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Role of Surveying in The Establishment and Maintenance of Geographic Information Systems

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Abstract

The most important component of the geographic information systems is the geographic information systems' database. The two basic data that characterise the geographic information systems are the graphic and non-graphic data. Surveying is mainly employed for the acquisition of graphic and non-graphic data in the geographic information systems. This paper discusses the role surveying plays in the establishment and maintenance of the geographic information systems mainly with respect to the establishment and maintenance of the geographic information systems' database.

Introduction

"Geographic Information Systems (GIS) are sets of powerful tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes" (Burrrough & McDonnell, 1998, p. 11). Surveying being the science that provides spatial information regarding the real world definitely plays a key role in the establishment as well as the maintenance of the GIS. Unlike the classical surveying science, contemporary surveying science now incorporates other methods of spatial data acquisition such as photogrammetry, hydrography, remote sensing, Geographic Positioning System (GPS), and geodesy, including classical surveying (which includes cadastral surveying, engineering surveying, topographic surveying, and mining surveying); as well as the GIS. It is important to note that data for GIS can be divided into two basic types: graphic and non-graphic. Graphic data, also called spatial data, include coordinates, and symbols that define features such as buildings, roads, or cities in a map. Non-graphic data, often called tabular data or attributes, are representations and descriptions of features in the map. Remote sensing data and analogue maps are the major primary sources of data into the GIS (Ehlers et al., 1989; Lunetta et al., 1991; Burrough & McDonnell, 1998; Lo & Yeung, 2007).

Role of surveying in the establishment of GIS

The establishment of the GIS involves determining the characteristics and combination of software, hardware, data, processes, and people that will meet the organization's GIS requirements. The challenge is to combine the organization's overall goals for GIS and the specific needs of the diverse users and applications, while developing an integrated and effective design. Data are the most important component of a GIS and should be given primary consideration. Case studies and industry experience indicate that organizations generally spend the largest portion as much as 80% of their GIS budgets on data. Accordingly, the largest portion of effort and consideration should be spent on the GIS data rather than the disproportional attention most people devote to technology. A GIS is, after all, a tool to use and maintain spatial data, so system design should focus on the data needed to do the organization's work and how they are to be handled (Walls, 1999; Bossler, 2002).

The individual data requirements of users and work processes are usually combined into an integrated design. The goal is usually to develop one version of a shared database that meets all users' needs with minimum redundancy and maximum usefulness and accessibility.

The design addresses several aspects of the data:

- Data characteristics are defined to suit the combined users' requirements. Each data entity is described in terms of data type, format, accuracy or resolution, attributes, amount, source, and maintenance responsibility and standards.
- Data relationships are identified and described through a data model.
- Data access and handling requirements are described, ensuring that each user and application will have access to needed data in required form.
- Data security needs are identified.
- Temporal aspects are identified to support applications and data management functions such as time series analysis, planning scenarios, backup, archive, and retrieval.
- Metadata are identified at the appropriate level and in terms of how they will be used.

The landbase or basemap is defined, based on users' needs. Content, accuracy, and maintenance procedures for this data set will affect most applications and users. This data set usually involves some of the largest creation or conversion costs, but also may provide opportunities for direct purchase and/or sharing.

For a large organization developing an enterprise GIS, the database design can be a very complex process, but it is necessary to fully support future applications and system growth and integration. Although it is possible to load data into a GIS without a complete data model, its future usefulness will be limited (Somers, 2002).

Data acquisition is a crucial stage of GIS establishment. This is the area where surveying plays a key role, since surveying science is employed in acquiring these spatial data. Data acquired by surveying method for input into the GIS include aerial photographs, existing, maps, rasterised image from remote sensing, relevant field data sources, data from classical survey methods, other forms of digital data, as well as data from GPS, and internet sources (mainly from open source spatial data environments) (see Figure 1). Data acquisition/collection is the procedure during which intended datasets are collected following geo-spatial data related standards or user designed rules. The final outputs of data collection are dataset series or databases, accompanied

With metadata or other required documents. In most cases, it is impossible and not necessary to collect all the data, and also the data collection procedure does not fall into Specific steps. The whole process may depend on the objective of data collection, data sources, and available resources. The sources for geo-spatial data are probably more numerous and of greater variety than in most other information. At the outset, the data, such as those identified as core datasets mentioned above, can be imported/input into the GIS from various sources, those may be (Somers, 2002):

-In various digital forms: vectors, raster, database, spreadsheet tables, satellite data, internet, and so on;

-Non-digital graphics, such as conventional maps, photographs, sketches, schematic diagrams, and the like;

-Conventional documents in registers and files;

-Compilations in scientific reports; and

-Collections of survey measurements expressed in coordinates or other units.

GPS, Ground Surveying, digital orthophotos and hardcopy photogrammetric products, satellite imagery, and scanned hardcopy maps are the example of primary sources data acquired by surveying science. It is highly recommended that a primary data source be utilized for new digital data collection if possible. Paper map is probably the most popular as the core source of geo-spatial data. Data collection/input remains the most expensive and time-consuming aspect of setting up a major GIS facility. Experience indicates that data collection accounts for 60-80% of the total cost (time and money) of a fully operational GIS. Remote sensing data also acquired by surveying science may be loosely defined as the collection of data about earth surface objects or targets by measurement methods involving no contact. Remote sensing sensors provide ready source of data or environmental information. The utility of remote sensing is in respect of providing overviews of environmental conditions, and information on the location, quality, and quantity of resources. Products are images generated as photographs (called as hardcopy or analogue) or an array of area measurements (digital data). In earlier days, the most commonly available remote sensing product is the aerial photograph. It represents a comprehensive data source that allows the direct collection of data related to topography, vegetation, land use, and human settlement patterns. Currently, a number of space-based satellite systems collect data regularly about earth resources at variety of ground resolution and temporal resolutions. The other type of satellite system is microwave radar system, which is very useful in the tropical region.

As clouds or rain does not hinder the radar signals, it is possible to acquire earth resource information even in cloudy or rainy day. Photogrammetry or photogrammetric mapping is the 'picture measurement', and regarded as one of the techniques of aerial photography. Aerial photographic information is transferred to planimetric and topographic maps, which, in turn are the bases for vector data, using the instrument called 'stereoplotter'. Some of the information can directly be generated by this technique, which however, is suitable for large-scale mapping. GPS is a military satellite-based navigational system by which new locational data can be generated. It

can also be used to verify the locations of existing data. GPS measured coordinates can Be within ±10 m accuracy, which can be improved to be within centimetres with the differential GPS depending on the location at different parts of the world. One of the drawbacks of GPS is that it requires a direct line of sight between the receiver and each satellite accessed. Examples uses of GPS include:
-Locating new survey control stations and upgrading the accuracy of old station positions
-Measuring terrain features that are difficult to measure by conventional means
-Updating road data
-Marine and car navigation
-Determining elevation differences
-Positioning offshore oil platforms, etc.

First-hand up-to-date information on terrain details, property lines, etc. can be generated by survey for the areas smaller than used for photogrammetric mapping. Modern surveying is computerised; a total station theodolite, can now store, process digital measurement data with the accuracies of ±1 to ±10 cm. Survey data may be entered in GIS whenever accurate map data are required (Somers, 2002).

A Diagrammatic flow chart of a generic data processing and archival storage procedure is given in Figure 2. Surveying plays an important role in the generation of metadata. Metadata is key to implementing a viable GIS. Metadata are "data about data", describing such things as the location, sources, content, quality, condition of existing data. Metadatabase systems are systems specifically designed to manage metadata i.e. to provide facilities for input, update, retrieval and reporting of data about data. Such systems are used at a variety of levels, for example, within a single institution or organization to organise and maintain their own data holdings in order to protect and maximise the investment in organising and structuring data. They are also used on a broader level to provide a mechanism through which data producers can ensure that potential users can be made aware of existing data and how it might be obtained. The systems may also vary in the types of data, which are described, for example, books, reports, maps, digital files, etc. Thus there is a wide range of relevant work, from bibliographic systems to handling of digital imagery. In general, metadata can be classified into two levels: geospatial metadata, and non-geospatial metadata. The spatial component of the data describes a collection of data, which have some commonality, e.g. a series of topographic maps or a collection of field survey reports. This level provides an initial view of the existence and contents of datasets (Somers, 2002; Bossler, 2002).

Role of surveying in the maintenance of GIS

One invaluable attribute of the GIS is that it is a dynamic application. In order to keep the GIS application up-to-date regular updating of the GIS database which commences from the updating of the graphic and non-graphic data is necessary. Therefore

Surveying science plays a key role in the updating of the GIS database since it is primarily employed in the acquisition of graphic and non-graphic data. In other words, Surveying data (such as remote sensing, photogrammetric, topographic, hydrographic, GPS, and cadastral data) which form the major data input into the GIS must be constantly reviewed. The constant review of these graphic and non-graphic data invariably affects the logical sequence of the GIS database and even the GIS overall architecture.

Ideally, maintaining a GIS database can be viewed as a process that begins with needs assessment continues through data acquisition and analysis, interpretation, data editing/updating, data archiving and data sharing with various users and organizations (Figure 3). The processes of database management system can be categorised into six components:

-An inventory of existing data and resources will have to be compiled, and priorities for implementation set.

-Data will have to be designed and organised by establishing structure within and among data sets that will facilitate their storage, retrieval and manipulation.

-Procedures will be required for data acquisition and quality assurance and quality control.

-Data set documentation protocols, including the adoption or creation of metadata content standards and procedure for recording metadata, will need to be developed.-Procedures for data archival storage, and maintenance of printed and electronic data will have to be developed, and,

-An administrative structure and procedures will have to be developed so responsibilities are clearly defined.

GIS maintenance mainly entails an updating procedure that involves more than the simple editing of features. Updating implies the resurvey and processing of new information. The updating function is of great importance during GIS implementation. The life span of most digital data can range anywhere from 1 to 10 years but the normal validation is 5 to 10 years. The lengthy time span is due to the intensive task of data capture and input, however often periodic data updates are recommended. These frequently involve an increased accuracy and/or detail of the data layer and changes in classification systems. Many times data updates are required on the results of a derived GIS product. The generation of a derived product may identify substantial errors or inappropriate classes for a particular layer. When this occurs updating of the data is required. In this situation the GIS operator usually has some previous experience or knowledge of the study area. In addition, the data update process is also a result of a physical change in the geographic landscape for instance forest fire. With this type of update new features are usually required for the data layer. Meanwhile, when existing features are altered, e.g. forest succession; there is a strong requirement for a historical record for updating process. Users should be aware of this requirement and design their database organisation to accommodate such needs. Depending on the particular GIS, the update process may involve some data manipulation and analysis functions

The general assumptions and concepts about data maintenance as follows:

-Spatial and attribute databases are dynamic and an ongoing maintenance strategy is essential for continue use. GIS databases can appreciate in value over time, if a maintenance strategy keeps the data current.

-Database maintenance both spatial and attribute data requires rigid procedures to assure data integrity, completeness, positional accuracy, lineage and maximum usability.

-With schedule maintenance, users always know the vintage of the data. Therefore, predictable results of queries can be obtained.

-The source for data updates often resides in many department, thus, data sharing mechanism should be created among data custodians. In some cases it may be advantages if the department that creates and/or uses specific information develops a strategy whereby maintenance occurs as part of their daily routine.

-Matrix or metadata illustrating characteristics about the data (spatial and attribute) should be created to hint data updating and maintenance. These characteristics should include last update, most reliable source, and name of data custodian, desired update frequency, desired position accuracy, and ability of department to update data or subcontract for maintenance.

-There are many different strategies to maintain data. A few of the more logical types of strategies are 1) continuous as change occurs, 2) scheduled as daily, weekly, monthly, or yearly, and 3) correction or update whenever used.

The process of updating GIS data can be divided into three steps:

-As the first step, changes, if any, of the landscape must be detected. This can be done, for example, either by a comparison of the GIS data with an up-to-date orthophoto, satellite imageries, or by field inspection. This is a quite a laborious process and often requires the largest amount of work. An automatic detection of changes in GIS is possible using multispectral remote sensing data such as the optical high-resolution satellite IKONOS and medium resolution satellite data (SPOT and Landsat). Furthermore, the comparison by hand of GIS data and orthophotos, requires high concentration and is error-prone.

-As the second step, various data sources must be used to add further attributes, which cannot be detected in the orthophoto. This can be for example a street name, ownership attributes or administrative borders, which have been, retrieved from very different data sources. In order to be able to work effectively, an optimization is necessary to ensure fast information and work flow. This optimization is strongly dependent on the legal and organizational responsibilities of the data producers.

-As the last step, the changes with all additional information have to be stored into GIS database. This operation step can be least partly being automated. Consistency checks can be done with automated checking programs, which ensure high quality data sets. Many functions for this purpose have been integrated in commercial GIS products (TRACKER VIEW by ESRI) and the user can program further application-specific procedures themselves (Somers, 2002; Bossler, 2002).

Conclusion

The importance of surveying in achieving a viable GIS application cannot be overemphasised. Unfortunately, the appealing and dynamic nature of the GIS tends to undermine the relevance of traditional surveying techniques. Even though most geo-based disciplines such as surveying, geography, geology, and town planning now incorporate GIS as a sub-discipline, there is intense discourse in the academia to treat GIS as a separate discipline.

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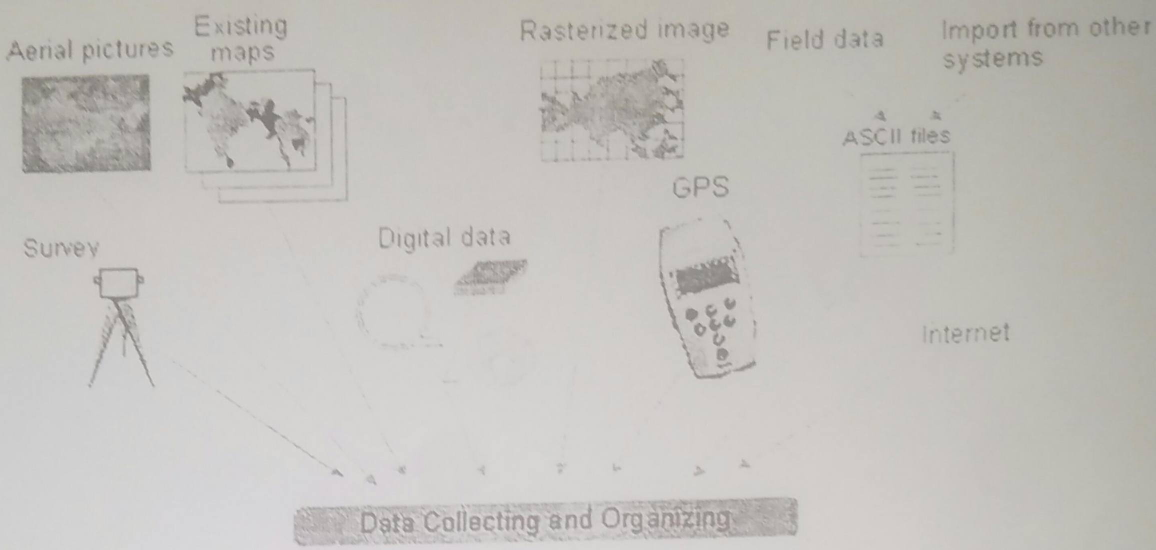

Figure 1 Data sources (Somers, 2002)

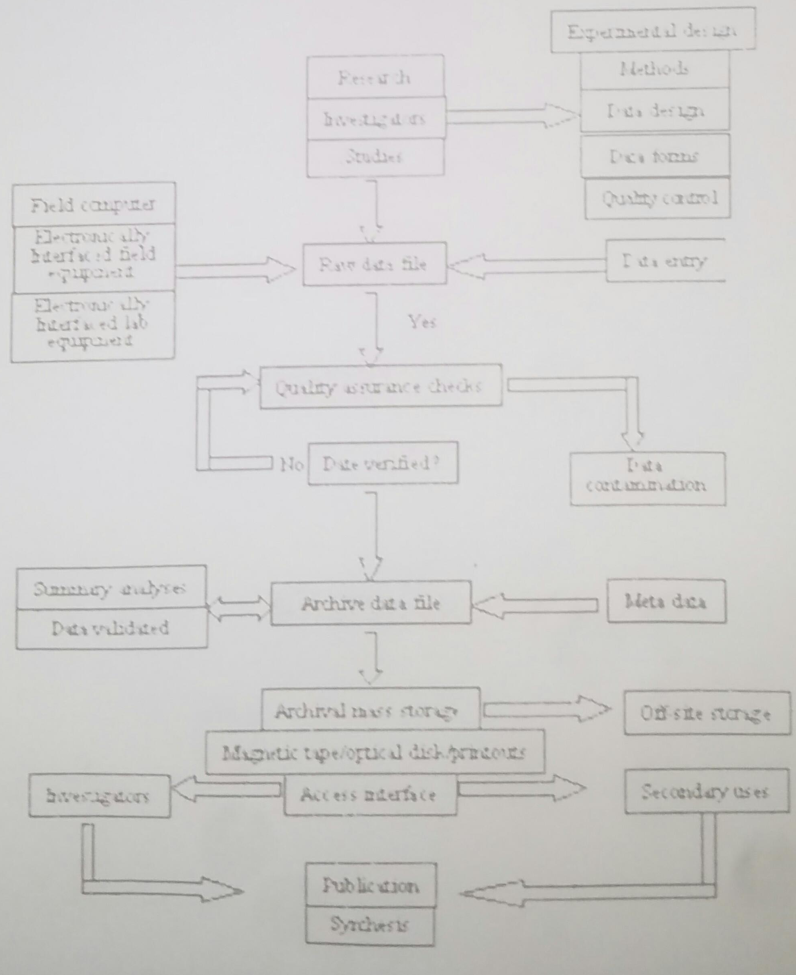

Figure 2 Diagrammatic flow chart of a generic data processing and archival storage procedure (Brunt, 2000)

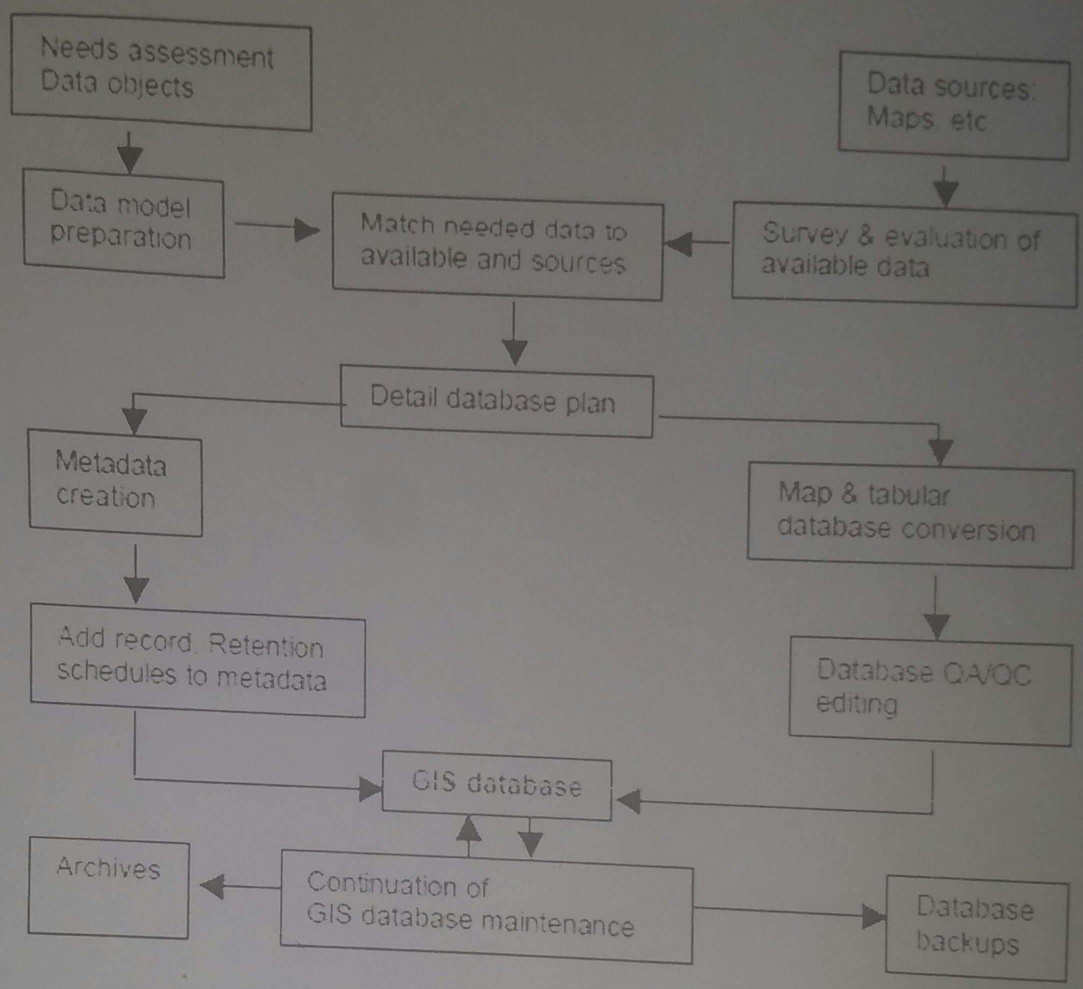

Figure 3 Lifecycle of a GIS database (Somers, 2002)