Geoscience Research, ISSN: 0976–9846 & E-ISSN: 0976–9854
Vol. 1, Issue 1, 2010, PP-01-06

Fundamentals of geoinformatics and its applications in geography

Mankari M.P.[1], Kodge B.G.[2], Kulkarni M.J.[1], Nagargoje A.U.[1]
[1]Department of Geography, M.U. College, Udgir, MS, India, mankari.manjunath@gmail.com
[2]Department of Computer Science, S.V. College, Udgir, Latur, MS, India, kodgebg@hotmail.com

Abstract- GIS has become a popular tool in recent studies in geography, environmental science, town planning, defense studies etc. In this paper we have made an attempt to present few, yet important aspects of Geoinformatics and applications of GIS in some branches of geographical research.
Keywords- Geographical Information System, Remote Sensing, Global Positioning System, Spatial Data, Vector and Raster file formats, River Morphology

1. Introduction

The art, science and technology dealing with the acquisition, storage, processing, production, presentation and dissemination of geoinformation is called geoinformatics. According to Burrough (1987) it is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying of spatial data form the real world. Geoinformatics is made up of Geographical Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS). It is the advancing science and technology, which can be used for research and development in any discipline. For a geographer, it is a powerful tool to generate and geocoded data and attribute database to help taking decisions appropriately for planning. Geographical Information System (GIS) is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information i.e. data identified according to location. Parker (1988) defined GIS as “an information technology which stores, analyses, and display both spatial and non-spatial data.

1.1 Objectives of GIS

• Optimization of efficiency of planning and decision making.
• Capacity to integrate information from various sources.
• Provide efficient means for data distribution and handing.
• Elimination of redundant data base.
• Complex analysis / query involving geographical referenced data to generate new information.

1.2 Elements of GIS

• Hardware: It is the physical unit (electronic machine) that ultimately performs the job. Monitor, printer, plotter, scanner digitizer etc.
• Software: A set of programs written to perform a specific job with the help of hardware. Operating system: windows 2000, 2007, Windows XP, Windows Vista, Unix etc.
GIS Software: Arcinfo, AraGIS, Arcview, Erdas, GRAM, GRAM++, Idrisi, ILWIS, Autocadmap etc.
• Data: Two types of data
a) Spatial data and
b) Non-spatial (attribute) data.
• Liveware: Users or people.
• Data Model:

A set of logical definitions for characterizing the geographical data in order to present spatial information and their attributes, the two approaches for data model are:
1. Raster representation and 2. Vector representation
Followings are few raster file formats commonly used in geoinformatics [8].
•ADRG - National Geospatial-Intelligence Agency (NGA)'s ARC Digitized Raster Graphics
•BIL - Band Interleaved by Line (image format linked with satellite derived imagery)
•CADRG - National Geospatial-Intelligence Agency (NGA)'s Compressed ARC Digitised Raster Graphics (nominal compression of 55:1 over ADRG)
•ECRG - National Geospatial-Intelligence Agency (NGA)'s Enhanced Compressed

ARC Raster Graphics (Better resolution than CADRG and no color loss)
•CIB - National Geospatial-Intelligence Agency (NGA)'s Controlled Image Base (type of Raster Product Format)
•Digital raster graphic (DRG) - digital scan of a paper USGS topographic map
•ECW - Enhanced Compressed Wavelet (from ERMapper). A compressed wavelet format, often lossy.
•ESRI grid - proprietary binary and metadataless ASCII raster formats used by ESRI
•GeoTIFF - TIFF variant enriched with GIS relevant metadata
•IMG - ERDAS IMAGINE image file format
•JPEG2000 - Open-source raster format. A compressed format, allows both lossy and lossless compression.
•MrSID - Multi-Resolution Seamless Image Database (by Lizardtech). A compressed wavelet format, often lossy.
•netCDF-CF - netCDF file format with CF medata conventions for earth science data. Binary storage in open format with optional compression. Allows for direct web-access of subsets/aggregations of maps through OPeNDAP protocol.

And Followings are few raster file formats commonly used in geoinformatics.
•Geography Markup Language (GML) - XML based open standard (by OpenGIS) for GIS data exchange
•AutoCAD DXF - Contour elevation plots in AutoCAD DXF format
•Shapefile (SHP)- ESRI's open, hybrid vector data format using SHP, SHX and DBF files
•Simple Features - Open Geospatial Consortium specification for vector data
•MapInfo TAB format - MapInfo's vector data format using TAB, DAT, ID and MAP files
•National Transfer Format (NTF) - National Transfer Format (mostly used by the UK Ordnance Survey)
•TIGER - Topologically Integrated Geographic Encoding and Referencing
•Cartesian coordinate system (XYZ) - Simple point cloud
•Vector Product Format - National Geospatial-Intelligence Agency (NGA)'s format of vectored data for large geographic databases.
•GeoMedia - Intergraph's Microsoft Access based format for spatial vector storage.
•ISFC - Intergraph's MicroStation based CAD solution attaching vector elements to a relational Microsoft Access database
•Personal Geodatabase - ESRI's closed, integrated vector data storage strategy using Microsoft's Access MDB format
•File Geodatabase - ESRI's file-based geodatabase format, stored as folders in a file system. ESRI also has an enterprise Geodatabase format for use in an RDBMS.
•Coverage - ESRI's closed, hybrid vector data storage strategy. Legacy ArcGIS Workstation / ArcInfo format with reduced support in ArcGIS Desktop lineup
•Spatial Data File - Autodesk's high-performance geodatabase format, native to MapGuide
•GeoJSON - a lightweight format based on JSON, used by many open source GIS packages
•SOSI Standard - a spatial data format used for all public exchange of spatial data in Norway
Grid formats (for elevation)
•USGS DEM - The USGS' Digital Elevation Model
•DTED - National Geospatial-Intelligence Agency (NGA)'s Digital Terrain Elevation Data
•GTOPO30 - Large complete Earth elevation model at 30 arc seconds
•SDTS - The USGS' successor to DEM
Other formats
•Binary Terrain - The Virtual Terrain Project's Binary Terrain format
•Dual Independent Map Encoding (DIME) – A historic GIS file format, developed in the 1960s
•Well-known text (WKT) – ASCII spatial projection description (ESRI uses a *.prj extension)
•Well-known binary (WKB) - Binary spatial projection description
•World file - Georeferencing a raster image file (e.g. JPEG, BMP)

1.3. Need of GIS

Collector, SP, Administrators, Academicians- University, MLA & MP, Environmentalist, Agriculturist, Disaster management cell e.g. For agricultural management GIS has to be considered multidimensional with attribute dimension, spatial dimension &temporal dimension GIS offers capabilities of integrating multisector, multilevel and multiperiod database.

GIS satisfy the following specific needs

1) The ability to preprocess data from large stores into a form suitable for analysis, including operation such as reformatting, change of projection, resampling and generalizations.

2) Direct support for analysis and modeling, so that from of analysis, calibration of models, forecasting, and prediction are all handled through instruction to the GIS.

3) Post processing of result including such operations as reformatting, tabulation, report generation, and mapping.

An information system is the chain of operations- planning, observation and collection of data- storage and analysis of data- Decision making process.

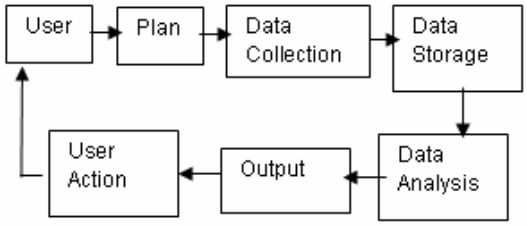

Fig. 1- Decision making process

Four key activities can be enhanced by using GIS

• Measurement
• Monitoring
• Mapping
• Modeling

Contributing disciplines to GIS.

•Geography
•Cartography
•Computer software
•Surveying
•Photogammetry
•Remote Sensing Technology
•Mathematics/Statistics

1.4 Steps in GIS analysis

• Importing Data
• Georeferencing
• Digitizing and editing
• Data analysis:

a) network analysis
b) Digital Elevation Model (DEM).
c) Morphometric analysis, etc.

• Query Building.

Remote Sensing (RS) means acquiring information about a phenomena or object or surface while at distance from it (without being physical contact with it)

2. Principles of Remote Sensing

Different objects return different amount and kind of energy in different bands of the electromagnetic spectrum incident upon it. This property of the object depends on structural, physical and chemical composition, surface roughness, angle of incidence, intensity and wavelength of radiant energy, hence we can identify various objects by collecting and analyzing returned energy.

2.1 Stages in RS

• Emission of energy or EMR (Sun)
• Transmission of energy from the source to the surface of the earth as well as adsorption and scattering of energy in the atmosphere.
• Interaction of EMR with the earth surface Reflection.
• Transmission of the energy from the surface to the remote sensor.
• Sensor data output.
• Data transmission, processing and analysis.

2.2. Platforms and Sensors

Platform is a stage to mount the camera or sensor to acquire the information about a target. Based on their altitude above the earth surface they are Ground borne. Air borne and Space borne.

Sensor is a device that gathers energy, converts it into a signal and presents it in a suitable form for obtaining information about the target under investigation. Two types of sensors :

1. Active and 2. Passive.

2.3. Resolution

Resolution is defined as the ability of the system to render the information at the smallest discretely separable quantity in terms of distance (spatial), wavelength band of EMR (spectral), time (temporal) and radiation quantity (radiometric).

2.4. Image Interpretation

An interpreter can derive lot of information by studying the quantitative and qualitative aspects of images and photographs. An image taken from air or space is a pictorial presentation of the pattern of a landscape. Two types of image interpretation.

1) Visual Image Interpretation: Elements are Shape, Size, Tone, Shadow, Pattern,

Geoscience Research, ISSN: 0976–9846 & E-ISSN: 0976–9854, Vol. 1, Issue 1, 2010

Texture, Location, Resolution, and Stereoscopic Appearance.
2) Digital Image Processing (DIP): can be categorized into the following types of computer—assisted operations:
(a) Image Rectification: aim at correcting distorted data
(b) Image Enhancement: increase the amount of information that can be visually interpreted form the data. E.g. Contrast, Edge, Band Ratioing.
(c) Image Classification: automatically categories all pixels in an image into land cover classes or themes. Two Types: (i) Unsupervised and (ii) Supervised classification: Ground truth sites should be large enough, well-distributed and readily identifiable on the toposheets and the image.
Global Positioning System (GPS) also called as NAVSTAR GPS (Navigational System with Time and Ranging) was created by the U.S. Department of Defense for defense reasons. This system is being used for many civil applications now a days.
It is a system of earth-orbiting satellites transmitting precisely timed signals (a similar system of Russian Federation: GLONASS - global navigation satellite system) which provides direct measurement of position on the Earth's surface and the location is expressed in latitude/longitude.
The GPS receiver measures the travel time of signals transmitted from triangulated satellites. It calculates the satellites' latitude, longitude, altitude and speed. GPS provides an address to every square meter of the earth's surface.

3. The Five Main Points of Global Positioning System

1. The basis of the GPS system is triangulation from the satellites. Triangulation is when distance is measured using the travel time of radio messages from satellite.
2. Two receivers are needed; the first receiver acts as a "reference point". It is stationary and monitors, transmits and records the corrections to errors. The second receiver is placed in a position that is recorded and calculates position of satellite (with data). Then it compares the answer with a known position; the difference is the error in the GPS signal.
3. The satellite and the receiver generate the same pseudo-random code at the same time. The distance to a satellite is determined by measuring the time it takes for a radio signal to reach us from that satellite.
4. This code allows for the GPS system to work with very low power signals and small antenna.
5. Distance to satellites is measured by accurate timing, using atomic clocks on board. Four satellite range measurements will reduce errors in timing.
3.1. Three major segments:
(i) Space Segment; Consists of 24 satellites at an altitude of 20200 km above the earth surface.
(ii) Ground control segment; Five ground stations distributed around the earth for monitoring and controlling the satellite system continuously
(iii) The user segment: includes all those who use GPS tracking equipment to receive GPS signals to satisfy positioning requirements.

4. Applications of Geoinformatics

Geoinformatics has become a popular tool in the recent studies in geography, environmental science, town planning, defense studies etc. some active domains for application of Geoinformatics are.

4.1 The main producers and sources

Topographical Mapping: National Mapping Agencies, private Mapping Companies
Land Registration and Cadastre.
Hydro graphic Mapping.
Military Organizations.
Remote Sensing companies and satellite agencies.
Natural resource surveys; Geologists; Hydrologists; Physical Geographers and Soil.
Scientists; Land Evaluators; Ecologists and Biogeographers; Meteorologists and Climatologists; Oceanographers.
The main types of geographical data available:
Topographic maps at a wide range of scales
Satellite and airborne scanner images and photographs
Administrative boundaries: Census tracts and census data; Postcode areas
Statistical data on people, land cover, land use at a wide range of levels.

Data from marketing surveys.
Data on utilities (gas, water, electricity lines, cables) and their locations.
Data on rocks, water, soil, atmosphere, biological activity, natural hazards, and disasters collected for a wide range of spatial and temporal levels of resolution.

4.2 Some current applications

Agriculture Monitoring and management from farm to national levels.
Archaeology site description and scenario evaluation.
Environment Monitoring, modeling, and management for land degradation; land evaluation and rural planning; landslides; desertification; water quality and quantity; plagues; air quality; weather and climate modelling and prediction.
Epidemiology and health location of disease in relation to environmental factors.
Forestry Management, planning, and optimizing extraction and replanting.
Emergency services Optimizing fire, police, and ambulance routing; improved understanding of crime and its location.
Navigation Air, sea, and land.
Marketing Site location and target groups; optimizing goods delivery.
Real Estate Legal aspects of the cadastre, property values in relation to location, insurance.
Regional / local planning Development of plans, costing, maintenance, management.
Road and railway planning and management..
Site evaluation and costing.
Cut and fill, computing volumes of materials.
Social studies Analysis of demographic movements and developments.
Tourism Location and management of facilities and attractions.
Utilities Location, management, and planning of water, drains, gas, electricity, telephone, cable services.
The various phenomenon on the earth can be studied using geoinformatics, as river morphology.

4.3 River Morphology

River morphology, primarily, deals with the formation, of channels and their characteristics. Morphological studies, therefore, include plan form, length and width of the channels, slope and sediments distribution along with the rivers, cross sectional geometry, sediment loads in relation to discharge and river stability. The investigations are more aimed at to find out causes, which are responsible for behavior of a river in a particular manner. The studies also deal with the causes and sites of aggradations and degradation along the river course. Erosion caused by the rivers is one of major problems of rivers flowing through alluvial plains. River morphological observation of help in identification of areas undergoing serve bank erosion and taking appropriate river engineering measures to combat bank erosion. Construction of spurs, embankment, dykes, etc. are primarily dependent on the river behavior- its dynamic nature. River morphological studies are of prime requisite while planning for construction of dam, barrage, culverts and so on. Selection of sites for sediments gauge stations needs morphological information of the rivers [9].

4.4 Information needs

The data is available, in general, in the form of maps, reports, charts, tables, etc. Use of maps in river basins studies is indispensable. The maps quite often are available in different formats and scales. Most crucial component of the river basin studies is a reliable, comprehensive, compatible and recent data on various watershed characteristics. Most of the data available today on the network.

5. Conclusion

Geoinformatics has become an inevitable tool in recent times for research, planning and projections of various aspects of different fields of studies.

References

[1] Deosthali V.H. (2006) Lecture notes prepared for the UGC sponsored Refresher course in Earth sciences (March 1-21,2006), University of Pune, Pune.
[2] Burrough P.A. and Mc Donnell R.A. (2005) Principles of Geographical information systems, Oxford University Press. UK.
[3] George Josph (2005) Fundamentals of Remote sensing, 2nd Edition, Universities Press. Hyderabad.
[4] Lillesand T.M. and Kiefer R. (2003) Remote sensing and Image

Interpretation : 3rd Edition, John Willey. New York.
[5] Agarwal C.S. and Garg P.K. (2002) Texlbook on Remote sensing, wheeler publishing, New Delhi.
[6] Reddy A.M. (2001) Tetbook of Remote Sensing and Geographical Information System, 2nd edition B.S. Publication. Hyderabad.
[7] Star J. and Estes J. (1990) Geographic Information System An Introduction, Prentice Hall. New Jersey.
[8] http://en.wikipedia.org/wiki/GIS_file_formats#Raster_formats
[9] Naik S. D. (2001) Dynamic Fluviogeomorphology of Brahmputra river and its erosion aspects- a case study of Kaziranga National Park, Assam, The Deccan Geographer, 39(1), 84-90.