What Is GIS?

Professional White Paper

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What is GIS

A geographic information system (GIS) is a computer-based tool for mapping and analyzing features 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, natural disasters, and homeland security—have critical geographic dimensions. Locating a prime site for a new business, finding the most productive soil for growing soybeans, or figuring out the best route for an emergency vehicle, are each local issues which have geographical components.

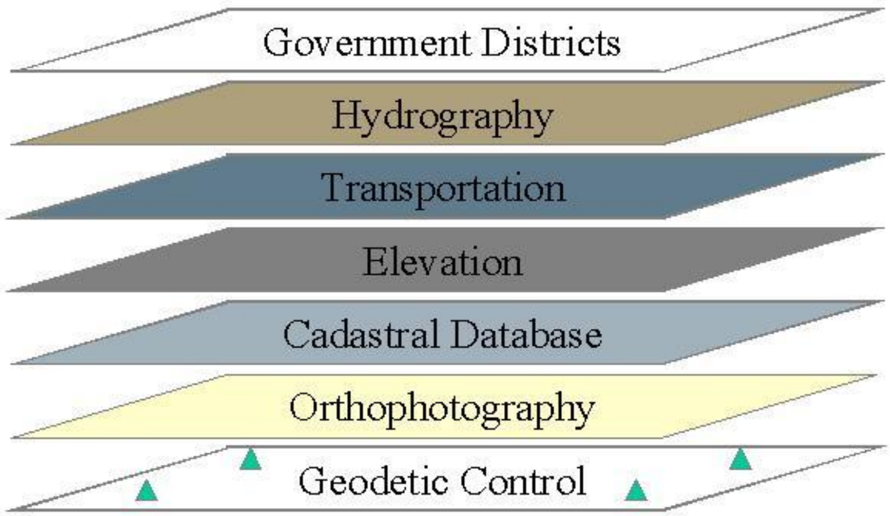
GIS will give you the power to create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas, and develop effective solutions like never before. GIS is a tool used by individuals and organizations, schools, governments, and businesses seeking innovative ways to approach everyday issues.

Mapmaking and geographic analysis are not new, but a GIS performs analytical tasks better and faster than do the old manual methods. And, before GIS technology, only a few people had the skills necessary to use geographic information to facilitate decision making and problem solving.

Today, GIS is a multibillion-dollar industry employing hundreds of thousands of people worldwide, and GIS is taught in schools, colleges, and universities throughout the world. Professionals in every field are increasingly aware of the advantages of thinking and working geographically.

How GIS Works

A GIS stores information about the world as a collection of thematic layers that can be linked together by geography. This simple but extremely powerful and versatile concept has proven invaluable for solving many real-world problems from tracking delivery vehicles, to recording details of planning applications, to modeling global atmospheric circulation.



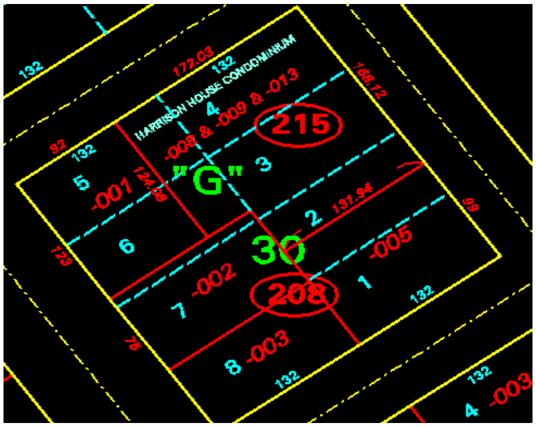
Geographic References

Geographic information contains either an explicit geographic reference, such as latitude and longitude or a national grid coordinate, or an implicit reference such as an address, postal code, census tract name, forest stand identifier, or road name. An automated process called geocoding is used to create explicit geographic references (multiple locations) from implicit references (descriptions such as addresses). These geographic references allow you to locate for analysis a particular feature, such as a business or forest stand, and an event, such as an earthquake, on the earth's surface.

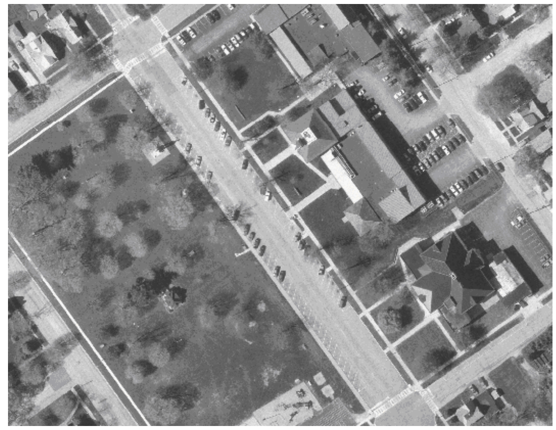
Vector and Raster Models

Geographic information systems work with two fundamentally different types of geographic models—the "vector" model and the "raster" model. In the vector model, information about points, lines, and polygons is encoded and stored as a collection of x,y coordinates. The location of a point feature, such as a bore hole, can be described by a single x,y coordinate. Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as sales territories and river catchments, can be stored as a closed loop of coordinates. The vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for hospitals. The raster model has evolved to model such continuous features. A raster image comprises a collection of grid cells rather like a scanned map or picture. Both the vector and raster models for storing geographic data have unique advantages and disadvantages. Modern Geographic Information Systems are able to handle both models.

Vector Data

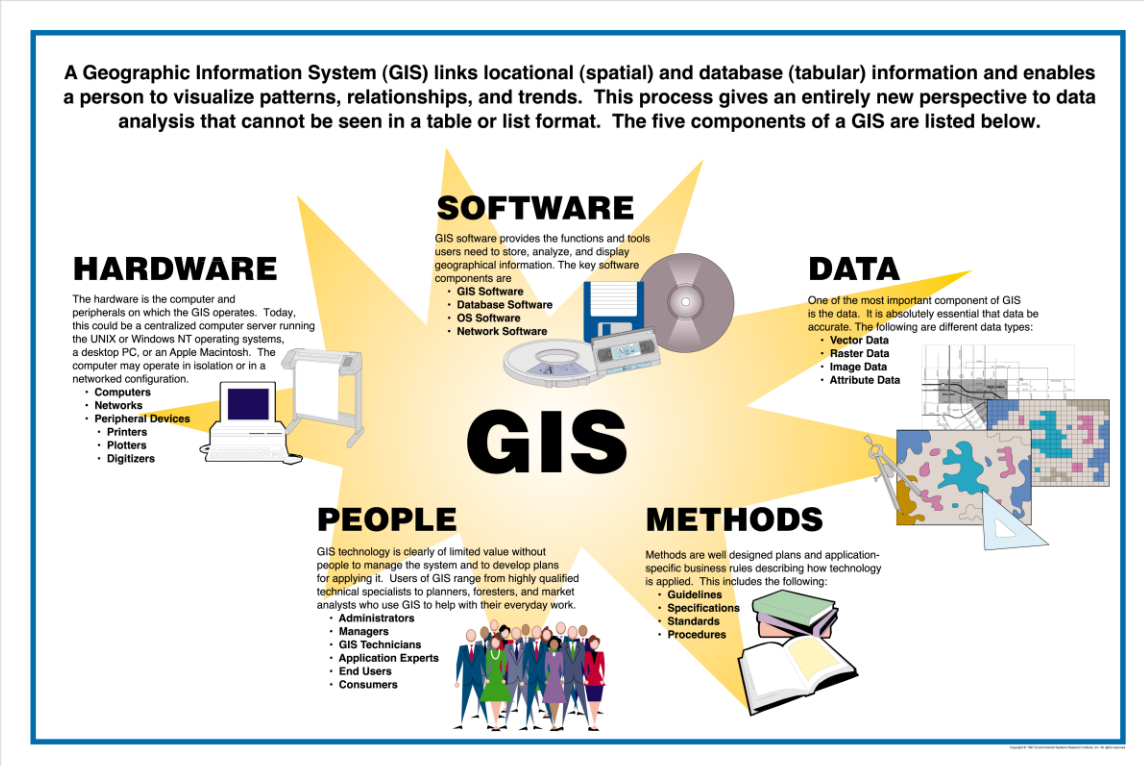


Raster Data



Components of a GIS

A working GIS integrates five key components: hardware, software, data, people, and methods.



<u>Hardware</u>

Hardware is the physical computer on which a GIS operates. Today, GIS software runs on a wide range of hardware types, from centralized computer servers to desktop computers (used in stand-alone or networked configurations) to handheld devices carried into the field.

<u>Software</u>

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components include:

- Tools for the input and manipulation of geographic information
- A database management system (DBMS)
- Tools that support geographic query, analysis, and visualization
- A graphical user interface (GUI) for easy access to tools

<u>Data</u>

Possibly the most important component of any GIS is the data. Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. A GIS will integrate spatial data with other data resources and can even utilize a DBMS—used by most organizations to organize and maintain their data—to manage spatial data.

As stated before, GIS data can be modeled in either vector or raster form. Vector datasets can be broken down further into point, line, or polygon datasets to represent features. Raster data is useful when using scanned or remotely sensed data. Another equally important data type, which really gives GIS its flashy analytical power, is the tabular dataset that houses specific attributes about a feature.

Point data often represents features with specific locations, such as fire hydrants, lighting strikes, or traffic accidents. Point data is commonly gathered through the use of a GPS, or Global Positioning System. A GPS is comprised of a collection of nearly 30 satellites that emit a code to establish a specific location anywhere on the earth's surface. These codes are collected using a GPS receiver, which provides the user with an exact location and elevation.

Line datasets represent linear features such as roads and utility lines. Line features, as with most features in a GIS, can carry additional information that further describes the characteristics of that feature. In the case of a road, its representative linear feature can carry the common road name, date constructed, materials used, load rating, and its overall condition. Any type of information that describes that line (or geographic feature) can be collected and associated to that feature. One of the advantages a linear feature provides is the ability to determine the length of the line. Users are able to determine the length of a county road, how far along the length a specific address is located, or how much cable wire will be needed to connect all houses in a new subdivision. Linear features are commonly assigned address ranges and travel directions. With these attributes, linear features can be used to determine traffic flows, plan routes for snow plows, or identify a location for the dispatch of an ambulance.

Polygon or area features are essential when considering area calculations. Polygons can show the acreage of a property, the square miles of flooded cropland, the hectares of tropical rain forest deforestation, or even the zip code of a region. Polygons are extremely useful when ancillary information is associated with polygon features. With help from GIS software, users can create a thematic map that depicts the associated information via the polygon. Thematic maps can be used to show patterns or trends within data and include such examples as presidential voting patterns by county, property values within a neighborhood, soil polygon characteristics, or population densities.

Raster data is comprised of small, individual raster cells with an identified value placed in that cell. Raster data is often associated with some type of imagery or remotely sensed photograph. While this is not always the case, raster data in a GIS can even be a scanned map that is geographically referenced to its real world location.

Tabular data is stored in rows and columns, like in a spread sheet or an accounting ledger. Each row is associated with a feature (i.e. cell tower, road segment, or parcel) and each column contains pieces of information about that feature. Tabular data is typically stored in a database. Relational databases management systems (RDBMS) are the workhorses in the data processing environment. In recent years, GIS is moving all their functionality and data storage into a RDBMS environment. Databases are very flexible and can process data very efficiently.

People

GIS technology is of limited value without people to manage or use the system and develop plans for applying it to real-world situations. Users of a GIS range from the technical specialists who design and maintain the system to those individuals who employ it in their everyday work. The people maintaining and using a GIS make it successful.

Methods

A successful GIS operates according to a well-designed plan and established business rules, which are the models and operating practices unique to each organization. Keeping data current with a defined set of procedures makes the data even more valuable after it has been created.

GIS Tasks

General-purpose Geographic Information Systems essentially perform six processes or tasks.

- Input
- Manipulation
- Management
- Query and Analysis
- Visualization

Input

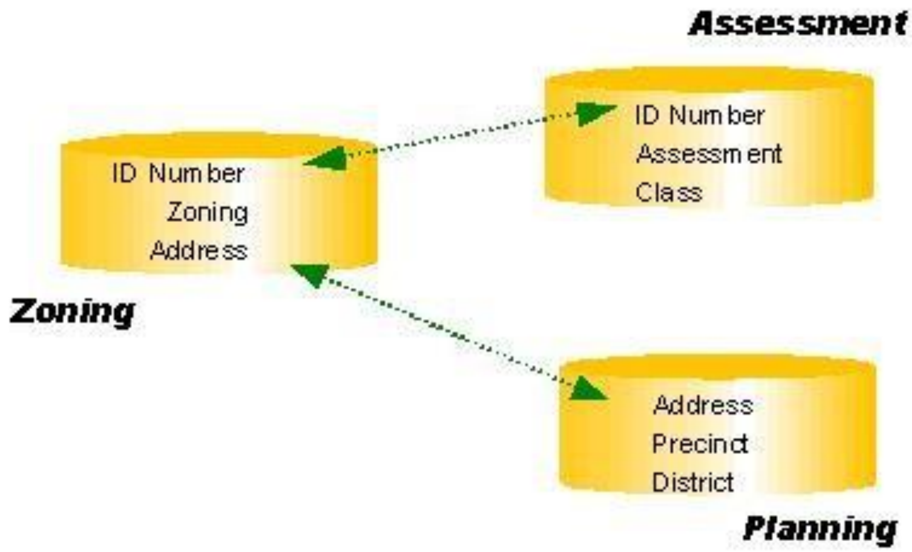
Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. The process of converting data from paper maps into computer files is called digitizing. There is a variety of digitizing methods; each method produces differing levels of geographic accuracy. Selecting the best method depends on the nature, completeness, and quality of the original source documents. Methods include scanning source documents, scanning and rectifying to a known coordinate system, heads-up digitizing, board digitizing, and reconstructing the geography using coordinate geometry and precision placement techniques. Today many types of geographic data already exist in GIS-compatible formats and can be obtained from data suppliers for loading directly into a GIS.

Manipulation

It is likely that certain data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with your system. For example, geographic information is available at different scales (detailed street centerline files; less detailed census boundaries; and postal codes existing at a regional level). Before this information can be integrated, it must all be transformed to the same scale (level of detail or accuracy). This could be a temporary transformation for display purposes or a permanent one required for analysis. GIS technology offers many tools for manipulating spatial data and for weeding out unnecessary data.

Management

For small GIS projects it may be sufficient to store geographic information as simple files. However, when data volumes become large and the number of data users increases, it is necessary to use a database management system (DBMS) to help store, organize, and manage data. A DBMS is nothing more than computer software for managing a database. Although they come in many different designs, the most useful DBMS for managing data in a GIS is the relational design, which stores data conceptually as a collection of tables. Common fields in different tables are used to link them together. This surprisingly simple design has been widely used primarily because of its flexibility and very wide deployment in applications both within and outside of a GIS.



Query and Analysis

Once you have a functioning GIS containing your geographic information, you can begin to ask simple questions such as:

- Who owns the land parcel on the corner?
- How far is it between two places?
- Where is land zoned for industrial use?

And analytical questions such as:

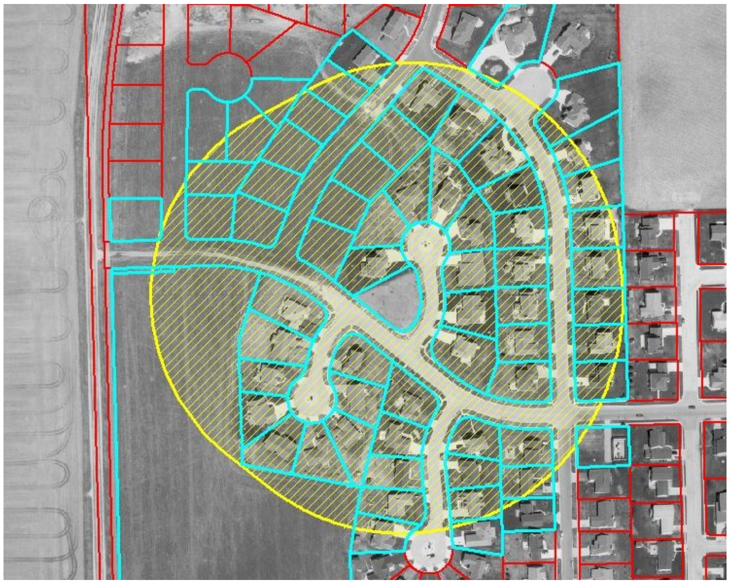
- Where are the sites that are suitable for building new houses?
- What is the dominant soil type of an oak forest?
- If a new highway is built here, how will traffic be affected?

GIS provides both simple point-and-click query capabilities and sophisticated analysis tools to provide timely information to managers and analysts alike. GIS technology really comes into its own when used to analyze geographic data to look for patterns and trends and to undertake "what if" scenarios. Modern GISs have many powerful analytical tools, but two are especially important.

Proximity Analysis

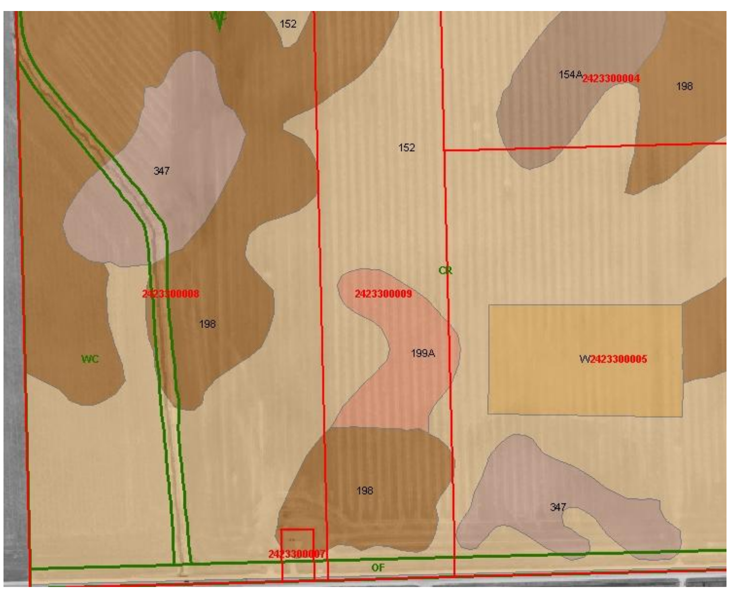
- How many houses lie within 100 m of this water main?
- What is the total number of customers within 10 km of this store?
- What proportion of the alfalfa crop is within 500 m of the well?

To answer such questions, GIS technology uses a process called buffering to determine the proximity relationship between features.



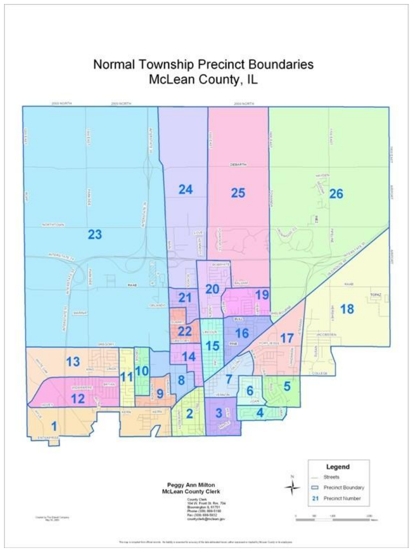
Overlay Analysis

The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership with tax assessment.



Visualization

For many types of geographic operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. While cartographers have created maps for millennia, a GIS provides new and exciting tools to extend the art and science of cartography. Map displays can be integrated with reports, three-dimensional views, photographic images, and other output such as multimedia.



Related Technologies

GISs are closely related to several other types of information systems, but it is the ability to manipulate and analyze geographic data that sets GIS technology apart. Although there are no hard and fast rules about how to classify information systems, the following discussion should help differentiate GIS from desktop mapping, computer-aided design (CAD), remote sensing, DBMS, and global positioning system (GPS) technologies.

Desktop Mapping

A desktop mapping system uses the map metaphor to organize data and user interaction. The focus of such systems is the creation of maps: the map is the database. Most desktop mapping systems have more limited data management, spatial analysis, and customization capabilities. Desktop mapping systems operate on desktop computers such as PCs, Macintoshes, and smaller UNIX workstations.

Computer Aided Drafting (CAD)

Computer Aided Drafting (CAD) systems evolved to create designs and plans of buildings and infrastructure. This activity required that components of fixed characteristics be assembled to create the whole structure. These systems require few rules to specify how components can be assembled and very limited analytical capabilities. CAD systems have been extended to support maps but typically have limited utility for managing and analyzing large geographic databases.

Photogrammetry/Remote Sensing

Photogrammetry and remote sensing is the art and science of making measurements of the earth using aerial photographs or digital imagery. These images are captured by cameras or light sensing devices carried on airplanes and satellites. These devices collect data in the form of images and provide specialized capabilities for manipulating, analyzing, and visualizing those images.

GPS

GPS or Global Positioning System is a collection of over 24 satellites that orbit the earth relaying radio signals to provide a coordinate position to a location on the earth's surface. Lacking strong geographic data management and analytical operations, they cannot be called true GISs.

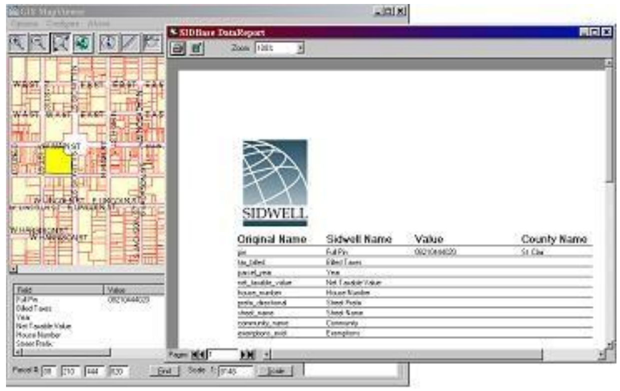
DBMS

Database management systems specialize in the storage and management of all types of data including geographic data. DBMSs are optimized to store and retrieve data and many GISs rely on them for this purpose. They do not have the analytic and visualization tools common to GIS. dimensional views, photographic images, and other output such as multimedia.

Making GIS Data Work for You

In today's global community, the more information you have at your fingertips, the easier it is to make an informed decision. In today's high-tech world, information comes in many different forms, from company reports and statistics generated internally to digital photos and multimedia from across the world.

Information can be overwhelming and the need for timely decisions calls not only for innovative ways to access accurate, up-to-the-minute information, but also for tools to help present the information in useful ways.



A geographic information system or GIS allows you to bring all types of data together based on the geographic and location components of the data. But unlike a static paper map, GIS can display many layers of information that is useful to you. You will be able to integrate, visualize, manage, solve, and present the information in a new way.

Relationships between the data will become more apparent and your data will become more valuable.

GIS will give you the power to create maps, integrate information, visualize scenarios, solve complicated problems, present powerful ideas, and develop effective solutions like never before.

Suggested Readings:
Geography Matters, An ESRI White Paper, September 2002