THE ROLE OF INTEGRATED PHOTOGRAMMETRIC SYSTEMS IN GIS TECHNOLOGY

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ABSTRACT

For the creation of digital topographic databases, photogrammetric systems are playing an important role in the collection of locational data for map features and digital elevation models. Initially, photogrammetric instruments were interfaced to digital computers for the capture of data sets as part of automated cartography and digital mapping systems and recently they are integrated in geographic information systems (GISs) as part of the data input subsystem. During the same period, digital image analysis systems and artificial intelligence techniques increased the usefulness of remotely sensed data from satellite or airborne sensors as a source of input for GISs.

The technologies used for the capture of error-free data in vector form using digital photogrammetric map compilation systems and automatic digitizing techniques are described. The role of the vector-based mapping systems and the raster-based digital image analysis systems in the development of geographic information systems, and the requirements imposed on these systems for the collection of topologically structured databases are given.

INTRODUCTION

Over the past two decades we have witnessed the development of automated cartography, digital mapping, and recently geographic information systems. Although, the common factor among these activities was the digital capture of spatial data, the users interest in the data shifted from the reproduction of maps through automated plotting and scribing facilities to the integration of data derived from a variety of sources and the manipulation, analysis and display of the data according to user defined specification.

The adaptation of the digital technology occurred gradually in three stages. During the first stage we were concerned with the development of computer hardware and software for the capture of spatial data in digital form and their editing and reproduction in analog map form through graphics and plotting facilities. The products generated matched conventional map design, and at the time it was hoped that the digital technology will lead to labour and cost savings.

Digital mapping was the prime target of the second stage, and integrated mapping systems were developed for the creation of digital topographic and cartographic data banks. Data was no longer captured with specific map in mind, but rather with the aim of establishing an archive of spatial data to meet a general set of demands.

During the second stage photogrammetry played an important role in the capture of digital data. Computer assisted photogrammetric map compilation from aerial photography were widely used for the collection of the true positions of mapping features in a three dimensional coordinate system. Also, remotely sensed data provided another source for the collection of digital map data.

To be able to manipulate the collected spatial data sets, their associated non-graphic attributes and the spatial relationships between the features, topological data structures were quickly adapted. This marked the start of the third stage, namely the development of geographic information systems (GISs). In a period of nearly ten years, GISs have become commonplace tools for the integration, storage, retrieval, manipulation, analysis and display of the spatial data in too many agencies around the world.

GISs are a natural progression for digital mapping systems by providing the users with the analytical tools required for decision making, in addition to the capabilities inherent in the digital systems. In GISs, graphic and non-graphic data from other disciplines can be linked to digital surveying and mapping data. This will widen the range of application of mapping data and increases the cost effectiveness of geographically referenced information.

The technologies used for the capture of error-free data in vector form using computer assisted photogrammetric map compilation systems, or the automatic digitization of map manuscripts are given. Also, the requirements imposed by the functional requirements of GISs on the collected spatial data sets are described. In addition, the role of remotely sensed data as a source of input to GISs and the integration of raster/vector based systems is given.

GEOGRAPHIC INFORMATION SYSTEMS (GISs)

GISs may be best described as systems able to accept large volumes of spatial data derived from a variety of sources and to effectively store, retrieve, manipulate, analyze and display these data according to user defined specifications [Marble and Peuquet, 1983].

The main software components of a GIS include subsystems to handle data input, editing, revision, retrieval, analysis and output of spatial information. The subsystems operate on a database consisting of spatial entities and their attributes and is tied to a common geographic reference.

This clearly demonstrates that , in contrast to digital mapping systems, GISs have different objectives and have more complex data structures to handle various types of data and their reference to spatial domain. Also, GISs should have the capability to inter-relate data sets, to carry out data manipulation functions, and to perform tasks related to the analysis and the presentation of the results. In general, in a GIS the emphasis will be on having capabilities for: data conversion between various locational data sets, the conversion between the basic locational primitives (point, line, grid cell/pixel or polygon), data retrieval based on user specified criteria, the aggregation or dissaggregation of geographical entities and their attributes, vertical integration of various data sets and the generation of various types of output.

To satisfy these functional requirements, a GIS consists of the following four basic subsystems:

- data input and editing
- data handling, storage and retrieval
- data manipulation and analysis
- data output and reporting

In GISs, locational data collection and editing is the largest single cost in the information cycle, and data availability is an important factor in their development. Ideally, on a national level, there should exist a base at the resolution and accuracy of medium/large large scale digital base mapping, and this base may be used for the creation of generalized spatial data set. This does not rule the existence of locational data at various scales (levels of resolution), or a combination thereof.

In the Surveys, Mapping and Remote Sensing (SMRS) Sector, of the Department of Energy, Mines and Resources (EMR), spatial data is collected from analog aerial photography, existing map data, remotely sensed digital imagery, and non-graphic data (e.g. taxonomy and other attributes), as shown in Figure 1.

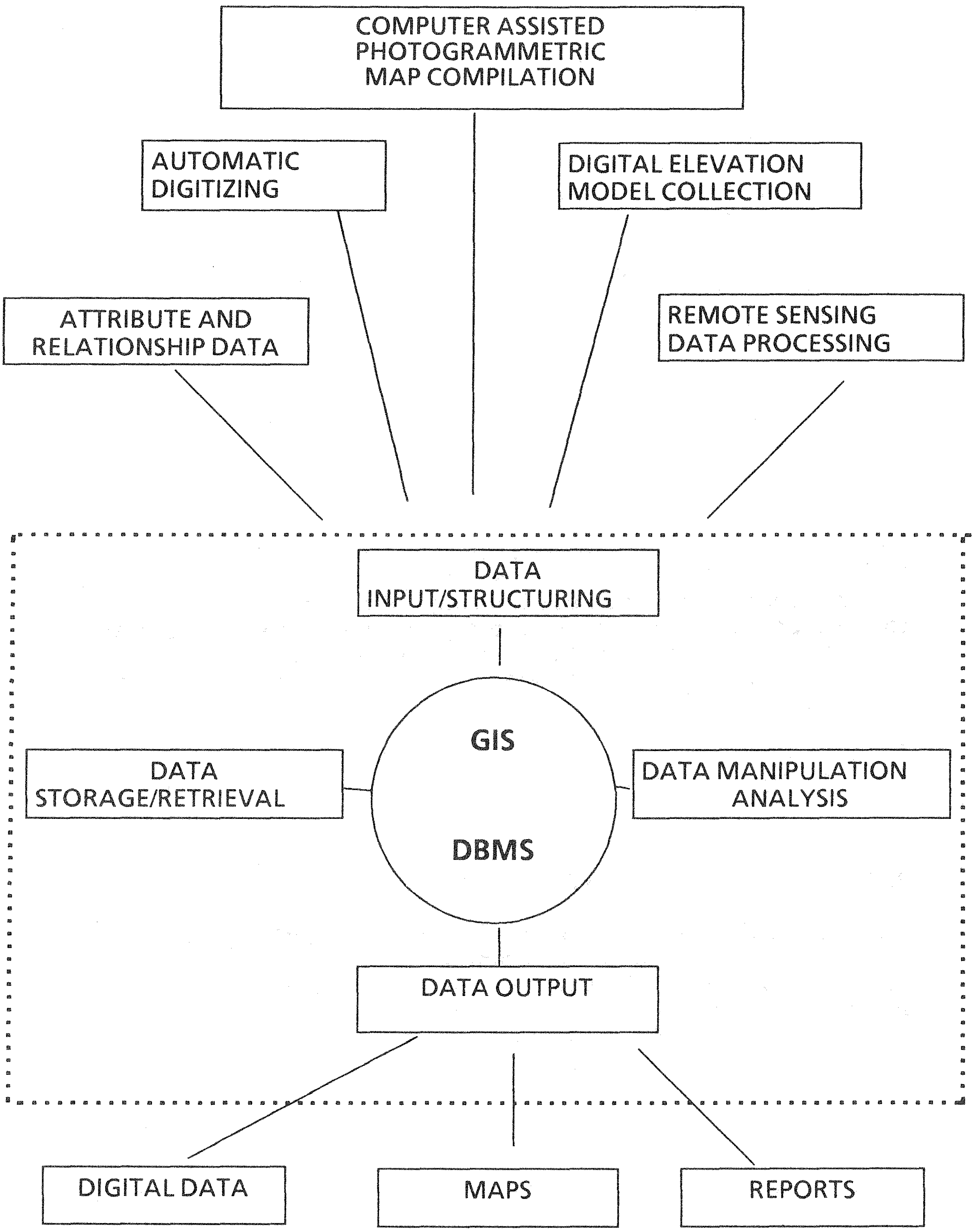

Figure 1: *Integrated Geographic Information Systems*

A GIS CONCEPTUAL MODEL

The entity-relationship model [Chen, 1976] is a popular model in data base applications. In this model, the real world is represented by entities, relationships and attributes. An entity is a distinguishable object in the environment, such as a road, a building or a lake, and relationship describes how the entities are related to each other. An attribute on the other hand is the property of an entity or a relationship, e.g. the name of the road is an attribute.

The features are described spatially as a set of topological elements called nodes, lines and areas. At the lowest level of abstraction, the geometric representation of a feature, defining its location and shape, will be constructed from one or a number of discrete points. This topological model uses coordinates to define the location and shape of topological elements. These elements, derived from graph theory, allow the coordinate positions to be members of the node, line and area topological elements, that combine to form a line graph, which explicitly records the spatial relationships of connectivity and adjacency.

The data structure for the topological conceptual model describes how the topological elements are to be arranged and what linkages will exist between them. The explicit linkage of nodes-to-lines and lines-to-areas define the objects in the digital environment as a graph containing the spatial relationship of connectivity and adjacency. From these, fundamental base relationships, higher order relationships and structures can be built.

The data structure also details how attribute information is related to the topological elements (nodes, lines and areas) and to entities constructed from them.

PHOTOGRAMMETRIC DATA COLLECTION

Digitization directly from aerial photography started in the early 1970's by interfacing photogrammetric instruments to digital computers (Allam, 1979) as part of our digital mapping system. The systems is used for the collection of topographic position data, with feature resolution and contents meeting the requirements of the 1:50,000 mapping specifications. For that, the photogrammetric instruments are equipped with linear or rotary encoders, and microprocessors provided the link between the instruments's measuring device and the computer.

The X, Y and Z coordinates are obtained by assigning a unique code for the feature and stereoscopically tracing this feature in the photogrammetric model. Based on the feature type, the operator digitizes the center line of the linear features, the center of point features and the edge of area features.

To collect error-free digital data two basic tasks are involved: the digitizing process and the display/editing process. While digitizing, the microprocessor accepts the encoder signals, computes photogrammetric model coordinates and transforms them to ground coordinate system. The computer coordinates are then transmitted to the graphic terminal.

The interactive graphic terminal constitutes an integral part of the photogrammetric workstation. The main components of the terminal are the digital memory, or frame buffers (in which the displayed image is stored as amatrix of intensity values), the display monitor, the display controller that passes the content of the frame buffer to the monitor and the keyboard. The system's software allows for the display and editing of the digitized features and the stereo plotter operator have unrestricted access to the digital data of the model he is compiling and of the adjacent stereo models.

The data structure for the digital photogrammetric map compilation systems follows a simple data model (spaghetti model), where features are represented as points or lines. In this model, the spatial location and shape of the feature, or portion or a feature, is defined by a sequence of 1 to n coordinates (X, Y and Z). Also, this model does not support spatial relationships between features.

For the integration of the "spaghetti model" data into GISs a conversion of this data structure to a "topological" data structure is necessary. Although some data capture systems from aerial photography allow for the direct capture of topologically structured data, software for topology building and topology editing is one of the important functions of the data input handling subsystem.

To build the topological structure, algoritims are required for building the network topology and polygon topology.

DIGITAL ELEVATION MODEL COLLECTION

In the context of this paper, reference to a digital elevation model (DEM) pertains to the regular grid DEM, as opposed to contours or irregular grids or networks.

DEM production has been on an ad hoc basis or as the byproduct of other mapping systems. The systems and techniques which have been used are:

a) The Gesalt Photomapper II/3 (GPM) [Allam, 1978]; and,
b) Contour-to-grid processing.

The GPM is a computer-controlled auto-correlating digital photogrammetric system designed to produce elevation models, orthophotos and photographic contours. The system consists of a pair of flying-spot scanners, a digital correlator module, computer and magnetic tape units, orthophoto and contour printer units, and an operator console.

The DEMs produced by the GPM systems are in raw form and are further processed to obtain the desired output. The data processing system was designed and developed in-house for the restructuring of the raw DEM data, and to reduce or possibly eliminate the errors in the DEM which arise due to limitations of the automatic correlation process. These errors include variations in photographic image density, elevation biases (abrupt relief changes and steep slopes), image contrast in the stereopair, and the effect of constant grey tone and lack of image signature over water bodies.

The software package currently in use to perform contour-to-grid processing has been acquired from Intergraph. The software computes a DEM from contour data by means of linear interpolation, based on the triangular irregular network approach. The process consists of three distinct steps: data preparation, processing and editing of DEM.

The input data are in the form of contours, drainage, ridge lines, breaklines, spot heights, and other topographic features which have x, y and z coordinates in the data base. The sources of data for this type of DEM processing are digital stereocompilation and the automatic digitizing systems.

AUTOMATIC DIGITIZING

To expedite the process of converting the initial map data from analog to digital form, a system for the mass digitization of existing graphics using raster scanning technology was installed in the Topographical Survey Division in 1984. This system consists of several subsystems, namely: the scanner, vectorization/processing system; the edit/tagging system; data file management system and the automated cartography output system.

The system is used for the conversion of the 1:250 000 national topographic map series from graphical to digital form. The analog overlays exist as colour-separated film plates for this series of 918 maps, and this is facilitating the use of raster scanning technology. Basically the contour, drainage, vegetation and transportation overlays are scanned, and the other overlays which normally include fewer features are manually digitized.

The scanner is a stand-alone system and is capable of accommodating graphics up to 60 x 100 cm. The captured raster data is recorded on a magnetic tape, which is processed for the generation of the initial data base map data.

The processing of the scanned data starts with the vectorization of the raster data i.e. conversion of data from raster to a vector form. The vector data file is then displayed to inspect the results of the vectorization process and to decide on the necessary post-processing batch edit operations. This may include the use of software for the editing of short connected or disconnected spikes, correction of "nodes" resulting from the intersection of two or more lines, etc. The data file is then transformed to a ground coordinate system.

Upon completion of this batch processing phase, the data files are not error free. In addition, the topographic features are not coded with their "cartographic codes" and the contour lines are not tagged with their proper height values.

To perform these on-line editing and coding operations, the data is transferred to the edit/tagging sub-system. The amount of editing required depends on the complexity of the graphic, quality of line and type of overlay.

For the contour overlays the editing is minimal, for example detecting bridges between close contour lines, closing long gaps due to contour labelling, etc. The tagging of the contours is also assisted by means of several functions, which speeds up the process of coding the contours with their height values.

Overlays where features are intersecting, e.g. hydrography or transportation pose additional problems because of the multi-nodes created at the intersections of lines with varying thickness. In addition, the nodes cause segregation of the feature, and to be able to code the entire feature with one code all segments have to be complexed together.

To integrate the automatic digitizing data into GISs, a conversion of the scan data structure to topological data structure is necessary. Although this data should yield the desired topological structure, topology building algorithms are needed to build the network topology and polygon topology.

EDITING

Editing refers to the process of detecting and correcting errors made at various stages of data capture. Editing is performed in an interactive mode using a graphic display and editing terminal, in a batch mode, or in a semi-automatic mode (interactive/batch).

While interactive editing is the most convenient and satisfying procedure from the operator's point of view, it is a costly and tedious operation, requiring dis-proportionate amounts of CPU time, and human resources. It is usually employed when errors are inadvertently made during the digital data capture phase, and where the operator wishes to see the immediate results of corrections he has applied.

Other modes of editing are also available and include automatic (batch) and semi-automatic editing. In batch mode editing, functions

spatial data set with "vector" data derived from the computer assisted photogrammetric map compilation or the automatic digitizing system.

INTEGRATION OF RASTER AND VECTOR DATA

In the SMRS Sector, EMR, digital cartographic data was integrated with digital remote sensing imagery. To achieve this, the ARIES digital image analysis manufactured by DIPIX Systems Limited (currently DIPIX Technologies Inc.) was interfaced with the vector-based digital mapping system manufactured by Intergraph. The two systems were integrated by means of a physical interface and a common data structure.

The integrated ARIES-Intergraph system was used for experimental digital map revision purposes. The spatial data in the Intergraph's format was rasterized and transferred to the ARIES system. Rasterization was achieved by assigning a certain number of Intergraph units of resolution to equal a pixel of the Thematic Mapper (TM) and the two files were registered using common control points.

For digital map revision, automatic classification programs, such as Maximum Likelihood Classifier which are available on the ARIES system were used. In addition, visual interpretation of cultural features proved to be more appropriate. The tests conducted on the system yielded an accuracy less than 2 pixels (Couture, 1988).

CONCLUSIONS

GISs have evolved as an important method of dealing with and integrating spatial data and are continuing to exhibit growth and future potential. The arrival of GIS in the mapping world occurred only in the past few years and already wide implications are happening due to the need for converting simplistic structures of the digital cartographic data to the topological data structure required by the GISs. The future challenge to GISs will be the integration of vector and raster based systems and the development of knowledge based GISs.

Data capture and editing are the most time-consuming tasks in creating cartographic or geo-based terrain information systems. Because of this, it is imperative that the data be collected to a set of requirements that satisfies the long-term requirements of the GIS data base. In addition, it is more economical to do the data acquisition only once to satisfy all the needs that are bound to appear in the future.

The field of digital data capture and editing is dynamic and challenging because the collected data has to undergo several operations before its acceptance as a part of the GIS data base. The user community is steadily expanding, and new applications are continually emerging that require more data and better hardware and software. It is an exciting era, and the success of the GIS data base creation will materialize only with the sharing of the captured digital information between all users concerned. A data base of geo-referenced information should be looked at as a national asset in the same way as the conventional map series are.

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