GeoChronicle Panorama, Vol.3, No.1, December 2023 pp.37-42

Geographical Information System (GIS): New Age Soft Skill to Geoscience Education

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Introduction

Geographical Information System (GIS) has become a vital skill in Geoscience education due to advancements in technology and the increasing availability of geospatial data. GIS enables geoscientists to integrate and analyze various types of geospatial data, such as satellite imagery, GPS data, geological maps, and environmental datasets, which are essential for understanding complex geospatial relationships and solving real-world geoscientific problems. It also provides a powerful platform for decision-making, allowing geoscientists to visualize and model scenarios, aiding in land use planning, disaster management, and environmental conservation. Geoscience education has embraced an interdisciplinary approach, with GIS playing a crucial role in bridging the gap between geology, geography, environmental science, and other related fields. GIS often works with remote sensing technology, which is vital for monitoring Earth's surface, atmosphere, and oceans.
Geoscience students with GIS proficiency have a competitive edge in the job market and can open up research opportunities in various geoscientific areas, such as climate change modeling and groundwater resource assessment. GIS also helps develop strong communication skills by allowing students to present findings visually through maps, charts, and reports. Geographic Information System, is a computerized, knowledge-based system that allows one to store, retrieve, and analyze geospatial data. It also allows one to make multi-criteria, logical, and conditional queries to search, find, and visualize a particular feature, or a set of features, patterns, attributes, or changes of a geographic phenomenon that occurred over a time at any given location. Geographic information system stands for the information available on the Earth in terms of features, population, environment, etc. and their analysis of utilization, impact, and estimation can be done with the system for the real world. It also assists one in finding areas that match certain conditions and also to ascertain the implications of certain actions.

Standard definition

Roger Tomilson was an English geographer, the first one to develop a modern computerized Geographic Information System (GIS) and is acknowledged as the 'Father of GIS". The widely accepted definition is given by Peter Burrough in 1986 states "*A Geographic Information System (GIS) is a specific information system applied to geographic data and is mainly referred to as a system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems*". This has been accepted by National Centre for Geographic Information and Analysis (NCGIA, 1990). Another definition of GIS by ESRI is as "A geographic information system (GIS) is a computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. The major challenges we face in the world today overpopulation, pollution, deforestation, and natural disasters have a critical geographic dimension."

Uniqueness of GIS

Geography is information about the earth's surface and the objects found on it, e.g. people, trees, buildings, roads, shorelines, etc. GIS then provides a system for organizing this knowledge. GIS helps manage, analyze, and distribute geographic knowledge. All around the world use GIS to create detailed maps, share information, identify problems, monitor changes, manage and respond to emerging events, and better understand trends by hundreds of thousands of organizations. Some applications of such complex software also include epidemic control(Co win database for covid vaccination management, availability of beds, oxygen, etc. during COVID-19 period), climate forecasting, the assessment of renewable energy potential(location of geothermal energy spot), logistics management, and more commonplace applications, including mobility (Uber, Lyft, Bolt, Flight

Radar) and delivery (Uber Eats, Swiggy, Zomato), as well as military in limited capacity but helping us strategically giving upper hand to find and fix solution in quick time to complexities.
Distinction of GIS from other information systems:

- GIS integrates spatial and other kinds of information within one system: it offers a consistent framework for analyzing space.
- GIS makes connections between activities based on spatial proximity.
- GIS provides the mechanisms for undertaking the manipulation and display of geographic knowledge.

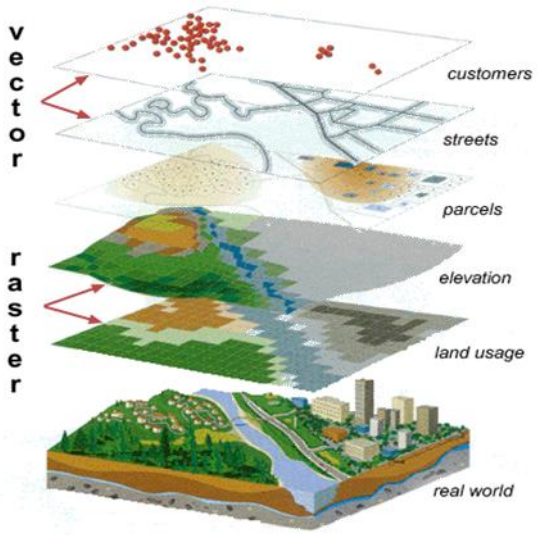

Fig. 1. The Concept of Layers (ESRI).

The above Figure 1 shows a more comprehensive and easy way to define GIS in layers of its data sets. A layer is the basic unit of geographic information that can be requested as a map from a server, Conceptually, a layer is a portion or stratum of geographic space in a particular area and could be considered equivalent of an element of the legend. The vector data model is based on the assumption that the Earth's surface is composed of discrete objects such as trees, rivers, lagoons, etc. (ESRI, 2010). The raster structure is based on a matrix of cells represented in rows and columns. Each cell stores information about a given variable such as precipitation, temperature, relative humidity, solar radiation, soil types, etc.

Components of GIS

There are mainly five main components that are necessary for this operation (Fig. 2).
Hardware: It is the computer by which we operate GIS. Now apart from high-end computers and supercomputers smart mobiles (android, windows mobiles) are used for the purpose of basic GIS. A colour printer is needed to take the output after the final operation.

Software: It helps you to produce maps and other graphic displays of geographic information for analysis and presentation. It creates maps and layers, visualization, and geocoding. The purpose of GIS software is to store, analyze, and display geographic information. It includes not only ArcView alone but also Excel, Statistical package, and GIS Products such as spatial analyst, network analyst, 3D analyst, and vendor programs made public such as Redistrict, and data network. A well-rounded GIS package has tools to support both vector and raster analysis. Over time you may develop preferences depending on the type of analysis being done. The main GIS software is often referred to as a desktop GIS package since GIS software is a large collection of tools that is key to the entire system.

Capture > Input > Analysis > Output

People: It is the users' part and is limited without people who manage the system and develop plans for applying it to real-world problems. It includes both the GIS experts and users and decision makers all kinds of you know a full spectrum of people are required in a GIS. Otherwise, if nobody is asking for new solutions from GIS then the development of GIS will stop. They are important as the GIS experts who collect the data, organize the data,

and maintain such systems maybe online systems like Google Maps or offline systems in some organizations or large enterprises. So, people are another very important component of GIS.

Methods: The method in GIS includes how the data will be accessed, stored, managed, processed, analyzed, and finally presented as output for a particular application. It is well-designed plans and/or business rules describing how the technology is or should be applied. This includes,

- Guidelines
- Specifications
- Standards and
- Procedures

Data: It is an important component of GIS and includes digitized and scanned data, databases, GPS field sampling attributes, remote sensing, and aerial photographs. The data used for this operation is of two types: raster data & vector data. Vector data are databases oriented to represent the world using points, lines, and polygons, these are useful for storing data and representations of features such as buildings, trails, and roads. The data is discrete. Examples of vector data models are Shapefiles (Esri), Triangulated Irregular Networks (TINs), and AutoCAD (.dxf files). Points are nondimensional and defined by x and y coordinates, polygons are the enclosure of one or more lines. These data are more database-oriented and very good at representing features for example rivers, lakes, boundaries, and roads.

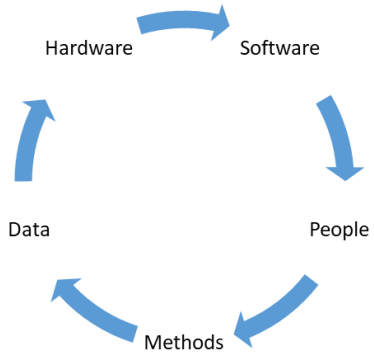

Fig. 2. Different components of GIS.

Raster data are analysis-oriented and It creates a continuous surface defined by a series of discrete grid cells. Each cell has a value that represents attribute data at that location. The data is a continuous representation of a study area and is therefore suited to data that is continuous such as terrain, vegetation, and natural resources. With raster data, you can create atmosphere models, density models, and remotely sensed data.

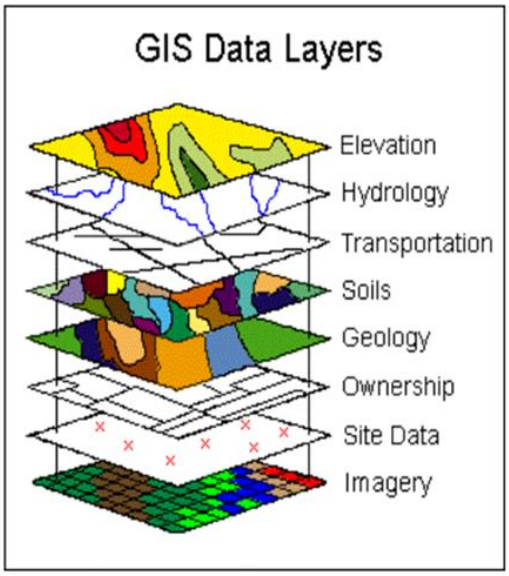

Fig. 3. Overview of GIS which shows the layers of data contain different information to get the final output.

Table 1. Data types, advantages, and disadvantages of GIS.

Data types	Advantages	Disadvantages
Vector Data (available from GPS surveys, manual digitizing)	• Compact data structure • Suitable for cases where data must closely represent hand drawn maps • Have an accurate advantage • Good for storing data that need topological information – they can store information of how a feature connects to others e.g. road networks • Good system for plotting data • Overlaying easily done	Complex data structure • Overlaying data is not simple • It doesn't represent data over surfaces well e.g. topography • Not a compact data structure
Raster Data (User interpolation of vector data, commercially available)	• Variability is well represented • Easy to understand	• Connective relationships are difficult to represent • Blocky appearance

How does GIS work?

GIS comprises computer tools for manipulating maps, digital images, and tables of geocoded (geographically located) data items. GIS is designed to bring together spatial data from diverse sources into a unified database. This includes a variety of digital data structures representing spatially varying phenomena as a series of simple, manageable data layers. In the case of economic censuses, for example, these layers may include agriculture, business, construction, government, manufacturing-, mining-, retail- and service- industries and transportation. Likewise, for preparing groundwater potential maps, for example, there may be layers of bedrock geology, depth to the water table, Bouguer gravity anomaly, airborne/ground magnetic anomaly, satellite imageries, and so on. All these are spatially registered so that they can overlap correctly at all locations. GIS provides tools for analyzing and modeling the interrelationships between individual layers. GIS users need to understand the spatial relationship between various kinds of spatial data they collect. For example, mineral exploration requires the simultaneous consideration of many kinds of spatial evidence for mineral deposits, such as the geology, structure, geochemical and geophysical characteristics of a region as well as location and type of old workings. GIS is now much more than a computer program package and it implies the science of geographic information management and analysis.

Popular GIS software

Vector–based GIS: ArcGIS (ESRI), Arcview, MapInfo
Raster-based GIS: Erdas Imagine9 Leica), ENVI (RSI), ILWIS(ITC), IDRISI (Clark Univ.)

Possibilities of works by GIS

GIS opens many solutions to the problems on Earth with its unique way of functioning:

- Facility mapping, Natural resources management, Decision support systems
- Disaster management, Environmental Impact Assessment
- Land use planning, Tax mapping, Water and sanitation mapping, Transportation routing

Advantages of GIS study

E-governance is now the prime focus of the government of India. The Bhuvan-NRSC platform is helping the people of India in a number of ways to locate Aadhar centers, giving access to huge data resources. It acts as a repository where data can be processed through My GIS. So plotting of lands, zoning of area to various categories for different uses like construction of roads, streets, drainages, and electric cable lining, etc.

- For Govt., estimation of natural resources present inside their territory, highway construction for transportation, etc. GIS plays a major role in averting incoming problems.
- For Military and Defense purposes, management of the battlefield and interpretation of satellite imagery is done by GIS.

- Scientific research employs GIS for geography, geology, botany, anthropology, sociology, economics, political science, epidemiology, and criminology to prepare their data sheets of different categories, and sub-categories.

Application of GIS in Earth Sciences

GIS provides a powerful way of visualizing the world and tools for solving complex problems. It also plays a vital role in scientific research, with a broad array of applications for spatial data and visualization in earth science. GIS study particularly in geology refers to the study of geomorphology, mass movements (slope stability, old deposits), channel erosion, and barrier island movement (Fig. 3).

- Geologists's job is to investigate the structure, composition, and changes over time of the planet. But it is impossible to keep a record of it due to its large volume. So Interpreting and visualising the data that comes from remote sensors are among the primary uses of geologists. GIS experts map out features of the earth's surface and offer guidance for natural resource management. For example, The U.S. Geological Survey provides researchers and organizations with a robust assortment of GIS data, such as topographic details for the entire country and interactive maps of the North American coastline. With detailed spatial information, it's possible to model subsurface water flow or assess the stability of terrain for oil and gas exploration.
- For the New Mexico Energy, Minerals, and Natural Resources Department, spatial data enables responsible exploration and reclamation operations. The department's Mining and Mineral division uses GIS to process permit applications and keep a tab on ongoing mining activity. The vastness and complexity of Earth's ocean can be studied by GIS with a focus on the study of the underwater world, salinity fluctuations, surface temperature, and wave heights. The ArcGIS Ocean Basemap offers professionals details on the sea floor and coastal regions, including depth values and the names of the features.
- GIS is now used as a powerful tool with a combination of GPS and widely available remote sensing data. It assists in the supply of humanitarian aid and also helps to mitigate environmental problems. Water is an important component of the environment and is considered as life, a cause of the existence and evolution of this modern society. Thakur et al. (2017) and Pradhan et al. (2021) integrated GIS with GPS and remote sensing data for hydrological modeling, models of integration, and their needs and reviewed the rapidly depleting groundwater and recharge potential condition. It concluded that large data sets and better methods can be used to solve complex problems.
- Artificial Intelligence (AI) is the ability of a computer or machine to perform cognitive functions. AI in couple with the GIS realm has given a wide range of computing facilities like geocomputing and geospatial artificial intelligence (GeoAI) for mapping. GeoAI has enhanced the traditional geospatial analysis and mapping. The applications of GeoAI and geocomputation, with studies conducted across 20 countries in North America, South America, Europe, Africa, and Asia, including the United States, Canada, Brazil, Spain, the United Kingdom, Denmark, Germany, Switzerland, Italy, Ghana, Tanzania, South Africa, Israel, China, South Korea, Myanmar, Thailand, Laos, Cambodia, and Vietnam. The studies contain a diverse range of topics, out of which it is divided into four categories: buildings and infrastructure, land use analysis, natural environment and natural hazards, and social issues and human activities. These categories reflect the broad applicability of geocomputation and GeoAI in solving complex geospatial and Earth-related problems.

Core Benefits of GIS

A modern GIS provides both simple point–and–click query capabilities and sophisticated analysis tools to provide timely information to managers and analysts alike. Analyse geographic data to look for patterns and trends, and to undertake 'what if' scenarios. Modern GIS has many powerful analytical tools, but these are especially important analyses of:

- Proximity
- Adjacency
- Containment
- Overlay
- Evaluation of connectedness (finding paths)

Using GIS and AI for smart urban development is a path-breaking initiative to ease and regulate traffic. Also, It can help to design technological solutions for construction companies to use available resources efficiently and improve information management. Besides traffic regulation, the public services system, Environmental protection, and domestic and foreign tourism can be improved.

Acknowledgments: Authors wholeheartedly express their gratitude to Dr. Santiswarup Sahoo, Asst. Professor, P.G. Dept. of Geology, Utkal University, Vani Vihar, Bhubaneswar for his encouragement to write this teacher-student relevant article. We also thank Dr. Banabehari Mishra, Hon'ble Patron for his constant effort in popularising geoscience education and service of greater interest to teacher-student.

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