Fundamentals of Geographical Information System and its Applications

*Dr.Ashok V Kurli, Associate Professor of Geography, Government First Grade College, Ranebennur.

Abstract

This paper attempts to study how geographic information system (GIS) a conceptualized framework that provides the ability to capture and analyse spatial and geographic data. GIS applications (or GIS apps) are computer-based tools that allow the user to create interactive queries (user-created searches), store and edit spatial and non-spatial data, analyze spatial information output, and visually share the results of these operations by presenting them as maps.   Geographic information science (or, GIScience)—the scientific study of geographic concepts, applications, and systems—is commonly initialized as GIS, as well. Geographic information systems are utilized in multiple technologies, processes, techniques and methods. They are attached to various operations and numerous applications, that relate to: engineering, planning, management, transport/logistics, insurance, telecommunications, and business. For this reason, GIS and location intelligence applications are at the foundation of location-enabled services, that rely on geographic analysis and visualization. GIS provides the capability to relate previously unrelated information, through the use of location as the "key index variable". Locations and extents that are found in the Earth's spacetime, are able to be recorded through the date and time of occurrence, along with x, y, and z coordinates; representing, longitude (x), latitude (y), and elevation (z). All Earth-based, spatial–temporal, location and extent references, should be relatable to one another, and ultimately, to a "real" physical location or extent. This key characteristic of GIS, has begun to open new avenues of scientific inquiry and studies.

GIS can be a great planning and decision making tool for telecom industries. GDi GISDATA enables wireless telecommunication organizations to incorporate geographic data in to the complex network design, planning, optimization, maintenance and activities. This technology allows telecom to enhance a variety of application like engineering application,   customer relationship management and location based services. GIS also can be used as a key tool to minimize accident hazard on roads, the existing road network has to be optimized and also the road safety measures have to be improved. This can be achieved by proper traffic management. By identifying the accident locations, remedial measures can be planned by the district administrations to minimize the accidents in different parts of the world. Rerouting design is also very convenient using GIS.

Key words: GIS, routing, planning, GIS applications, computer mapping

Introduction

Geographic Information Systems, or GIS, are computer and software tools for gathering and analyzing data connected to geographic locations and their relation to human or natural activity on Earth. GIS data can be used to gather and analyze data about the surface of the earth, and to create layered maps, charts and 3D models of geographical features including mountains, rivers, forests, streets or buildings. Industries and governments use GIS tools to better understand everything from urban planning to climate change. In 1960 the world's first true operational GIS was developed in Ottawa, Ontario, Canada, by the federal Department of Forestry and Rural Development. CGIS was an improvement over "computer mapping" applications as it provided capabilities for overlay, measurement, and digitizing/scanning. It supported a national coordinate system that spanned the continent, coded lines as arcs having a true embedded topology and it stored the attribute and locational information in separate files. As a result of this, Tomlinson has become known as the "father of GIS", particularly for his use of overlays in promoting the spatial analysis of convergent geographic data.

CGIS lasted into the 1990s and built a large digital land resource database in Canada. It was developed as a mainframe-based system in support of federal and provincial resource planning and management. Its strength was continent-wide analysis of complex datasets. The CGIS was never available commercially.

In 1964 Howard T. Fisher formed the Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design (LCGSA 1965–1991), where a number of important theoretical concepts in spatial data handling were developed, and which by the 1970s had distributed seminal software code and systems, such as SYMAP, GRID, and ODYSSEY – that served as sources for subsequent commercial development—to universities, research centers and corporations worldwide.

By the late 1970s two public domain GIS systems (MOSS and GRASS GIS) were in development, and by the early 1980s, M&S Computing (later Intergraph) along with Bentley Systems Incorporated for the CAD platform, Environmental Systems Research Institute (ESRI), CARIS (Computer Aided Resource Information System), MapInfo Corporation and ERDAS (Earth Resource Data Analysis System) emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures.

In 1986, Mapping Display and Analysis System (MIDAS), the first desktop GIS product was released for the DOS operating system. This was renamed in 1990 to MapInfo for Windows when it was ported to the Microsoft Windows platform. This began the process of moving GIS from the research department into the business environment.

By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to explore viewing GIS data over the Internet, requiring data format and transfer standards. More recently, a growing number of free, open-source GIS packages run on a range of operating systems and can be customized to perform specific tasks. Increasingly geospatial data and mapping applications are being made available via the World Wide Web (see List of GIS software § GIS as a service).

Objective:

This paper intends to explore and analyze **Geographic Information Systems** (**GIS**) store, analyze, and visualize data for geographic positions on Earth's surface. Also investigate it's unique technology features that offers a radically different way in which to produce and use the terrainmaps

GIS technology

Modern GIS technologies use digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a CAD program, and geo-referencing capabilities. With the wide availability of ortho-rectified imagery (from satellites, aircraft, Helikites and UAVs), heads-up digitizing is becoming the main avenue through which geographic data is extracted. Heads-up digitizing involves the tracing of geographic data directly on top of the aerial imagery instead of by the traditional method of tracing the geographic form on a separate digitizing tablet (heads-down digitizing). Heads-down digitizing, or manual digitizing, uses a special magnetic pen, or stylus, that feeds information into a computer to create an identical, digital map. Some tablets use a mouse-like tool, called a puck, instead of a stylus.   The puck has a small window with cross-hairs which allows for greater precision and pinpointing map features. Though heads-up digitizing is more commonly used, heads-down digitizing is still useful for digitizing maps of poor quality.

Geoprocessing is a GIS operation used to manipulate spatial data. A typical geoprocessing operation takes an input dataset, performs an operation on that dataset, and returns the result of the operation as an output dataset. Common geoprocessing operations include geographic feature overlay, feature selection and

analysis, topology processing, raster processing, and data conversion. Geoprocessing allows for definition, management, and analysis of information used to form decisions.

Relating information from different sources

GIS uses spatio-temporal (space-time) location as the key index variable for all other information. Just as a relational database containing text or numbers can relate many different tables using common key index variables, GIS can relate otherwise unrelated information by using location as the key index variable. The key is the location and/or extent in space-time.

Any variable that can be located spatially, and increasingly also temporally, can be referenced using a GIS. Locations or extents in Earth space–time may be recorded as dates/times of occurrence, and x, y, and z coordinates representing, longitude, latitude, and elevation, respectively. These GIS coordinates may represent other quantified systems of temporo-spatial reference (for example, film frame number, stream gage station, highway mile-marker, surveyor benchmark, building address, street intersection, entrance gate, water depth sounding, POS or CAD drawing origin/units). Units applied to recorded temporal-spatial data can vary widely (even when using exactly the same data, see map projections), but all Earth-based spatial–temporal location and extent references should, ideally, be relatable to one another and ultimately to a "real" physical location or extent in space–time.

Related by accurate spatial information, an incredible variety of real-world and projected past or future data can be analyzed, interpreted and represented. This key characteristic of GIS has begun to open new avenues of scientific inquiry into behaviors and patterns of real-world information that previously had not been systematically correlated.

GIS uncertainties

GIS accuracy depends upon source data, and how it is encoded to be data referenced. Land surveyors have been able to provide a high level of positional accuracy utilizing the GPS-derived positions. High-resolution digital terrain and aerial imagery, powerful computers and Web technology are changing the quality, utility, and expectations of GIS to serve society on a grand scale, but nevertheless there are other source data that affect overall GIS accuracy like paper maps, though these may be of limited use in achieving the desired accuracy.

In developing a digital topographic database for a GIS, topographical maps are the main source, and aerial photography and satellite imagery are extra sources for collecting data and identifying attributes which can be mapped in layers over a location facsimile of scale. The scale of a map and geographical rendering area representation type, or map projection, are very important aspects since the information content depends mainly on the scale set and resulting locatability of the map's representations. In order to digitize a map, the map has to be checked within theoretical dimensions, then scanned into a raster format, and resulting raster data has to be given a theoretical dimension by a rubber sheeting/warping technology process known as georeferencing.

A quantitative analysis of maps brings accuracy issues into focus. The electronic and other equipment used to make measurements for GIS is far more precise than the machines of conventional map analysis. All geographical data are inherently inaccurate, and these inaccuracies will propagate through GIS operations in ways that are difficult to predict.

Data representation

GIS data represents real objects (such as roads, land use, elevation, trees, waterways, etc.) with digital data determining the mix. Real objects can be divided into two abstractions: discrete objects (e.g., a house) and continuous fields (such as rainfall amount, or elevations). Traditionally, there are two broad methods used to store data in a GIS for both kinds of abstractions mapping references: raster images and vector. Points, lines, and polygons represent vector data of mapped location attribute references.

A new hybrid method of storing data is that of identifying point clouds, which combine three-dimensional points with RGB information at each point, returning a "3D color image". GIS thematic maps then are becoming more and more realistically visually descriptive of what they set out to show or determine.

Data capture Applications

Example of hardware for mapping (GPS and laser rangefinder) and data collection (rugged computer). The current trend for geographical information system (GIS) is that accurate mapping and data analysis are completed while in the field. Depicted hardware (field-map technology) is used mainly for forest inventories, monitoring and mapping.

Data capture—entering information into the system—consumes much of the time of GIS practitioners. There are a variety of methods used to enter data into a GIS where it is stored in a digital format.

Existing data printed on paper or PET film maps can be digitized or scanned to produce digital data. A digitizer produces vector data as an operator traces points, lines, and polygon boundaries from a map. Scanning a map results in raster data that could be further processed to produce vector data.

Survey data can be directly entered into a GIS from digital data collection systems on survey instruments using a technique called coordinate geometry (COGO). Positions from a global navigation satellite system (GNSS) like Global Positioning System can also be collected and then imported into a GIS. A current trend in data collection gives users the ability to utilize field computers with the ability to edit live data using wireless connections or disconnected editing sessions. This has been enhanced by the availability of low-cost mapping-grade GPS units with decimeter accuracy in real time. This eliminates the need to post process, import, and update the data in the office after fieldwork has been collected. This includes the ability to incorporate positions collected using a laser rangefinder. New technologies also allow users to create maps as well as analysis directly in the field, making projects more efficient and mapping more accurate.

Remotely sensed data also plays an important role in data collection and consist of sensors attached to a platform. Sensors include cameras, digital scanners and lidar, while platforms usually consist of aircraft and satellites. In England in the mid 1990s, hybrid kite/balloons called helikites first pioneered the use of compact airborne digital cameras as airborne geo-information systems. Aircraft measurement software, accurate to 0.4 mm was used to link the photographs and measure the ground. Helikites are inexpensive and gather more accurate data than aircraft. Helikites can be used over roads, railways and towns where unmanned aerial vehicles (UAVs) are banned.

Recently aerial data collection has become more accessible with miniature UAVs and drones. For example, the Aeryon Scout was used to map a 50-acre area with a ground sample distance of 1 inch (2.54 cm) in only 12 minutes.

The majority of digital data currently comes from photo interpretation of aerial photographs. Soft-copy workstations are used to digitize features directly from stereo pairs of digital photographs. These systems allow data to be captured in two and three dimensions, with elevations measured directly from a stereo pair using principles of photogrammetry. Analog aerial photos must be scanned before being entered into a soft-copy system, for high-quality digital cameras this step is skipped.

Satellite remote sensing provides another important source of spatial data. Here satellites use different sensor packages to passively measure the reflectance from parts of the electromagnetic spectrum or radio waves that were sent out from an active sensor such as radar. Remote sensing collects raster data that can be further processed using different bands to identify objects and classes of interest, such as land cover.

Web mining is a novel method of collecting spatial data. Researchers build a web crawler application to aggregate required spatial data from the web. For example, the exact geo-location or the neighborhood of apartments can be collected from online real estate listing websites.

When data is captured, the user should consider if the data should be captured with either a relative accuracy or absolute accuracy, since this could not only influence how information will be interpreted but also the cost of data capture.

After entering data into a GIS, the data usually requires editing, to remove errors, or further processing. For vector data it must be made "topologically correct" before it can be used for some advanced analysis. For example, in a road network, lines must connect with nodes at an intersection. Errors such as undershoots and overshoots must also be removed. For scanned maps, blemishes on the source map may need to be removed from the resulting raster. For example, a fleck of dirt might connect two lines that should not be connected.

Raster-to-vector translation : data in different formats

Data restructuring can be performed by a GIS to convert data into different formats. For example, a GIS may be used to convert a satellite image map to a vector structure by generating lines around all cells with the same classification, while determining the cell spatial relationships, such as adjacency or inclusion.

More advanced data processing can occur with image processing, a technique developed in the late 1960s by NASA and the private sector to provide contrast enhancement, false color rendering and a variety of other techniques including use of two dimensional Fourier transforms. Since digital data is collected and stored in various ways, the two data sources may not be entirely compatible. So a GIS must be able to convert geographic data from one structure to another. In so doing, the implicit assumptions behind different ontologies and classifications require analysis. Object ontologies have gained increasing prominence as a consequence of object-oriented programming and sustained work by Barry Smith and co-workers.

Projections, coordinate systems, and registration

The earth can be represented by various models, each of which may provide a different set of coordinates (e.g., latitude, longitude, elevation) for any given point on the Earth's surface. The simplest model is to assume the earth is a perfect sphere. As more measurements of the earth have accumulated, the models of the earth have become more sophisticated and more accurate. In fact, there are models called datums that apply to different areas of the earth to provide increased accuracy, like North American Datum of 1983 for U.S. measurements, and the World Geodetic System for worldwide measurements. The latitude and longitude on a map made against a local datum may not be the same as one obtained from a GPS receiver. Converting coordinates from one datum to another requires a datum transformation such as a Helmert transformation, although in certain situations a simple translation may be sufficient.

In popular GIS software, data projected in latitude/longitude is often represented as a Geographic coordinate system. For example, data in latitude/longitude if the datum is the 'North American Datum of 1983' is denoted by 'GCS North American 1983'.

Spatial analysis with GIS

GIS spatial analysis is a rapidly changing field, and GIS packages are increasingly including analytical tools as standard built-in facilities, as optional toolsets, as add-ins or 'analysts'. In many instances these are provided by the original software suppliers (commercial vendors or collaborative non commercial development teams), while in other cases facilities have been developed and are provided by third parties. Furthermore, many products offer software development kits (SDKs), programming languages and language support, scripting facilities and/or special interfaces for developing one's own analytical tools or variants. The increased availability has created a new dimension to business intelligence termed "spatial intelligence" which, when openly delivered via intranet, democratizes access to geographic and social network data. Geospatial intelligence, based on GIS spatial analysis, has also become a key element for security. GIS as a whole can be described as conversion to a vectorial representation or to any other digitisation process.

GIS is proven as an organization-wide, enterprise and enduring technology that continues to change how local government operates. Government agencies have adopted GIS technology as a method to better manage the following areas of government organization:

Economic Development departments use interactive GIS mapping tools, aggregated with other data (demographics, labor force, business, industry, talent) along with a database of available commercial sites and buildings in order to attract investment and support existing business. Businesses making location decisions can use the tools to choose communities and sites that best match their criteria for success. GIS Planning is the industry's leading vendor of GIS data web tools for economic development and investment attraction.

- Public Safety operations such as Emergency Operations Centers, Fire Prevention, Police and Sheriff mobile technology and dispatch, and mapping weather risks.

- Parks and Recreation departments and their functions in asset inventory, land conservation, land management, and cemetery management.

- Public Works and Utilities, tracking water and stormwater drainage, electrical assets, engineering projects, and public transportation assets and trends.

- Fiber Network Management for interdepartmental network assets

- School analytical and demographic data, asset management, and improvement/expansion planning

- Public Administration for election data, property records, and zoning/management.

- The Open Data initiative is pushing local government to take advantage of technology such as GIS technology, as it encompasses the requirements to fit the Open Data/Open Government model of transparency. With Open Data, local government organizations can implement Citizen Engagement applications and online portals, allowing citizens to see land information, report potholes and signage issues, view and sort parks by assets, view real-time crime rates and utility repairs, and much more. The push for open data within government organizations is driving the growth in local government GIS technology spending, and database management.

- Geologists use GIS in a various applications. The GIS is used to study geologic features, analyze soils and strata, assess seismic information, and or create three dimensional (3D) displays of geographic features. GIS can be also used to analyze rock information characteristics and identifying the best dam site location.

Conclusion

As an emerging technology itself, the field of geographic information systems (GIS) is constantly evolving. Over a span of twenty years, members of the geographic information community have seen this technology evolve from command line, workstation-based software to tools that can now be used in the cloud and via mobile devices. Today a well-developed GIS systems are used to protect the environment. It has become an integrated, well developed and successful tool in disaster management and mitigation. GIS can help with risk management and analysis by displaying which areas are likely to be prone to natural or man-made disasters. When such disasters are identified, preventive measures can be developed. By the help of GIS technology

the agricultural, water and forest resources can be well maintain and manage. Foresters can easily monitor forest condition. Agricultural land includes managing crop yield, monitoring crop rotation, and more. Water is one of the most essential constituents of the environment. GIS is used to analyze geographic distribution of water resources. They are interrelated, i.e. forest cover reduces the storm water runoff and tree canopy stores approximately 215,000 tons carbon. GIS is also used in afforestation.

References

1. "Queensland University of Technology, Undergratuate Program - Spatial Science (Surveying)". Archived from the original on 2008-07-19. Retrieved 2008-06-14.

2. "Curtin University - Spatial science courses". Archived from the original on 2014-09-10. Retrieved 2014-07-31.

3. University of Tasmania, Centre for Spatial Information Science, Courses Archived 2008-07-25 at the Wayback Machine

4. "University of Adelaide, Major in Ecology and Spatial Science" (PDF). adelaide.edu.au. Archived from the original (PDF) on 21 August 2014. Retrieved 2 April 2014.

5. Melbourne University - Spatial Information Science

6. "Surveying and geospatial sciences - RMIT University".