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Geographic Information System- A Modern Approach

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Abstract

The use of maps in historical research is not new because maps can convey spatial information more efficiently than the written word. Imagine trying to convey the spatial information found on a map of any place, war etc through words such a tedious task but a map more clearly conveys the network-like relations between the bits of information. The managing of spatial data generally involves process of data acquisition, storage and maintenance, analysis and output. Earlier it has been done using analogue data sources and manual processing, but now the use of modern technologies it is much easier to handle spatial data. The technology used in this sphere is Geographic Information Systems (GIS). The GIS software makes it possible to create large amounts of different data, combining different layers of information to manage and retrieve the data in a more useful manner. GIS technology is becoming essential tool to combine various maps and knowledge engineering, Geo-Positioning Satellites; the field also involves some of the oldest sciences and professions, such as geometry land surveying and remote sensing information to generate various models, which are used in real time environment. This paper deals with some of the features of a GIS, the universal trends in this era and the technology behind it. It also describes the preference of using interactive media to implement a GIS by extending its efficiency to produce geographic and other information. This paper also identifies some of the main areas where Multimedia GIS systems could be very valuable.

Keywords: - history of GIS and fundamental elements of GIS, data models and elementary spatial analysis.

1. Introduction

GIS has come of age. Over the past twenty years, those inside the community have marveled each year at the expanding sophistication and power of our tools. Geographical Information Systems (GIS) are computer-based systems that enable users to collect, store, and process, analyze and present spatial data. It produces an electronic representation, called spatial information, about the Earth's natural and artificial features. A GIS references these real-world spatial data elements to a coordinate system. These features can be separated into different layers. A GIS system stores each category of information in a separate "layer" for ease of maintenance, analysis, and visualization for example; layers can signify land characteristics, sample data, demographics information, ecological facts, roads, land use, river drainage and flood plains, and rare wildlife habitats. Different applications create and use different layers. A GIS can also store attribute data, which is descriptive information of the map features. This attribute information is placed in a database separate from the graphics data but is linked to them. A GIS allows the assessment of both spatial and attribute data at the same time. Also, a GIS lets users search the attribute data and relate it to the spatial data. Therefore, a GIS can combine geographic and other types of data to generate maps and reports, enabling users to collect, manage, and interpret location-based information in a planned and systematic way. In short, a GIS can be defined as a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information.GIS systems are dynamic and permit rapid updating, analysis, and display. GIS collect data from various diverse sources such as satellite imagery, aerial photos, maps, ground surveys, and global positioning systems (GPS).

2. History of GIS development

The idea of simulate different layers of data on a series of base maps, and relating things geographically, has been around much older fashion than computers invention. Thousands years ago, the early man used to draw pictures of the animals they hunted on the walls of caves. These animal drawings are track lines and tallies thought to depict migration routes. While simplistic in comparison to modern technologies, these early records mimic the two-element structure of modern geographic information systems, an image associated with attribute information. The earliest use of the geographic method, in 1854 by John Snow, who outline a cholera outbreak in London using points to produce the locations of some individual cases. His study of the distribution of cholera led to the source of the disease, a contaminated water pump within the heart of the cholera outbreak. While the basic elements of topology and theme existed previously in cartography, the John Snow map was unique, using cartographic methods, not only to depict but also to analyze, clusters of geographically dependent phenomena for the first time.

The early 20th century saw the development of "photo lithography" where maps were separated into layers. Computer hardware development urge by nuclear weapon research led to general-purpose system "mapping" applications by the early 1960s. In the year 1962, the world's first true operational GIS "Canada Geographic Information System" (CGIS) was developed by the federal Department of Forestry and Rural Development in Ottawa, Canada by Dr. Roger Tomlinson. It was used to store, analyze, and manipulate data collected for the Canada Land Inventory (CLI). It is an initiative to determine the land capability for rural Canada by mapping information about soils, agriculture, recreation, wildlife, forestry, and land use at a scale of 1:50,000. CGIS was an upgrading over "mapping" applications as it provided capabilities for overlay, measurement, and digitizing or scanning. It supported a national coordinate system that extend the continent, coded lines as "arcs" having a true ingrained topology, and it stored the element and location specific

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information in a separate files. Dr. Tomlinson is known as the "father of GIS," for his use of overlays in promoting the spatial analysis of convergent geographic data. In 1964, Howard T Fisher created the Lab for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design, where a number of essential theoretical concepts in spatial data handling were developed. This lab had most important guidance on the development of GIS until early 1980s. Many pioneers of newer GIS "grew up" at the Harvard lab and had distributed seminal software code and systems, such as 'SYMAP', 'GRID', and 'ODYSSEY'. By the early 1980s, M&S Computing, Environmental Systems Research Institute (ESRI) and CARIS emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, conjoin the first generation approach to separation of spatial information with a second generation approach to organizing attribute data into database structures. More functions for user interaction were developed mainly in a graphical way by a user friendly interface (Graphical User Interface), which gave to the user the ability to sort, select, extract, reclassify, reproject and display data on the basis of complex geographical, topological and statistical criteria. During the same time, the development of a public domain GIS begun by the U.S. Army Corp of Engineering Research Laboratory (USA-CERL) in Champaign, Illinois, a branch of the U.S. Army Corps of Engineers to meet the need of the United States military for software for land management and environmental planning. In the years 1980s and 1990s industry growth were spurred on by the growing use of GIS on UNIX workstations and the personal computers. By the end of the 20th century, the rapid growth in various systems had been build up and up to mark on relatively few platforms and users were start to export the concept of viewing GIS data over the Internet, requiring uniform data format and transfer standards. Recently, number of free, open source GIS packages are developed, which run on a range of operating systems and can be customized to perform specific tasks. As computing power increased and hardware prices slashed down, the GIS became a viable technology for state development planning. It has become a real Management Information System (MIS), and thus able to support decision making processes.

3. GIS Subsystems

A GIS has four main functional subsystems. These are:

- Data input subsystem;
- Data storage and retrieval subsystem;
- Data manipulation and analysis subsystem; and
- Data output and display subsystem.

3.1 Data Input - A data input subsystem allows the user to capture, collect, and transform spatial and thematic data into digital form. The data inputs are usually derived from a combination of hard copy maps, aerial photographs, remotely sensed images, reports, survey documents, etc.

3.2 Data Storage and Retrieval-The data storage and retrieval subsystem organizes the spatial data and their elements or characteristics, in a format which allows it to be quickly retrieved by the user for analysis, and pass accurate updates to make the database. This component usually involves use of a database management system (DBMS) for maintaining attribute data. Spatial data information is usually programmed and maintained in a proper file format.

3.3 Data Manipulation and Analysis-The data manipulation and analysis subsystem allows the user to define and execute spatial and attribute procedures to generate derived information. This subsystem is the main part of the GIS as like the spirit of a GIS, and generally differentiate it from other database information systems and computer-aided drafting (CAD) systems.

3.4 Data Output-The data output subsystem allows the user to produce graphical representation such as statistical reports, maps, derived information products.

The decisive function for a GIS is, design and analysis the spatial data. It is essential to realize that the GIS is not a new discovery, this technique has a rich past that used in a variety of disciplines. Scientists and experts have been actively processing geographic data and promoting their techniques since the 1960's. Today's generic, geographic information system is distinguished from the geo-processing of the past by the use of computer automation to integrate geographic data processing tools in a friendly and comprehensive environment. The introduction of refined computer techniques has generated the multi-disciplinary application of geo-processing methodologies, and provided data integration capabilities that were logistically impossible before.

4. Fundamental Elements of GIS

Geographic Information System is part of technology which stores, analyses and display both spatial and non–spatial data. The GIS has been divided into four elements. They are hardware, software, data, and people. Table-1 gives complete details of different elements.

Table 1 Element of GIS

Sr no	Element of GIS	Details
1	Hardware	Hardware is the part of computer on which a GIS operates for example:- Type of Computer Platforms, Modest Personnel Computers, High performance workstations, Input Devices and Output devices.
2	Software	GIS software provides functions and tools needed to input and store geographic data. It also provides tools to perform data analysis, and displays geographic information in the form of maps or reports. All GIS software packages rely on database management system (DBMS) for input modules, editing, manipulation, analysis, storage and management of the geographic and attribute data.
3	Data	GIS using digitizing for digitally encoding geographic features, such as buildings, roads or county boundaries. Digitizing is done by tracing the location, path or boundary of geographic features-attribute data, spatial data remote sensing data, global database on a computer screen or digitizing tablet.

4	People	The real power of a GIS comes from the people who use them. Today GIS is being used by people, in many different fields, as a tool that enables them to perform their jobs more effectively.

5. Applications area of Multimedia GIS

Table 2 Different Areas where GIS is used

Area	GIS Applications
Facilities Management	locating underground pipes & cables planning facility maintenance telecommunication network services energy use tracking & planning
Environment and Natural Resources Management	suitable study for agricultual cropping management of forests, agricultual lands, water resources, wetlands etc. environmental impact analysis disaster management and mitigation waste facility site location
Street Network	car navigation (routing & scheduling) locating houses and streets site selection ambulance services transportation planning
Planning and Engineering	urban planning regional planning route location of highways development of public facilities
Land Information System	cadastre administration taxation zoning of land use land acquisition

6. Data Models

Translation of real world geographical difference into separate substance is done through data models. It represents the connection among the real world domain of geographic data and computer representation of these features. Data models discussed here are for representing the spatial information. Data models are of two types: Raster and Vector. In raster model ecological data represent in a set of cells and each cell is independently

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addressed with the value of an element. Every unit contains a single value and every location corresponds to a particular unit. One set of cell and associated value is a LAYER. Raster models are uncomplicated and it is easy and faster way to analysis spatial data. Raster data models require a huge volume of data to be stored, fitness of data is limited by cell size and output is less beautiful. Figure 1 shows representation of vector and raster mechanism. Vector data model uses line segments or points represented by their explicit x, y coordinates to identify locations. Connecting set of line segments forms area objects. Vector data models need less storage space and their outputs are significant, evaluation of area boundary is exact and manipulation is faster and convenient. Spatial analysis is complex task to design a software program. The vector model is tremendously valuable for demonstrate discrete features, but less helpful for describing constantly varying features such as soil type or accessibility costs for hospitals. The raster model has evolved to make such type of model that having such continuous features. A raster representation comprises a collection of grid cells rather like a scanned map or picture. Both models are used for storing geographic data and both have their unique advantages and disadvantages. Modern GIS software's are able to handle both models.

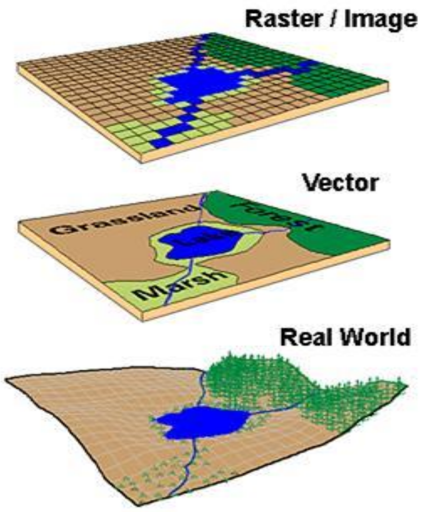

Figure 1: Vector and Raster data examples

6.1 Layers and Coverage

The common requirement to access data on the basis of one or more classes has resulted in several GIS employing organizational schemes in which all data of a particular level of classification, for example- road and rail network, buildings, rivers or vegetation types are grouped into so called layers or coverage. The model of layers is to be found in both vector and raster models. The layers can be combined with each other in various ways to create new layers that are a function of the individual ones. The attribute of each layer within a layer-based GIS is that all locations with each layer may be said to belong to a single region or cell, whether it be a polygon bounded by lines in vector system, or a grid cell in a Raster system. But it is possible for each region to have multiple attributes. The Figure 2 shows layers and coverage concept in GIS.

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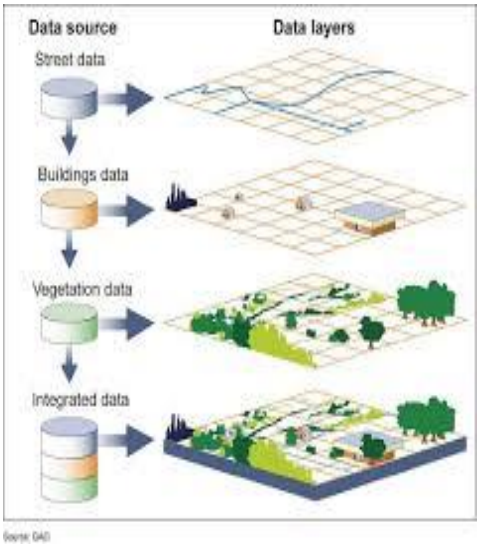

Figure 2: Layers and Coverage concept in GIS

6.2 Data Structures

There are number of different ways to organize the data inside the information system. The choice of data structure affects both Data storage volume and processing efficiency. Three basic data structures are – Relational, Hierarchical and Network for storing and manipulating attribute data in addition to spatial information.

6.2.1 Relational data structure organizes the data in terms of two-dimensional tables where each table is a separate file. Each row in the table is a record and each record has a set of attributes. Each column in the table is an attribute. Different tables are related through the use of a common identifier called KEY. Relation extracts the information, which are defined by query.

Example of Relational Database

Name	FName	City	Age	Salary
Smith	John	3	35	$280
Doe	Jane	1	28	$325
Brown	Scott	3	41	$265
Howard	Shemp	4	48	$359
Taylor	Tom	2	22	$250

6.2.2 Hierarchical data structure stores the data in a way that a hierarchy is maintained among the data items. Each node can be divided into one or more additional node. Stored data gets more and more detailed as one branches further out on the tree.

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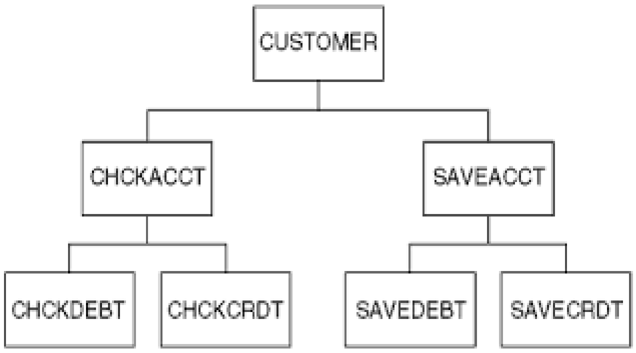
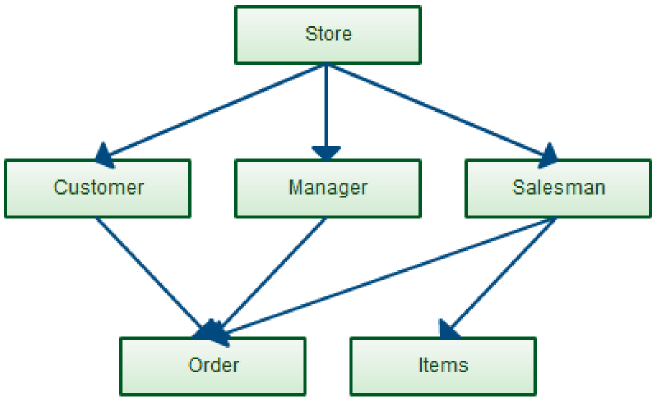


Hierarchical Data Structure

6.2.3 Network data structure is similar to hierarchy structure with the exception that in this structure a node may have more than one parent. Each node can be divided into one or more additional nodes. Nodes can have many parents. The network data structure has the limitation that the pointers must be updated every time a change is made to database causing considerable overhead.



7. Spatial Analysis

Whether it is effective utilization of natural resources or sustainable development or natural disaster management, selecting the best site for waste disposal, optimum route alignment or local problems have a geographical component; geoinformatics will give you power to create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas, and develop effective solutions like never before. In brief it can be described as a supporting tool for decision-making process. Map making and geographic analysis are not new, but a GIS performs these tasks better and faster than do the old manual methods. GIS can cross-examine ecological data and retrieve related information, called identification. It can generate new set of maps by query and analysis. GIS apply procedure and logical tasks that are particularly useful for spatial analysis include:

- Single layer operations
- Multi layer operations/ Topological overlay

- Geometric modeling

Calculating the distance between geographic elements i.e. finding area, length and perimeter or geometric buffers that include:

- Network analysis
- Surface analysis
- Raster/Grid analysis

Geoinformatics is used in various areas like skill management, development, ecological monitoring, population analysis, insurance estimation, and health service, risk mapping and many other applications. The following list shows few applications in natural resource management:

- Agricultural development
- Land evaluation analysis
- Change detection of vegetated areas
- Analysis of deforestation and associated environmental hazards
- Monitoring vegetation health
- Mapping percentage vegetation cover for the management of land
- Crop acreage and production estimation
- Wasteland mapping
- Soil resources mapping
- Groundwater potential mapping
- Geological and mineral exploration
- Snow-melt run-off forecasting
- Monitoring forest fire
- Monitoring ocean productivity etc.
- GIS application in Forestry

With the rise of World Wide Web, new Internet protocols such as the Hypertext Transfer Protocol (HTTP), as well as easy to use interfaces, tools and languages the Internet has become a core for GIS functionalities from the client side without even any GIS software. The GIS field is still evolving and it will be the major force in various walks of life dealing with geographic information.

8. Conclusions

Geographic Information System (GIS) is used by multi-disciplines as tools for spatial data handling in a geographic environment. Basic elements of GIS consist of hardware, software, data and people. GIS is considered one of the important tools for decision making in problem solving environment dealing with geo-information. GIS in real meaning is an applied science that will help to ascertain the ground level realities with the help of spatial data obtained from various resources. In GIS one can integrate data from various sources such as Remote Sensing Data and

Satellite Imagery data sources etc. Geographical Information System (GIS) is the most important and useful system for decision making in Agricultural sector by the functionaries. GIS will help to ascertain the ground level realities with the help of spatial data obtained from various resources. In GIS one can integrate data from various sources such as Remote Sensing Data and Image with that of data of land records and agricultural census. It would be more appropriate to use GIS applications in agro-based enterprise to ascertain the scope of activities and monitoring of activities.

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