

GEOGRAPHICAL INFORMATION SYSTEMS

Introduction

In a general sense, a GIS can be thought of as a computer based system that integrates, stores, edits, analyzes, shares and displays geographic information for the purpose of informing decision making. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data, maps, and present the results of all these operations.

GIS started in 1960 with the discovery that computers can be programmed to store maps. A welcome idea that overcame the drudgery in hand cartography

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- The first ever built geographic information system-Canadian Information Systems (CGIS) was fathered by Rogers Tomlinson.

1) Basic Definitions of GIS

In defining GIS there seems to be a universal one but in all there are common grounds all. For instance looking at the following authors conceptualization, certain terms keep recurring.

- *"Computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations. Practitioners also regard the total GIS as including operating personnel and the data that go into the system."* [USGS](#)
- *Burrough in 1986 defined GIS as, "Set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes"*
- *"A computer-based tool for mapping and analyzing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps."* [ESRI](#)
- *"An integrated system of computer hardware, software, and trained personnel linking topographic, demographic, utility, facility, image and other resource data that is geographically referenced."* [NASA](#)
- *"Set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes " -Burrough 1986 GIS*
- *, "A computer based system that provides four sets of capabilities to handle geo-referenced data :*
 - *data input*
 - *data management (data storage and retrieval)*
 - *manipulation and analysis*
 - *data output. " Arnoff in 1989*

2) Levels of GIS (spatial) data sets

There are two broad formats of spatial data sets in GIS namely: Raster data set and vector data sets. While the vector data sets are a generalization of features represented by lines points and polygons, the raster data set are presented in grid cells. Usually this could present a gamut of information such as contained in a satellite remote sensing images. There are several sources of data as discussed above, but broadly, we have satellite remote sensing images, global positioning system, hard copy topographical maps, population census tracks, field data, records from offices such as hospitals etc.

Geographic Data Types

Basically there are two (2) types of data in GIS, these are;

1. (i) raster data model or
2. (ii) vector data model.

Data Requirements and Acquisition in GIS

Data requirements for Public health will consist of spatial and non-spatial data. However, the sources of these data, the methods of their acquisition, spatial coverage, processing/analysis are important for consideration

3) Phases in Geographical Information System building

The following phases are involved in building up a GIS

1. Data capture; including digitizing,
2. Creation of attribute database for the digitized features
3. Database development (may include spatial joins of additional tables)
4. Spatial analysis

4) Data input and spatial data capture subsystem

Data input in GIS include Scanning, Importing of Imageries, Importing of tables. Once the data has been imported, data capture can be done and this comes in form of Digitizing (which could be “On-screen” or with the aid of digitizing) tablets, Importation of spatial database tables as event layers etc.

5) Spatial data management subsystem

Spatial database should be managed through constant update by a spatial database manager. GIS is data driven and hence the spatial analysis are tied to the richness of the spatial database.

6) Data presentation subsystem

GIS presents results of analysis in graphical forms. Visualisation in GIS often involves the following techniques:

- Thematic mapping,
- Natural Breaks,
- Equal Ranges,
- Equal Counts,
- Quantile and

- Standard Deviation

GIS can break up features into five groups, based on the "Natural Breaks" statistical method. You can change the number of categories and the type of statistical classification by clicking on the "Classify..." button. You can choose one of the following classifications: "Equal Area", "Equal Interval", "Natural Breaks", "Quantile", and "Standard Deviation".

Opening up the "Color Ramps:" menu bar lets you choose a different set of colors than the default "Red monochromatic" ramp colors. If none of the available color ramps are suitable, you can change each color individually by double-clicking on the corresponding symbol. This will bring up a color and style palette.

7.) *Remote sensing data as input into GIS*

Remote Sensing technology has no doubt contributed immensely to data acquisition in GIS. The ability to capture agricultural and environmental data by various satellites at different resolutions makes spatio-temporal data readily available for agricultural, environmental, defence, planning etc. Time series satellite data for vegetation, land surface temperature, Incident photosynthetically active radiation, sea surface temperature, cloud temperatures etc. other data include Digital elevation, soil moisture Evapo-transpiration.

8.) *Basic principles in remote sensing*

Remote sensing is the acquisition of information about an object or phenomenon, without making physical contact with the object. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation emitted from aircraft or satellites).

- The first requirement for remote sensing is to have an energy source to illuminate the target.
- This energy for remote sensing instruments is in the form of electromagnetic radiation (EMR).
- Earth's natural and man-made features that first receive energy from the sun or an artificial source such as a radar transmitter.
- Different objects return different types and amounts of EMR back to space (spectral responses).
- The amount reflected back to space is captured by the sensor on board satellite platform and telemetered back to the earth receiving station.
- Since different object reflects (based on their spectral responses) different quantities of EM radiation and the Objective of remote sensing is to detect these differences with the appropriate instruments called sensors, then the image produce show different colour pattern and the differences are interpreted making it possible to identify and assess a broad range of surface features and their conditions

10) *GIS as a scientific tool in environmental management*

Geographical Information Science (GIS) finds more applications in the fields of environmental management, toxicology and epidemiology. More and more assurance of timely control Bubonic plagues is given through accurate predictions and decision support with respect to interventions.

Since GIS is unique in efficient storage, manipulation, analysis and seamless integration and display of large quantities of environmental data, it has given investigators grand support in rapid environmental and agricultural surveys. In recent past, GIS has been developed for a wide range of applications in precision farming, prediction of toxicity in air and groundwater, solid waste management, spatial decision support for citing of environmental facilities and public health safety studies to list a few.

Since it is a spinoff of Information Communication Technology, GIS through mapping and modeling of spatial information enables better form of communication between people in research and the society at large. Available evidence from literature reveals the extreme usefulness of GIS application in specific areas of environmental/public health such as chemical contamination of water and water borne diseases. For instance GIS application in the exposure of man to contaminated drinking water by non volatile organic compounds (VOC) in groundwater reservoir has been demonstrated. It was possible with this, to determine extent of contamination and location of vulnerable population on the public water supply network

11) *Concept and components of GIS*

You will observe that in all definitions of GIS presents some common and recurrent terms namely: Computer (hard ware and soft ware), Geographical data and Personnel. This clearly points out that before a system can pass for a GIS it must have the following components

It implies then that a working GIS integrates these five key components namely:

- hardware
- software
- data
- people and
- methods



Figure 1: Components of a GIS.

Hardware

It consists of the computer system on which the GIS software will run. The computer forms the backbone of the GIS hardware, which gets it's input through the Scanner, key board or a digitizer board. 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 softwares in use are MapInfo, ARC/Info, AutoCAD Map, etc.

Data

The digital map forms the basic data input for GIS, maps can be purchased scanned Geo-referenced digitized and developed into GIS by building database. Geographic data and related tabular data can also be collected in-house through questionnaire or field surveys and geo-referenced with the aid of Global Positioning System receivers.

People

there are three categories of people when it comes to GIS; these are the solution seekers, solution providers and software developers.

Method

There are various techniques used for map creation and further usage for any project. The map creation can either be automated raster to vector creator or it can be manually vectorized using the scanned images.

12) *Relevance of GIS in environmental planning and analysis*

GIS are not just used for electronic map-making but today are major tools for the management of our physical and social environment. GIS are used to assist political decisions and play a part in market research, in the management of utility services, in automated navigation systems and in many other fields. Spatial data are usually based on two, dichotomous paradigms, exactly defined entities in space, such as land parcels, or the continuous variation of single attributes, such as temperature or rainfall. Methods for modelling both kinds of phenomena and storing them in spatial databases are described in detail, including the use of geostatistics for interpolating from points to continuous fields. Examples of how spatial data and an analysis of their spatial interactions are used to solve a wide range of practical problems ranging from site-location analysis through land degradation, the optimizing of timber extraction from forests, management and prediction of natural disasters such as floods and urban renewal projects. GIS is extremely relevant in the fields of geography, hydrology, geology, environmental science, epidemiology, radioecology, ecology, agriculture, and land management.

13) *Principles of GIS*

GIS technology and its implementation are most easily understood within the context of underlying principles. The following basic principles have been identified as common among successful GIS projects throughout the world.

Principle 1: A GIS is a data-driven, data-based information system

Principle 2: GIS data and maps must be maintained (regularly updated).

Principle 3: A GIS is most useful when geographic references are registered on a consistent, continuous coordinate system.

Principle 4: A GIS has topology (Additional explicit definitions of the relationships among cartographic features (points, lines, polygons, etc.) must be established

Principle 5: A GIS has many uses and should be shared by many different functions (a multi-use, shared system can prevent duplication of the common information and duplication of the effort to maintain it and facilitate the sharing of data among the many organizations and functions that need this common data).

Principle 6: A GIS contains hardware and software that are constantly undergoing change which improves its functionality over time

Principle 7: A GIS grows incrementally in terms of technology, cost, and administrative support needed. Therefore, a long-term commitment is needed to assure success.

Principle 8: A GIS causes changes in procedures, operations, and institutional arrangements among all users. No longer can data be “guarded” by one individual. No longer can a worker make changes to a map or record that is the responsibility of some other function without a formal procedure to ensure accuracy.

Principle 9: A cadre of trained, educated, motivated, and dedicated people is crucial to a successful GIS program. There must be time and resources to have current staff educated on GIS concepts and trained on selected GIS software.

14) Source, acquisition and management of environmental data

Primarily, GIS data sources include the following.

1. Base maps such as topographic maps, national, state or local government administrative boundary maps etc. obtainable from the Federal Survey, States Ministries of Lands etc.
2. Research findings from research centres/Institutions obtained from field with GPS acquisition etc. Such can be obtained from Universities, Institutes, hospitals etc.
3. Demographic data which can be obtained from agencies like Federal Office of Statistics (FOS), National Data Bank (National Identity Card Management System), National Population Commission, Meteorological Stations etc.
4. Satellite Remote Sensing derived data: like vegetation Index data, Land surface temperatures, Precipitation, topography etc available from agencies like NASA, NOAA etc.
5. Global positioning system geo-statistical data

15) Capturing extraction, storage and analysis of spatial data for decision making

The handling of spatial data usually involves processes of data acquisition, storage and maintenance, analysis and output. The introduction of modern technologies has led to an increased use of computers and information technology in all aspects of spatial data handling. The software technology used in this domain is Geographic Information Systems (GIS). GIS is being used by various disciplines as tools for spatial data handling in a geographic environment.

Data capture entails entering information into the GI system. There are a variety of methods used to enter data into a GIS where it is stored in a digital format.

1. 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.
2. Survey data can be directly entered into a GIS from digital data collection systems on survey instruments using a technique called Coordinate Geometry (COGO). Positions from a Global Navigation Satellite System (GNSS) like Global Positioning System (GPS), another survey tool, can also be directly entered into a GIS.
3. 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.
4. Aerial photographs can also be scanned and used to digitize features directly from stereo pairs of digital photographs. These systems allow data to be captured in two and three dimensions, with elevations measured directly from a stereo pair using principles of

[photogrammetry](#). 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.

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.

16) *Relational analysis of environmental phenomenon*

From the data types available for GIS, it can be verified that the problems of spatial analysis deal with *environmental* data. The spatial analysis is composed by a set of chained procedure that aims at choosing of an inferential model that explicitly considers the spatial relationships present in the phenomenon. In general, the modeling process is preceded by a phase of *exploratory analysis*, associated to the visual presentation of the data in the form of graphs and maps and the identification of spatial dependency patterns in the phenomenon under study.

One type analysis of environmental phenomenon is known as *point pattern analysis* the object of interest is the very spatial location of the events under study. An example is in studies aiming at estimating the risk of diseases around nuclear plants.

Another type of analysis is called *Interpolated surface analysis* which shows a pattern of spatial distribution of variability concentration of continuous data such as air or ground water pollution. For *surface analysis*, the objective is to reconstruct the surface from which the samples were measured. For example, consider the distribution of profiles and soil samples of an area. Methods like universal kriging, co-kriging,

Another type is the *areal analysis*, most of the data here are drawn from population survey like census, health statistics and real estate cadastre. These areas are usually delimited by closed polygons where supposedly there is internal homogeneity, that is, important changes only occur in the limits. Clearly, this is a premise that is not always true, given that frequently the survey units are defined by operational (census tracts) or political (municipalities) criteria and there is no guarantee that the distribution of the event is homogeneous within these units.