EFFECTIVE WAYS TO REVISE DIGITAL MAPS AND GIS DATABASES IN URBAN AREAS

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ABSTRACT

The objective of this paper is to provide a methodology developed by Analytical Surveys, Inc. (ASI) for revisions of large-scale maps in urban areas. While the GIS sector is booming the demand for map data upgrading and map revision increases. There is a huge demand for better and more actual map information. Standard map revision techniques are not able to fulfill these demands because of the conditions of the existing (old) digital map data. A brief description of problems encountered with existing (old) digital map data that may have been translated from the original compilation files to a particular Computer Aided Design (CAD) or Geographic Information System (GIS) environment. During this process data may have been lost, distorted or wrong classified. Prior to the actual revision process the user's files are translated back to photogrammetric files and enhanced to allow to view the old map superimposed upon the new photography with a minimal displacement. In order to comply with the requirements to view the data within a stereoscopic or photogrammetric model it is necessary to add elevation values to the old 2-D maps. The development of digital elevation models (DEM) from existing data is reviewed.

1 Introduction

For the past 15 years municipalities and local government agencies all over the world contracted digital mapping services to produce large-scale maps. In the past five years the increasing demand for reliable and comprehensive digital data for various purposes governed the need for the integration of diverse geographic information, managed by a Geographic Information System (GIS). The objective of this paper is to provide a methodology for revision of large-scale maps in urban areas and especially addresses the problems encountered with existing (old) digital map data which may have been already translated from the original photogrammetric files to a particular Computer Aided Design (CAD) or GIS software environment.

Analytical Surveys, Inc., (ASI) has developed a method in which prior to the actual revision process, the user's files are translated back to the photogrammetric files and enhanced to allow to view the old map superimposed upon the new photography with minimal displacement. Because of the requirement to be able to view the data in an analytical stereoplotter it is necessary to add elevation values to the old 2-D data. The discussed approach and the associated updating procedures are based on several projects successfully completed by Analytical Surveys, Inc.

2 Background

Within the last five years several cities and counties throughout the United States have contracted Analytical Surveys, Inc. (ASI), a digital mapping company located in Colorado Springs, CO, to undertake multiple tasks projects: revision of the digital source data, translation into the format of the new target system and development of a GIS database from these new structured digital files.

With the shift from the analogue to the "digital Era" in the last two decades users and providers of digital maps data have successfully used the tremendous enhancements of computers and software. Analysis of digital maps produced in the 1980's showed that data collection was limited to the basic functions of CAD systems. The large-scale maps generated over urban areas at scales of 1:1,200 and 1:2,400 (1"=100' and 1"=200') were typically referred as "CAD maps" and had been used primarily for plotting, planning and other basic engineering tasks. In the last five years this was complemented with the introduction of advanced CAD software and even more sophisticated Geographic Information Systems (GIS). Even so users have become more knowledgeable in the use of new software and hardware the content and the quality of the existing digital maps has not improved in the same pace.

At the time of the generation of the existing maps, issues such as line snapping, edge match, over and under shoot were not as important as they are in today's GIS environment for building topological correct databases. The original photogrammetric files might have undergone up to three translations prior to their current use in a GIS. Different data conversion programs and approaches were used for these translations, most of them providing a standard "one-to-one" translation. These translations might have distorted the original data structure or introduced new errors. In most instances errors and mistakes made to the graphic elements were not detected or corrected as long as the visual content of the map was maintained. Users might have introduced additional errors as a result of in-house editing of graphic elements. The most common errors are the placement of a graphic element on the wrong layer or the attachment of the wrong attribute.

In order to satisfy these multiple task requirements ASI has developed a methodology to solve the problem of data inconsistency especially the problem of missing attributes of existing contour in particular and the map revision process in general. The final result of all processing, revision and enhancement should result in "GIS-ready" topological structured data that may form the base for a GIS database. Especially the topographic features that are required for the generation of a DEM undergo the most rigorous checks.

3 Preparation Stage

A preparation stage is introduced prior to the digital revision process to permit smooth operations. Familiarization with the accuracy requirements, map specifications, and required material is one of the initial step. The preparation stage is sequenced to provide systematic, standardized procedures that economize operator effort and minimize error. As a primary check, all original data is loaded onto the system and checked for systematic errors.

Prior to the actual updating or map revision process the original files are converted into ASI's Processing Software (APS). During this translation each element will, in addition to its original attributes, receive additional attributes to allow for identification of a possible modification. At this stage in the preparation, one of the strategically placed quality control checks is performed-check of compliance with the original database design.

Over the years most of the digital graphic files or maps may have been translated from the original files to the user's particular GIS software environment. For example, data for an individual map sheet might be available in three separate files, a Digital Terrain Model (DTM) file containing breaklines and masspoints, a contour file and a file containing all planimetric features. In addition the user may have subsequently modified the original files in a way that may have result in a loss of attributes and/or complete loss of map data. Existing graphic elements may have an artificial elevation value of "0", other erroneous elevation values or no elevation at all and are therefore not suitable for the photogrammetric updating process. Contour lines with missing elevation value cause displacement and distortion of the existing data up to the point were stereoscopic viewing is impossible. It is therefore necessary to introduce the exact or approximate elevation value for each of the graphic elements.

Part of the preparation phase is to determine the quality and usability of the original DTM and/or contour files. The analysis identifies and categorizes the graphic elements into different groups, e.g., contours without elevation tag, contours with an elevation tag that is out of range, contours without tag but with a text string associated, mass point file with holes, etc.

To use the client files, which contain in general the map data, a corner file and header file must be created. Support files that contain data effecting the appearance of each file are set up and their environment variables defined. These support files include files defining color, weight, style, symbols, patterns, text feature codes, theme numbers, source ID's, etc. When the operating environment is established the data is loaded. The time stamping of the new data is an operational issue. It will facilitate the editing process as it will distinguish between the old data and the new positional data.

The number and location of the control and check points are based on the points generated as a result of the analytical aerotriangulation process. The registration of the new compilation model for integration with the "old" map digital data can be performed in two ways. If the ground coordinates of the lower left corner are available, this can be accomplished by simple translation in x-and y-direction using one corner point. Otherwise, registration can be done by a six-parameter affine transformation using well-identified control points.

4 Development of a DEM

Prior to the compilation of the update areas on an analytical stereoplotter with superimposition, such as ASI's Zeiss P-33 with superimposition, the map files are translated to ASI's proprietary Processing Software (APS). Within APS we are developing a DEM from all available and in the preparation stage identified useful data. Within APS the data is passed through numerous routines and analysis to prepare a photogrammetric usable file for revision. Convex hulls of the new aerotriangulated models are generated and map sheets are cut to match the model extension.

A DTM represents terrain relief, thus the shape of the (topographic) surface in 3-dimensional space. To indicate in a GIS the elevation of a graphic element an elevation attribute may be attached. Other features of the terrain such as hydrography, land use, cultural, etc., are traditionally represented in 2-D. If necessary the third dimension can be added to the two-dimensional digital map files by the use of a DEM.

The photogrammetric procedure for generating DEM's is to measure stereoscopically the elevation of terrain points in an analytical stereoplotter. The point distribution can be regular, quasi regular, or random, with a certain average density. From these observations a (regular) grid is interpolated which represents the DEM. Normally, the average density of the derived grid is 2-3 times higher than the number of the originally observed terrain points.

To solve the problem of incorrect or missing elevation information ASI constructs a preliminary DEM using all photogrammetric established points within a model in addition of any recoverable elevation values from the existing DTM or contour file. As a first step a dense mesh is generated, overlaid and intersected with the two dimensional index contours and checked against the first DEM iteration. At that point preliminary elevations are given to the index contours to the nearest 10 feet. Depending on the quality of the original data a search for intersecting index contours is expanded to 20 feet or until a satisfactory match is achieved. Intermediate contours are included in the next processing step where intersections with the mesh are calculated and the elevation value determined.

The elevation attribute is attached to the contours to make them three dimensional. The newly generated DEM serves as the base for the draping process of the planimetric and topographic features necessary for the photogrammetric revision and acquisition process. In order to generate topological correct contours automatic processes are used to close gaps and delete overlapping line segments within contours lines. Any planimetric displacement of contour lines that may have been originated from graphic editing or cartographic displacement will cause an additional error in the DEM and cannot be corrected.

Existing spot elevations may be used as an indicator of the correctness of the contours and the DEM in general. Elevation data can be analyzed to determine whether or not these data are accurate enough for a particular application (Zhing Lee,1988). To further enhance the accuracy of the DEM breaklines must be introduced. Coordinate values of selected planimetric features, e.g., hydrographic features, road edges, etc., are compared with the DTM file. If a match can be achieved, the planimetric features will be reclassified as breaklines and the correct elevation value from the DTM as an attribute attached. It is understandable that not all planimetric features will match or can be classified as breaklines.

5 Mapping and Map Revision

In order to detect the changes and make revisions it is necessary to view the new aerial photography and the existing data stereoscopically at the same time. Only when reviewed stereoscopically changes can be identified and the map revision performed.

Map revision operations of existing vector or point data from aerial photographs require several steps: interpretation, change detection, collection of new data, and integration of old and new data in the database. One of the effective methods for extraction of new data is by superimposition of the existing digital data over recent acquired aerial photography and update the database by collecting the new information from the stereo model (Regan & Amenakis,1994). The superimposition and the data collection can be performed in several ways (e.g., Welch, 1989, Bouloucos et al., 1992). Map revision or modifications can pertain to a change of the thematic description, to a change of the z-coordinate (elevation) or to a change of position (x, y).

After the topographic and draped planimetric features are downloaded to the Zeiss P-33 equipped with superimposition, the photogrammetric technician visually scans the model for any feature changes or additions by comparing the superimposed old map to the features in the stereo model. Terrain changes are identified and "fenced" to ensure seamlessness between the old and new contour and DTM data set. Inside the fenced area all existing vectors and points are deleted and replaced by points collected through photogrammetric compilation methods. Furthermore, in tagging all updated features we are able to identify the areas of changes. Contours within the updated area are generated from newly collected masspoints and breaklines using the Triangular Irregular Network (TIN) concept. Extensive data processing is used to edit the entire map. This is the stage where automatic editing and enhancement of the data use APS software to develop topology and the continuity of the data. Plots in different colors may be generated and are used in the following quality control check.

6 Final QC Process

Translation to the target system based on specifications and database design completes the updating process. Virtually all of our processing procedures were developed for quality control, topological structuring and aesthetic enhancement of cartographic data. To ensure that all data was correctly translated, the files are interactively examined on a graphics workstation by a GIS specialist.

Special attention is given to the continuity of the existing and new contours through edge match techniques. Edge matching is the term used to describe the process of making two adjacent digital files graphically and mathematically continuous so that the features on both sheets continue from one file (data set) into the other without break, disjoin or discontinuity. In addition within APS we are checking for the elevation attribute within the contour line. In general there are many options available, ASI has restricted the processing to a given layer number(s) or feature code(s); and joining lines with the same contour value (Regan & Armenakis, 1994).

Manual measurements of elevation points, using conventional stereoplotter, is expensive and time consuming. New techniques using automatic elevation extraction, implemented in a softcopy photogrammetric system, can generate massive amounts of elevation data with reliable accuracy (Khames, Scarpace, 1995; Ackerman, Krzystek, 1995). Future developments in this area are expected to increase productivity and accuracy.

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