Geographic Information System

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Almost every phenomenon we come across varies with space where it belongs to. Often we need to evaluate geographically varied data as a single variable, or analysis integrating several variables, and extract information and visualize them in an illustrative form to make important decisions. Geographic Information System (GIS) which is capable of dealing with spatial information is one versatile tool specially designed for this purpose.

Geographic information system

Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The acronym GIS is sometimes used for Geographical Information Science or Geospatial Information Studies which refer to the academic discipline, or career of working with geographic information systems. In the simplest terms, GIS is the merging of cartography, statistical analysis and database technology. Remote sensing or satellite imagery which was derived from spectroscopy provides additional data into GIS. Other attribute data can also be incorporated into GIS with the help of a portable instrument called Global Positioning System (GPS) which can communicate with a specific satellite network and record geographic location of the data considered.

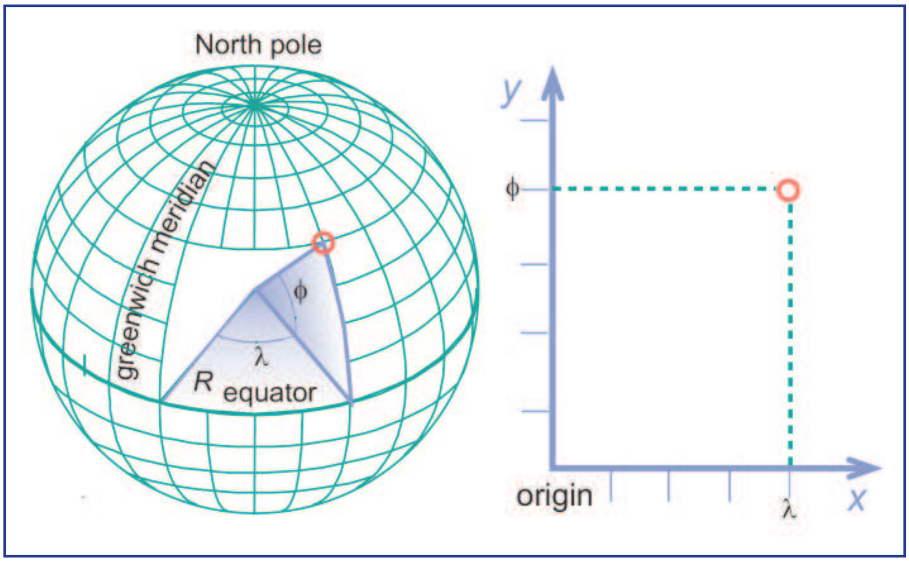

Figure 1 **Two 2D spatial referencing approaches through geographic coordinates (x, y)**

How GIS represent the real world

GIS allow mapping any location on the earth in a two dimension plain relative to the Greenwich line and the equator to represent parts of the surface of the Earth on a flat paper map or on a computer screen. The curved horizontal reference surface must be mapped onto the 2D mapping plane.

In GIS, homogenous collections of geographic objects such as roads, towns, buildings, districts and others are organized into data themes or layers. Many types of software exist offering a rich collection of tools for processing geographic data layers to derive many relations between the geographic elements they contain. In a Geographical Information System we can represent real world and objects in formats that can be stored, handled and displayed in a computer. The two most commonly used formats for representing the real world objects are vector and raster data models.

In a vector model the real world can be represented and modelled as homogeneous and discrete features. Features can be points, lines or polygons. For example a city or a well can be represented as a point, roads or rivers as a line and lakes a polygon. For all of these three types of features an attribute code is created in the database to identify the object. Points are stored as discrete coordinate's pair, lines as sets of coordinates and polygons in the same way as a line having the same beginning and ending coordinates. The Database can be furthermore filled with other characteristics and attributes concerning the objects.

In the raster model the real world is represented in continuity as a gridded matrix. Spatial and attribute data are stored together for each cell in the grid. Each cell in the raster model corresponds to a location. The location of each grid cell is defined by row and column coordinates with associated attribute value. Selection of either the vector or the raster format depends on the application and on the aim of the user. Vector format is used to represent entities with clear boundaries such as buildings, roads, districts etc. Raster format is used to represent occurrences which are continuous in nature such as temperature, altitude, pollution. A GIS can simultaneously manage both types of data formats. Furthermore, there are many tools available for conversion from the one format to the other, which have been improved in the last few years.

Advantages of GIS

Geographic Information Systems have a number of advantages compared to the traditional mapping systems. Traditional maps are static, with fixed projection, scale and coordinate systems; it is difficult to combine multiple map sheets, and overlays are restricted. They are difficult to copy and share between many users.

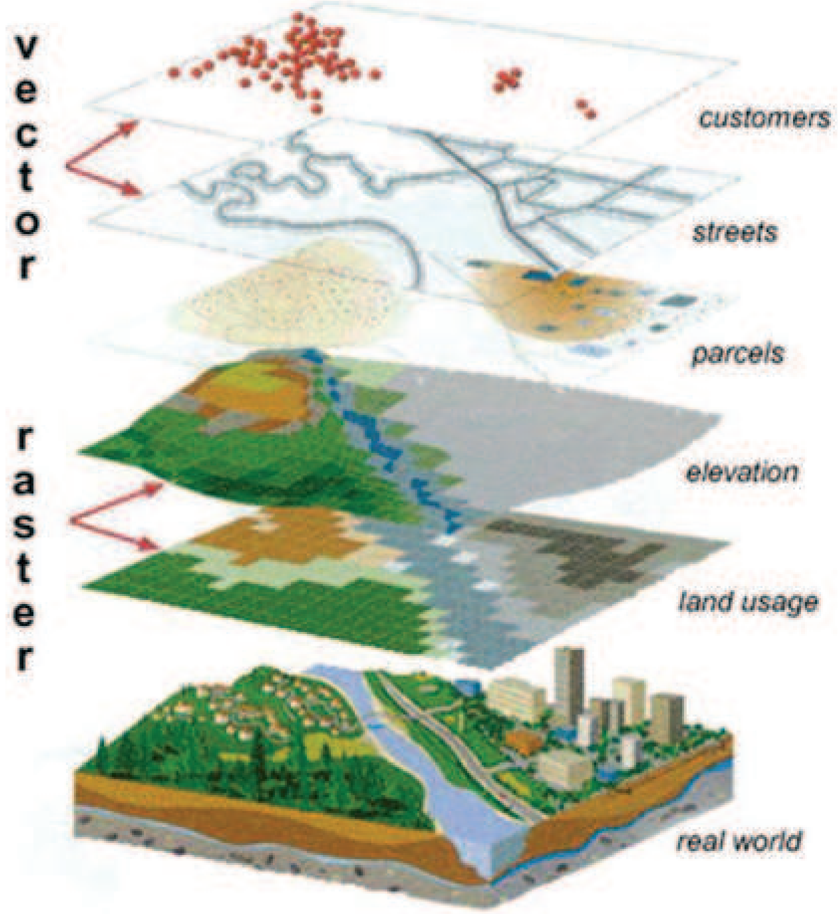

Figure 2 Layer representation model of real world in GIS

It is easy to update data in GIS, by analysing spatial data and converting to new scales or coordinate systems. Maps can be easily combined and overlaid, offering various types of information. Densities, quantities and patterns of a specific item in a specific area can be easily derived and terrain models can be generated to aid 3D visualization.
Data is digitally organized in a GIS, so the user has no need to store numerous maps, datasheets and charts. There is no need for manual checks, the search is done automatically by computers, making work easier, cost effective and less time consuming. Interactive maps provide information about how geographical features interact with each other. Users can point to a location and retrieve information, perform editing and analysis, discover new relationships between objects and phenomena. Access to geographic information is easy and there is a range of tools which give the capability to interact with the map contents.

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 from space (satellite or aircraft) to observe by means of propagated electromagnetic radiation reflected or emitted by the object or surface. Reflected sunlight (visible & infrared region) is the most common source of radiation measured by sensors mounted on satellite or aircraft.

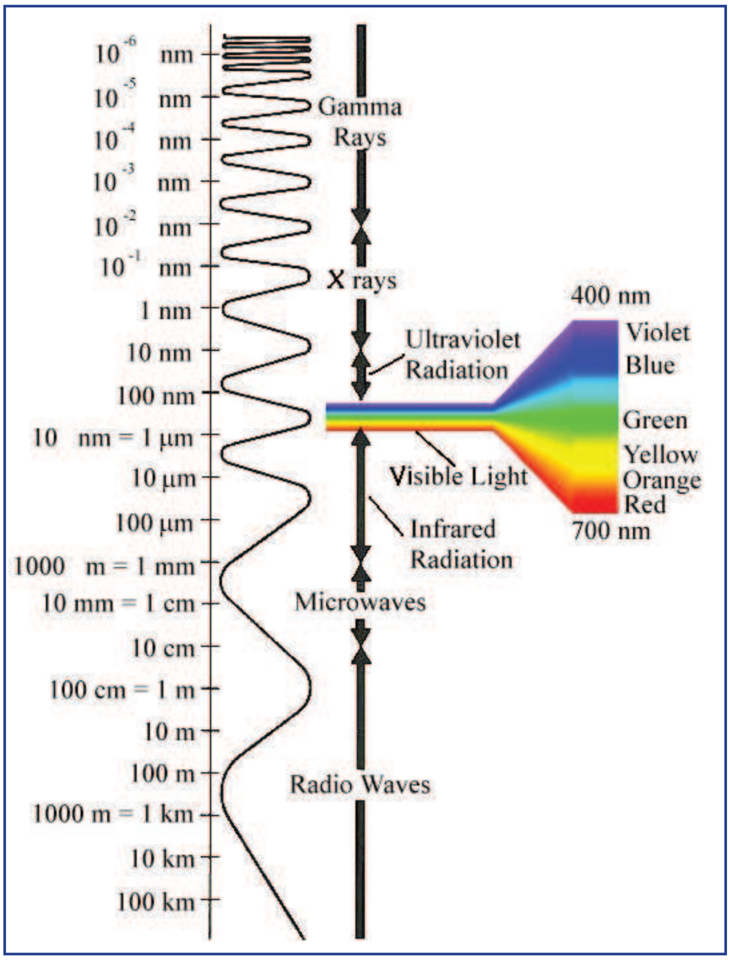

Figure 3 Electromagnetic Spectrum

Satellite images are the most widely used data that are compatible with raster GIS. Satellite image consistent with grid containing reflectance values belong to visible and infrared (IR) region, and contains bands that belong to Blue, Green, Red and IR bands for each grid cell recorded in a format that can be combined with GIS.

The quality of remote sensing data consists of its spatial, spectral, radiometric and temporal resolutions.

Spatial resolution
The size of a pixel that is recorded in a raster image – typically pixels may correspond to square areas ranging in side length from 1 to 1,000 metres.

Spectral resolution
The wavelength width of the different frequency bands recorded – usually, this is related to the number of frequency bands recorded by the platform. Current Landsat

Figure 4 Portable GPS receiver

collection is that of seven bands, including several in the infra-red spectrum, ranging from a spectral resolution of 0.07 to 2.1 µm. The Hyperion sensor on Earth Observing-1 resolves 220 bands from 0.4 to 2.5 µm, with a spectral resolution of 0.10 to 0.11 µm per band.

Radiometric resolution

This is the number of different intensities of radiation the sensor is able to distinguish. Typically, this ranges from 8 to 14 bits, corresponding to 256 levels of the gray scale and up to 16,384 intensities or "shades" of colour, in each band. It also depends on the instrument noise.

Temporal resolution

The frequency of flyovers by the satellite or plane, and is only relevant in time-series studies or those requiring an averaged or mosaic image as in deforest monitoring. This was first used by the intelligence community where repeated coverage revealed changes in infrastructure, the deployment of units or the modification/ introduction of equipment. Cloud cover over a given area or object makes it necessary to repeat the collection of said location.

Global Positioning system

Global Positioning System satellites transmit signals to equipment on the ground. GPS receivers passively receive satellite signals; they do not transmit. GPS receivers require an unobstructed view of the sky, so they are used only outdoors and they often do not perform well within forested areas or near tall buildings. GPS operations depend on a very accurate time reference, which is provided by atomic clocks. Each GPS satellite has atomic clocks on board.

Each GPS satellite transmits data that indicates location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are farther away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate its position in three dimensions.

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There are at least 24 operational GPS satellites at all times. The satellites, operated by the U.S. Air Force, orbit with a period of 12 hours. Ground stations are used to precisely track each satellite's orbit.

Determining Position

A GPS receiver "knows" the location of the satellites, because that information is included in satellite transmissions. By estimating how far away a satellite is, the receiver also "knows" it is located somewhere on the surface of an imaginary sphere centered at the satellite. It then determines the sizes of several spheres, one for each satellite. The receiver is located where these spheres intersect. The coordinates of required location can be incorporated in to GIS.

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