Geographic information system

From Wikipedia, the free encyclopedia

A **geographic information system (GIS)**, or more commonly referred to as a **geospatial information system** or Geographic Information Science, is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, and present the results of all these operations. **Geographic information science** is the science underlying the applications and systems, taught as a degree program by several universities.

Geographic information system technology can be used for scientific investigations, resource management, asset management, Environmental Impact Assessment, Urban planning, cartography, criminology, history, sales, marketing, and route planning. For example, a GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, a GIS might be used to find wetlands that need protection from pollution, or a GIS can be used by a company to find new potential customers similar to the ones they already have and project sales due to expanding into that market.

Contents

History of development

35,000 years ago, on the walls of caves near Lascaux, France, Cro-Magnon hunters drew pictures of the animals they hunted. Associated with the 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.

Possibly the earliest use of the geographic method, in 1854 John Snow depicted a cholera outbreak in London using points to represent the locations of 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 outbreak.

Original map by Dr. John Snow showing the clusters of cholera cases in the London epidemic of 1854

While the basic elements of topology and theme existed previously in cartography, the John Snow map was unique, using cartographic methods to depict clusters of a 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 spurred by nuclear weapon research would lead to general purpose computer "mapping" applications by the early 1960s. The year 1964 saw the development of the world's first true operational GIS in Ottawa, Ontario by the federal Department of Energy, Mines, and Resources. Developed by Roger Tomlinson, it was called "Canadian Geographic Information Systems" (CGIS) and was used to store, analyse, and manipulate data collected for the Canada Land Inventory (CLI)—an initiative to determine the land capability for rural Canada by mapping information about soils, agriculture, recreation, wildlife, waterfowl, forestry, and land use at a scale of 1:250,000. A rating classification factor was also added to permit analysis.

CGIS was the world's first "system" and was an improvement over "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."

CGIS lasted into the 1990s and built the largest 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 data sets. The CGIS was never available in a commercial form. Its initial development and success stimulated various commercial mapping applications being sold by vendors such as ESRI, MapInfo, Intergraph, General Electric (GE Smallworld), and CARIS to successfully incorporate 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. The 1980s and 1990s industry growth were spurred on by the growing use of GIS on Unix workstations and the personal computer. 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 export the concept of viewing GIS data over the Internet, requiring data format and transfer standards. More recently, there is a growing flavor of free, opensource GIS packages such as GRASS GIS and Quantum GIS which run on a range of operating systems and can be customised to perform specific tasks .

Techniques used in GIS

Data creation

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 hardcopy map or survey plan is transferred into a digital medium through the use of a computer-aided drafting (CAD) program, and georeferencing capabilities.

Relating information from different sources

If you could relate information about the rainfall of your state to aerial photographs of your county, you might be able to tell which wetlands dry up at certain times of the year. A GIS, which can use information from many different sources in many different forms, can help with such analyses. The primary requirement for the source data consists of knowing the locations for the variables. Location may be annotated by x, y, and z coordinates of longitude, latitude, and elevation, or by other geocode systems like ZIP Codes or by highway mile markers. Any variable that can be located spatially can be fed into a GIS. Several computer databases that can be directly entered into a GIS are being produced by government agencies and non-government organizations. Different kinds of data in map form can be entered into a GIS.

A GIS can also convert existing digital information, which may not yet be in map form, into forms it can recognize and use. For example, digital satellite images generated through remote sensing can be analyzed to produce a map-like layer of digital information about vegetative covers. Another fairly developed resource for naming GIS objects is the Getty Thesaurus of Geographic Names (GTGN), which is a structured vocabulary containing around 1,000,000 names and other information about places[1] (http://gis.ednet.ns.ca/gis_uses_in_US.htm).

Likewise, census or hydrologic tabular data can be converted to map-like form, serving as layers of thematic information in a GIS.

Data representation

GIS data represents real world objects (roads, land use, elevation) with digital data. Real world objects can be divided into two abstractions: discrete objects (a house) and continuous fields (rain fall amount or elevation). There are two broad methods used to store data in a GIS for both abstractions: Raster and Vector.

Raster

Raster data type consists of rows and columns of cells where in each cell is stored a single value. Most often, raster data are images (raster images), but besides just color, the value recorded for each cell may be a discrete value, such as land use, a continuous value, such as rainfall, or a null value if no data is available. While a raster cell stores a single value, it can be extended by using raster bands to represent RGB (red, green, blue) colors, colormaps (a mapping between a thematic code and RGB value), or an extended attribute table with one row for each unique cell value. The resolution of the raster data set is its cell width in ground units. For example, in a LIDAR raster image, each cell may be a pixel that represents an area of 3 meters by 3 meters. Usually cells represent square areas of the ground, but other shapes can also be used.

Digital elevation model, map (image), and vector data

Vector

Vector data type uses geometries such as points, lines (series of point coordinates), or polygons, also called areas (shapes bounded by lines), to represent objects. Examples include property boundaries for a housing subdivision represented as polygons and well locations represented as points. Vector features can be made to respect spatial integrity through the application of topology rules such as 'polygons must not overlap'. Vector data can also be used to represent continuously varying phenomena. Contour lines and triangulated irregular networks (TIN) are used to represent elevation or other continuously changing values. TINs record values at point locations, which are connected by lines to form an irregular mesh of triangles. The face of the triangles represent the terrain surface.

Advantages and disadvantages

There are advantages and disadvantages to using a raster or vector data model to represent reality. Raster data sets record a value for all points in the area covered which may require more storage space than representing data in a vector format that can store data only where needed. Raster data also allows easy implementation of overlay operations, which are more difficult with vector data. Vector data can be displayed as vector graphics used on traditional maps, whereas raster data will appear as an image that may have a blocky appearance for object boundaries. Vector data can be a lot easier to register, scale, and reproject. This can make it much simpler to combine vector layers from different sources. Vector data are more compatible with relational database environment. They can be part of a relational table as a normal column and processes using a multitude of operators.

Non-spatial data

Additional non-spatial data can also be stored besides the spatial data represented by the coordinates of a vector geometry or the position of a raster cell. In vector data, the additional data are attributes of the object. For example, a forest inventory polygon may also have an identifier value and information about tree species. In raster data the cell value can store attribute information, but it can also be used as an identifier that can relate to records in another table.

Data capture

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. Positions from a Global Positioning System (GPS), another survey tool, can also be directly entered into a GIS.

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.

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 2 and 3 dimensions, with elevations measured directly from a stereo pair using principles of photogrammetry. Currently, analog aerial photos are scanned before being entered into a soft copy system, but as high quality digital cameras become cheaper this step will be 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 to identify objects and classes of interest, such as land cover.

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.

In addition to collecting and entering spatial data, attribute data is also entered into a GIS. For vector data, this includes additional information about the objects represented in the system.

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 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 colour rendering and a variety of other techniques including use of two dimensional Fourier transforms.

Since digital data are 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.

Projections, coordinate systems and registration

A property ownership map and a soils map might show data at different scales. Map information in a GIS must be manipulated so that it registers, or fits, with information gathered from other maps. Before the digital data can be analyzed, they may have to undergo other manipulations—projection and coordinate conversions, for example—that integrate them into a GIS.

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 that apply to different areas of the earth to provide increased accuracy (e.g., North American Datum, 1927 - NAD27 - works well in North America, but not in Europe). See Datum for more information.

Projection is a fundamental component of map making. A projection is a mathematical means of transferring information from a model of the Earth, which represents a three-dimensional curved surface, to a two-dimensional medium—paper or a computer screen. Different projections are used for different types of maps because each projection particularly suits certain uses. For example, a projection that accurately represents the shapes of the continents will distort their relative sizes. See Map projection for more information.

Since much of the information in a GIS comes from existing maps, a GIS uses the processing power of the computer to transform digital information, gathered from sources with different projections and/or different coordinate systems, to a common projection and coordinate system.

Spatial analysis with GIS

Data modeling

It is difficult to relate wetlands maps to rainfall amounts recorded at different points such as airports, television stations, and high schools. A GIS, however, can be used to depict two- and three-dimensional characteristics of the Earth's surface, subsurface, and atmosphere from information points. For example, a GIS can quickly generate a map with isopleth or contour lines that indicate differing amounts of rainfall.

Such a map can be thought of as a rainfall contour map. Many sophisticated methods can estimate the characteristics of surfaces from a limited number of point measurements. A two-dimensional contour map created from the surface modeling of rainfall point measurements may be overlaid and analyzed with any other map in a GIS covering the same area.

Additionally, from a series of three-dimensional points, or digital elevation model, isopleth lines representing elevation contours can be generated, along with slope analysis, shaded relief, and other elevation products. Watersheds can be easily defined for any given reach, by computing all of the areas contiguous and uphill from any given point of interest. Similarly, an expected thalweg of where surface water would want to travel in intermittent and permanent streams can be computed from elevation data in the GIS.

Topological modeling

In the past years, were there any gas stations or factories operating next to the swamp? Any within two miles and uphill from the swamp? A GIS can recognize and analyze the spatial relationships that exist within digitally stored spatial data. These topological relationships allow complex spatial modelling and analysis to be performed. Topological relationships between geometric entities traditionally include adjacency (what adjoins what), containment (what encloses what), and proximity (how close something is to something else).

Networks

If all the factories near a wetland were accidentally to release chemicals into the river at the same time, how long would it take for a damaging amount of pollutant to enter the wetland reserve? A GIS can simulate the routing of materials along a linear network. Values such as slope, speed limit, or pipe diameter can be incorporated into network modelling in order to represent the flow of the phenomenon more accurately. Network modelling is commonly employed in transportation planning, hydrology modelling, and infrastructure modelling.

Cartographic modeling

The term "cartographic modeling" was (probably) coined by Dana Tomlin in his PhD dissertation and later in his book which has the term in the title. Cartographic modeling refers to a process where several thematic layers of the same area are produced, processed, and analyzed. Tomlin used raster layers, but the overlay method (see below) can be used more generally. Operations on map layers can be combined into algorithms, and eventually into simulation or optimization models.

Map overlay

The combination of two separate spatial data sets (points, lines or polygons) to create a new output vector data set. These overlays are similar to mathematical Venn diagram overlays. A union overlay combines the geographic features and attribute tables of both inputs into a single new output. An intersect overlay defines the area where both inputs overlap and retains a set of attribute fields for each. A symmetric difference overlay defines an output area that includes the total area of both inputs except for the overlapping area.

Data extraction is a GIS process similar to vector overlay, though it can be used in either vector or raster data analysis. Rather than combining the properties and features of both data sets, data extraction involves using a "clip" or "mask" to extract the features of one data set that fall within the spatial extent of another data set.

In raster data analysis, the overlay of data sets is accomplished through a process known as "local operation on multiple rasters" or "map algebra," through a function that combines the values of each raster's matrix. This function may weigh some inputs more than others through use of an "index model" that reflects the influence of various factors upon a geographic phenomenon.

Automated cartography

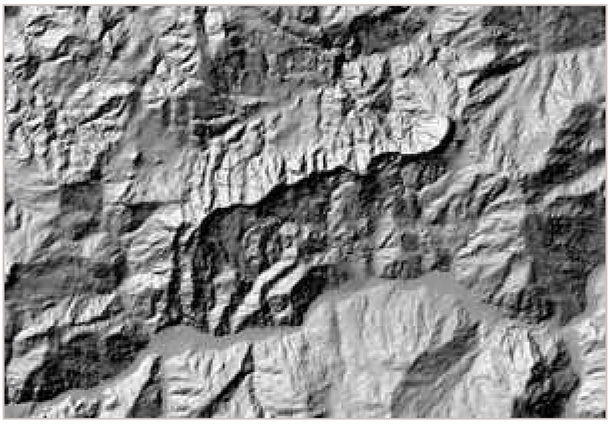
Digital cartography and GIS both encode spatial relationships in structured formal representations. GIS is used in digital cartography modeling as a (semi)automated process of making maps, so called Automated Cartography. In practice, it can be a subset of a GIS, within which it is equivalent to the stage of visualization, since in most cases not all of the GIS functionality is used. Cartographic products can be either in a digital or in a hardcopy format. Powerful analysis techniques with different data representation can produce high-quality maps within a short time period. The main problem in Automated Cartography is to use a single set of data to produce multiple products at a variety of scales, a technique known as Generalization.

Geostatistics

Using Geostatistics to predict fields from points. Point pattern analysis. A way of looking at the statistical properties of spatial data. What makes it different from other kinds of statistics is the use of graph theory and matrix algebra to reduce the number of parameters in the data being analyzed. This is necessary because it is actually the second-order properties of the GIS data that need analyzing.

When we measure any phenomena, our observation methods dictate the accuracy of any subsequent analysis. Whether our study is concerned with the nature of traffic patterns in an urban core, or with the analysis of weather patterns over the Pacific, there will always contain a variable or a degree of precision which escapes our measurement; this is determined directly by the scale and distribution of our data collection, or survey methods. In order to apply statistical relevance to spatial analysis, an 'average' must be determined so that points, or gradients, outside of any immediate measurement may be included as to their predicted behavior. Limitations in statistics and data collection mean that it is impossible to directly measure a continuum without the inferential methods of analysis, of which, several forms of interpolation are used in order to predict the behavior of particles and locations not directly measured.

Interpolation is the process by which a surface is created, usually a raster data set, through the input of data collected at a number of sample points. There are several forms of interpolation, each which treats the data differently, depending on the properties of the data set. In comparing interpolation methods, the first consideration should be whether or not the source data will change (exact or approximate). Next is whether the method is subjective, a human interpretation, or objective. Then there is the nature of transitions between points: are they abrupt or gradual. Finally, there is whether a method is global (it uses the entire data set to form the model), or local where an algorithm is repeated for a small section of terrain.



Hillshade model derived from a Digital Elevation Model (DEM) of the Valestra area in the northern Apennines (Italy)

Digital elevation models (DEM), triangulated irregular networks (TIN), Edge finding algorithms, Theissen Polygons, Fourier analysis, Weighted moving averages, Inverse Distance Weighted, Moving averages, Kriging, Spline, Trend surface analysis.

Regionalized variable theory

Spatial Autocorrelation Principle: Data collected at any position will have a greater similarity to, or influence on, those locations within its immediate vicinity.

Geocoding

Geocoding is calculating spatial locations (X,Y coordinates) from street addresses. A reference theme is required to geocode individual addresses, such as a road centerline file with address ranges. The individual address locations are interpolated, or estimated, by examining address ranges along a road segment. These are usually provided in the form of a table or database. The GIS will then place a dot approximately where that address belongs along the segment of centerline. For example, an address point of 500 will be at the midpoint of a line segment that starts with address 1 and ends with address 1000. Geocoding can also be applied against actual parcel data, typically from municipal tax maps. In this case, the result of the geocoding will be an actually positioned space as opposed to an interpolated point.

It should be noted that there are several (potentially dangerous) caveats that are often overlooked when using interpolation. See the full entry for Geocoding for more information.

Various algorithms are used to help with address matching when the spellings of addresses differ. Address information that a particular entity or organization has data on, such as the post office, may not entirely match the reference theme. There could be variations in street name spelling, community name, etc. Consequently, the user generally has the ability to make matching criteria more stringent, or to relax those parameters so that more addresses will be mapped. Care must be taken to review the results so as not to erroneously map addresses incorrectly due to overzealous matching parameters.

Reverse geocoding

Reverse geocoding is the process of returning an estimated street address number as it relates to a given coordinate. For example, a user can click on a road centerline theme (thus providing a coordinate) and have information returned that reflects the estimated house number. This house number is interpolated from a range assigned to that road segment. If the user clicks at the midpoint of a segment that starts with address 1 and ends with 100, the returned value will be somewhere near 50. Note that reverse geocoding does not return actual addresses, only estimates of what should be there based on the predetermined range.

Data output and cartography

Cartography is the design and production of maps, or visual representations of spatial data. The vast majority of modern cartography is done with the help of computers, usually using a GIS. Most GIS software gives the user substantial control over the appearance of the data.

Cartographic work serves two major functions:

First, it produces graphics on the screen or on paper that convey 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. Web Map Servers facilitate distribution of generated maps via the web technology.

Second, other database information can be generated for further analysis or use. A list of all addresses within 1 mile of a toxic spill for instance.

Graphic display techniques

Traditional maps are abstractions of the real world, a sampling of important elements portrayed on a sheet of paper with symbols to represent physical objects. People who use maps must interpret these symbols. Topographic maps show the shape of land surface with contour lines; the actual shape of the land can be seen only in the mind's eye.

Today, graphic display techniques such as shading based on altitude in a GIS can make relationships among map elements visible, heightening one's ability to extract and analyze information. For example, two types of data were combined in a GIS to produce a perspective view of a portion of San Mateo County, California.

- The digital elevation model, consisting of surface elevations recorded on a 30-meter horizontal grid, shows high elevations as white and low elevation as black.
- The accompanying Landsat Thematic Mapper image shows a false-color infrared image looking down at the same area in 30-meter pixels, or picture elements, for the same coordinate points, pixel by pixel, as the elevation information.

A GIS was used to register and combine the two images to render the three-dimensional perspective view looking down the San Andreas Fault, using the Thematic Mapper image pixels, but shaded using the elevation of the landforms. The GIS display depends on the viewing point of the observer and time of day of the display, to properly render the shadows created by the sun's rays at that latitude, longitude, and time of day.

Spatial ETL

Spatial ETL tools provide the data processing functionality of traditional Extract, Transform, Load (ETL) software, but with a primary focus on the ability to manage spatial data. They provide GIS users with the ability to translate data between different standards and proprietary formats, whilst geometrically transforming the data en-route.

GIS software

GIS software is the main method through which geographic data is accessed, transferred, transformed, overlaid, processed and displayed. Various software form integral components of this interface to GIS data. There are numerous commercial, open source and even shareware products that fill these roles. Commercial software is mostly used in industry with ESRI being the leader, while government and military departments often use custom software, open source products, such as GRASS, or more specialized products. The public and small organizations generally use free GIS readers, rapidly expanding online resources or shareware.

Background

Originally up to the late 1990's, when GIS data was mostly based on large computers and used to maintain internal records, software was a stand-alone product. However with increased access to the internet and networks and demand for distributed geographic data grew, GIS software gradually changed its entire outlook to the delivery of data over a network. GIS software is now usually marketed as combination of various interoperable applications and API's.

Data creation

GIS processing software is used for the task preparing data for use within a GIS. This transforms the raw or legacy geographic data into a format usable by GIS products. For example an aerial photograph may need to be stretched (orthorectified) so that its pixels align with longitude and latitude gradations (or what ever grid is needed). This can be distinguished from the transformations done within GIS analysis software by the fact that these changes are permanent, more complex and time consuming. This a specialized high-end type of software is generally used by person skilled in photogrammetry and / or GIS processing aspects of computer science. In addition, AutoCAD, normally used for draughts of engineering projects, can be configured for the editing of vector maps, and has some products that have migrating towards GIS use. It is especially useful as it has strong support for digitization. Raw geographic data can be edited in many standard database and spreadsheet applications and in some cases a text editor may be used as long as care is taken to properly format data. Examples are OrthoEngine and ArcEditor

Geodatabases

A geodatabase is a database with extensions for storing, querying, and manipulating geographic information and spatial data.

Management and analysis

GIS analysis software takes GIS data and overlays or otherwise combines it so that the data can be visually analysed. It can output a detailed map, image or movie used to communicate an idea or concept with respect to a region of interest. This is usually used by persons who are trained in cartography, geography or a GIS professional as this type of application is complex and takes some time to master. The software performs transformation on raster and vector data sometimes of differing datums, grid system, or reference system, into one coherent image. It can also analyse changes over time within a region. This software is central to the professional analysis and presentaton of GIS data. Examples include the ArcGIS family of ESRI GIS applications (which replaced ESRI's older Arc/INFO), Smallworld, XMap and GRASS.

Statistical

GIS statistical software uses standard database queries to retrieve data and analyse data for decision making. For example, it can be used to determine how many persons of an income of greater than 60,000 live in a given street block. The data is sometimes referenced with postal/zip codes and street locations rather than with geodetic data. This is used by computer scientists and statisticians with computer science skills, with an objective of characterizing an area for marketing or governing decisions. Standard DBMS can be used or specialized GIS statistical software. These are many times setup on servers so that they can be queried with web browsers. Examples are MySQL or ArcSDE.

Readers

GIS readers are applications, usually free, that are distributed to allow the public to easily view maps created via a GIS, as well as view GIS-managed data. By definition, they usually allow very little if any editing of the map or underlying map data. Readers can be normal standalone applications that need to be installed locally, though they generally then connect to data servers over the Internet to access the relevant information. Readers can also be included as an embedded application within a web page, obviating the need for local installation. Readers are designed to be relatively simple and easy to use, tending to emphasize global coverage, visible light raster data and accessible vector data. Google Earth, ArcReader and GeoPDF are examples.

Web API

This is the evolution of the scripts that were common with most early GIS systems. An application programming interface is a set of subroutines (organized as object oriented programming) designed to perform a specific task. GIS API's are designed to manage GIS data for its delivery to a web browser client from a GIS server. They are accessed with commonly used scripting language such as VBA or javascript. They are used to build a server system for the delivery of GIS that is to made available over an intranet or publicly over the internet.

Mobile transfer

While not strictly a GIS application, there are applications that take GIS data and format and transfer that data in a scaled down, limitation-aware manner to PDA and GPS Receiver devices so they can be used for field applications.

Open-source GIS software

Most requirements that can be set for a GIS can be satisfied with free or open-source software. Recently an international foundation (OSGeo (http://www.osgeo.org/)) was started to support and build the highest-quality open source geospatial software.

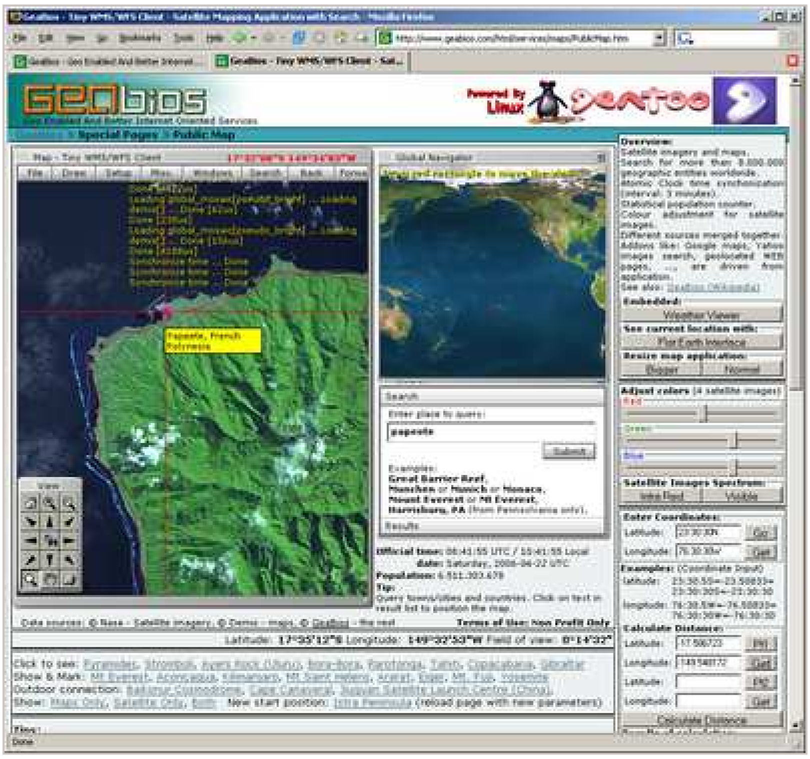
With the broad use of non-proprietary and open data formats such as the Shape File format for vector data and the Geotiff format for raster data, as well as the adoption of Open Geospatial Consortium (OGC) protocols such as Web Mapping Service (WMS) and Web Feature Service (WFS), development of open source software continues to evolve, especially for web and web service oriented applications.

Well-known open source GIS software includes GRASS GIS, Quantum GIS, MapServer, GDAL/OGR, PostGIS, uDig, OpenJUMP, gvSIG, and others (http://www.bestpricecomputers.co.uk/glossary/geographic-information-system.htm#free).

The future of GIS

Many disciplines can benefit from GIS technology. An active GIS market has resulted in lower costs and continual improvements in the hardware and software components of GIS. These developments will, in turn, result in a much wider use of the technology throughout science, government, business, and industry, with applications including real estate, public health, crime mapping, national defense, sustainable development, natural resources, transportation and logistics. GIS is also diverging into location-based services (LBS). LBS allows GPS enabled mobile devices to display their location in relation to fixed assets (nearest restaurant, gas station, fire hydrant), mobile assets (friends, children, police car) or to relay their position back to a central server for display or other processing. These services continue to develop with the increased integration of GPS functionality with increasingly powerful mobile electronics (cell phones, PDA's, laptops).

OGC standards



GeaBios - tiny WMS/WFS client (Flash/DHTML)

Open Geospatial Consortium (OGC) in short is an international industry consortium of 333 companies, government agencies and universities participating in a consensus process to develop publicly available geoprocessing specifications. Open interfaces and protocols defined by OpenGIS Specifications support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT, and empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications.

GIS products are broken down by the OGC into two categories, based on how completely and accurately the software follows the OGC specifications.

Compliant Products are software products that comply to OGC's OpenGIS® Specifications. When a product has been tested and certified as compliant through the OGC Testing Program, the product is automatically registered as "compliant" on this site.

Implementing Products are software products that implement OpenGIS Specifications but have not yet passed a compliance test. Compliance tests are not available for all specifications. Developers can register their products as implementing draft or approved specifications, though OGC reserves the right to review and verify each entry.

Web mapping

Google Maps is different from other web map servers (like MapQuest, Yahoo! Maps, or Rand McNally (http://www.randmcnally.com/)) because Google Maps exposes an API that enables users to associate attributes with interactive maps. This is in effect a GIS. However Google Maps is largely "point" oriented and other than using different point markers, you have to click on the markers to get the metadata. Tools also exist for serving your own web maps, including commercial options such as ArcIMS, and open source tools such as the popular MapServer.

Global change and climate history program

Maps have traditionally been used to explore the Earth and to exploit its resources. GIS technology, as an expansion of cartographic science, has enhanced the efficiency and analytic power of traditional mapping. Now, as the scientific community recognizes the environmental consequences of human activity, GIS technology is becoming an essential tool in the effort to understand the process of global change. Various map and satellite information sources can combine in modes that simulate the interactions of complex natural systems.

Through a function known as visualization, a GIS can be used to produce images - not just maps, but drawings, animations, and other cartographic products. These images allow researchers to view their subjects in ways that literally never have been seen before. The images often are equally helpful in conveying the technical concepts of GIS study-subjects to non-scientists.

Adding the dimension of time

The condition of the Earth's surface, atmosphere, and subsurface can be examined by feeding satellite data into a GIS. GIS technology gives researchers the ability to examine the variations in Earth processes over days, months, and years.

As an example, the changes in vegetation vigor through a growing season can be animated to determine when drought was most extensive in a particular region. The resulting graphic, known as a normalized vegetation index, represents a rough measure of plant health. Working with two variables over time would then allow researchers to detect regional differences in the lag between a decline in rainfall and its effect on vegetation.

GIS technology and the availability of digital data on regional and global scales enable such analyses. The satellite sensor output used to generate a vegetation graphic is produced by the Advanced Very High Resolution Radiometer (AVHRR). This sensor system detects the amounts of energy reflected from the Earth's surface across various bands of the spectrum for surface areas of about 1 square kilometer. The satellite sensor produces images of a particular location on the Earth twice a day. AVHRR is only one of many sensor systems used for Earth surface analysis. More sensors will follow, generating ever greater amounts of data.

GIS and related technology will help greatly in the management and analysis of these large volumes of data, allowing for better understanding of terrestrial processes and better management of human activities to maintain world economic vitality and environmental quality.

In addition to the integration of time in environmental studies, GIS is also being explored for its ability to track and model the progress of humans throughout their daily routines. A concrete example of progress in this area is the recent release of time-specific population data by the US Census. In this data set, the populations of cities are shown for daytime and evening hours highlighting the pattern of concentration and dispersion generated by North American commuting patterns. The manipulation and generation of data required to produce this data would not have been possible without GIS.

Using models to project the data held by a GIS forward in time have enabled planners to test policy decisions. These systems are known as Spatial Decision Support Systems

See also

- Cartography
- Digital raster graphic
- Geodesy
- Geoinformatics
- Geographic information science
- Geoinformation
- Geomatics

- Geo (marketing)
- List of GIS software
- Comparison of GIS software
- Open Source Geospatial Foundation
- Open GIS Consortium
- Remote sensing
- Virtual globe
- Topologically Integrated Geographic Encoding and Referencing (TIGER), a US standard for GIS data
- At-location mapping
- GIS in archaeology
- Historical GIS

Textbooks

- Berry, J.K. (1993) *Beyond Mapping: Concepts, Algorithms and Issues in GIS*. Fort Collins, CO: GIS World Books.
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- Chang, K.S. (2005) *Introduction to Geographic Information System, 3rd Edition*. McGraw Hill.
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- Longley, P.A., Goodchild, M.F., Maguire, D.J. and Rhind, D.W. (2005) *Geographic Information Systems and Science*. Chichester: Wiley. 2nd edition.[3] (http://www.wiley.com/go/longley/)
- Thurston, J., Poiker, T.K. and J. Patrick Moore. (2003) *Integrated Geospatial Technologies: A Guide to GPS, GIS, and Data Logging*. Hoboken, New Jersey: Wiley. [4] (http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471244090.html)
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- Wheatley, David and Gillings, Mark (2002) *Spatial Technology and Archaeology. The Archaeological Application of GIS*. London, New York, Taylor & Francis.

External links

- Federal Geographic Data Committee (http://www.fgdc.gov/) — United States federal government standards agency
- GIS Lounge (http://gislounge.com/)
- NCGIA Core Curriculum in GIS (http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/toc.html) — lecture notes for educators written by the National Center for Geographic Information Analysis (NCGIA).
- Open Geospatial Consortium, Inc. (http://www.opengeospatial.org/)
- USGS GIS Poster (http://erg.usgs.gov/isb/pubs/gis_poster/) — Frequently cited "What is GIS" poster.

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Techniques	Cartography · Geographic Information Science (GIS) · Geostatistics · Remote sensing · Spatial data analysis · Qualitative methods

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