PHOTOGRAMMETRY AND FIELD COMPLETION - AN INTELLIGENT APPROACH.

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ABSTRACT

The evolution of geographic information systems has created new customers for digital topographic databases, those clients have very demanding requirements particularly in the large scale domain. The typical major parts of geospatial database production are; photogrammetric data collection, editing and insertion of additional information from existing maps or other sources, and field completion. The last part is the most accurate source of information both thematically and positionally, but it is also the most expensive one. We are proposing a new approach that will make field completion work more efficient and cost effective. Use of spatial analysis techniques allows the identification of areas to be completed, optimization of field completion missions --routing, selection of methods and instruments, costing, etc.-- and eventually provides the necessary quality indicators. This has been achieved utilizing GIS/CAD software tools. The developed software provides analysis tools that inject intelligence in the planning and in every step of the field completion operation.

1. INTRODUCTION

Large scale mapping is a very long, multistage and costly process especially when we consider the term mapping in its broader sense that is spatial database production.
The typical major parts of geospatial database production are; photogrammetric data collection, editing and insertion of additional information from existing maps or other sources, and field completion.

The process of photogrammetric data collection has been developed rapidly in the last years with the introduction of high quality modern cameras with forward motion compensation and the modern analytical plotters and digital photogrammetric workstations.
With the new hardware we can achieve high positional accuracy, whereas with the superimposition (image injection) techniques we can check the completeness of the database while with the available zoom options we can enlarge our viewing ability, interpret the model space, identify objects and extract features rather easily.

In a large scale mapping environment maps may have to satisfy a variety of purposes:
- planning of city development
- management of public properties
- execution of construction work
- GIS databases for municipalities and utility companies for their specific application (electricity, gas, cable TV, telephony, water e.t.c)

The characteristics of large scale urban maps are: the very high density of objects per unit of surface in the terrain that have to be represented on the map, the survey of invisible objects such as the cable-, pipe-, and wire-conduits and the high accuracy required especially when construction work have to be carried out --widening of streets, renovation of city quarters, construction of subways, etc.--.
Moreover, in urban areas, changes may occur rapidly requiring much effort to keep the map up-to-data (old buildings being demolished new buildings being erected, but also sudden "letdown" of squatters may be observed).

The survey and mapping of the multitude of objects that are necessary in the large scale domain, can be done either by terrestrial methods or in combination with photogrammetric stereo restitution. Application of photogrammetry, as compared with the use of field survey exclusively, aims primarily to a faster production rate, the maps become available earlier, and secondly aims to the redaction of costs.

However, photogrammetry has a number of limitations and is not always effective. For example dense conifer forest, deciduous forest in leaf, swampland of tall grasses and featureless terrain such as sand dunes can be mapped in more details by ground survey techniques. Furthermore there is no substitute for on-site inspection of terrain features, especially in large-scale mapping of built-up areas, where a considerable volume of underground detail and paved surface is encountered.

In addition, with the evolution of GIS there is a need for descriptive information that can be acquired only in the field, e.g., usage of building - commercial, industry, residential or needs for data verification in the field to ensure greater thematic and positional accuracy.

For these reason there is a great demand for field completion in the process of producing high quality large scale databases.

The basic objectives of field completion are:

- to select information from areas which were obscure at the photogrammetric workstation.

- to complete thematic classification and to add supplementary data. Some users may require the inclusion of a specific type of information in their geographic database (e.g., identification of electricity network elements and collection of their attributes, classification of buildings according to their usage and number of floors, etc.).

- to verify that the map conforms to accuracy requirements.

In this paper we are proposing a new approach that will make field completion work more efficient, cost effective and less error pron. The use of spatial analysis techniques allows the identification of areas to be completed, optimization of field completion missions --routing, selection of methods and instruments, costing, etc.-- and eventually provides the necessary quality indicators. This has been achieved utilizing GIS/CAD software tools.

2. INTEGRATION OF GIS, PHOTOGRAMMETRY AND FIELD COMPLETION

The creation of a geospatial database is typically a multistep process where GIS with its spatial analysis functions and different types of data are involved. Figure 1 illustrates the process and the various stages for its creation.

We will describe how we integrate those phases to one work flow with special attention to the new modules.

Our approach concerns mainly with the last stages C, D and E considering that the initial spatial database has been created in the stages A and B.

A. Planning - The process starts when the client approves the answer to his request for proposal (RFP). At this step the requirements should fully be analyzed and categorized. Some demands can be achieved only with field completion, whereas others can be satisfied with data collected by photogrammetric means.

The planning stage also includes:

- detailed schedule with missions list and completion time.
- designing of a photogrammetric flight configuration
- translation of the specification into detailed instructions
- preparation of a data collection menu --table of symbols, linetypes etc.

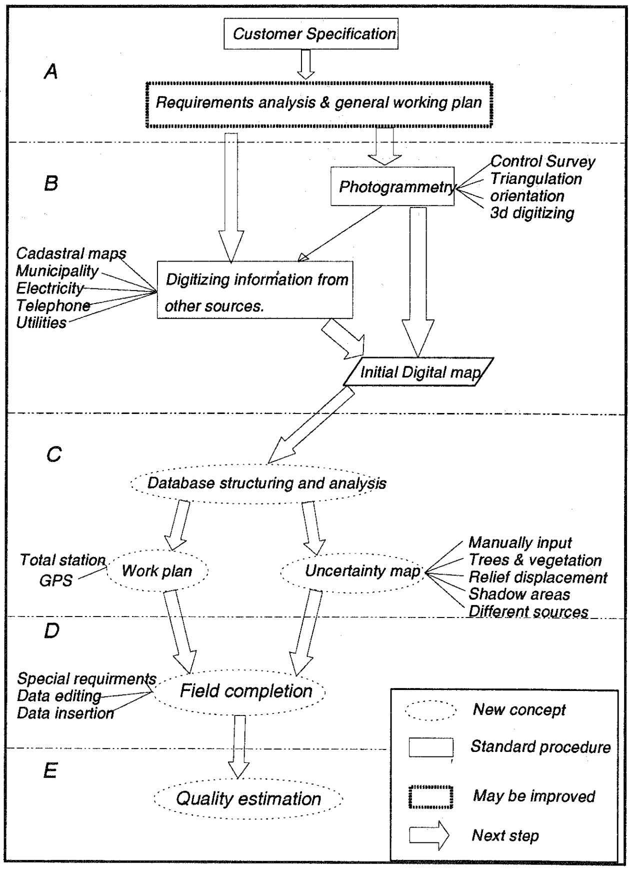

Figure 1 : *Spatial database creation*

B. Data collection - This is the "indoor" -office - data collection stage, it is initiated and directed by the first phase of planning and preparation. The collection of photogrammetric data and data from other sources is done at this stage.

Collection of data from other sources consists of two steps:

- gathering of maps and information from the archives of related organizations --Municipality, Electricity company, Telephone company, Surveying Department etc.--

- transferring the collected data to digital form. This is done with digitizing tables connected to a computer with a CAD software. The operator needs to have the photogrammetric database as a source for georeferencing, i.e., the additional information is positioned according to prominent features which appears both in the photogrammetric database and in the map.

C. Database analysis - This phase is actually the weakest part in the chain of normal mapping procedures. In the proposed work flow, plays an important role.

The operator during the photogrammetric data collection phase inserts in a specific layer the areas that were unclear, uncertain and where he thinks it should be a closer investigation, from the field surveyor.

The developed software analyses, shows and marks all the uncertain areas and produce a comprehensive map of field completion work.

This map includes; the areas designated for field completion during the planing stage, zones that were sun shaded, regions covered by trees and vegetation, with obscured areas due to relief displacement, and objects or places where was a dispute between the different sources of information and, of course, those areas marked by the photogrammetric operator as doubtful.

Following the software menu the user can plan the field work activities and choose the surveying methods to be used.

There are two software modules one is aimed at surveying using total station and portrays the areas that are invisible from particular ground points, while the second module is intended for GPS surveying and presents the areas that cannot be surveyed by GPS.

D. Field completion: Field completion, being time consuming and costly operation it should be performed in the most effective way. We propose, the field data collection to be done, using a portable computer and especially designed software. The CAD software can present the initial digital map in any required scale, can also edit and modify it in the surveying site. The developed functions are used for quick insertion of new elements using common surveying techniques arcsection/right angle /distance & direction and also data collected from surveying instruments. The surveyor does not need to remember all the lists of symbols with their defined layers but rather to navigate quickly through the menus.

E. Quality control - One of the objectives of field completion is to verify and check that the map conforms to a certain accuracy specification. Our software prompt the user to identify check points and to input their measured position. At the end of the work and after the collection of a sufficient number of points, the software computes quality parameters based on the coordinate differences, and adds this important information into a metadata file (a file with relevant information describing the geodatabase).

We can clearly see that using this approach, the integration between photogrammetry and field completion becomes stronger and more natural, the GIS/CAD software indicates the areas of field completion and enables the insertion of the collected information directly into the database.

3. SYSTEM IMPLEMENTATION

3.1 Programming considerations

The system is a LISP program written in ArcCAD software environment. Input into the system is the initial database (the outcome of stages A and B in Figure 1). The initial database consists of graphical elements, i.e., points, lines, polygons and symbols arranged in the database in "spaghetti mode".

Three important features are used extensively in the developed modules:

- Layer structure:

The graphical elements in the "Spaghetti" file are divided into layers, each layer contains the graphical elements that belong to a group of objects, e.g., layer "2200" contains all the polygons that represent buildings/houses, layers 2801 contains individual trees, etc.

Consequently the basic tool that allows to select a group of objects, is the layer separation. For example when we want to display only the trees in the database we select layer 2801 and we "freeze" the other layers. The layer structure is also used when new information is produced, e.g., when the sun-shaded areas are evaluated the corresponding polygons are placed in a new layer called "shad".

- Blocks and attributes:

An important element in AutoCAD is the block. A block, like a symbol, is an ensemble of simple graphical elements (points & lines). However, unlike symbol elements, there are attributes attached to the block. An attribute is a textual descriptor or additional information of the object. The block is a convenient tool for insertion of data, because during the insertion of a block the user is requested to fill the attribute information, i.e., most questions that will be the block's attributes. Block attributes can be visible or invisible and they can be transferred from the graphic data file to a tabular database.

- Combined environment -ArcCAD & AutoCAD: ArcCAD is the GIS engine for AutoCAD, that is why we can work in a full 3D CAD environment and when is required to use GIS commands the database is transferred to GIS structure and spatial analysis commands can be selected.

The transfer to a GIS database structure consist of three phases; define a "theme" and a dataset, copying the relevant layer to that "theme", and finally cleaning the dataset/"theme", automatically the required GIS database files are created.

In addition is always possible to shift and use the powerful CAD commands within the GIS.

3.2 System modules

Figure 2 illustrates the flow chart of activities and the developed modules of the proposed system.

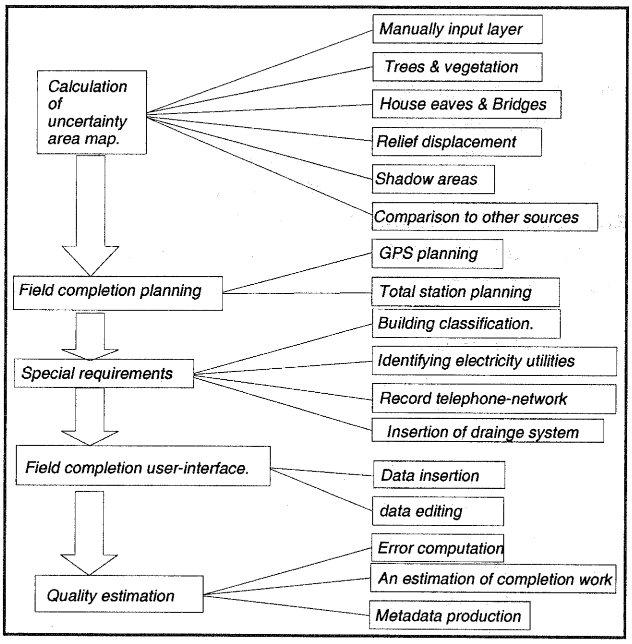

Figure 2 : *System Flow-Chart*

3.2.1 Uncertainty map calculation module

This module is the core of the system, includes spatial diagnostics of the initial database, created by photogrammetry, and presentation of the photogrammetrically obscured areas (relief displacement, sun shadows, covered areas, etc.). Furthermore, does a geographic comparison of the database produced by photogrammetry and other available geospatial sources to detect missing objects. This operation uses GIS overlay functions to indicate disagreements between the positionally accurate database (i.e., collected by photogrammetry) and the thematically accurate database (e.g., electricity network map).

There are six components that together produce the map of uncertainty:

- Manually inserted layer - This layer is produced by the photogrammetric workstation operator. The operator marked the areas he was unsure of details or were invisible due to irregular conditions such a cloud cover, atmospheric haze, smoke clouds, hot spots etc.

- Trees and vegetation - Those layers are marked automatically as uncertain because features under these objects are invisible. However the user can give an area threshold in square meters and the software marks only those polygons that are bigger than the threshold.

- House eaves and bridges - When there is a request to map foot prints of houses, the distance between foot prints and roof lines should be measured in the field. Moreover details near or under bridges may be of interest. In this module a layer with the appropriate information is produced.

- Relief displacement - The program computes the relief displacement of each building. It takes each point in the polygon and shifts it according to its height. The shifting is done from each vertex in the direction opposite to the projection center. Connect all the shifted points to each other and to their original position.

A layer of displacement (named "disl") is produced. The program advances to the ArcCAD environment, first defines "theme" and "coverage" from the appropriate layers (e.g., data-set "house" from layer "2200" and data-set "shade" from layer "disl"), then it cleans dataset/"theme" and the database can be managed from the GIS system. Next the program uses ArcCAD analysis function "erasecov" to erase features from a theme that overlap with features in another theme (see figure 3)

The result is the final theme called "disl", which is "shade" minus "houses" and is displayed in red.

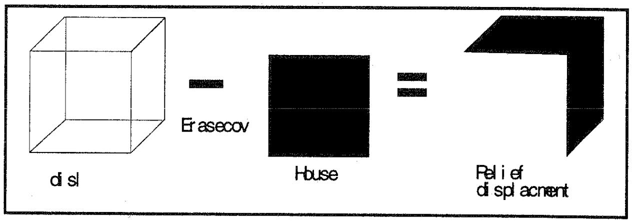

Figure 3 : *The Erasecov operation*

- Shaded areas - The programme examines the entire project area and presents the parts that are obscured and blanked out by the presence of shadows. Terrain features like buildings, cliffs and precipitous relief can cast shadows over pertinent details and it is for the field surveyor to measure these details. The user inputs the sun's angular altitude, then with a similar procedure as in the relief displacement module, the layer "shadl" with sun-shadows is produced.

- **Comparison to other sources**- In this module a comparison is made between the database, collected via photogrammetry, with other sources like municipality maps, telephone and electricity network maps etc., to monitor possible missing features. Basically this module is using two ArcCAD functions "buffer" and "erasecov" and with those functions it present the missing objects.
The user inputs the names of layers to be compared and the search area radius (this parameter is variable depending on the positional accuracy of the digitized map).

3.2.2. Field completion planning.

The information about the amount of obscured areas, missing objects, the type of areas to be completed and possible special requirements, are at this point known. The surveyor has to choose the surveying method to be used in the field work --GPS, total station or simple measuring tape--.

Interactive analysis of the surveying sites is done to plan the field work. This module performs line-of-sight predictions for total station survey and satellite masked areas evaluation for GPS measurements. Consequently, there are two modules in the system one for GPS and one for total station.

GPS planning: The aim of the GPS planning module is to portray the areas that will be masked from satellites and therefore cannot be measured by GPS, or while surveying with a GPS in a kinematic mode those areas should be avoided, otherwise "lock" it may be lost and GPS initialization is necessary. Furthermore the program presents the known control points that may be used for the project. There are distinguished in benchmarks and triangulation points. In this way the surveyor can design the GPS network before field work.

Total station planning: The objective of this module is to assist the surveyor in planning his work if total station is going to be used. The program present the known control points classified according to their accuracy levels, e.g., < 10 cm. Next, a choice is made of a point for instrument position, to maximize command of the terrain to be completed, and having visibility to control points.

3.2.3 Special requirements.

This module addresses the special requirement of the client that is to say the customers' specifications. Spacial tools for collecting additional types of information such as electricity network elements, building classifications, telephone utilities, drainage systems, etc., are provided in this module.

3.2.4 Data insertion & data editing.

This module was developed to serve the surveyors in the field in the data acquisition procedures. The data collection user interface provides the surveyor with most useful geometric functions to insert new objects directly into a portable computer according to the required data model. These surveying functions include arcsection, right-angle prism, polar positioning, etc., and they enable rapid data collection using a simple measuring tape. Moreover the CAD environment comprises many functions and operations to display, edit and add new information.

3.2.5 Quality estimation.

Quality control, is based on field measurements. The system checks if the map conforms to the accuracy requirements. The surveyor makes a number of measurements to verify the relative accuracy and a number of measurements to check absolute positions. Finally the software produces a report which describes the database, its accuracy parameters and the number and type of details that were newly collected and inserted in the data base.

4. FURTHER IMPROVEMENT AND CONCLUSIONS

We have presented a system that can intelligently envisage all the uncertainty zones that require field completion surveys in the production of geospatial databases. The developed software provides analyzing tools that injects intelligent and global consideration into every step of the field completion operation. Initial experiments have shown that this concept of using GIS for the planning and analyzing of field completion work is effective and improves the data collection productivity. It should be noticed that the system can be useful not only for field completion tasks but also for mapping projects where an initial database does exists, e.g., database revision projects.

However there are few system modules that can be improved, and we are in the process of improving them.

- **Obscured areas algorithm** - The models used for calculating relief displacement, shading and GPS masked areas, use the absolute Z coordinates minus the average ground level of each object vertex to calculate the shift. That model is good for flat areas. Nonetheless, if the ground height changes rapidly then we need to subtract the local height from every point (i.e., for every point we need to have its height difference from the surrounding). A good way to get the height difference of every point is to use a DTM file of the area. The interpolated value of ground height at vertex X,Y easily can then be obtained and be used in calculations.

- **More intelligent approach** - More intelligent software means an Expert System. Many features of expert systems may be employed for our purpose. Using inserted knowledge, e.g.,
- electricity poles are numbered sequentially from 100 to 800
- it is most probably to find telephone utilities near roads
- in every entrance to a city may find an electricity transformer
- the maximum distance between electricity poles is 90 m.
- electricity lines will not be positioned above houses, etc.

the software will be able to find (using the expert system engine) all the conflicts and missing objects in the database and then give another more intelligent support to the surveyor.

- **Additional GIS features** - Further GIS functions than those available in ArcCAD are required for operations aiming to improve the planing of field work activities, e.g., operation like:
- network computation of the shortest path
- spatial computation of line of sight for the analysis of intervisibility between set up point and control point using DTM information

- **GPS planning** - This module was intended to show our concept, nevertheless for proper planing, skyplot diagrams (the exact trajectory of the satellites in that specific day and place) need to be computed, and to be combined with the information currently evaluated from the existing module.

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