An overview of Geographical Information Systems

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Abstract

This paper represents the overviewof Geographical Information System and its applications to improve the performance of various sectors. GIS collects data, processes and analyzes for collaborative decision making about the use of land and environment. GIS is being used by various disciplines as tools for spatial data handling in a geographic environment. This article deals with fundamentals of GIS such as Geoinformatics, types of GIS; GIS subsystem; Elements, functions and applications of GIS.

Keyword: Geographical Information System, GIS sub-system, Spatial Information analysis, Geoinformatics

1 INTRODUCTION

Geographical Information Systems (GIS) are computer-based systems that enable users to collect, store, process, analyze and present spatial data.It provides an electronic representation of information, called spatial data, about the Earth's natural and man-made features. A GIS references these real-world spatial data elements to a coordinate system. A GIS can also store attribute data, which is descriptive information of the map features.

2GEOINFORMATICS

Geoinformatics is the integration of different disciplines dealing with spatial information. It is also defined as the art, science or technology dealing with the acquisition, storage, processing, production, presentation and dissemination of geoinformation.

3 TYPES OF GIS

Four-dimensional GIS

While spatio-temporal geo-representations can handle two dimensions of space and one of time, four-dimensional GIS are designed for three dimensions of space and time.

Multimedia/hypermedia GIS

Multimedia/hypermedia GIS allow theuser to access a wide range of georeferenced multimedia data (e.g., simulations, sounds and videos) by selecting resources from a georeferenced image map base. A map serving as the primary index to multimedia data in a multimedia geo-representation is termed a hypermap. Multimedia and virtual geo-representations can be stored either in extended relational databases, object databases or in application-specific data stores.

Web GIS

Widespread access to the Internet, the ubiquity of browsers and the explosion of commodified geographic information has made it possible to develop new forms of multimedia geo-representations on the Web.Many current geomatics solutions are Web-based overtaking the traditional Desktop environment and most future ones are expected to follow the same direction.

Virtual Reality GIS

Virtual Reality GIS have been developed to allow the creation, manipulation and exploration of geo-referenced virtual environments, e.g., using VRML modelling (Virtual Reality Modelling Language). Virtual Reality GIS can be also Web-based. Applications include 3D simulation for planning (to experiment with different scenarios).

4 GIS SUBSYSTEMS

A GIS has four main functional subsystems. These are:

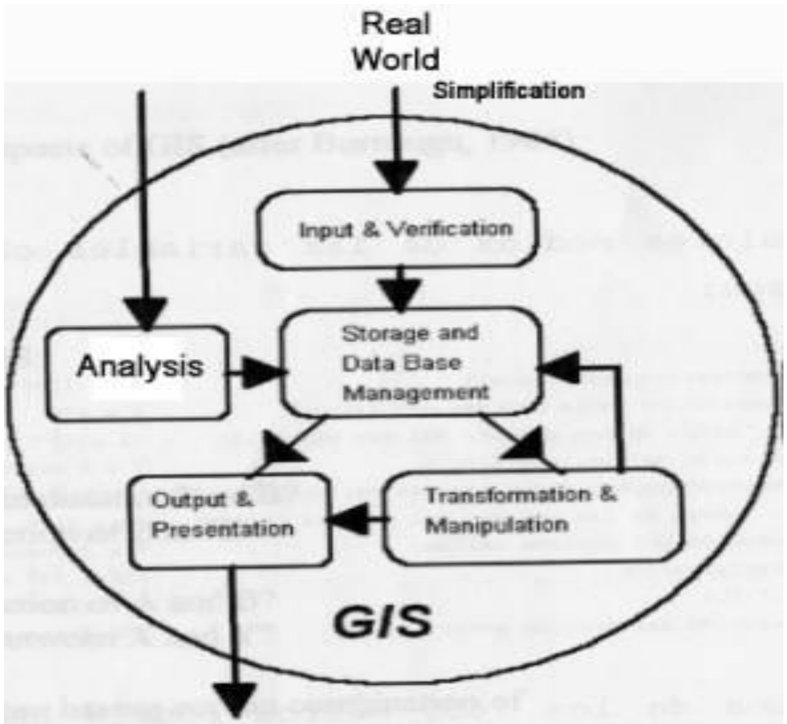

Fig 1: GIS Subsystem

Data Input Subsystem

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.

GIS Data Types

These data will contain maps of different detail levels (maps of the county, its main cities and villages, maps of the archaeological and historical sites etc.), photos of places and monuments, video images, text (in many languages), music and sound.For more complex applications, multimedia data can be remotely sensed imagery, scanned maps, digitized video clips, DTMs, one or more dimensional measurements, simulation model outputs and others. Most of them are complicated objects, which have large data volumes, intensive processing requirements and rich semantics.The basic data types in a GIS reflect traditional data found on a map. Accordingly, GIS technology utilizes two basic types of data. These are:

Spatial data

Spatial data describes the absolute and relative location of geographic features.

Attribute data

Attribute data describes characteristics of the spatial features. These characteristics can be quantitative and/or qualitative in nature. Attribute data is often referred to as tabular data.The coordinate location of a forestry stand would be spatial data, while the characteristics of that forestry stand, e.g. cover group, dominant species, crown closure, height, etc., would be attribute data. Other data types, inparticular image and multimedia data, are becoming more prevalent with changing technology. Depending on the specific content of the data, *image data* may be considered either spatial, e.g. photographs, animation, movies, etc., or attribute, e.g. sound, descriptions, narration's, etc.

Sources of Data

A wide variety of data sources exist for both spatial and attribute data. The most common general sources for spatial data are:

- Hard copy maps
- Aerial photographs
- Remotely-sensed imagery
- Point data samples from surveys
- Existing digital data files

This spatial data is usually in analog form and needs to be converted to digital form before it can be used. Maps can be digitized, or hand-traced with at computer mouse, to collect the coordinates of features.Attribute data has an even wider variety of data sources. Any textual or tabular data than can be referenced to a geographic feature, e.g. a point, line, or area, can be input into a GIS. Attribute data is usually input by manual keying or via a bulk loading utility of the DBMS software.

Data Editing and Quality Assurance

Data editing and verification is in response to the errors that arise during the encoding of spatial and non-spatial data. The editing of spatial data is a time consuming, interactive process that can take as long, if not longer, than the data input process itself.

Several kinds of errors can occur during data input. They can be classified as:

- Incompleteness of the spatial data: This includes missing points, line segments, and/or polygons.
- Locational placement errors of spatial data: These types of errorsusually are the result of careless digitizing or poor quality of the original data source.
- Distortion of the spatial data: Thiskind of error is usually caused by base maps that are not scale-correct over the whole image, e.g. aerial photographs
- Incorrect linkages between spatial and attribute data: This type of erroris commonly the result of incorrect unique identifiers (labels) being assigned during manual key in or digitizing.
- Attribute data is wrong or incomplete:Often the attribute datadoes not match exactly with the spatial data. Missing data records or too many data records are the most common problems.

Data Storage, Editing and Retrieval Subsystem

The second necessary component for a GIS is the data storage and retrieval subsystem. The Data Storage and retrieval subsystem organizes the data, spatial and attribute, in a form, which permits it to be quickly retrieved by the user for analysis, and permits rapid and accurate updates to be made to the database. This component usually involves use of a database management system (DBMS) for maintaining attribute data. Spatial data is usually encoded and maintained in a proprietary file format.

Organizing Data for Analysis

Most GIS software organizes spatial data in a thematic approach that categorizes data in vertical *layers*. The definition of layers is fully dependent on the organization's requirements. Typical layers used in natural resource management agencies or companies include forest cover, soil classification, elevation, road network (access), ecological areas, hydrology, etc.

Editing and Updating of Data

Perhaps the primary function in the data storage and retrieval subsystem involves the editing and updating of data. Frequently, the following data editing capabilities are required:

- Interactive editing of spatial data
- Interactive editing of attribute data
- The ability to add, manipulate, modify, and delete both spatial features andattributes (independently or simultaneously)
- Ability to edit selected features in a batch-processing mode.

Data Retrieval and Querying

The ability to retrieve data is based on the unique structure of the DBMS and command interfaces are commonly provided with the software. Most GIS software also provides a programming subroutine library, or macro language, so the user can write their own specific data retrieval routines if required.Querying is the capability to retrieve data, usually a data subset, based on some user-defined formula. These data subsets are often referred to as *logical views*. Often the querying is closely linked to the data manipulation and analysis subsystem. Querying can be either by example of by content.

Data Manipulation and Analysis Subsystem

The Data Manipulation and Analysis subsystem allows the user to define and execute spatial and attribute procedures to generate derived information. This subsystem is commonly thought of as the *heart of a GIS*, and usually distinguishes it from other database information systems and computer-aided drafting (CAD) systems.

Manipulation and Transformations of Spatial Data

The maintenance and transformation of spatial data concerns the ability to input, manipulate, and transform data once it has been created. Some specific functions are:

- Coordinate thinning: involves the reduction of the coordinate pairs (X and Y) from arcs.
- Geometric Transformations
- Map Projection Transformations
- Edge Matching
- Interactive Graphic Editing

Analytical Functions in a GIS

The primitive analytical functions that must be provided by any GIS are:

- Retrieval, Reclassification, and Generalization
- Topological Overlay Techniques
- Connectivity Functions

Data Output and Display Subsystem.

The Data Output subsystem allows the user to generate graphic displays, normally maps, and tabular reports representing derived information products. This subsystem conveys the results of analysis to the people who make decisions about resources. Wall maps and other graphics can be generated, allowing the viewer to visualize and thereby understand the results of analyses or simulations of potential events.

5. FUNCTIONS OF GEOGRAPHIC INFORMATION SYSTEMS:

1. Automated Mapping: Replicating paper maps on computers.
2. Thematic Mapping: For instances using customer information and demographic data.
3. Map Overlay or Composite Mapping: Producing a map from several layers of data.
4. Spatial Querying: Obtaining information from a database in response to identification of particular conditions.
5. Spatial Browsing: Exploring the contents of a database in response to identification of particular conditions.
6. Spatial Problem Solving: For example deducing inclusions of points in polygons, or for spatial decision-making incorporating both spatial and logical deductive reasoning.
7. Analysis of Spatial Data: Tasks which deal with the attributes of entities, like the average size of sales territories or the degree to which product sales are related to weather conditions.
8. Creating Spatial Statistics: Tasks that require measurements of spatial properties of phenomena, like the total distance traveled by a vehicle on a road network.
9. Analysis of Spatial Statistics: Tasks which treat spatial properties as attributes, for example the correlation between the highway network connectivity and levels of economic development.
10. Spatial Analysis: Encompassing tasks, including simulation, which use a variety of tools of spatial statistics and location-based problem solving.

6. ELEMENTS OF GIS

S. No.	Elements of GIS	Details
1.	Hardware	Type of Computer Platforms Modest Personnel Computers High performance workstations Minicomputers Mainframe computers Input Devices Scanners Digitizers Tape drivers CD Keyboard Graphic Monitor Output Devices Plotters Printers
2.	Software	Input Modules Editing MRP Manipulation/ Analysis Modules Modeling Capability
3.	Data	Attribute Data Spatial Data Remote Sensing Data Global Database
4.	Liveware	People responsible for digitizing, Implementing using GIS Trained personnel

Table 1: Elements of GIS

7 APPLICATIONS OFGIS

Education

Education is a field where integration of multimedia and GIS can bring enormous benefits. Students will learn faster and more efficiently. In addition, it will be possible to individualize learning and tune it to particular preferences of each student.

Mapmaking

GIS can use and combine all layers that are available for an area, in order to produce an overlay that can be analyzed by using the same GIS. Such overlays and their analysis radically change decision-making process that include, among others:

- Site selection
- Simulation of environmental effects (for example, creating perspective views of a terrain before and after mining)
- Emergency response planning (for example, combining road network and earth science information to analyze the effects of a potential earthquake)

Land Information

GIS has aided management of land information by enabling easy creation and maintenance of data for land records, land planning and land use. GIS makes input, updates, and retrieval of data such as tax records, land-use plan, and zoning codes much easier then during the paper-map era.

Infrastructure and Utilities

GIS technologies are also widely applied to the planning and management of public utilities. Typical uses include management of the following services: electric, gas, water, roads, telecommunication, storm sewers, TV/FM transmitting facilities, hazards analysis, and dispatch and emergency services.

Environmental

The environmental field has long used GIS for a variety of applications that range from simple inventory and query, to map analysis and overlay, to complex spatial decision-making systems such as forest modeling, air/water quality modeling and monitoring, environmentally sensitive zone mapping, analysis of interaction between economic, meteorological and hydrological & geological change.

Natural Hazards

Areas vulnerable to earthquakes, floods, cyclones, storms, drought, fire, volcano, land slides, soil erosion can be used to accurately predict future disasters.

Forestry

GIS has been emerging as a strong tool for many areas of forestry, from harvesting schedules to urban forestry.

Military GIS

GIS offers a virtually unique ability to aggregate, automate, integrate and analyze geographical data, which further enhance the intelligence base for defense operations

Oceanography

GIS enables study of sea level change, marine population, sea surface temperature, and coral reef ecosystem.

Water Resources

GIS enables spatial representation of ground water resources, waste quality, watershed management, surface water management, and water pollution.

GIS in agriculture and soil

Data includes information on the country's land resources including physiography, soils, climate, hydrology, cropping systems and crop suitability.

7 CONCLUSIONS

Geographic Information System (GIS) is used by multi-disciplines as tools for spatial data handling in a geographic environment. GIS is considered one of the important tool for decision making in problem solving environment dealing with geo-information.

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