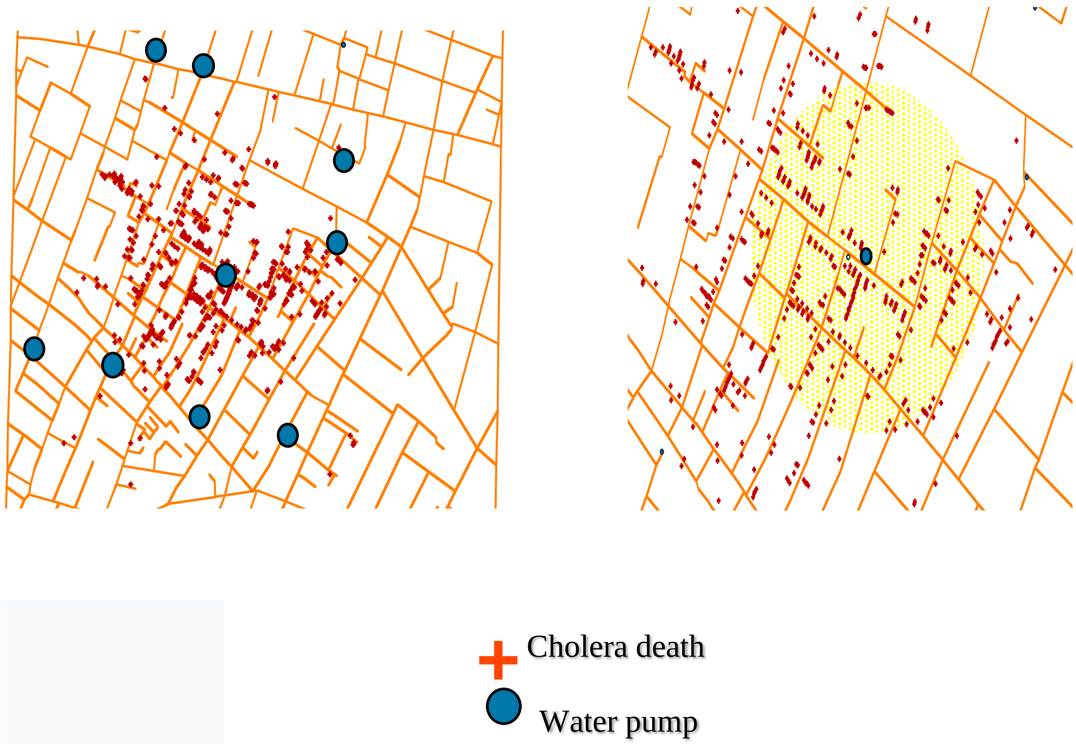
Geographical information system

A Brief History of GIS

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 phenomenon for the first time.

The evolution of GIS

GIS is a relatively new branch of information technology. The term GIS did not appear until the early 1960s when the Canada Geographic Information System (CGIS) was developed. During this apparently short span of history, both the technology used to construct GIS and the functions of GIS have undergone considerable changes. GIS as we understand it today is very different from its predecessors. In the following sections, we will trace the evolution of GIS from its inception in the early I 960s to the present time, as summarized in Figure, with a view to explaining how it has come to what it is today.

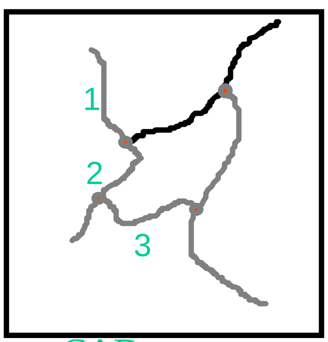
Stage of Development	(a) The formative years	(b) Maturing Technology	(c) GI Infrastructure
Time frame	1960-1980	1980-1990	1990-presnt
Technical environment	•Mainframe computer •Proprietary software • Proprietary data structure • Mainly raster-based	• Mainframe and minicomputers • Geo-relational data Structure • Graphical user interface New data acquisition technologies (GPS. redefinition of datum, remote sensing)	• Workstations and PCs • Network/Internet • Open systems design • Multimedia • Data integration • Enterprise computing • Object-relational data model
More users	• Government • Universities •Military	• Government • Universities •Utilities • Business • Military	•Government •Universities and schools •Business •Utilities •Military me general public
Major application areas	•Land and resource management • Census • Surveying and mapping	• Land and resource management •Census •Surveying and mapping •Facilities management • Market analysis	• Land and resource management • Census • 5urveng and mapping • Facilities management • Market analysis Utilities Geographic data browsing

The formative years 1960-1980

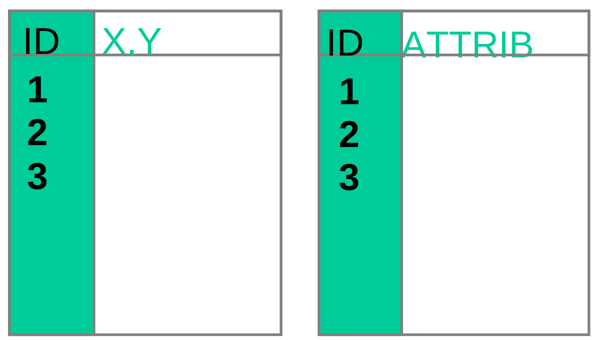
As a computer-dependent application, the origin of GIS could be traced to research and development in electronic data processing dating back to the 1940s and 1950s. The idea of processing large amounts of complex data electronically was quickly picked up by many government agencies to build computer systems for geographic data handling. The CGIS, for example, was conceptualized in the early 1960s and became operational in 1971 (Torniinson et al., 1976). The purpose of CGIS was to address the needs of land and resource information management of the federal government of Canada. This system has been generally recognized as the first GIS ever produced.

This technology has developed from:

- Digital cartography and CAD
- Data Base Management Systems



CAD



Data Base Management System

In 1973, the USGS started the development of the Geographical Information Retrieval and Analysis System (GIRAS) to handle and analyze land-use and land cover data (Mitchell et al., 1977). There were similar systems developed in Europe.

The growing interest in computer-based map data processing also initiated several active research and development programs in universities in Europe and North America. Notable examples included, among many others

(1) The Harvard Laboratory for Computer Graphics, where the arguably first contemporary vector GIS called ODESSEY was developed;

(2) The Center for Urban and Regional Analysis, University of Minnesota, which housed the Minnesota Land Management Information System (MLMIS), one of the exemplary state GIS in the United States;

(3) The Experimental Cartographic Unit (ECU) at the Royal College of Art in London, England, which was concerned primarily with the generation of high-quality maps using computers; and

(4) The Department of Geography, University of Edinburgh, Scotland, where the widely used GIMMS (Geographic Information Mapping and Management System) package was developed.

The 1960s and 1970s thus represented the important formative years of GIS (Figure). During these two decades, hundreds of software packages for handling and analyzing geographic information were produced (Marble, 1980). These early generations of systems were developed and used mainly by government agencies and universities, for very specific data management and research objectives.

As noted, land and resource management was the primary application area of these systems. However, there were also many other isolated attempts to apply this newly found technology to different fields of science and technology, including defense, utilities, transportation, oil exploration, urban planning, population census, as well as surveying and mapping.

The Years of Maturing Technology From The Early 1980s To The Mid – 1990s

The technical paper of Corbett **(1979)** on the concept of ***topology*** as applied to spatial data was a major milestone in the development of GIS concepts and techniques. In the context of geographic data structure, topology refers to the spatial relationships of ***adjacency, connectivity,*** and ***containment*** among topographic features. Using the concept of topology, geographic data can be stored in a simple structure that is capable of representing their attributes (i.e., what they are), locations (i.e., where they are), as well as their relationships (i.e., how they are spatially associated with one another). The concept of topological data structure largely solved the data representation problem that hindered the development of GIS in the early years. It significantly reduced the complexity of applying geographic data for spatial analysis, thus making GIS much easier to implement and use.

In 1982, Environmental Systems Research Institute, Inc. (ESRI) released Arclnfo, based on minicomputers. This particular GIS software package was one of the first vector-based GIS to use the *georelational data model* that employed a hybrid approach to geographic data process in (Morehouse, 1989). In this approach, graphic data are stored using the topological data structure, while attribute data are stored using the relational or tabular data structure.

Other GIS software packages developed using a similar data model in the mid-1980s included, for example, INFOMAP by Synercom in the United States and CARIS by Universal Systems Limited in Canada.

The ability to port GIS application to the microcomputer platform in the late 1980s led to the development of MapInfo, SPANS, PC-Arclnfo, and several other PC-based systems. Following its strength In the CAD area, Intergraph released its Modular GIS Environment (MGE) in 1989.

It led to the integration of raster and vector geographic data, as well as the integration of geographic data with other types of business data in what is called the *enterprise-computing environment.* It also nurtured the concept of open GIS that aimed to develop systems capable of sharing technical and data resources with one another. The development of GIS was greatly accelerated by the phenomenal growth of computer technology in the 1990s. With advances in operating systems, computer graphics, database management systems and computer-human interaction, and graphical user interface (GUI) design.

Some GIS incorporated real-time data input facilities, advanced data modeling routines and scientific visualization technologies that positioned them among the most advanced and sophisticated types of computer applications.

The age of Geographic Information Infrastructure Started in The mid-1990s

The concept of *information infrastructure* emerged in the early 1990s when the United States government proposed the National Information Infrastructure (Nil) initiative (NAE, 1994; NAPA, 1998). The objective of this initiative was to provide all U.S. citizens access to information affecting their lives that pertains to government, health care, education, and community development. As geographic information was important to well over half of all public services and economic activities in the society, it was soon recognized that this particular type of information should become a special component of the Nil in its own right.
In 1994, President Clinton issued Executive Order 12906 supporting the implementation of a National Spatial Data Infrastructure (NSDI) that he defined as the "technology, policies, standards, and human resources to acquire, process, share, distribute, and improve utilization of geospatial data." Similar national geographic information infrastructure initiatives have also been established in Canada, the European Union, Australia, New Zealand, and many other countries.

In order to operate within the conceptual framework of geographic information infrastructure, GIS is now designed, constructed, and applied very differently from its predecessors. A typical GIS today has the following technical and operational characteristics.

1. It is part of (computer network rather than a stand-alone computer configured using advanced processors and memory systems, and sharing input/output connectivity and data storage facilities with different types of mainstream information technology applications.
2. It is made up of multitier, distributed software components that allow geographic information processing functions to be performed across multiple processors, computer clusters, and data storage systems.
3. It is connected to the Internet for access to data and technical resources available on the World Wide Web (WWW), and for distributing the geographic information it contains to any interested person or organization anywhere in the world.

4. It is developed using industry standards for computer systems development methodology, software development tools, database connectivity, and communications protocols as well as user interfaces,
5. It contains a set of off-the-shelf software applications that allows it to perform common data- processing functions in input/output, database administration, spatial analysis, and generation of information products; it also provides a scripting language for users to develop task-specific applications quickly.
6. It uses data stored locally in its own hard drives and data drawn from a local server through local area networks (LAN), as well as data obtained from national, regional, and corporate data warehouses through the Internet.

7. It is capable of using raster and vector data and it can integrate geographic data with other forms of business data in a totally integrated manner.
8. It is capable of presenting the results of information retrieval and analysis using multimedia technologies that include sound, graphics; and animation,
9. It is tightly coupled with other software applications such as statistical analysis and visualization. Which enhance its spatial analysis functionality, as **well as** spreadsheet and word processing, which are capable of using its output in other desktop applications.
10. It supports multi-user information needs ranging from sophisticated spatial problem solving and complex business decision making, to relatively simple information query and browsing.

In view of the critical role that GIS plays in the daily life of individuals and the business operations of business and government organizations, there is definitely no better word than "infrastructure to describe what these systems really are today.

Development with Disciplines

Geographical information Systems are the result of linking parallel developments in many separate spatial data processing disciplines.

Essentially, all these disciplines are attempting the same sort of operation—namely to develop a powerful set of tools for collecting, storing, retrieving at wilI, transforming, and displaying spatial data from the real world for a particular set of purposes. This set of tools constitutes a Geographical Information System' (some technique times a Geographic Information System. Geographical data describe object from the real word in terms of

(a) Their position with respect to- a known coordinate system,

(b) Their attributes that are unrelated to position (such as co lour, cost, pH, incidence of disease, etc.) and

(c) Their spatial interrelations with each other (topological relations), which describe how they are linked together or how one can travel between.

Concept

Combination of three words

- Geographic/Geospatial Information
  - information about places on the earth's surface
  - knowledge about "what is where when"

    (Don't forget time!)
- Information Technologies
  - technologies for creating and processing this information
    - Global Positioning Systems (GPS)
    - Remote Sensing (RM)
    - Geographic Information Systems (GIS)
- GIS--what's in the S?
  - Systems: the technology
  - Science: the concepts and theory

A system of integrated computer-based **tools** for end-to-end **processing** (capture, storage, retrieval, analysis, display) of data using **location on the earth's surface** for interrelation in support of **operations management, decision making, and science**

Definition

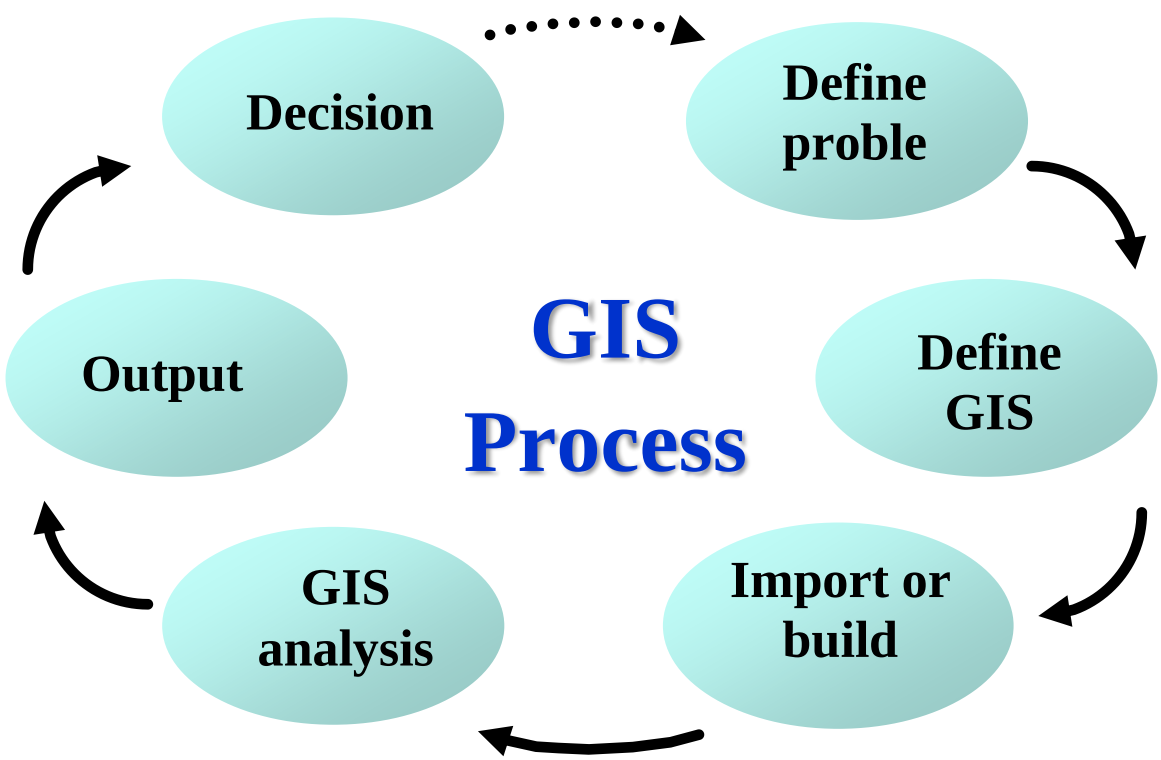
A GIS is a toolbox

- ***"a powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes"*** (Burrough, 1986).

- "***automated systems for the capture, storage, retrieval, analysis, and display of spatial data."*** (Clarke, 1995).

A GIS is an information system

- ***An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data"*** (Star and Estes).



2) Maps and spatial information

Definition

- according to the International Cartographic Association, a map is:
  - a representation, normally to scale and on a flat medium, of a selection of material or abstract features on, or in relation to, the surface of the Earth

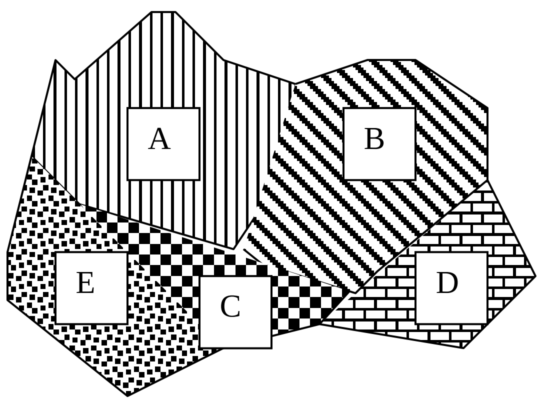
Spatial information (Developmental phases)

The collection of data about the spatial distribution of significant properties of the earth’s surface has long been an important part of the activities of organized societies) From the earliest civilizations to modern times. spatial data have been collected by navigators, geographers, and surveyors and rendered into pictorial Form by the Map makers or cartographers Originally maps were used to describe far off places, as an aid for navigation and for military strategists (Hodgkiss 1981). In Roman times, the agrimensores,or land surveyors, Were an important part of government, and the result of their work may still be seen in vestigial form in the landscape of Europe today(Dilke 1971). The decline of the Roman Empire led to the decline of surveying and map making Only in the eighteenth century did European civilization once again reach a state of organization such that many governments realized the value of systematic mapping of their lands.

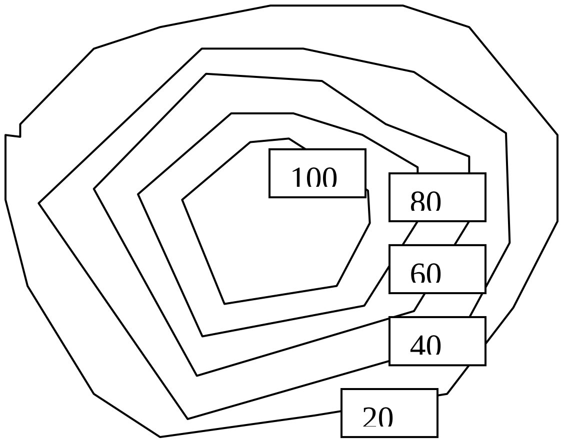
National government bodies were commissioned to produce topographical maps of whole countries. These highly disciplined institutes have continued to this day to render the spatial distribution of the features of the earth’s surface, or topography, into map form.

As the European powers increased their influence over the globe,. They spread their ideas and methods of map making to the countries that fell under their sway. A scientific study of the earth advanced, so new material needed to be mapped. The developments in the assessment and understanding of natural resources—geology, geomorphology, soil science, ecology, and land—that began in the nineteenth century and have continued to this day, provided new material to be mapped Where as topographical maps can be

The term thematic map' is very widely and loosely applied and is used not only for maps showing a general purpose theme such as 'soil' or 'landform' but for much more specific properties such as the distribution of the value of the soil pH over an experimental field, the variation of the incidence of a given disease in a city, or the variation of air pressure shown on a meteorological chart. The theme may be qualitative or quantitative.



The term choropleth map' is used in this Wok in a very general sense. Some cartographers prefer to use the term only for maps displaying census tracts or administrative areas. They prefer the term 'chorochromatic' for maps of soil or geology in which the boundaries, have been defined by field or aerial photo survey and the units are distinguished by different color,. In each case, the data structure is similar: boundaries define polygons enclosing areas that are assumed to be uniform, or to which a single description can be applied. Because all data structures are the same, the term 'choropleth' is used throughout, to include all these variants.



In the twentieth century, the demand for maps of the topographic and specific theme, of the earth's surface such as natural resource has accelerated greatly. Stereo aerial photography and remotely sensed imagery have allowed photogrammetrists to map large areas with great accuracy. The same technology has also given the earth resource scientists. The resulting thematic maps have been a source of useful information for resource exploitation and management

The need for spatial data and spatial analysis has not been restricted to earth scientist. Urban planner and cadastral agencies need detail information about the distribution of land and resource in towns and cities. Civil engineers need to plan the routes of roads and canals and to estimate construction costs. In police departments need to know the spatial distribution of various kinds of crime, medical organization the distribution of sickness and disease, commercial interests the distribution of sales outlet and potential market. The enormous infrastructure of what are collectively known as utilities – i.e. water, gas, electricity, telephone lines, sewerage systems – all need to be recorded and manipulated in map form . these information was encoded in form of points, lines and area..

Advantages of data collection

First, the original data had to be greatly reduced in volume, or classified, in order to make them understandable and represent able; consequently, many local details were often filtered away and lost.

Second, the map had to be drawn extremely accurately and the presentation, particularly of complex themes, had to be very clear.

Third, the sheer volume of information meant that areas that at large with respect to the map scale could only be represented by number of map sheets. It is a common experience that one's area of interest is frequently near the junction of two, it not more, map sheets!

Fourth, once data had been put into a map, it was not cheap or easy to retrieve them in order to combine them with other spatial data.

Fifth, the printed. map.is static qualitative document

More recently aerial photograph, but more especially tile satellite image, have made it possible to see how landscapes change over time, to follow the slow march of desertification or erosion or the swifter progress of forest fire, floods, locust swarms or weather systems.

Gradually it has come to be realized that the Often very striking images produced from remotely sensed data only have a real value if they can be linked to ground truth—a certain amount of field survey is essential for proper interpretation And to facilitate calibration, the images have to be located properly with respect to a proper geodic grid, otherwise the information cannot be related to a definate place. The need for a marriage between remote sensing, earthbound - survey, and cartography arose, which has been made possible by the class of mapping tools known as Geographical information Systems, or GIS.

3) Computer assisted cartography and map analysis

(Changeover to computer mapping)

Howard T.Fisher who in 1963 elaborated Edgar M. Harwood's Idea of using the computer to make simple maps by printing statistical values on a grid of plain paper.

Fisher's program SYMAP. short for SYnagraphic mapping system (the name has its origin in the Greek word synagein, meaning to bring to-gather). Includes a set of modules for analyzing data, manipulating them to produce çhoropteth or isoline interpolations, and allows the results to be displayed in many ways using the overprinting of line printer characters to produce suitable grey scales.

SYMAP was the first in a line of mapping programs that was produced by an enthusiastic, internationally known and able staff Among these programs were the well-known grid cell (or raster) mapping programs GRID and IMGRID that allowed the user to do in the computer.

Cartographers had begun to adopt computer technology in the 1960s, but these were until recently largely limited to aids for the automated drafting and preparation of masters for printed maps.

Why Computer assisted cartography

Rhind (1977) was able to present the following cogent list of reasons for using computers in cartography

1. Scientists wishing to make maps quickly to see the results of modeling, or to display data from large archives already in digital form, e.g. census tables

- quality was not a major concern
- SYMAP was the first significant package for this purpose, released by the Harvard Lab in 1967

2. Cartographers seeking to reduce the cost and time of map production and editing

3. To make existing maps more quickly.

4. To make existing maps more cheaply,

5. To make maps for specific user needs,

6. To make map production possible in situations where skilled staff a unavailable.

7. To allow experimentation with different graphical representations of the same data.

8. To facilitate map making and updating when the data are already in digital for.

9. To facilitate analyses of data that demand interaction between statistical analyses and mapping.

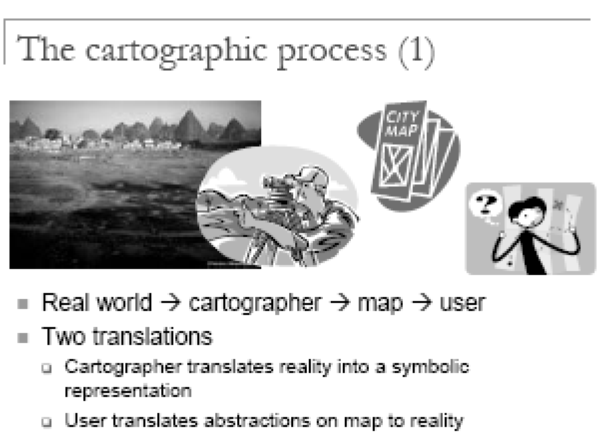
10. To minimize the use of the printed map as a data store and thereby to minimize the effects of classification and generalization on the quality of the data.

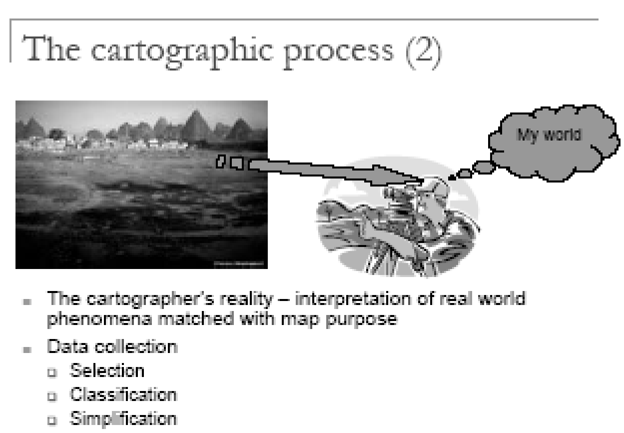
11. To create maps those are difficult to make by hand, e.g. 3-D maps or stereoscopic maps.

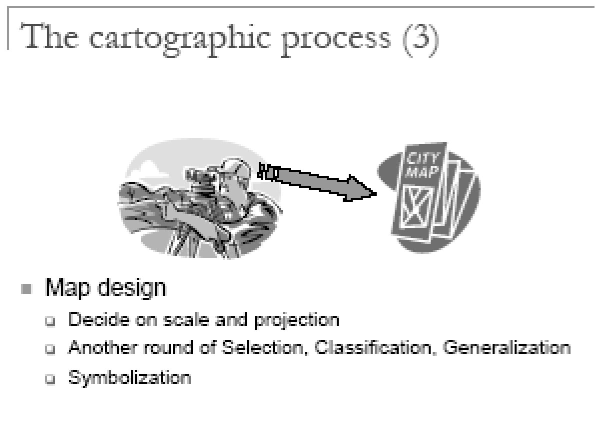
12. To create naps in which selection and generalization procedures are explicitly defined and consistently executed.

13. Introduction of automation an lead to a review of the whole map-making process, which can also lead to savings and improvements.

Process







Development

By the late 1970, there had been considerable investments in the development and application of computer-assisted cartography, particularly in North America by government and private agencies. Literally hundreds of computer programs and systems were developed for various mapping applications. There are estimated to be approximately 1000 geographical information system now installed In North America with a prognosis of 4000 systems by 1990.

In Europe the development proceed on a smaller scale than in North America but major strides in using and developing computer-assisted cartography have been made by several nations, notably Sweden, Norway, Denmark, France, The Netherlands, The United Kingdom and West Germany

- Now today, far more maps are made by computer than by hand
    - now few mapmakers are trained cartographers
- It is now clear that once created, digital data can serve purposes other than map-making, so it has additional value

Advantages of computer cartography

- lower cost for simple maps, faster production
- greater flexibility in output - easy scale or projection change - maps can be tailored to user needs
- other uses for digital data

Disadvantages of computer cartography

- relatively few full-scale systems have been shown to be truly cost-effective in practice, despite early promise

- high capital cost, though this is now much reduced
- computer methods do not ensure production of maps of high quality
  - there is a perceived loss of regard for the "cartographic tradition" with the consequent production of "carto junk"

4) Map analysis

Map analysis tools might at first seem uncomfortable, but they are simply extensions of traditional analysis procedures brought on by the digital nature of modern maps. Since maps are “number first, pictures later,” a *map-ematical* framework can be can be used to organize the analytical operations. Like basic math, this approach uses sequential processing of mathematical operations to perform a wide variety of complex map analyses. By controlling the order which the operations are executed, and using a common database to store the intermediate results, a mathematical-like processing structure is developed.

In grid-based *map analysis*, the spatial coincidence and juxtaposition of values among and within maps create new analytical operations, such as coincidence, proximity, visual exposure and optimal routes. These operators are accessed through general purpose map analysis software available in many GIS systems, such as MapCalc, GRASS, ERDAS or the Spatial Analyst extension to ArcGIS. While the specific command syntax and mechanics differs among software brands, the basic analytical capabilities and spatial reasoning skills used in map analysis form a common foundation.

Kind of maps

- in practice we normally think of two types of map:
- topographic map - a reference tool, showing the outlines of selected natural and man-made features of the Earth
  - often acts as a frame for other information
  - "Topography" refers to the shape of the surface, represented by contours and/or shading, but topographic maps also show roads and other prominent features

thematic map - a tool to communicate geographical concepts such as the distribution of population densities, climate, movement of goods, land use etc.

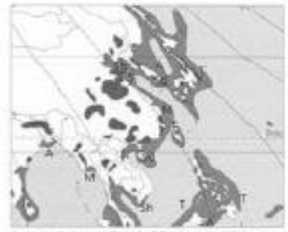
Examples

A gallery of map types - Point symbol map

Point symbol map: Detail of Precious Metals (p. 55)

Source: Goode's World Atlas

Area symbol maps



Area symbol map: Detail of Tobacco and Fisheries (p. 44)

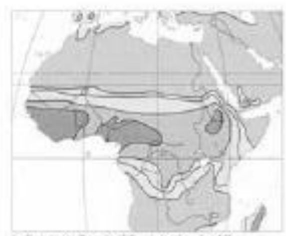
Source: Goode's World Atlas

Dot maps

Dot map: Detail of Sugar (p. 43)

Source: Goode's World Atlas

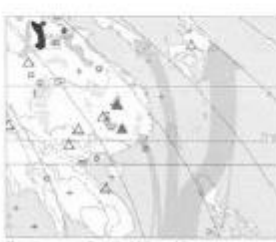
Isoline maps



Isoline map: Detail of Precipitation (p. 19)

Source: Goode's World Atlas

Flow line maps



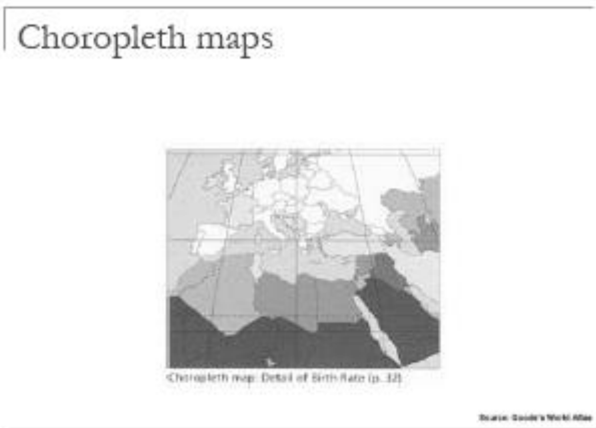
Flow line map: Detail of Mineral Fuels (pp. 58-59)

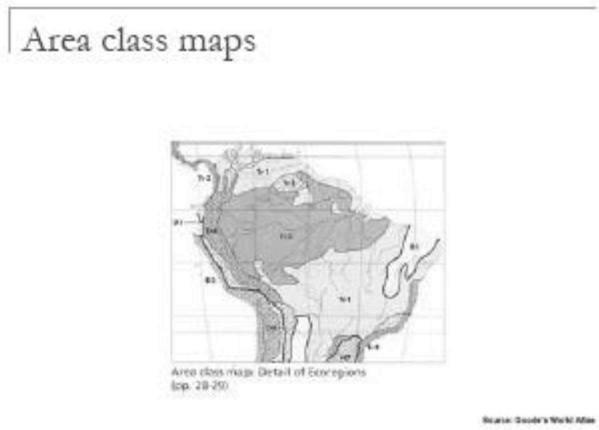
Source: Goode's World Atlas

Proportional symbol maps

Proportional symbol map: Detail of Exports (p. 68)

Source: Goode's World Atlas



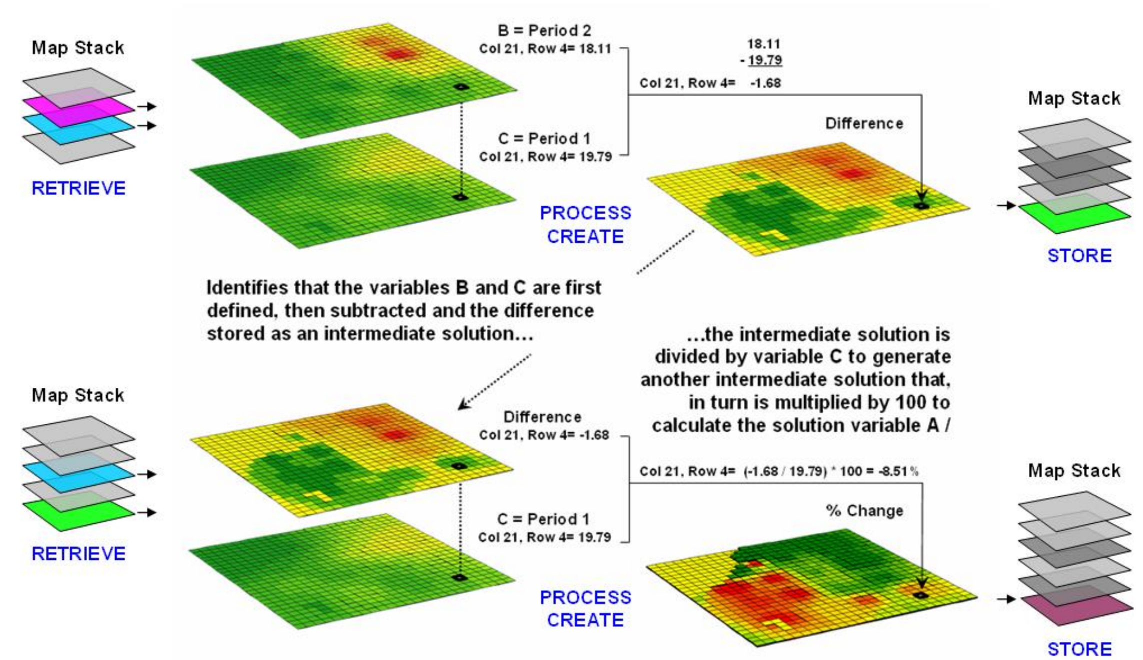


Fundamental condition for map analysis

There are two fundamental conditions required by any map analysis package—a *consistent data structure* and an *iterative processing environment*. The characteristics of a grid-based data structure by introducing the concepts of an analysis frame, map stack and data types. The traditional discrete set of map features (points, lines and polygons) are extended to map surfaces that characterize geographic space as a continuum of uniformly-spaced grid cells. This structure forms a framework for the map-ematics underlying map analysis and modeling.

The second condition of map analysis provides an iterative processing environment by logically sequencing map analysis operations and serves as the focus of this paper. This involves:

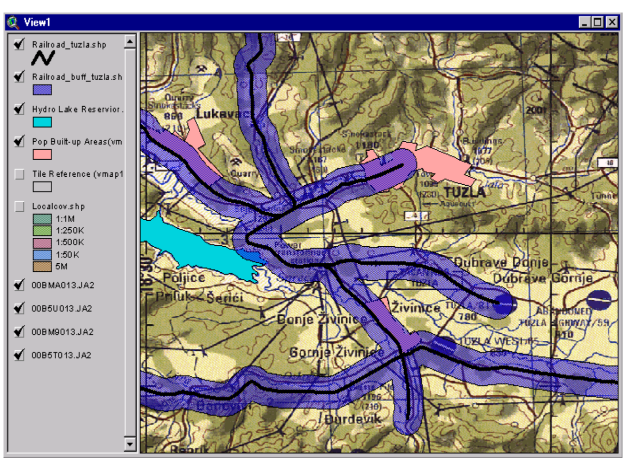
- **retrieval** of one or more map layers from the database,
- **processing** that data as specified by the user,
- **creation** of a new map containing the processing results, and
- **storage** of the new map for subsequent processing.



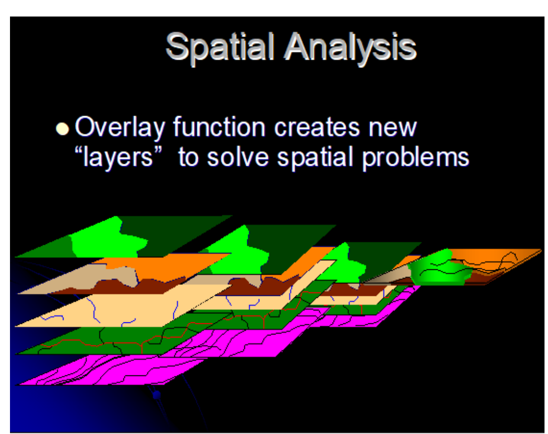
The processing steps shown in the figure are identical to the traditional solution except the calculations are performed for each grid cell in the study area and the result is a map that identifies the percent change at each map location. Map analysis identifies what kind of change (termed the thematic attribute) occurred where (termed the spatial attribute). The characterization of *what* and *where* provides information needed for further GIS modeling, such as determining if areas of large increases in animal activity are correlated with particular cover types or near areas of low human activity.

Fundamental map analysis operations

Within this iterative processing structure, four fundamental classes of map analysis operations can be identified. These include:

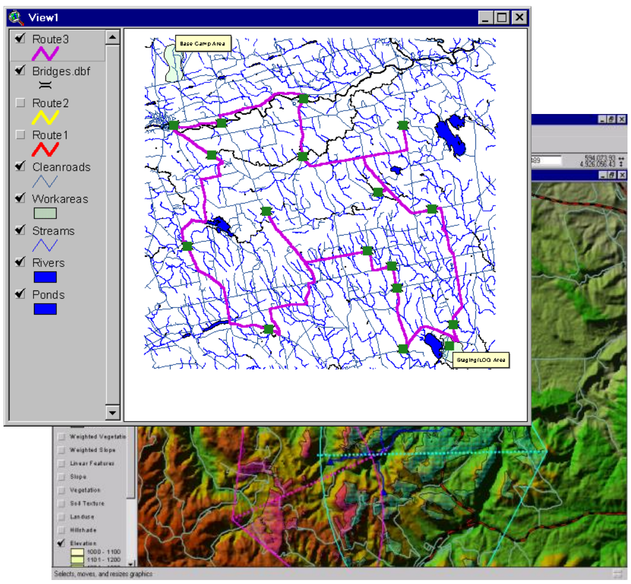


— **reclassifying Maps** that involve the reassignment of the values of an existing map as a function of its initial value, position, size, shape or contiguity of the spatial configuration associated with each map category.



— **Overlaying Maps** that result in the creation of a new map where the value assigned to each location is computed as a function of the independent values associated with that location on two or more maps.

— **Measuring Distance and Connectivity** that involve the creation of a new map expressing the distance and route between locations as straight-line length (simple proximity) or as a function of absolute or relative barriers (effective proximity).



— **Characterizing and Summarizing Neighborhoods** that result in the creation of a new map based on the consideration of values within the general vicinity of target locations.

In addition to flexibility, there are several other advantages in developing a generalized analytical structure for map analysis. The systematic rigor of a mathematical approach forces both theorist and user to carefully consider the nature of the data being processed. Also it provides a comprehensive format for learning that is independent of specific disciplines or applications. Furthermore the flowchart of processing succinctly describes the components and weightings capsulated in an analysis.

5) Components of GIS

Conventionally, the construction and functions of GIS were explained by dividing them into subsystems of input, processing, analysis and output. we adopt the prevailing concept that an information system is made up of four components. Namely, data technology, application, and people. We will explain how a typical GIS works from this more embracing vie of information systems.

The Data Component of GIS

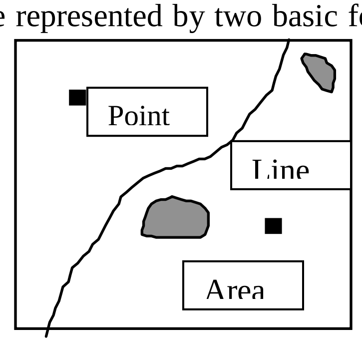
Geographic data record the locations and characteristics of natural features or human activities that occur on near Earth's surface. Depending on their nature and use, geographic data can be categorized into three distinct types, namely,

1) ***The geodetic control network****:* - The geodetic control network is the foundation all geographic data. It provides a geographical frame work by which different sets of geographic data can spatially cross-referenced with one another. Geodetic control networks are established by high-precision surveying methods and vigorous computation at the national 'or, as in the case of North America, continental level.

2) ***The topographic base****:* - The topographic base is normally created as the results of a basic mapping program by national, state/provincial, and local government mapping agencies. The contents of the topographic data base can be obtained by various methods of Ian surveying, but generally speaking photogrammetry appears to be the method of choice.

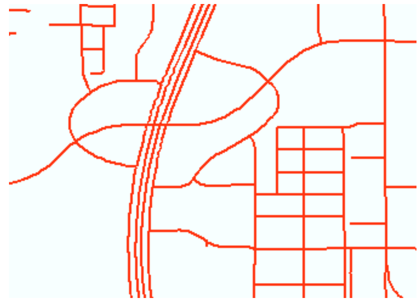
3) ***The graphical overlays:*** - Graphical overlays are thematic data pertaining to specific GIS applications. These overlays of physical features can be d rived directly from the topographic base, such as ft road and drainage networks, vegetation cover, and buildings. Graphical overlays pertaining to socioeconomic activities, such as population, parcel boundaries, natural resource values, and land-use status, Can be obtained only by site investigation, field survey's, remote sensing and other forms of data collection methods.

Within a digital geographic database, all data are represented by two basic forms that include



Vector: - Vector data depict the real world by means of discrete points, lines, and polygons. These data are best suited for representing natural and artificial features that can be individually identified.

Network (Extension of vector data):- A network is a set of interconnected linear feature through which materials, goods and people are transported or along which communication of information is achieved like roads, railway, air routes, pipeline etc



***Raster*: -** Raster data depict the real world by means of grid of cell spectral or attribute values. This data are not good for representing individually identifiable features but are ideal for a variety of spatial analysis functions.

	0	1	2	3	4	5	6	7	8	9
0								R	T	
1							R			T
2		H					R			
3							R			
4					R	R				
5				R						
6			R		T	T		H		
7			R		T	T				
8		R								
9		R								

Surface(Extension of raster data) (Figure 1.5).:- Surface data depict the real world by means of a set of selected points or continuous lines of equal values. These data can be analyzed and displayed two or three dimensions. They are most suited for natural phenomena with changing values across an extensivearea.

Conventionally, geographic data have been organized as separate layers in the geographic database according the proprietary data structures of individual software vendors

The Technology Component of GIS

The technology component of GIS can be explained in terms of hardware and software

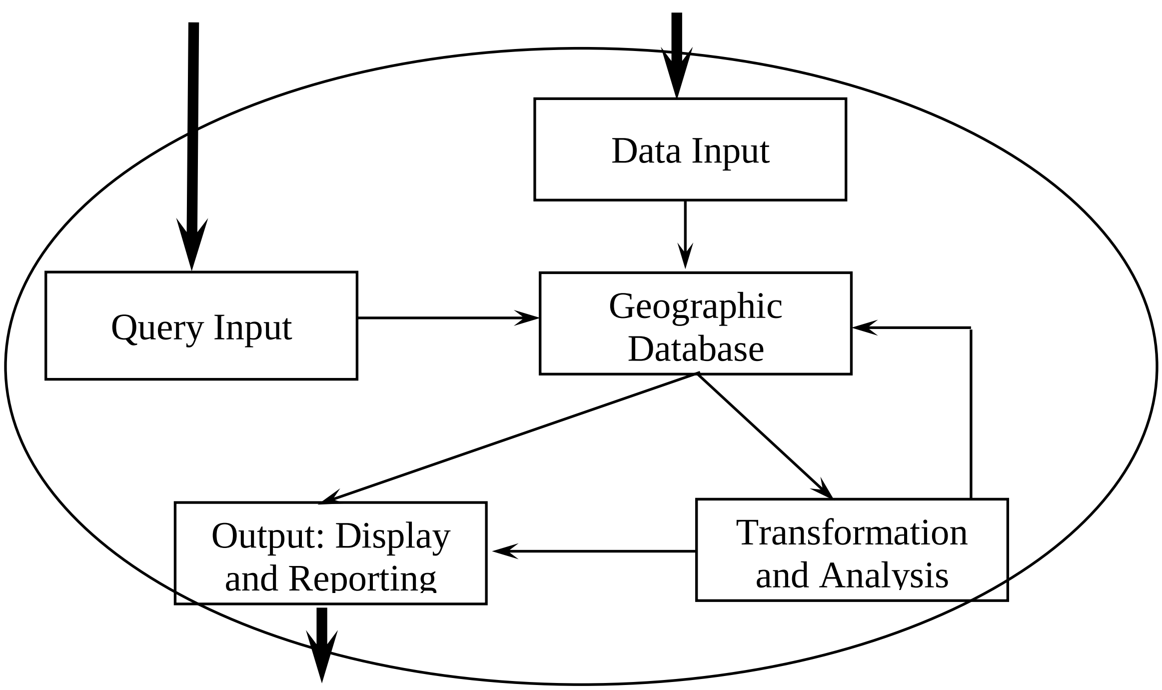
Hardware

It consists of the computer system on which the GIS software will run. The choice of hardware system range from 300MHz Personal Computers to Super Computers having capability in Tera FLOPS. The computer forms the backbone of the GIS hardware, which gets it's input through the Scanner or a digitizer board. Scanner converts a picture into a digital image for further processing. The output of scanner can be stored in many formats e.g. TIFF, BMP, JPG etc. A digitizer board is flat board used for vectorization of a given map objects. Printers and plotters are the most common output devices for a GIS hardware setup.

Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. GIS software's in use are MapInfo, ARC/Info, AutoCAD Map, etc. The software available can be said to be application specific. When the low cost GIS work is to be carried out desktop MapInfo is the suitable option. It is easy to use and supports many GIS feature. If the user intends to carry out extensive analysis on GIS, ARC/Info is the preferred option. For the people using AutoCAD and willing to step into GIS, AutoCAD Map is a good option.

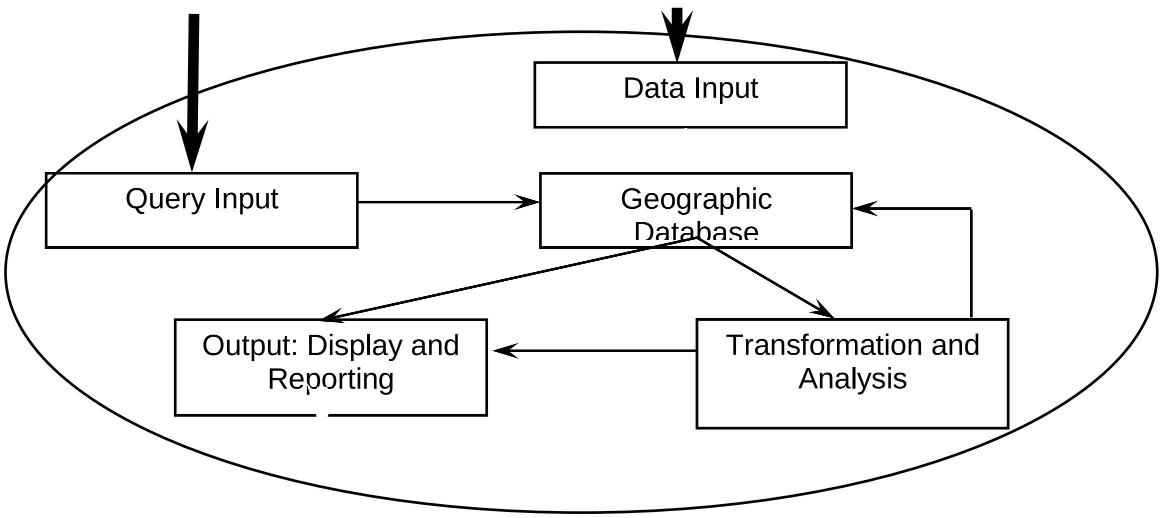
GIS software Components



GIS software modules

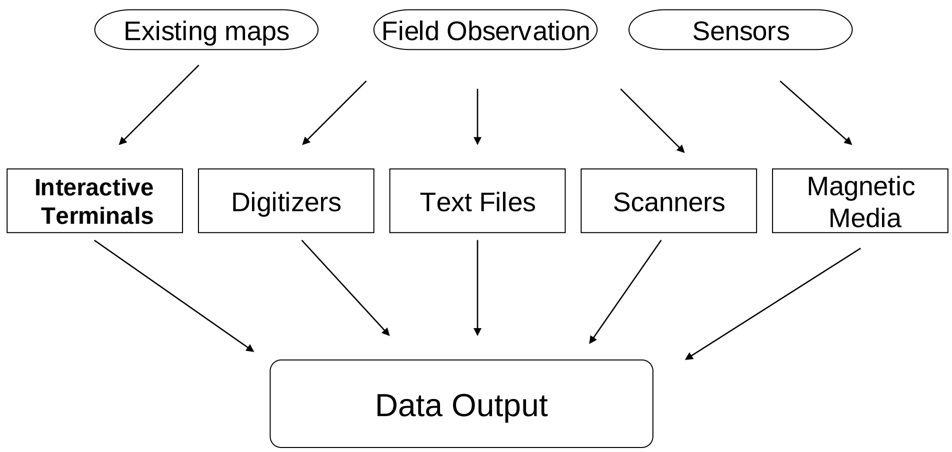
The Software package for a geographical information system consists of five basic technical Modules. The basic modules are sub-systems for:

(a) Data input and verification;
(b) Data storage and database management;
(c) Data output and presentation;
(d) Data transformation;
(c) Interaction With the user)



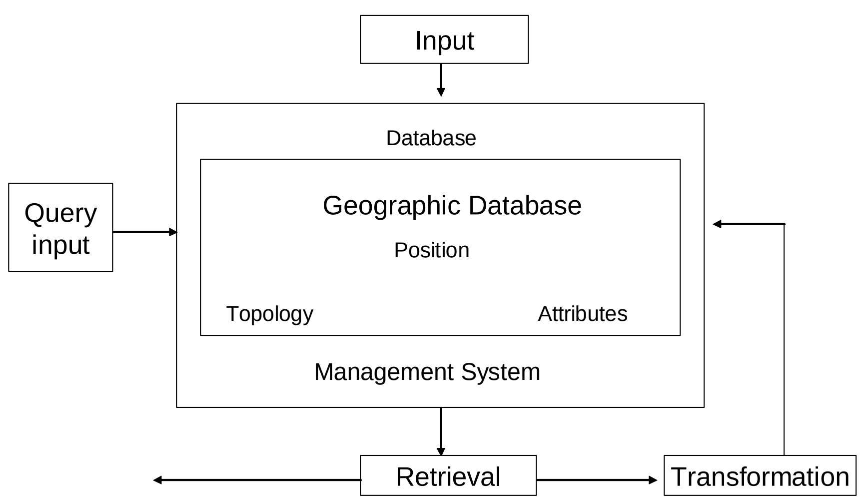
Data input covers all aspects of transforming data captured in the form of existing maps, field observations and sensors (including aerial photography satellites, and recording instruments) into a compatible digital form. A wide range of computer tools is available for this purpose, including the interactive terminal or visual display device (VDU), the digitizer, lists of data in text files, Scanner (in satellites or aero planes for direct recording of data or for converting maps and photographic images),and the devices necessary for recording data already written on magnetic media such as tapes, drums, and disks. Data input, and the verification of data needed to build a geographical database.

Data input



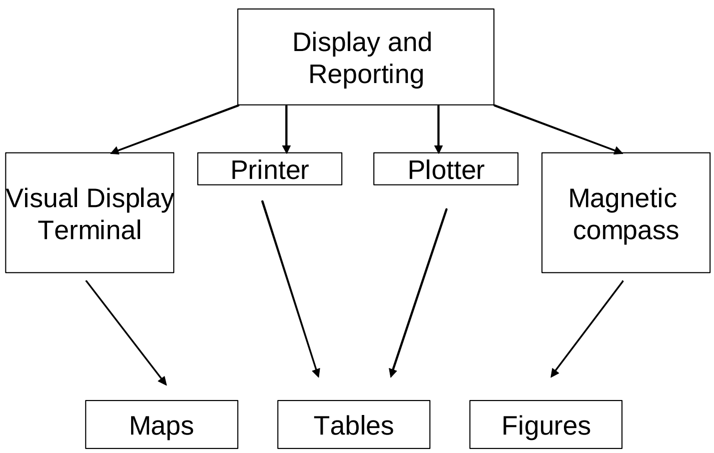
Data storage and database management concerns the way in which the data about the position. Linkages (topology), and attributes of geographical elements (points, lines, and areas representing object on the earth's surface) are structured and organized both with respect to the way they must be handled in the computer and how they are perceived by the users of the system. The computer program used to organize the database is known as a Database Management System (DBMS).

Geographic Data Base



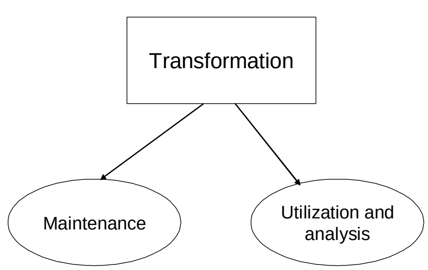
Data output and presentation concerns the ways the data are displayed and -the results of analyses are reported to the users. Data may be presented as maps, ties, and figures (graphs and charts) in a variety of ways. Ranging from the ephemeral image on a cathode ray tube (CRT) through hard-copy output drawn on printer or plotter to information recorded on magnetic media in digital form.

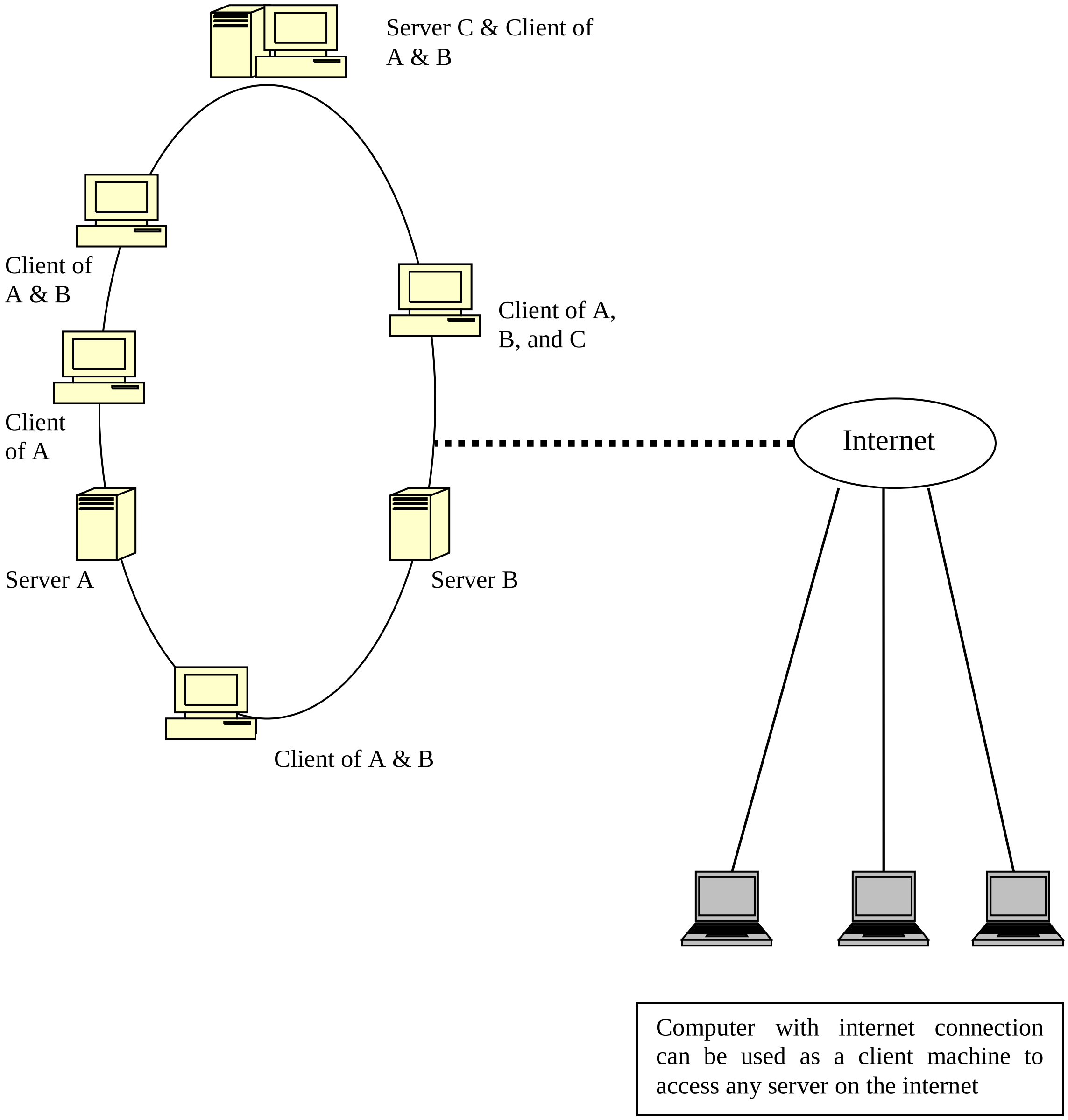
Display and Reporting



Data transformation embraces two classes of operation namely
(a) transformation needed to remove errors from the data or to bring them up to date or to match them to other data sets and
(b) The large array of analysis methods that can be applied to the data in order to achieve answers to the questions asked of the GIS. Transformations can operate on the spatial and the non-spatial aspects of the data, either separately or in combination.

Transformation





The client/server computing architecture. In the client/server computing architecture, a server can have many clients and a client can access multiple servers simultaneously. A computer can be used as a dedicated server or client, and it can also be used as a server and a client at the same time.

Client/server computing is based on the concept of division of work among different machines in a local or distributed computer network, A server is the computer on which data and software are stored. A client, on the other hand, is the computer by which the users access the server. The application programs can be executed on either the sewer or the client computer. In the client/server environment, a client can access multiple servers, and similarly, a server can provide services to a number of clients at the same time. For GXS that are implemented on the client/server architecture, processor-intensive operations and data management are most commonly performed in the workstation class of servers, and PCs are used as the clients that provide the graphical interface to the system. Such a configuration, which combines the processing power of workstations and the economy of using PCs, has replaced the mainframes and minicomputers as the dominant hardware platforms for GIS.

The Application Component of GIS

The application components of GIS can be explained from three perspectives: areas of applications, nature of applications, and approaches of implementation. Table summarizes the major areas of GIS application today. It is interesting to note how quickly these applications have grown in a relatively short history of development.

Sectors	***Application Areas***
Academic	• Research in humanities, science and engineering • Primary and secondary schools—school district delineation, facilities management, bus routing • Spatial digital libraries
Business	• Banking and insurance • Real estate—development project planning and management, sales and renting services, building management • Retail and market analysis • Delivery of goods and services
Government	• Federal government—national topographic mapping, resource and environmental management, weather services, public land management, population census, election, and voting

	• State/provincial government—surveying and mapping, land and resource management, highway planning and management • Local municipal government—social and community development, land registration and property assessment, water and wastewater services • Public safety and law enforcement—crime analysis, deployment of human resources, community policing, emergency planning and management • Health care • International development and humanitarian relief
Industry	• Engineering—surveying and mapping, site and landscape development, pavement management • Transportation—route selection for goods delivery, public transit, vehicle tracking • Utilities and communications—electricity and gas distribution, pipelines, telecommunications networks • Forestry—forest resource inventory, harvest planning, wildlife management and conservation • Mining and mineral exploration • Systems consulting and integration
Military	• Training • Command and control • Intelligence gathering

As the areas of GIS application have become *more* diversified, the nature of CIS applications has also undergone significant changes over the years.

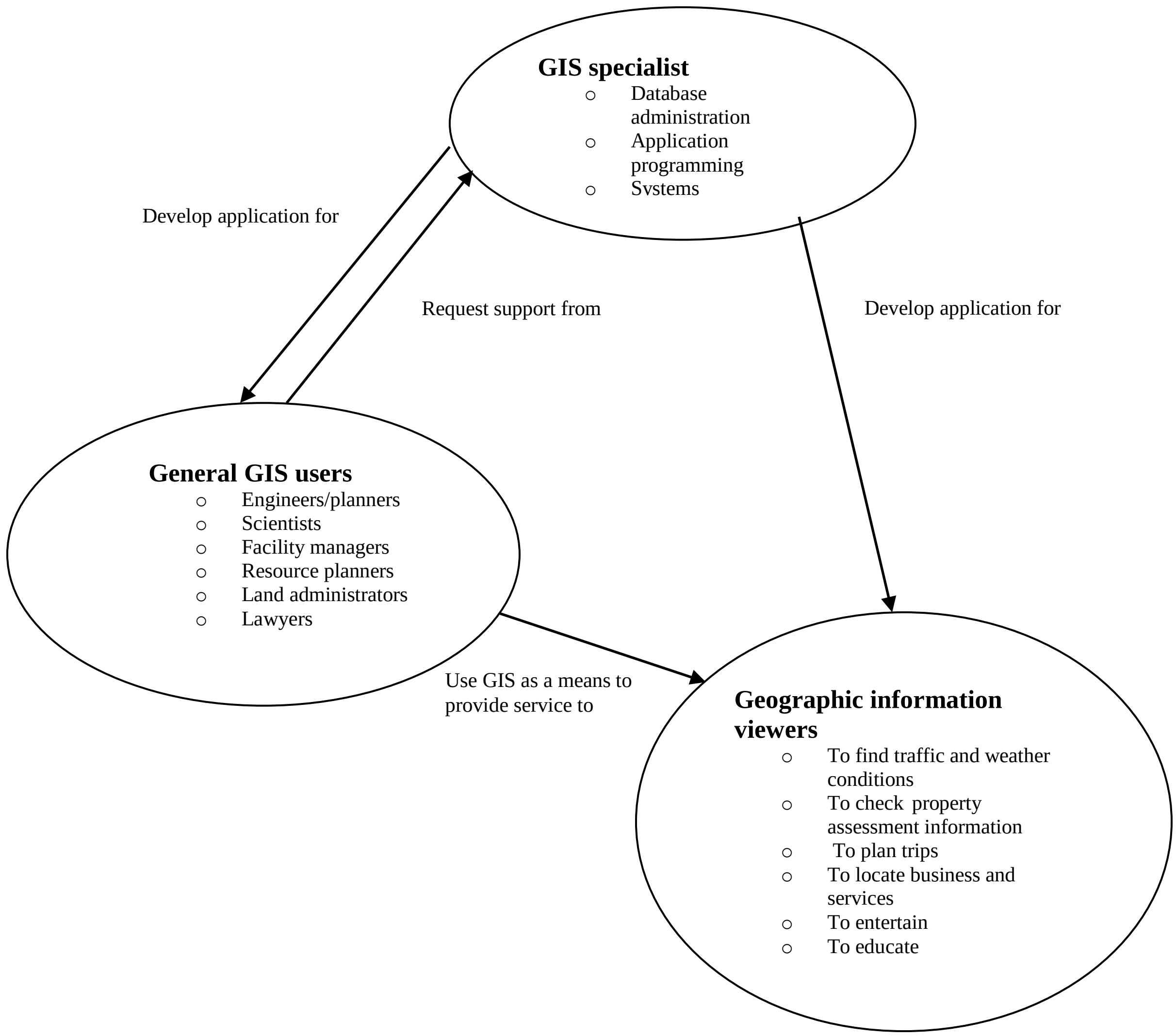
The advent of the internet has fundamentally revolutionized the nature of GIS applications. The Internet began as a computer network for military communications and for the exchange of scientific information in 1969. It has now become an international& computer network of networks logically consisting of millions of academic, military, government, and commercial computers in a cooperative collaboration. By using different protocols of the Internet such as the World Wide Web (WWW) and File Transfer Protocol (Fl?), GIS have now become a virtual global system that offers all kinds of geographic information services via a worldwide system of computer networks (see Chapter 12 and Appendix A). At present 015 serves not only as the means for geographic data management and spatial decision support, it also provides the mechanism for geographic information resource sharing and the communication of spatial information and knowledge as well (Harder, 1998).

The People Component of GIS

GIS users range from technical specialists who design and maintain the system to those who use it to help them perform their everyday work. The people who use GIS can be broadly classified into two classes. The CAD/GIS operator, whose work is to vectorise the map objects? The use of this vectorised data to perform query, analysis or any other work is the responsibility of a GIS engineer/user.

In the past, Users were seldom formally recognized as a component of GIS because the profile of the user community in the early days of GIS was extremely simple. Many users developed applications for their own use, probably with the assistance of one or more specialist computer programmers. Others used turnkey systems that were commercially obtainable from software vendors. The use of a particular GIS application was usually limited to a small number of people. There was no direct Interaction between the users and the computer because data processing was done in the batch mode. The human factor in GIS was therefore largely taken for granted by all the parties concerned.

According to their information needs and the way they interact with the system, GIS users in general can be classified into three categories:



GIS users and their relationships.

- ***Viewers: -*** Viewers are the public at large whose only need is to browse a geographic database occasionally for referential information. The primary requirements for viewers are accessibility to information and ease of use of the system. Viewers in general are passive users who play no active role in the design and operation of GIS. However, since viewers probably constitute the largest class of users, their acceptance or rejection of the technology will have very significant impacts on the development of GIS as a whole.
- ***General user: -*** General users are people who use GIS for conducting business, performing professional services, and making decisions. This group of users includes facility managers, resource planners, scientists, engineers, land administrators, layers, business entrepreneurs, and politicians. The diversity of the

membership of general user’s means that their requirements may vary considerably among one another ranging from relatively simple spatial queries to very complicated temporal—spatial modeling. The variation in the technical background of these users also implies that their modes of computer—human interaction is different among individual users. Unlike viewers, general users are active users because GIS is implemented to support their information needs. As a result, this group of users usually has direct and considerable influence on the successful use of GIS in an organization.

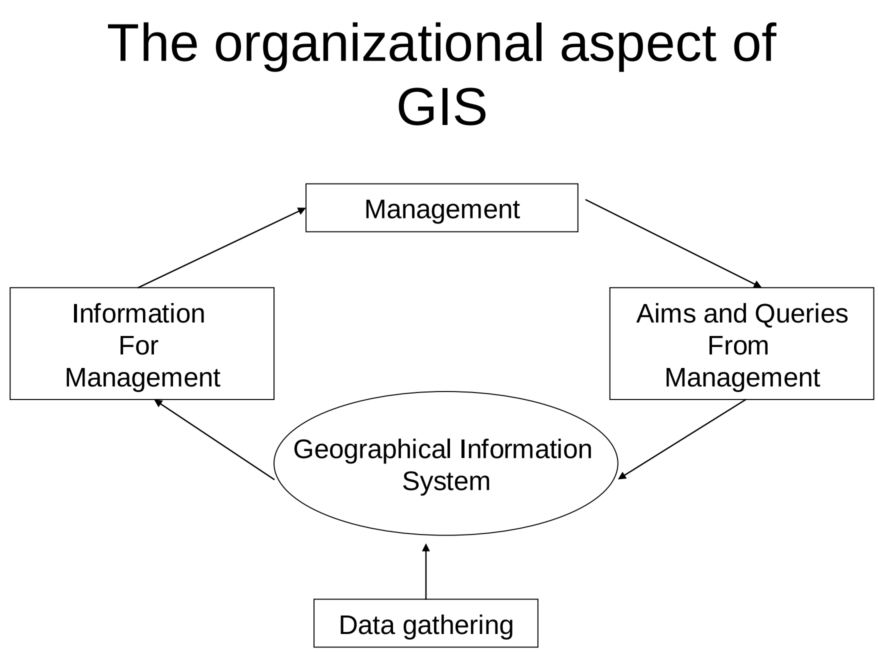
- ***GIS specialists****:*-GIS specialists are people who actually make GIS work. They include 015 managers, database administrators, application specialists, systems analysis, and programmers. They are responsible for the maintenance of the geographic database and the provision of technical support to the other two classes of users. They also build applications for advanced spatial data analysis and modeling, and they produce information products according to the specifications of other users. Although GIS specialists are usually small in number, they play the most direct role in the success of GIS implementation in an organization.

6) People and GIS

Most definitions of US focus on the hardware, software, data and analysis components. However, no GIS exist in isolation from the organizational context, and there must always be people to plan, implement and operate the system as well as make decisions based on the output. GIS projects range from small research applications where one user is responsible for design and implementation and output, to international corporate distributed systems, where teams of staff interact with the GIS in many different ways. In most organizations the introduction of GIS is an important event, a major change bringing with it the need for internal restructuring, retraining of staff and improved information flows. Research has been undertaken to highlight the factors that promote successful GIS and it has been suggested that in certain business sectors, innovative flexible organizations with adequate resources and straightforward applications are more likely to succeed. However, not all GIS are successful. There is evidence that many systems fail, and more are under-used. So the issues surrounding how to choose a system and how to implement it successfully require examination.

The organizational aspects of GIS

The five technical sub-systems of GIS govern the way in which geographical information can be processed but they do not of themselves guarantee that any particular GIS will be used respectively. In order to be used effectively, the GIS need to be placed in an appropriate organizational context. It is simply not sufficient for an organization to purchase a-computer and some software and to hire or retrain one or two enthusiastic individuals and then to expect instant success. Just as in all organizations dealing with complex products, as in manufacturing industry new tools can only be used effectively if they are properly integrated into the whole work process and not tracked on as an afterthought to do this properly requires not only the necessary investments in hardware and software, but also in the retraining of personnel and managers to use the new technology in the proper organizational context. In the 1970s the high price of many commercial systems' sold for geographical information processing made managers cautious of making expensive investments in then the new and untried technology. In recent years the falling hardware prices have encouraged automation, but skilled personnel and good, reasonably priced software have remained Scarce. There are still many choices open to an organization wishing to invest in geographical information systems.



How People/Organization Using GIS

Operational applications

Operational GIS applications are concerned with managing facilities and assets: For example:

• A utility company may use GIS to identify assets such as pylons and masts in need of routine maintenance;
• A waste management company may use GIS to route waste collection vehicles; or
• A property management company may maintain hotel buildings and grounds with the help of maps and plans from its GIS.

Management / tactical applications

Management (or tactical) GIS applications are concerned with distributing resources to gain competitive advantage. For example:
• A ski holiday company may use GIS to identify appropriate potential & customers to receive direct mailings;
• An education department might use GIS to produce options for school closures when deciding how to distribute limited resources; or
• A telecommunications company might use GIS to identify and evaluate possible communications mast sites to serve the maximum possible population.

Strategic applications

Strategic GIS applications are concerned with the creation and implementation of an organizations strategic business plan. For example:
• A ski equipment retailer may decide which geographical areas to target over the next five years after geodemographic analysis using GIS;
• A local government organization may decide on budget reallocations after analysis of population growth or decline in certain areas using modeling and GIS; or
• A catering business may decide to expand a restaurant chain to 100 outlets after analysis of the location of its competitors with GIS.

Maps and there influence on character of spatial data

The traditional method for storing analyzing and presenting spatial data is the map. In GIS map is the one of the fundamental "source of data" In maps only two things is Important. One understands maps and another one is how they produced is an essential starting point for exploring the characteristics of spatial data. Maps take different forms and come at different range of scale, for example thematic map and topographic maps.

Thematic maps:
Thematic maps shows data relating to a particular theme or topic. Soil, geology, geomorphology, population and transport.

Topographic maps:
Topographic maps contain a diverse set of data on different themes. Land use, relief and cultural features.

Many different types of maps are create mapping processes is of a general nature. During this process we follow some processes.

- Purpose
- Scale
- Feature
- Representation
- Generalization
- Map projection
- Spatial referencing system
- Annotate

Purpose:-

- All maps and other sources of spatial data are generated with a purpose in mind
- Purpose slightly linked with idea of scale

- Spatial data set will create influence the quality and spatial detail provided by the data set
- Behind that we use data for appropriate situation

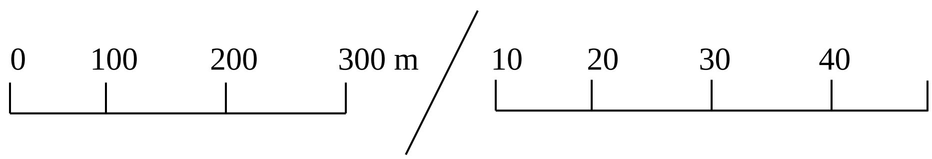
Scale:-

Scale can be defined as the ratio of a distance on the map to the corresponding distance on the ground.
Scale can be expressed in one of three ways as a ratio scales a verbal scale or a graphical scale.

Ratio – **1:5000 / 1:1,000,000**

Verbal **1 cm represents 50 m / 1 cm represent 10km**

Graphical



Spatial Entities:-

Traditionally, maps have used symbols to represent real world features map having three basic symbols types: points, lines and areas. Each is a simple tow – dimensional model that can be used to represent a feature in the real world. These simple models have been developed by cartography to allow then portray three - dimensional feature in two dimensional on a piece of paper. The method chosen to represent spatial features will depend on the scale used.

Generalization:-

All spatial data are a generalization or simplification of real world features. In other uses generalization is introduced by the limitation of the technical procedures used to produce data. The grin size of photographic film or the resolution of a remote sensing device will determine the level of detail discernible in the resulting air photo or satellite image. The entire data source used in GIS – aerial photographs satellite images, census data, particularly maps – contains Generalization. The simplification of detail is necessary in order to maintain clarity. The relationship between scale and detail referred to as ***scale related Generalization***.

Projection:-

Projection is necessary one because spatial entities locate in two dimensions. The method by which the "world is laid flat" is use to help projection. Doing the process introduce error into spatial data. Spatial data character varies depending on the projection method chosen. Shape and distance are distorted the accuracy world is spherical shape visualize the two dimension in flat surface is difficult.

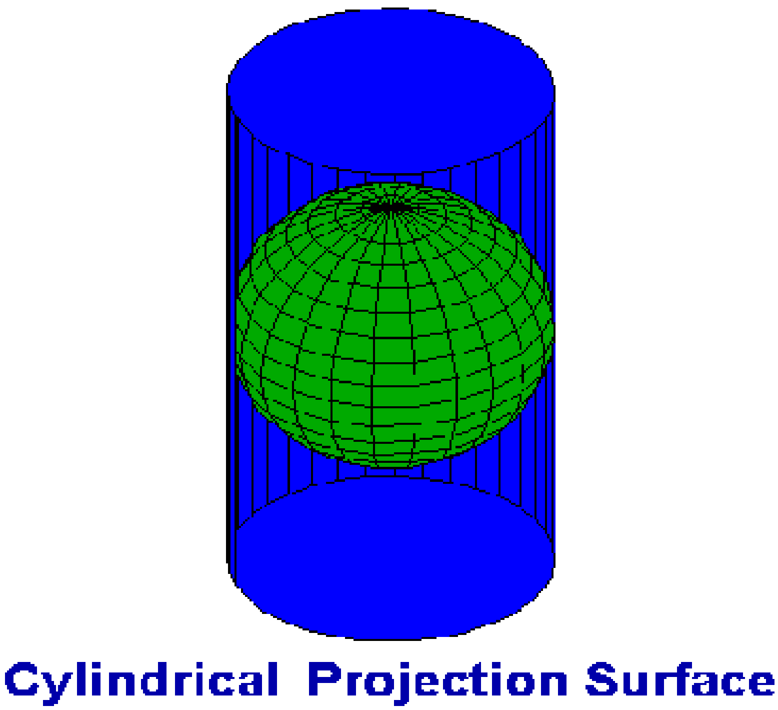
We Use Different Types of Projection

Example:

1. Cylindrical projection
2. Azimuthal projection
3. Conical projection

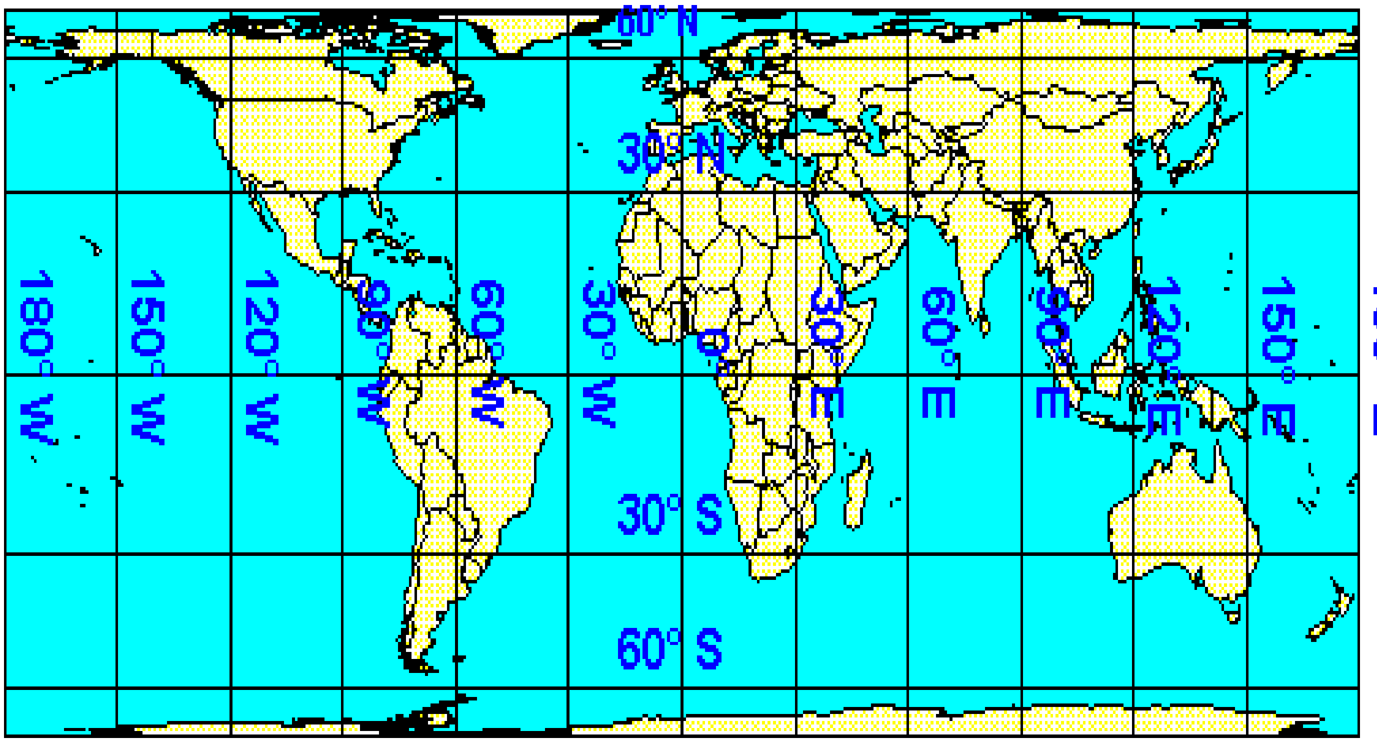
Cylindrical projection:

- Countries near the equator in true relative portion.
- Distance increases between countries located towards top and bottom of mage.
- The view of the poles is much distorted.
- Area for the most part is preserved.



Cylindrical projection (light in a circular room analogy)

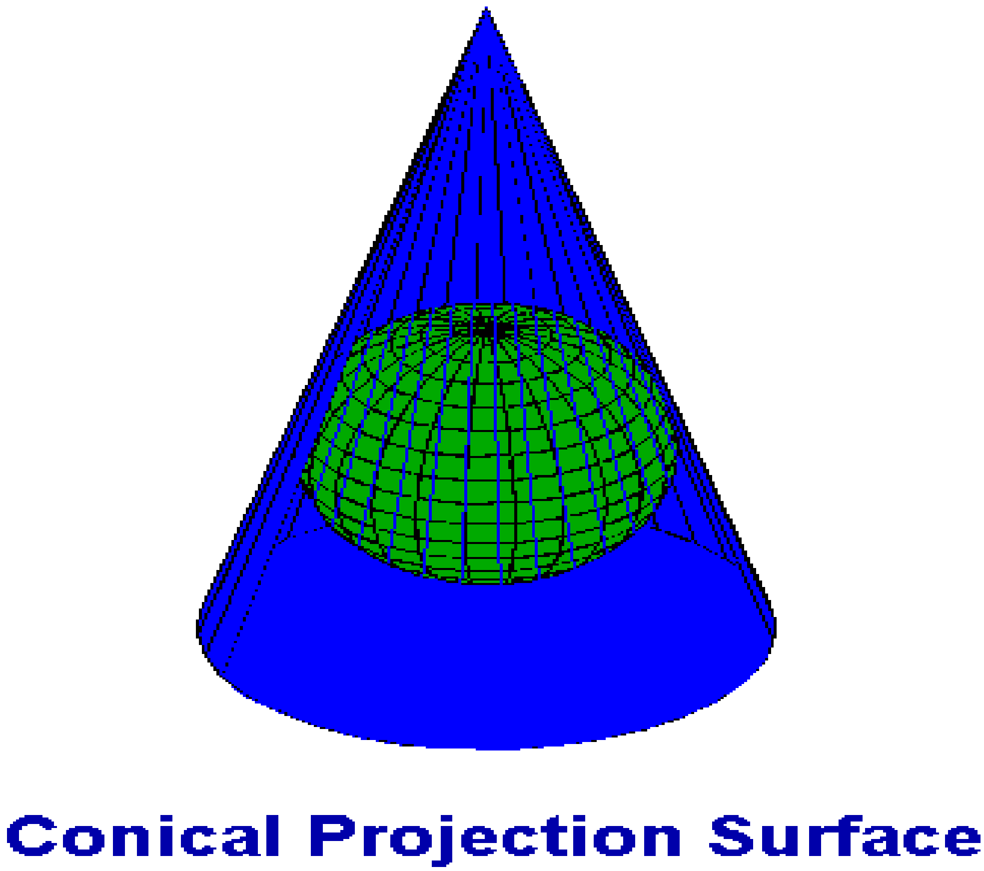
Cylindrical projection



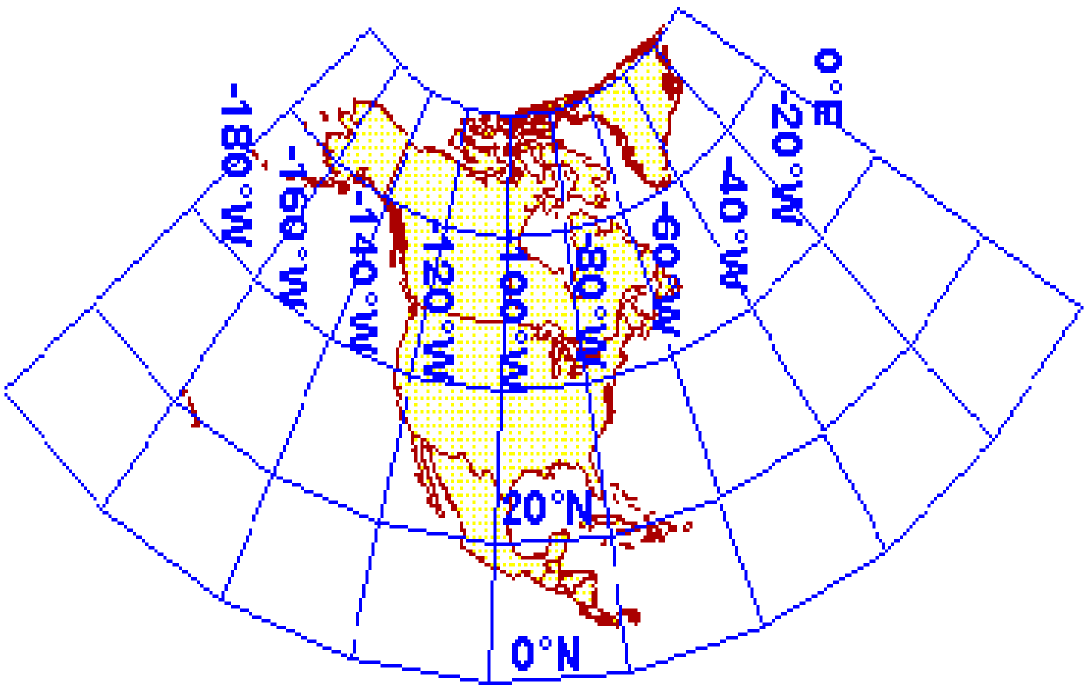
Cylindrical Equal-Area

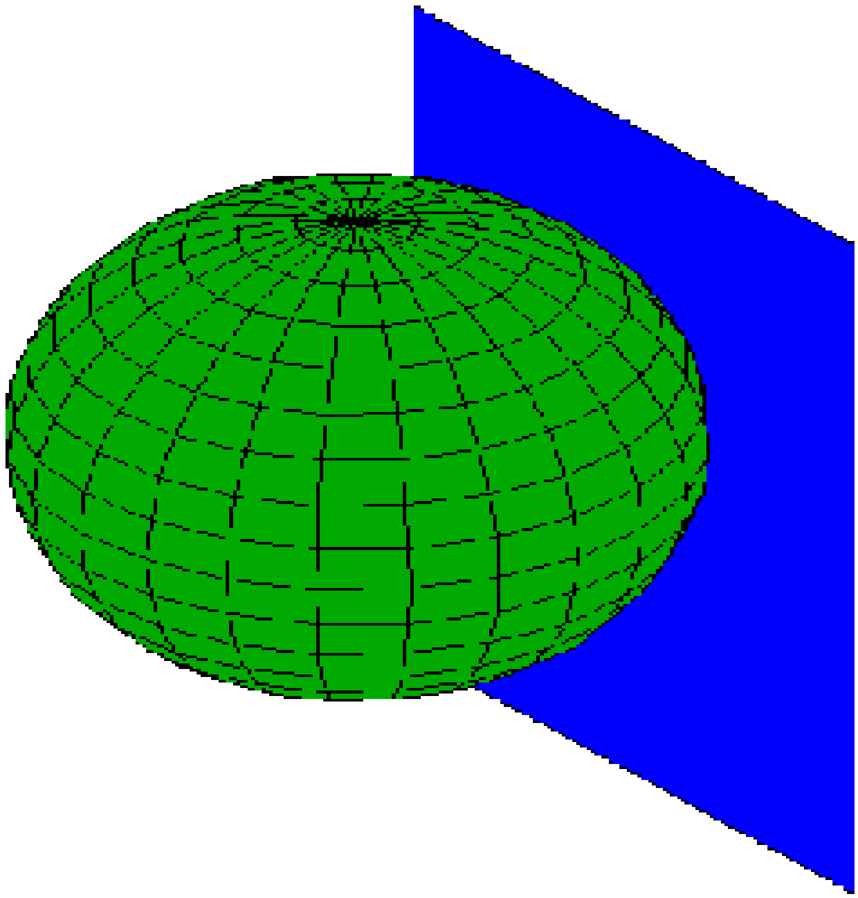
Conical projection:

- Area is distorted.
- Distance is much distorted towards the bottom of the image.
- Scale for the most part is preserved



Conical projection

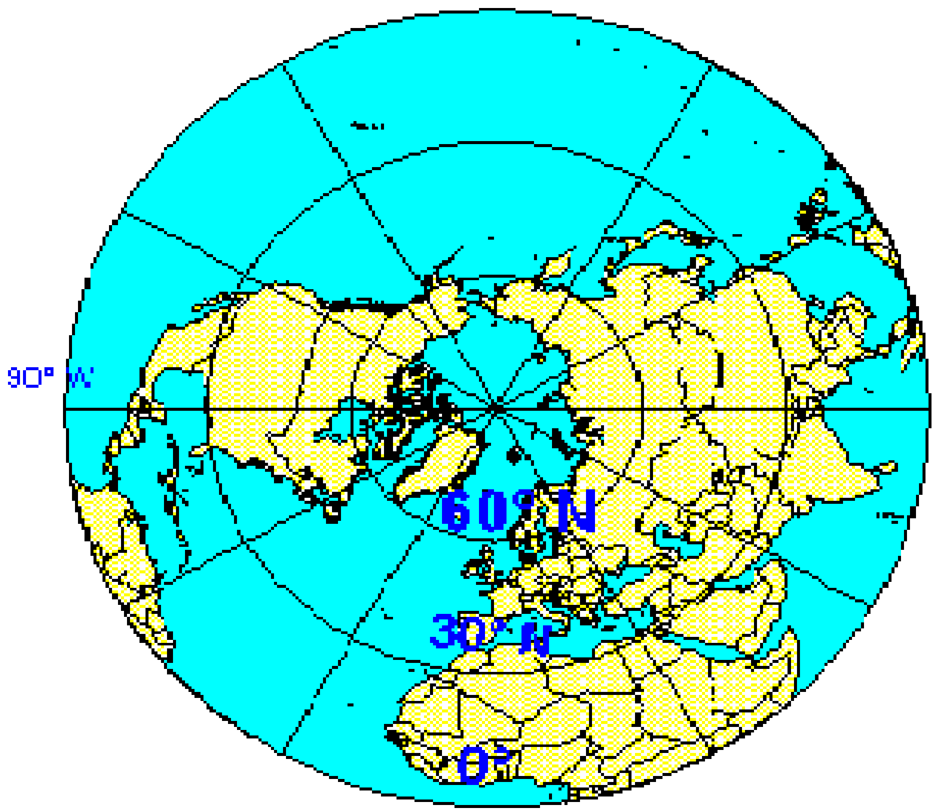

-180°W
-160°W
-140°W
-120°W
-100°W
-80°W
-60°W
-40°W
-20°W
0°E
20°N
0°N



Azimuthal projection:

- Only a part of the earth surface is visible.
- The view will be of half the globe or less.
- Distortion will occur at all four edges.

- Distance for the more part is preserved.



Azimuthal Equidistant

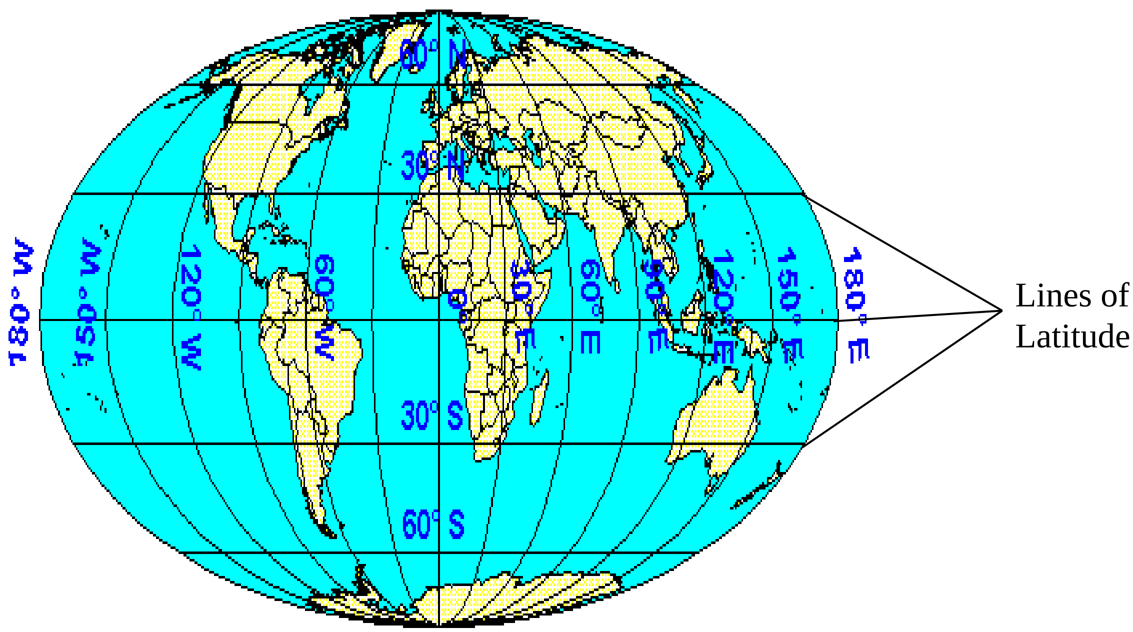
Spatial Referencing:-

- Referencing system is used to locate a feature on the earth's surface or a two dimension representation of this surface such as a map.
- Several methods of spatial referencing exist all of which can be grouped into three categories.

❖ Geographical co-ordinate system

❖ Rectangular co-ordinate system

❖ Non-co-ordinate system



Latitude and

Geographic Co-Ordinate System:-

This is a one of true co-ordinate system. The location of any point on the earth surface can be defined by a reference using latitude and longitude.

➢ The line of latitude starts at one pole and radiate out ward until they converge at the opposite pole.

- Line of latitudes runs parallel to one another.

- So we locate the particular point in one area latitude and longititude are parallel towards equator. The point distance may be varying.

- The shortest distance between two points on the earth surface is known as the great circle distance.

- Using lines of latitude and longitude any point on the earth surface can be located by a reference given in degrees and minutes.

- The latitude and longitude referencing system assumes that the earth is a perfect sphere. Unfortunately this is not correct.

- Rugged and complicate areas are here ignored.

QTM

The quaternary triangular mesh referencing system tries to deal with irregularities in the earth surface.

Rectangular Co-Ordinates:-

At present most of the spatial data available for using in GIS exist in two dimensional forms. In order to make use of there data a referencing system which use rectangular co-ordinates is required.

- Grid (or) reticule is placed on top of the map this reticule is obtained by projection the lines of latitude or longitude from our representation of the world as a globe onto a flat surface.
- All rectangular co-ordinate systems are designed to allow the mapping of specific geographical region.

For example:

UK ordnance surveys national grid another one universal transverse Mercado plane gird system.

- Ordinance survey national gird is a rectangular grid system based on the transverse Mercator projection.

Non Co-Ordinate System:-

Non co-ordinate systems provide spatial references using a descriptive code rather than a co-ordinate.

For example:-
Postal codes, widely used throughout the world sum postal codes numeric example (America India) otherwise alpha numeric – UK

All spatial referencing system has problems associated with them

- Spatial entities may be mobile animals, cars and people move.

- Spatial entities may change-rivers meanders, roads can be relocated and policy areas redefined

.

- The same objects may be referenced in different ways
  -house may be represented and referenced as both a point and an area on maps of different scale.

- In additionally GIS users met some problems choosing appropriate referencing system can be difficult

Topology:-

Topology is the term used to describe the geometric characteristics of objects. Which don't change under transformation? Such as stretching or bending and are independent of any co-ordinate system. ***Bernhardsan- 1992***

Topology as it relates to spatial data, consists of three elements-ardency, containment and connectivity. ***-Borrough-1986***

-ardency and containment describes the geometric relationships. Which exists between area features?

Thematic Characteristics of Spatial Data:-

Attributes are the non spatial data associated with point, line and area entities attributes are the characteristics of an entity

- ❖ A point represents a hotel
- ❖ A line represent a road
- ❖ And area represents a forest

Each spatial entity may have more then one attribute associated with it.

Example:-

- ❖ A point representing the hotel may have a number of other attributes. The number of rooms the standard of accommodation address of the hotel owner.

- ❖ The character of attribute data themselves can influence the utility of data sets in GIS analysis.

- ❖ Important one characteristic is the scale of measurement used to record and report the data.

Other Sources of Spatial Data:-

We have considered the characteristics of spatial data and their thematic dimension other sources of spatial data including.

Census and survey data:-

Census and survey data are collection of related information. They may be spatial in each item in the collection has a spatial reference are location on the surface of the earth to be identified.

For example.

- *Population census*
- *Employment data*
- *Agricultural census*
- *and marketing data*

Aerial photograph:

- Aerial photography was the first method of remote sensing.
- It is capturing of image from a position above the earth surface or without contact with the object of interest.
- An aerial photograph is a 'snapshot' of the earth at a particular instant in time.

Satellite images:

- Satellite image are collected by sensors on board a satellite.
- Sensors on board this satellite detect radiation from the earth for different parts of the electromagnetic spectrum.
- The multispectral scanner on four different wave bands, near infrared, the image red, green and blue band.
- Scanned image are stored as a collection of pixels which have representing the amount of radiation received by the sensor from that portion of the earth surface.

Trotter (1991) considers the advantages of remotely sensed data for GIS applications in the area of natured resource management to be.

- Low cast relative to other data sources.
- Currency of imager.
- Accuracy.
- Completeness of data, and
- Uniform standards across an area of interest.

Field data sources:

Surveying and GPS:

There are several methods of collecting raw data in the field for direct input into a GIS. There are most often used when the required data do exist in any other readily available format such as a map or satellite images. Traditional manual surveying techniques using chains, plane, tables, level and theodolites are example of direct field measurement, but the data collected need to be written down on paper first.

A relatively new technique of field data collection which has found particular favor with GIS user is the use of satellite navigation system or GPS (global positioning system). There portable backpack or hand-held device that use signals form GPS satellite to work out the exact location of the user on the earth's surface in terms of (x,y,z) co-ordinates using trigonometry. Portion fixes are obtained quickly and accurately literally at the push of a button.

The accuracy obtainable form civilian GPS receivers range from 100m to as 0.5 m depending on how they are used while there are military versions. Originally designed to within a few centimeters. Originally designed for real time navigation purpose most GPS receiver will store collected co-ordinates and associated attribute information in their internal memory so they can be downloaded directly into a GIS database.