

Geoinformatics technological trends – expanding to diversified application areas

V. K. Dadhwal and P. L.N. Raju

Indian Institute of Remote Sensing (NRSA), Dehradun

Introduction

The computer based GIS concepts began to be explored in 1960s, originally in North America with significant contribution from US Bureau of Census, US Geological Survey and Harvard Laboratory of Computer Graphics. The government agencies as stated above discussed the possibilities of applying computer-based technology to handle numerical census data for deriving useful information and the first demonstration of these census analyses was done in late 60s (Tomlinson, R.F., 1987) by creating a mapping package called SYMAP capable of producing maps, particularly to create outputs for census data. Commercial agencies started to develop and offer GIS software since then. Notable among them are ESRI, Intergraph, Laserscan and AutoDesk etc. Early 1970s saw an era of research on stable data structures to store and analyze map data, which lead to the introduction of topology, which deals with spatial interrelationship with neighborhood objects, into GIS. Topology and the related graph theory proved to be effective and efficient tools to provide logically consistent two-dimensional data representations (Burrough, 1990). Several pioneering efforts were initiated during 70s and 80s in experimentation and practice of the technology with underlying concepts and procedures of modern GIS technology.

Emergence of Personal Computer in 1980s facilitated the real growth of GIS usage and also the advancement in the research front. During the early 80s, spatial database management systems (SDBMS) were developed with the linkage of computer mapping abilities with traditional database management systems (Burrough 1990). Relational database technology became standard and integral part of GIS for handling spatial/aspatial data. In this period data structure concepts were stabilized with accuracy standards and geospatial query functionalities were enhanced.

The 1990's earmarked the stabilization of GIS realizing the potential for many applications. Many

organizations started using GIS as a potential tool for widespread applications. This period saw breakthrough in various domains like object-orientation in system and database design, recognition of geoinformatics as a professional activity, and spatial information theory as the theoretical basis for GIS. Boom in Internet has contributed for developing GIS tools in World Wide Web. Increased use of World Wide Web has lead to the development of new Internet protocols, easy to use interfaces (browsers), tools and languages (XML, GML, .NET, Java), Web GIS, OPEN GIS.

21st century has revolutionized the usage of GIS by integrating a number of RS and spatial inputs and the GPS with the support of PDA. Parallel developments will make GIS a part and parcel of mobile communication devices for common man's need like finding information in a new place, e.g. the nearest ATM, hotels, emergency and utility services etc., through Location Based Services (LBS).

It is estimated that GIS market is growing at the rate of 10 – 15% annually and it contributed 15% out of the booming IT market. There is a huge market for GIS in the world and it is estimated that global expenditure on GIS software, hardware and services is US \$ 34 billion per annum (Venugopal and Senthil 2001). India alone is spending 200 Million US \$ annually (Gupta 2003). Out of the various GIS core business components (software, services, hardware and data products), software business revenues are 67%, major earners are being Environmental Systems Research Institute (ESRI), Intergraph that accounts for the half of the total revenues (Daratech report, 2003)

GIS: Progress from tool to science

Geographical Information System (GIS) has evolved from a mere powerful spatial technological tool into a Spatial Science covering broad spectrum of fields starting from survey, mapping, modeling, management to decision theory. A discussion forum launched to debate on "GIS is a tool or science?"

was initiated in 1993 brought out many views about GIS (Wright et. al, 1997): some strongly feel that it is considered merely a tool as it helps only in manipulation of spatial data, combines elements of computer science, geography and enabling technology in problem solving environment (Skelly (1993), Petican (1990), Groom (1993), Feldman (1993)). At the same time, many others argue that it is not only a tool but also it is definitely a science as it addresses vast issues such as understanding of modeling spatial phenomena (Carlson 1993), study of spatial data uncertainty and error, data lineage and how GIS is adopted by agencies (Wright et., al 1993), spatial data representation and developing algorithms to solve a problem and apply it to test a theory (Sandhu, 1993). According to some, GIS is considered as part of a broader information science (Wright et al., 1993), an environment as well as a method used to discover, explore, and test spatial theory (Laffey, 1993) and concepts that the tools seek facilitate, automate, and develop are strongly rooted in science (Bartlett, 1993). Amidst diverse views, growth of GIS is phenomenal and expanded to many areas like Environmental & Earth Sciences, Urban Planning & Infrastructure Development, Socio-Economic outreach, business enterprise and technological domains, converging them under geoinformatics umbrella and making itself an inevitable scientific field.

ICT – major boon for advances in Geoinformatics

Information and Communication Technology (ICT) has revolutionized and helped GIS to great extend. According to *Peter Croswell (2005)* five important trends have exerted profound influence on geotechnology industry and user community:

1. Pervasive high-performance computing
2. Digital connectivity
3. Geographic data capture and compilation
4. Geographic data management and visualization
5. Standards and open system

Moore (Moore's law) has predicted more than 25 years back that the processing power of computers doubles every 18 months for the same cost and this is true even today. Increase in processing speed, availability of computers at affordable cost, increase of analysis functionalities, and availability of web resources made it possible in expanding the scope of

GIS. In the last five years, hardware advances have offered GIS users a growing array of realistic and effective solutions for field and mobile computing needs as well.

The Internet has been a driver for overall IT development, and it forced the trend in digital connectivity. It has lead to the development of Internet GIS (also called web GIS), that has played a major role in expanding the GIS usage, helping the users to access the geoinformation at low cost in client-server environment and it will continue to further with standards and better services.

GIS technology has always been a tool for data visualization-portraying complex spatial data and patterns through the use of 2-D and 3-D maps and displays. Technology for the visualization of geographic information has taken significant leaps in the last 25 years. During this time, GIS users have seen tremendous advances in graphic display and large-format plotting. Realistic 3-D city models as well as 3-D environment data, atmosphere and ocean in individual horizontal layers can be investigated.

Open standards and specifications has become an issue due to the diverse formats and structures from different softwares have complicated the integration efforts. Over the last ten years major developments have taken place for the open standards and specifications. OCC (Open Geospatial Consortium), ISO-TC 211, GSDI and many others at world wide and country level played a key role in development of these standards and it is continuing to expand along with the ICT technological trends.

As indicated above, the technological trends can be categorized into five and summarized in the following table.

S.No	Category	Technological Trends
1	Data	Multispectral to Hyperspectral Low Spatial resolution to High Spatial resolution Mono imaging to Stereo Imaging
2	Hardware	Workstation to PC based PCs to Mobile / pocket PCs
3	Software	Desktop level to webbased GIS/Image analysis to Mobile GIS
4	Internet	Low bandwidth – Broad brand based Web services (Google Earth / Wekemia etc.)
5	Standards	Proprietary based standards to Open standards

As a whole the technological developments in geoinformatics lead to branch out to many areas. They are:

- Spatial multimedia
- Open GIS/ Free GIS
- GIS Customization
- Spatial Modeling
- Geo-Visualization
- Data Warehouse and large database handling
- Knowledge discovery and Data mining
- Geo-Computation
- Mobile GIS /Fleet Management / Location Based Services
- Web GIS /Distributed GIS
- Spatial Data Infrastructure and GeoInformation Management
- Digital Photogrammetry
- ALTM
- Sensor Web enablement
- Metadata and clearing houses
- Interoperability/Open standards and specifications

Geoinformatics Technological trends – India's contribution

In India, major developments have taken place during the last decade with significant contribution coming from Department of Space (DOS) emphasizing the GIS applications for Natural Resources Management. Notable among them are Integrated Mission for Sustainable Development (IMSD), Natural Resource Information System (NRIS) from ISRO / Department of Space, Decentralized Planning at village level and development of GRAM ++ from Department of Science and Technology, creation of resource database and information systems from different ministries from Government of India etc. DOS, DST, Geological Survey of India, Forest Survey of India, National Informatics Centre, Centre for Spatial Data Management System, State Remote Sensing Centres, Indian Institute of Technology centres, Universities and Colleges) have helped in expanding GIS usage in India.

India's National Spatial Data Infrastructure (NSDI) is a major inter-institutional recent initiative to establish geospatial database infrastructure for providing easy and open access of geoinformation to the users, which may trigger further expansion and growth of GIS research and applications. IIRS is also playing major role in GIS through education and training programs at the National and International level and is contributing towards Indian NSDI initiative through research and capacity building. (Raju, P.L.N. et al, 2005)

Role of IIRS in Geoinformatics Research and Technological trends

IIRS has developed limited expertise in some areas such as cellular automata, agent based modeling, cognitive mapping, fuzzy analytical hierarchy process, LBS, WebGIS, SDSS and geoinformation management for many application requirements (Table 2)

Table 2: Geoinformatics Technology Research at IIRS

S.No.	Research Areas	Applied for
1	Intelligent noise removing	For smoothing classified image
2	Cellular Automata	Land cover change
3	Agent based modeling	Urban sprawl
4	Cognitive Mapping	Forest certification
5	Fuzzy Analytical Hierarchy Process	Decision making
6	Location Based Services	Emergency services
7	WebGIS / InternetGIS	Biodiversity Information System
8	SDSS using multi-criteria analysis	Biodiversity conservation
9	Spatial Data Mining using Decision Tree technique	For better classification of an image
10	Geoinformation Management	Urban Process Business Reengineering
11	Multi-Objective Conflict Analysis	Wasteland Reclamation
12	Object Oriented Classification	Feature extraction

Table 3: A glimpse of possible research challenges in Geoinformatics

Sly. No.	Areas of Interest	Applications	Possible Geoinformatics Research areas
1	Environmental Sciences	Mapping & Distribution Analysis (all themes) Land Dynamics Hyper Spectral Analysis Disaster Preparedness	<ul style="list-style-type: none"> ● Spectral Reflectance Characterization and its influence <ul style="list-style-type: none"> ● Information Extraction techniques ● Data mining techniques ● Mapping level vs Resolution <ul style="list-style-type: none"> ● Sub-Pixel Characterization ● Scale Variation Vs. contextual relationships ● Multi-Resolution Crisp/Fuzzy Analysis ● Generalization Techniques ● Ontology (conceptual domain knowledge) ● Markov Chain Model ● Cellular Automata approach ● Agent Based Modeling ● Time synchronization in high level architecture ● Land subsidence through interferometry ● Spectral Library Creation & Matching ● Advanced classification algorithms ● Models for zonation and prediction ● Simulation 2D, 3D & 4D ● Networked data accessibility (NSDI and Natural Resource Repository (NRR) of DST and DOS initiatives)
2	Urban Planning and Infrastructure Development	Land Information System Planning Support System	<ul style="list-style-type: none"> ● Automated Feature Extraction (Object oriented Technique) ● Network Concepts and analytical algorithms ● Optimal allocation / disposal algorithms ● Urban Process Re-engineering in municipalities (Geoinformation Management) ● Demand/allocation/growth/migration influence on Master Plan development
3	Socio-Economic Development	Population Migration Economic Distribution Health Issues	<ul style="list-style-type: none"> ● Simulation algorithms ● Disease Dispersion pattern characterization and analysis ● Regional impact analysis (e.g., linking of rivers etc.) ● Village Resource Information System ● Neighborhood mapping
4	Business Enterprise	Marketing Strategies	<ul style="list-style-type: none"> ● Business Processes and spatial integration ● Workflow Management ● Potential resource identification and distribution strategies
5	Technology	DBMS GPS Mobile Devices ICT Location Based Service Digital Photogrammetry LIDAR	<ul style="list-style-type: none"> ● Object Oriented Data Models ● Geodetic controls ● Satellite based Automated Real-time distributed processing ● XML, GML integration ● Geospatial data visualization algorithms for mobile devices ● Protocols, Ontology Web Language, Wireless Application Protocol (WAP) ● Road and flyover discrimination ● 3D Visualisation of Urban Environment
6	Standards	Software Metadata Spatial Data Infrastructure	<ul style="list-style-type: none"> ● Interoperability models ● Certification Algorithms ● Accessibility issues in distributed environment ● Policies for Geoinformation Management

A glimpse of possible research challenges in geoinformatics that are of interest for IIRS perspective are given in the Table 3.

References

1. Bartlett, D. November 5, 1993a. Geography Department, Cork University, Ireland. Re: GIS as a Science [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available
e-mail: GISL@UBVM.CC.BUFFALO.EDU.
2. Burrough, P.A. (1990) - Principles of Geographical Information System for Land Resources Assessment.
3. Carlson, C. L. October 28, 1993a. Northern Illinois University. Re: Value of Peer Review [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available e-mail: GISL@UBVM.CC.BUFFALO.EDU.
4. Dartech Forecast (2003), Daratech Reports GIS Revenues Forecast to Grow 8% to \$1.75 billion in 2003; Utilities and Government Increase Spending. Website <http://www.daratech.com> accessed on 11.12.2004
5. Feldman, M. November 1, 1993a. Community Planning, University of Rhode Island. Re: GIS as a Science & Value of Peer Review [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available e-mail: GISL@UBVM.CC.BUFFALO.EDU.
6. Groom, A. November 1, 1993. Christchurch City Council, New Zealand. Re: Tool or Science? [Discussion]. *Geographic Information Systems Discussion List* [Online].
7. Gupta R 2003 Opensource GIS softwares - UNDP
8. Laffey, S. C. November 4, 1993. Department of Geography, Northern Illinois University. Re: GIS as a Science [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available
e-mail: GIS-L@UBVM.CC.BUFFALO.EDU.
9. Peter I. Croswell, 2005, Know the past to understand the present and future, Croswell is an executive consultant at PlanGraphics Inc.; website : <http://www.geoplance.com/uploads/OnlineExclusives/techtrends.asp> accessed on June 22, 2006.
10. Petican, D. J. October 29, 1993. University of Waterloo, Canada. Re: GIS as a Science [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available e-mail: GISL@UBVM.CC.BUFFALO.EDU.
11. Sandhu, J. November 1, 1993a. Environmental Systems Research Institute, Redlands. Re: GIS as a Science [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available
e-mail: GISL@UBVM.CC.BUFFALO.EDU.
12. Skelly, C. W. October 28, 1993a. James Cook University, Australia. GIS & Remote Sensing Research [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available e-mail: GIS-L@UBVM.CC.BUFFALO.EDU.
13. Tomlinson, R.F., 1987. "Current and potential uses of geographical information systems," The North American experience. *International Journal of Geographical Information Systems* 1:203-18.
14. Venugopal, K. and Senthil, R., 2001. Geomatics Education in India – A view point, 22nd Asian Conference on Remote Sensing, 5-9 November 2001, Singapore.
15. Wright, D. J. October 28, 1993a. Department of Geography, UC-Santa Barbara. Re: Value of Peer Review [Discussion]. *Geographic Information Systems Discussion List* [Online]. Available e-mail: GIS-L@UBVM.CC.BUFFALO.EDU
16. Wright, Dawn J., Goodchild, Michael F and Proctor, James D. (1997), "Demystifying the Persistent Ambiguity of GIS as "Tool" Versus "Science"" *Annals of the Association of American Geographers*, 87(2): 346-362, 1997.
17. P.L.N. Raju, Jeganathan C., Sameer Saran, Vandita Srivastava, Ram Mohan Rao and Dadhwal V.K., (2005), Research developments in Geoinformatics – Role of IIRS Vol.10,No.4 & Vol.11, No.1 Issue Dec 2004 & March 2005, page 41-53

About the Keynote Speaker



Dr. Vinay Kumar Dadhwal, (b April 9, 1957) is Dean, Indian Institute of Remote Sensing (NRSA), Hyderabad since July 2004, and currently also Director (In-charge), UN Centre for Space Science and Technology Education in Asia Pacific (UN CSSTE-AP), Dehradun. He graduated in Botany Honours from Delhi Univ. (1976) and obtained Masters (1978) & PhD (1983) in Plant Physiology from Indian Agricultural Research Institute, New Delhi.

During 1983 to 2004 he worked at Space Applications Centre (ISRO), Ahmedabad in various capacities, including Head, Crop Inventory & Modelling Division (1998-2004). He has extensive research experience in use of remote sensing for crop forecasting, irrigation monitoring, satellite agrometeorology and impact of sensor characteristics on agricultural applications. His research contributions also include carbon cycle modeling for terrestrial biosphere of India, crop simulation models and remote sensing based land surface datasets for climate models. He has co-authored 85 journal publications and many reports and has guided 2 PhD students.

Dr. Dadhwal is currently on Terrestrial Carbon Observation (TCO) Panel of Global Terrestrial Observation System (GTOS) of FAO, was Co-chair, Internat. Society Photogramm. & Remote Sensing (ISPRS) Working Group VII/6 (Monitoring Global Change) (2002-2004), Member, Transition Team, iLEAP of IGBP-II (2003). He received Indian Science Congress, Young Scientist Award (1987), Indian National Science Academy (INSA), Young Scientist Medal (1989), Indian National Remote Sensing Award (1999) and Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Award for Space Applications (1998-1999).

INVITED TALKS

ELECTROTECH ENTERPRISES

B-78/774, Gandhi Nagar, Bandra (E),
Mumbai-400 051, Maharashtra State, India.

Proprietor : **Shri. D.V. Karandikar**

B. E. Telecommunication

Contact : *Mobile: 9323821935*

Phone: 26426279

Manufacturers of :

- Electronic Equipments.
- Test Instruments and Educational Equipments.
- Specialized Research Equipments as per Customer's requirement.

Application of Regional GIS data bases in effective planning and implementation in developmental activities - An Example of Chhattisgarh State

Dr. Ashok Kumar Joshi¹, Dr. Y. V. N. Krishna Murthy² and Dr. V. Jayaraman³

1. Regional Remote Sensing Service Centre, Department of Space

2. Govt. of India, Post Box 439 Shankar Nagar, Nagpur – 440 010

3. NNRMS-RRSSC, ISRO Headquarter, New BEL Road, Bangalore

In order to optimize and sustain outputs from primary systems to meet the growing demands of rising population, developmental planning with integrated approach has been accepted world over. This approach helps optimal management and better utilization of natural resources towards improving living condition of the people. The practical approach in planning directed at preservation, conservation, development and management of natural resources of the region for the benefit of people has to operate within the framework of physical and biological attributes, socio-economic conditions and institutional constraints. The physical and biological attributes comprise baseline data on geology, hydrology, soil, land use / land cover, climate, demography, flora and fauna. Socio-economic condition relates to information on basic needs of people, input-output relationship, marketing and transportation arrangement, developmental incentives and facilities, such as technologies, equipments, labor, material, energy/power etc. Institutional constraints relate to laws, regulations and ordinances; Governmental policies and priorities; political acceptability; accepted customs, beliefs and requirements of the people, and administrative support.

The newly formed State of Chhattisgarh is endowed with natural resources like forest (44%); mineral resources like Coal, Iron, Limestone, Bauxite, Dolomite and Tin; rich in flora and fauna; wide range of crops and cropping pattern with paddy as the major crop and cultural diversity. The geographical area of Chhattisgarh comprises 1,35,000 sq km with a population of 20.80 Million and density of 154 persons / sq km with a decennial growth of 18%. The percentage of rural population is around 80%; and the percentage of SC and ST population is 12% and 32%, respectively total amounting to 44.6% and the total literacy rate is 65%.

Chhattisgarh constitutes 16 districts with 98 tahsils and 20308 revenue villages. The multiplicity of natural resources and their uses and the conflicts it may cause among the stakeholders and various interests makes its planning at different level to be considerably complex. Hence, database of Natural Resources, Socioeconomic, Infrastructure and other collateral information is prerequisite for project planing, implementation and impact assessment.

The focal point from the Govt. of Chhattisgarh is CHiPS and in collaboration with Regional Remote Sensing Service Centre, Nagpur, ISRO/DOS, to implement the project within the time frame of 24 months. This project involves –

- i. **Generation of natural resources database** for the State of Chhattisgarh on 1:50000 scale using IRS LISS-III data
- ii. **Development of spatial database for road network** using IRS PAN data
- iii. **Go-referencing of village (cadastral) maps** using high resolution IRS PAN + LISS-III data.

This mammoth task has been planned and organized, by RRSSC, Nagpur with the participation of 12 entrepreneurs having a support technical staff of more than 300. Stringent quality check procedures have been adopted for the generation of digital databases; with periodic validation by the respective user departments. NNRMS standards and codification scheme has been adopted for the digital databases for the seamless data retrieval across the State through district, tahsils and village, and further linking with the geo-referenced village (cadastral) maps.

Integration of natural resources information facilitates in identifying the potentials and limitations of different parcels of land and when matched against

the demand, alternative suggestions are developed within the unrealized production potential for both the land and water resources.

The overlay of geo-referenced village (cadastral) maps on the satellite data is providing invaluable information for better planning of rural development programmes. Many examples have been demonstrated to the officials of the state government, NGOs and other related institutions on effective use of this technology for better management of rural resources. Some of the observations are -

- Drainages not shown in the existing maps and cadastral maps have been updated from high-resolution satellite data which are vital for water conservation.
- Micro watershed boundaries could be delineated even in relatively flat areas.
- Mapping and monitoring of inherent soil moisture available along drainages in different kind of terrains.
- Identification and prioritization of silted small and medium water bodies and village tanks for de-silting purpose.
- Identification of eroded lands that need to be treated in the upstream of the water bodies.
- Locating suitable wastelands for energy plantation in the catchments of village tanks.
- Identification of survey numbers (farmers) that are affected by natural calamities for compensation.
- Identification of water-logged and salt-affected lands, survey number-wise for treatment and reclamation.
- Collection of water levy for the water being provided through various irrigation schemes to farmers growing cash-crops.

In general, satellite data has been used for mapping natural resources, and derive land and water resources development plan upto micro-watershed level for implementation through state government. To assist in implementation of such plans and identifying the beneficiaries, the action plans have been transferred on cadastral maps. Since the watershed is a natural management unit, the villages falling within a watershed have been geo-referenced using high-resolution satellite data and mosaiced to

identify the beneficiaries from ridge to valley.

Implementation of the action plans in the field is a complex process as it involves the transfer of the technology from lab to land. In most of the cases the administrative head of Zilla Parishad is the nodal officer for plan implementation with active participation of officials from line departments, non-governmental organizations (NGOs), voluntary agencies, Self Help Groups and progressive farmers. The prescriptive measures in the developmental planning include area specific activities like check dams, nala bunds, continuous-contour-trenches (C.C.T.), social forestry etc. and locale specific activities like tube wells, farm ponds, paddy bunding, agro-forestry etc.

The funding for the plan implementation emphasizes the involvement of individual farmer and also should benefit certain strata of society i.e. landless population, below poverty line population, small and marginal farmers, target group population etc. Depending upon the socio-economic status of the farmer, the associated beneficiaries, and the nature of activity, the funding norms will vary. The ownership of land under study is a pre-requisite to identify the individual farmer; his socio-economic status and his willingness to participate in developmental programmes, which play a major role in successful implementation of the action plan in the field.

The cadastral maps that have the parcel boundaries, which define the land ownership, do not have any geodetic coordinates. Hence it limits the direct access to the landowners, the databases on the potential of their land and developmental alternatives that are populated on geodetic coordinates. To meet such a requirement, a unique approach and methodology has been developed to geo-reference the cadastral maps with the high resolution satellite data providing seamless access to the databases and resultant action plans from regional level to local level. This has given a breakthrough in reaching the people, understanding their requirements and refining the action plans of land and water resource development involving the local wisdom. Further it has also facilitated the monitoring the impact of plan implementation at watershed level as well as the economic benefits accrued to individual farmers. This technique has facilitated in monitoring survey number-wise impact of the developmental activity in the watershed on temporal basis.