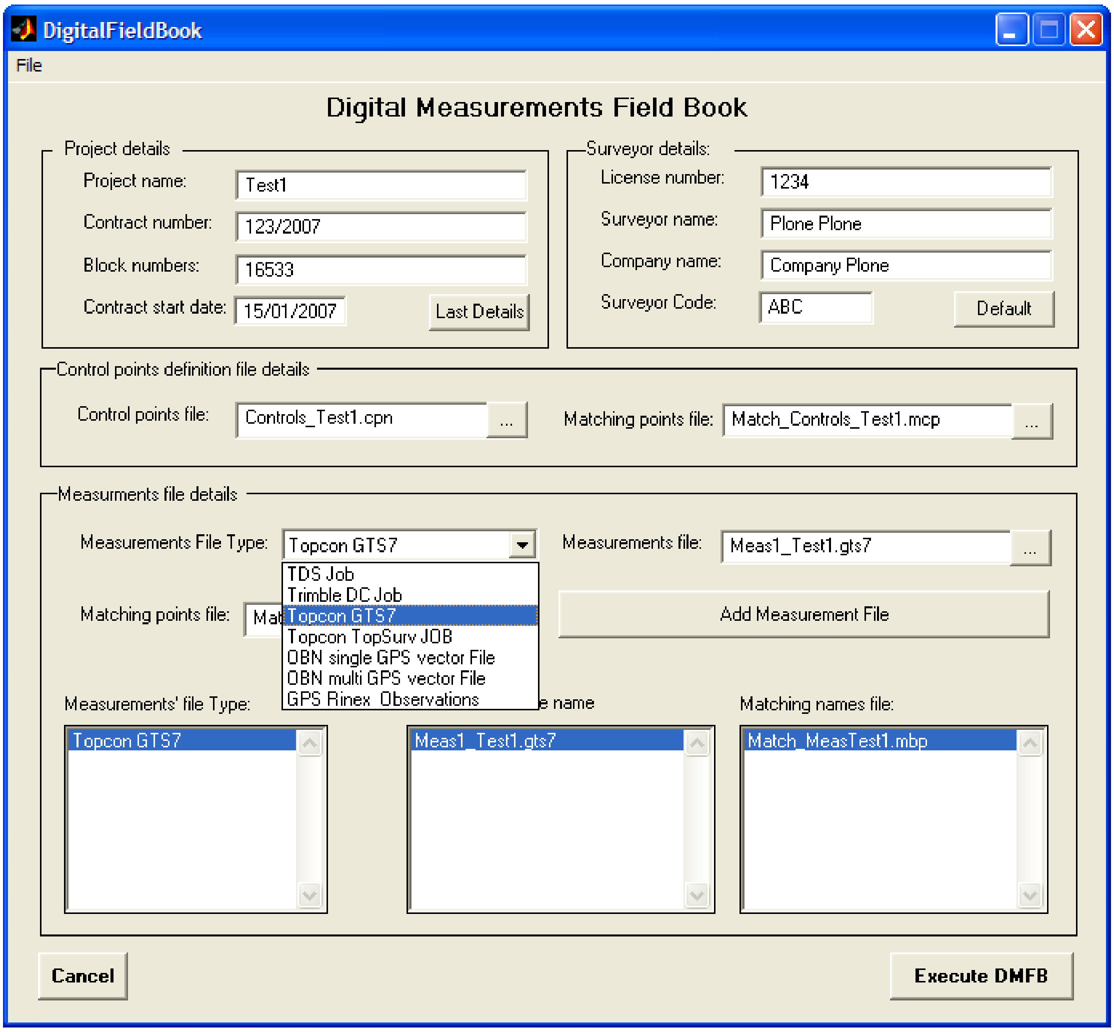

Figure 2: The user interface of the main application which produces the digital field book file

7. SUMMARY AND DISCUSSIONS

The first part of this paper raised essential issues on a conceptual level for implementing the LDC. Obviously, many conceptual, technical and geodetic steps could be suggested and discussed for contributing to solve these interesting issues. Parts of these suggestions are detailed in the second part of the paper. The final part of this paper intended to focus on one technical solution that should be adopted in order to overcome some financial and geodetic problems that may slow down LDC implementation process by highlighting and expanding on the requirement for licensing the digital identity of every new cadastral point as one of essential technical steps toward the implementation of the future ideal LDC. It was shown that for fulfilling such an unusual mission there is a conceptual need for developing a web-based system for an automated validation of the cadastral measurements and their adherence to the surveying regulations and criteria.

Every national surveying agency can define the exact tasks and functions of such an automated system. For example, it should be decided whether the system will compute the final license component of every new cadastral point or just validate it.

The advantages of fully automated validation system are vast, to repeat but a few:

- It may serve as an important step towards the legalization of the future cadastral database.
- Establishing a high, computed and homogenous component accuracy for every point in the future cadastral database (which could to be dynamic, according to Jarroush and Even-Tzur, 2007).
- Accelerating the cadastral point identity licensing process, and in return accelerating the title registration process as a whole.
- Providing statistical analysis tools for the submitted data reports. Such an analysis could enable a review of the accuracy strictness degree recommended by the surveying regulations. This, for example, could highlight specific problematic criteria or problematic methods or tools at use.
- Raising the professional level of the licensed surveyor in the country. This will be a result of the surveying agency's ability to classify the surveyors' professionalism based on the automated validation system (for example, according to the number of failed cadastral measurements projects vs. their approved reports, the system could supply each surveyor with a grade or classification, which could be used for evaluating them professionally.)
- Reducing the need for executing field measurements aimed at examining the project measurements' compliance with the regulations.

The only disadvantages of such a web-base system revolve around the claim that it could reduce the position of the surveyor. It is our claim that such a system will do the contrary, as it will encourage negligent surveyors to be more precise in executing high quality cadastral project measurements, a fact that could lead to an increase in their status and enable raising their fees. As a result, the surveyors' position in the professional community will be improved.

It should not be forgotten that a web-based automated validation system is one of two possible solutions that are proposed for overcoming the financial, technical (geodetic) and other issues involved in the implementation of the cadastral point identity licensing mission in the future LDC era. The second solution relies on licensing software designated for this purpose.
The DMFB structure and execution application shown in the paper are just a proposal. Every surveying agency can adopt these concepts and a matching specialized design that would match its cadastral requirements.

Finally, although the use of the DBMF principle, toward an automatic validation system of the surveyors' regulations criteria, does not pretend to be the core of the main implementation issue, it stills considered an innovative approach to it.

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BIOGRAPHICAL NOTES

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