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Geoinformatics: A blend of geospatial information technologies for regional development

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Abstract

Geoinformatics is a science dealing with the geospatial information, principally informatics, acquisition systems and digital data processing. There are many disciplines and techniques which are constituting to the geoinformatics namely, geomatics, geodesy, photogrammetry, remote sensing, geographic information systems, cartography, global navigation and positioning satellite systems, decision support systems, and Web-GIS for mapping. So, the geoinformatics is the integration of different disciplines dealing with geospatial information and technologies. The new technological revolution impacted to the functionality of geoinformatics, especially in many disciplines which were progressed rapidly over recent past like processing of observations to the GIS, DSS, and expert systems.

Geoinformatics technology provides the emphasis for community involvement on a large scale for testing to enhance and retain earth sciences research for the betterment of the humanity. So, the spatial and non-spatial information storage into digital form and the interlinkages between them can be made on the basis of geographic proximity. The data availability from different geographical regions can often proposes for new insights and explanations of the world. Such interconnection are often possible with the help of Geoinformatics which is playing a vital role in understanding and managing earth resources for sustainable development. So, the high-quality education and professional oriented training in geoinformatics will definitely open large avenues for job opportunities at the local, regional and global levels for the regional development and planning.

Keywords: Geoinformatics, geospatial technologies, geospatial information, experts systems, regional development

Introduction

Geoinformatics is the integration of different disciplines dealing with geospatial information. Geospatial information is forever related to geographic space. It signifies to the immediate geographic world. Geographic space is the space of topography, landuse/landcover, climatic, cadastral, and other landscape features of geographic world. Geographic information systems technology is applied to manipulate objects in geographic space, and to obtain information from spatial facts (Goodchild, 1992) [29]. Spatial data management encompasses many disciplines. Each of these disciplines are differentiated on the basis of characteristics as firstly, the advancement of spatial notions: geography, reasoning science, linguistics, psychology; secondly, the procedure of capturing and processing of spatial data: remote sensing, photogrammetry, surveying and cartography; thirdly, the formal and theoretical foundation: computer science, expert systems, mathematics, statistics; fourthly, the application fields: geographical analysis, environmental sciences, geosciences, biosciences, urban and regional development and planning (Goodchild, 2004) [30].

In order to share the geospatial information, the Global Spatial Data Infrastructure (GSDI) facility was set-up for international information cooperation which came into existence in July 2003. The term spatial data information was officially introduced as information related to three-dimensional space to the terrestrial globe (Crompvoets, *et al*., 2004) [23]. The fundamental objective of the GSDI organization is to encourage international cooperation and collaboration in support of local, national, and international spatial data infrastructure developments which will allow all the nations to better address their social, economic, and environmental issues at large. So, the geospatial information is a good definition of the space which is measured, described, and represented in its three dimensions and to be made available over and over again (Burrough and McDonnell, 1998) [14].

More recently, there have been emerged the enterprise geodatabase as the central storehouse for spatial data, handling. It provides continuous data without tile edges, in an open relational database such as Dbase 2®, Oracle®, Informix®, and SQL Server™. All these facilitates to the production of a wide range of valuable analytical and cartographical products. Though, it is centred on a geodatabase that not only supplies the major seamless GIS data; but also provides the full specifications, procedures, and outcomes for all products along with the freedom and tools to create top-quality cartography in real time (Chang, 2008) [17].

So, the noteworthy issues like the global climate change and shrinking resources have heightened our awareness that how much humanity depends on the dynamic and complex systems of the earth's environment. For judicious management of the existing resources and excavating new ones in view of the environment sustainability requires an enhanced level of cooperation and a sensible usage of our growing geo-databases, at large (Clarke, *et al*., 2006) [18]. So, the geoinformatics is the integration of different disciplines dealing with geospatial information i.e. informatics, geodesy and thematic data as schematically presented in the Figure 1.1.

Earlier, a term similar to geoinformatics and sometimes used synonymous to this is geomatics. It was initially introduced in Canada, and became standard term in French speaking countries. Laurini and Thompson (1992) refer to it as "the fusion of ideas from geosciences and informatics". The term geomatics, nevertheless, was not ever fully recognised in the United States where the term geographic information science (GIS) is preferred. In view of this, the GIS is defined as "research on the generic issues that surround the use of GIS technology, impede its successful implementation, or emerge from an understanding of its potential capabilities" (Goodchild, 1992) [29].

Geoinformatics is a new discipline and broadly defined as technical science. It has been developed from informatics and geodesy as specialised information technology to work with different thematic data which are referenced to geographic location. The main objective of geoinformatics is to collect, store, analyse and visualise data with the help of computer. Geoinformatics is an essential tool of planning and monitoring of the social and economic development. Besides this, it involves many technical processes and at the same time is a progressive technical science focussing on the theoretical and technical background. However, the geoinformatics is an assimilation of the geospatial databases, geospatial analyses, modelling, human-computer interaction (Ehlers, 1993) [27], both wired and wireless technologies for solutions to the real world problems.

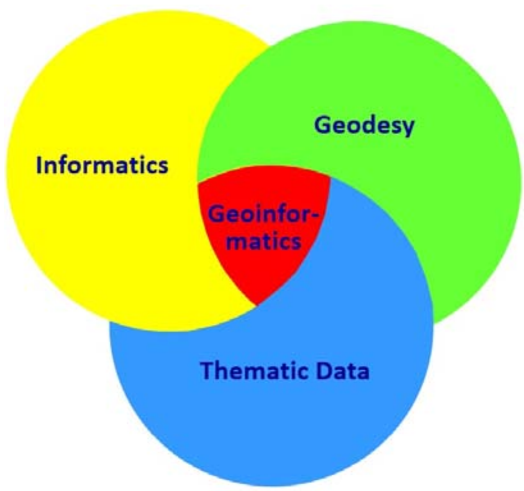

Fig 1.1: Geoinformatics and background sciences.

There are numerous opinions concerning to the definitional aspect of the geoinformatics. It is naturally significant to all the disciplines which use data identified by their locations. Geoinformatics deals with spatial and non-spatial data, their methods of acquisition, management, analysis, display, and dissemination. In addition to this, it is "the scientific field that attempts to integrate different disciplines studying the methods and techniques of handling spatial information" (Heywood, *et al*., 2009) [35]. In lieu of this, the geoinformatics has also been described as "the science and technology dealing with the structure and character of spatial information, its capture, its classification and qualification, its storage, processing, portrayal and dissemination, including the infrastructure necessary to secure optimal use of this information". Likewise, it is defined as "the art, science or technology dealing with the acquisition, storage, processing, production, presentation and dissemination of geoinformation" (Ehlers, 1993) [27]. In other words, the geoinformatics is defined as "the science and technology of measuring, storing, organising, analysing, visualising data related to phenomena occurring on or near the earth's surface". So, the geoinformatics is one of the widely used geospatial science using the latest technology which is dealing with solutions for the regional real world problems based on analyses of the information related to the earth.

Geography

The Geography possesses an inherent unambiguous and an epistemological self-sufficiency such as to offer effective tools for an understanding of the real world. The scholarly work of geography encompasses to a vast range of natural anthropical phenomena. Geography, in fact, is based on the discoveries of physical and human sciences, performs an explanatory synthesis in order to examine interactions, causes, effects, and evolutionary propensities (Goodchild, 1992 and 2004) [29, 30]. Geography is a succeeding and productive means to accomplish accurate environmental, provincial and regional strategies (Gomarasca, 2007) as is presented through the Figure 1.2.

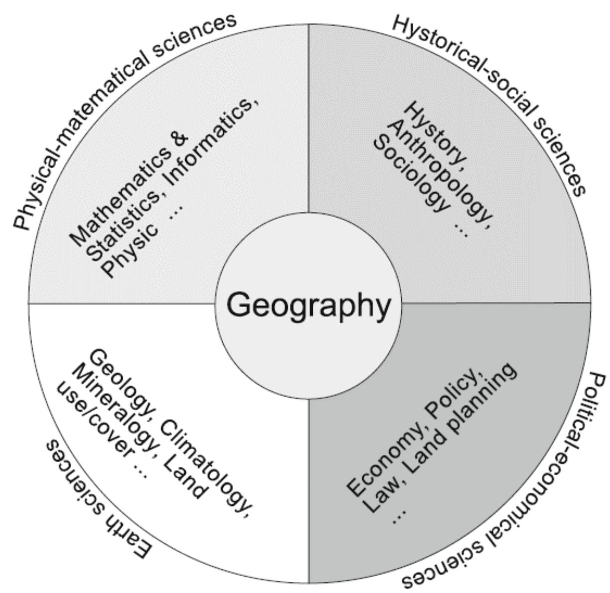

Fig 1.2: Schematic Depiction of Sub-Disciplines of Geography.

The Geography of settlement investigate to study the condition of humans on the physical landscape and the relationships between organized human societies and natural environments, in context to the terrestrial geosystem and in each one of the ecosystem at different scales at the local, regional and global levels (Livingstone, 1992) [49]. During investigation of phenomena, the perceptions, interactions, hierarchies, and different developments correspond to each other. The whereabouts of any kind of phenomenon cannot therefore be confined to an absolute analysis. Rather, it must be understood in relation to increasing extent of the situations (Lo, 2009) [50]. So, such a situation must not be understood as the location of a place only. But it must comprehend the concepts of distribution, association, and spatial concentration. In such a way, the distance can not only be metrical; but it can also be temporal, economical, and social in nature.

The term topography is defined as topo means place and graphia means writing. The topography is basically concerning with the graphical and metric description of sites and situations of the physical landscape exists on surface of the earth (Zebker and Goldstein, 1986) [73]. Until the 18th Century, the topography as a discipline was defined as practical geometry. Its main functional characteristic was the survey and subsequently representation of the territory. The study of topography was started with and as part of the geodesy. The field of topography is a combination of procedures for direct land survey. So the topography is a combination of methods and tools to comprehensively measure and represent details of the earth's surface as the planimetry, altimetry, tachymetry and land surveying of the real world.

For instance, the planimetry method is applied to determine the relative positions by the representation of points on the earth's surface with reference to the same surface orientation. Whereas, the altimetry is concerned to determine the height of the points on the earth's surface with reference to the geoid surface (Seeber, 1993) [63]. In addition to this, tachymetry is useful and applied for both the planimetric and altimetric survey zone's of the earth's surface. So, the land surveying is used to conduct fields plotting for the measurement of areas. Such land surveying also takes into account the transfer and rectification of land parcel borders, and level zones of the physical surface of the earth.

Cartography

Cartography is the art and science of making maps. Maps have a long history. The earliest maps date back to 6000 B.C., the prehistoric wall paintings. Moreover, the cartography has been resultant of the continuous development of human skills for more than 4,000 years. Over this period, a range of methods and techniques have been evolved to ensure clarity of communication while maximizing the usefulness of the map contents (Beishlag, 1951) [6]. In order to create high-quality cartography there requires the use of appropriate modern technology. Such technological involvement delivers efficient processes which strengthen to the human creative and expressive skills in order to communicate the essential spatial message effectively in this information technology age.

The Cartography is used to supply a possible explanation of the shape and dimension of the earth and its natural and artificial details, through graphical or numerical representation of more or less wide areas, subsequently following static procedures (Lawrence, 1971) [46]. In other words, a map is a graphic representation of particular part of the earth's surface based on precise rules. At the global level, the International Association of Cartography (IAC) defined to cartography as "a discipline dealing with the conception, production, distribution, and study of maps". Besides this, "a map is a symbolised image of geographic reality, representing selected features or characteristics, resulting from the creative effort of its author's choices, and it is designed for use when spatial relationships are of primary relevance".

It is a fact that the cartography takes advantage of traditional domains of knowledge such as physics, geometry, design, geography, engineering, in addition to this, during the last century, of operational statistics and numerical calculation through electronics for the demanding explanation of the facts. Cartography also has a straight connexion with other disciplines for measuring and representing the physical surface of the earth "from its extensive complexity to its smaller detail" (Harvey, 2009) [34]. So, the attention should be drawn to the use of the terms representation and projection of surface of the earth, which is a composite arrangement and cannot be substituted with a geometric characteristics. It would be more appropriate to recommend representation on a plane of the reference surface rather than projection of the earth surface. Because the representation of the earth's curved surfaces on a plane involves many situations like stretching, shrinking, and tearing which ultimately resulting into the interruptions. So, as a matter of fact, it is simple to applying the laws of projective geometry, in this way an area of the earth's surface is considered projected from a particular point of view while spread over the three basic projection surfaces as the plane, cylinder and geometric projection for the real world surface.

A map typically comprises by a series of real themes or a number of coverages or layers that are often combined to produce the final product as a map, especially in case of ESRI. A map also holds descriptive information as a legend which help in detailed interpretation of the map (Monmonier, 1985) [55]. A map can also offers an interpretation for landscape features of the earth's surface. Several map layout components are like scale, units and data layers in form of themes or coverages which are the inherent part of a cartography. This not only allows users to perform spatial queries; but also to measure distances. Such as, the map scale expresses to the user that how the map relates to the represented real world features. There are several ways of representation of map scales. Universally, it describes the relation between a particular map units to the number of same units in the real world. For instance, it is presented as 1: 1000. This scale represents that 1 inch on the map is equivalent to 1000 inches in the real world. In other words, it also communicates the map units to an established real-world unit of measure, such as 1 inch equal to 2.5 miles (Lawrence, 1971) [46]. So, all these ways assist to the users to measure the real-world distances on the map.

Over the periods, a number of organizations have been involved in production of cartographic standard products world widely. This is the resultant effects of the several international, national and regional mapping agencies working for both the civilian and military purposes. For instance, the United States Geological Survey (USGS), Ordnance Survey in Great Britain, Survey of India (SOI). The Open GIS Consortium (OGC) proposed for the Open Web Services (OWS) to avail geoservices to the people. Actually, the Geoservices are web based services for any kind of geoinformation. Geovisualization services are of the utmost interest in mobile cartography. So, at present, the cartographic solution is laid on the geodatabase which is providing a logical, structured framework to store data for cartographic production and presentation (Kraak and Ormeling 2003; MacEachen and Kraak, 2001; MacEachen and Monmonier, 1992) [43, 41, 53]. Many cartographic organizations desired to centralize database in order to avoid the fragmentation and inefficiencies by the individual and group users. In this context, there is ongoing need to place GIS and Cartography into the world of enterprise information technology (IT). This would definitely help to take advantage of commodity facilities for backup, data replication, and data management at the local, regional and global levels.

Geoinformatics: Disciplines and Technologies

Geoinformatics is a science dealing with the geospatial information, principally informatics, acquisition systems and digital data processing. There are many disciplines and techniques which are constituting to the geoinformatics namely, geomatics, geodesy, photogrammetry, remote sensing, geographic information systems, cartography, global navigation and positioning satellite systems, decision support systems, and Web-GIS for mapping (Konecny, 2003 and Yang *et al.*, 2011) [40, 72]. So, the geoinformatics is the integration of different disciplines dealing with geospatial information and technologies which are discussed in the following paragraphs.

The Geomatics is primarily concerned with the survey of the earth. The Geodesy is the scientific discipline that deals with the measurement and representation of the earth. The Photogrammetry is a science which deal with the preparation and determining of the geometric properties of objects from aerial photographic images (Philipson, 1997) [59]. The Remote Sensing takes into account to the acquisition of information about an object or phenomenon, without making physical contact with the object. The Geographic information systems deals with the data capture, storage, analysis, management and presentation with reference to geographic location (Schuurman, 2004) [62]. The Cartography is an art and science which is dealing with the study and practice of map making. The Global navigation satellite system is a system of satellites that provide autonomous geospatial positioning with global coverage. The Web-GIS mapping involves to the process of designing, implementing, generating and delivering maps on the World Wide Web (Peng and Tosu, 2003) [57].

Earlier, the geoinformation process could be separated into individual disciplines, such as surveying, geodesy, photogrammetry, remote sensing, and cartography during the analogue mapping era. Presently, there are different data acquisition methods such as terrestrial GPS-surveys, aerial photogrammetry, satellite photogrammetry, laser scanning, photo interpretation, digital processing of remotely sensed images which are themselves competing each other in term of the excellence and expenses (Avery, 1992) [5]. In this context, these disciplines and technologies application must have been geared corresponding to the global, regional or local levels. So, over the periods, it is not surprising that "geomatics", "geo-informatics" or "geoinformation" emerged as a new integrated academic disciplines (Konecny, 2003) [40] which is schematically presented in the Figure 1.3.

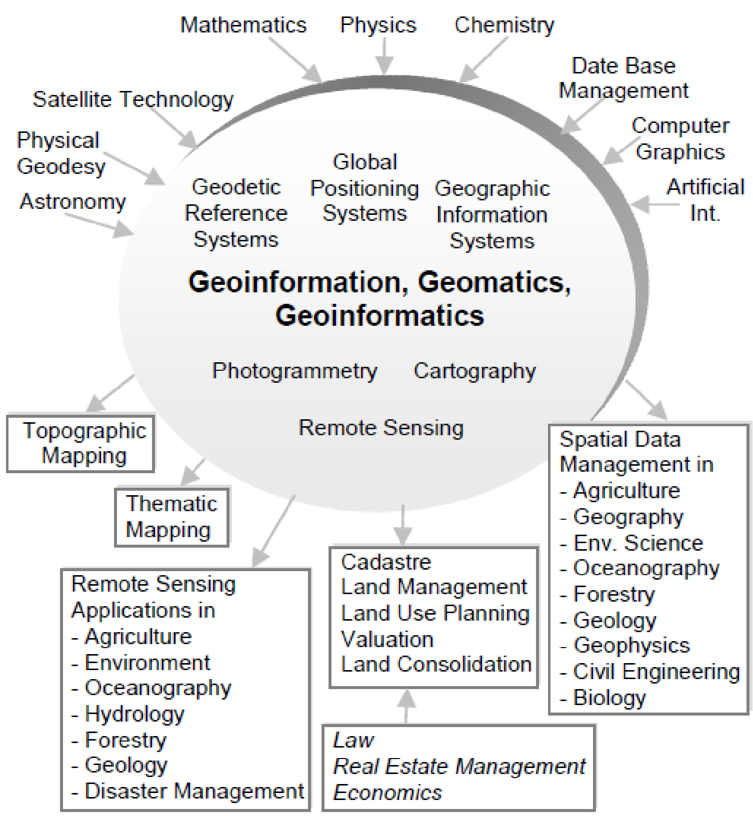

Fig 1.3: Schematic Development of Geoinformation, Geomatics and Geoinformatics.

Geomatics

The geomatics is simplified to comprehend by layman as the *geo* means earth and the *matics* means the informatics. The term geomatics was created at Laval University in Canada in the early 1980's, based on the concept that the increasing potential of electronic computing was revolutionizing surveys which gave representation to it as a science. So, the geomatics is defined as "a systemic, multidisciplinary, integrated approach to selecting the instruments and the appropriate techniques for collecting, storing, integrating, modelling, analysing, retrieving at will, transforming, displaying, and distributing spatially georeferenced data from different sources with well-defined accuracy characteristics and continuity in a digital format" (Yang *et al*., 2011) [72]. So, a large number of initiatives have been taken to develop world widely usage of geomatics as a discipline and its techniques for the directive of geospatial information. More clearly, the geo-information takes into account the adequate use of earth observation data for studying, managing and solution for the real world problems as the environmental hazards and risks assessment and so on.

Geodesy

The Geodesy is the science which describes the shape and dimension of the earth. In other words, the geodesy purposes at the determination of the geometrical and physical shape of the earth and its orientation in context to the space. The branch of geodesy is primarily concerned with determining the physical shape of the earth which is called as physical geodesy. The Physical geodesy is different from other geomatics sub-disciplines because it is mainly concerned with field quantities as the scalar potential field or the sectorial gravity and gravitational fields. All these are continuous quantities, as opposed to point fields, networks, pixels, etc., which are discrete by nature.

There are two branches of the geodesy as the gravimetry and the positioning astronomy. The former branch determines the earth's gravity and its anomalies. The earth's gravity determines shape of the earth. The geoid is the equipotential surface of the gravitational field. The Gravity field theory uses a number of tools from mathematics and physics. For instance, the Newtonian gravitation theory which is relatively not required at present. In lieu of this, there are the potential theory, vector calculus, special functions (legendre), partial differential equations, boundary value problems and signal processing (Seeber, 1993) [63]. So, the gravity field theory is intermingling with many other disciplines. A few instances may explain the importance of physical geodesy to individual disciplines. The Earth science disciplines are rather operating on a global scale than the engineering applications which are found more pronounced to the local scenario. Although, this difference is not fundamental in nature.

Whereas, the positioning astronomy is the second branch of geodesy. It is used for determining the position of the points on the globe through the observation of stars and artificial satellites, which are referred to the laws of celestial mechanism. So, the geodesy is primarily concerned to determine the shape and the size of the earth. It defines the surface of reference in its complete form, the geoid, as well as in its simplified form, the ellipsoid on the one hand. And, the external gravitational field as a function of time on the other hand.

Photogrammetry

Photogrammetry was introduced in the nineteenth century. The photogrammetry is applied for processing of metric detailed information about an object through measurements made on aerial photograph. So, the qualitative information about an object are obtained through the photo interpretation process (Wolf, 2001) [67]. Accordingly, the meaning of photogrammetry and photo interpretation have been extended from classical photo interpretation to the usage of digital aerial photograph processing and interpretation through the application of computer analysis techniques to digital aerial photographs (Avery and Berlin, 1992) [5]. However, the photogrammetry is defined as the "art, science and technology to obtain valid information about physical objects and the environment, through the processes of collection, measure and interpretation of images (photographic or digital) and analogue or digital representation of the models of electromagnetic energy derived from survey systems (photographic cameras or scanning systems), without contact with the objects" (Kasser and Engles, 2002) [39].

Photogrammetry is also used to determine the position and shapes of the objects through measurement techniques from the aerial photograph. The photogrammetry is one of the important source for most of the data on topography such as the ground surface elevations, spot heights, relief features and so on which are based on accurate measurement techniques from the aerial photographs. More recently, there have been the fast development in the digital photogrammetry which is taken over to the analogue photogrammetry (Linder, 2009) [48]. In this process, the digital camera systems are carried on aeroplanes and even on space craft's for space digital photogrammetry, typically from above the ground or surface of the earth.

It is worthy to note that both the traditional (analogue) and digital photogrammetries are based on the same fundamental principles. Due to the fast technological development in digital photogrammetry, especially with the availability of high-resolution satellite data which appeals to reconsider the traditional approach of the central perspective in photogrammetry (Rabus, *et al*., 2003) [60]. Whereas, the photogrammetry is moving from its formalisms towards more complex projective geometries which are more connected with the acquisition methods of satellite imagery and new aerial photogrammetric digital cameras. So, such rigorous reconstruction of the geometric correspondence between image and object at the moment of data procurement remains the principal scope for the development of the digital photogrammetry.

Remote Sensing

The remote sensing was introduced since the early 1970's. Remote sensing is used to acquire territorial and environmental data along with different methods and techniques for successive processing and interpretation. In other words, the remote sensing encompasses the use of instruments or sensors to capture the spectral and spatial relations of objects and materials recognisable at a distance normally from above the earth's surface by the satellites (Lillisand, *et al*., 2004) [47]. The remote sensing satellite data with reference to the same area are collected periodically which may vary from a few hours, days to some weeks. This provides the possibility to provide an updated stereo data for 3-D thematic cartography. There is the only limit which is represented by the geometric resolution of the sensors with respect to the geometric precision of a map. So, the remote sensing takes into account to both the acquisition from a distance of qualitative as well as the quantitative information with reference to any site and the situation of the surface of the earth. In addition to this, there are number of methods and techniques which are subsequently used for the elaboration and interpretation of the remote sensing data.

The remote sensing includes techniques which are used to derive information for a site at a known distance from the sensor. There are two types, the active and passive remote sensing. In case of the former, the passive remote sensing, the source of information is obtained through the scattered or absorbed solar and emitted thermal radiation of earth. Such forms of electromagnetic radiation allows to study and characterize objects through their spectrally variable response obtained from the earth's surface. All the elements on the earth surface reflects, absorbs, and transmits amount of an incident radiation to different proportions according to the structural, chemical, and chromatic qualities of various properties. On the basis of electromagnetic radiance, the information is reaching to the sensor from the objects situated on the earth surface. So, the passive remote sensing is centred on the solar radiation which is intermittently emitted the most recognised source of energy from the Sun (Atkinson, *et al*., 2013) [4]. Whereas, in case of the active remote sensing, the sensor itself is having its own source of energy, so it function both ways at the same time the emitter and receiver of the electromagnetic energy. For instance, the active remote sensing principle is used by the Radio Detection and Ranging (RADAR) system for collection of information. In other worlds, the RADAR remote sensing system is built on the principle of the emission and successive recording of the returning signal (backscattering) by which the distance of an object is determined through the microwaves which wavelength is normally ranging between 1 mm to 1 m (meter) (Bloom, 1982) [8].

Remote sensing technology is extensively used in various field as the geology, geochemistry, lithology, mineral exploration, geomorphology, hydrology, meteorology oceanography, biology, biogeography etc. In addition to this, it is also valuable for the studies of classification of agricultural and forestry resources, permanent land monitoring, urban planning and development, disaster management and risk assessment and so on. In this context, there are wide applications of the remote sensing particularly in environmental sciences for environmental pollution monitoring as well as the natural resources exploration, management and sustainable development (Green, *et al*., 1994) [32]. In spite of the facts that there are many limitations of remote sensing, a considerable increase has been witnessed both in the number of missions over the periods. It is important to mention that there is continuous technological advancements and developments which have been responsible in enhancement of the geometric, temporal, radiometric, and spectral resolutions. By and large, such kinds of technological improvements naturally impacted to the territorial planning, natural land resources mapping and management, and in monitoring environmental dynamic processes. So, the photogrammetry and remote sensing are principal tools for acquisition and processing of data and subsequently its management by the geographic information systems, by way of the analyses and visualisation of the geoinformation which forms an indispensable part of present time for various purposes of planning and development at the various levels. So, it does not make sense anymore to consider topographic and thematic mapping by photogrammetry and remote sensing separate from geographic information systems.

Geographic Information Systems

The Geographic Information Systems (GIS) origin dates back to the 1960's, in the second half of the twentieth century. The initial developments were originated in the North America with the organizations such as US Bureau of the Census (USBC), the US Geological Survey (USGS) and the Harvard Laboratory for Computer Graphics (HLCG) and the Environmental Systems Research Institute (ESRI) as a commercial organisation. In the rest of the world, other major originators were the Canadian Geographic Information Systems (CGIS) in Canada, Natural Experimental Research Centre (NREC), Department of Environment (DOE) and the notable organizations in United Kingdom (UK). All these organisation were involved in early developments of the GIS. In addition to this, the laboratory for Computer Graphics and Spatial Analysis of the Harvard Graduate School of Design (HGSD) or the State University of New York (SUNY) at Buffalo, United Kindgom also achieved worldwide recognition in GIS (Campbell and Ian, 1995) [15]. Since then, the commercial agencies were started to develop and offer GIS softwares. Among them the toady's market leaders are as the ESRI, Intergraph, Autodesk, etc.

In India, the major developments have been taken place for over the last two-decades, particularly with significant contribution of the Department of Space (DOS) with the emphasis on the GIS applications for Natural Resources Management. Noteworthy to mention among them are the Natural Resource Information System (NRIS), Integrated Mission for Sustainable Development (IMSD) and Bio-diversity Characterisation at National Level. Along with this, the Indian Institute of Remote Sensing (IIRS) is also playing an important role through dissemination of education and training programs in GIS at the National and International levels. More recently, a number of the commercial organizations have realized the importance of GIS for many applications like the natural resource management, infrastructure development, facility management, business and market applications in the country, India.

The Geographical Information Systems is based on the powerful combination of technological equipments capable of unloading, recording, updating, transforming, representing, and processing georeferenced spatial data (Wise, 2002) [66]. GIS applied to produce useful results and their analysis on the basis of relational databases with spatial interpretation and outputs often in form of tables and maps. So, the GIS can be described as the computer-based programme for capturing, storing, checking, integrating, analysing and displaying data which is spatially referenced to the earth.

In spite of the facts that there have been lots of development in the field of GIS, there is no clear-cut unanimous definition. By and large, the different people have different opinions regarding the concept of GIS definition on the basis of its capability and purpose. In this context, some of the well know views and definitions of GIS are expressed as "a computer-assisted system for the capture, storage, retrieval, analysis and display of spatial data, within a particular Organization" (Clarke, *et al*., 2006) [19]; likewise "a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world" (Burrough, 1987) [12]; similarly "a computer-based system that provides the following four sets of capabilities to handle georeferenced data: input, data management (data storage and retrieval), manipulation and analysis, and Output" (Aronoff, 1989) [2]; and also taken into consideration to development as "an internally referenced, automated, spatial information system".

Moreover, it is "a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the earth". Similarly, it is "an institutional entity, reflecting an organisational structure that integrate technology with a database, expertise and continuing financial support over time" (Bonham-Carter, 1994) [9]. Besides this, it is "an information technology which stores, analyses and display both spatial and non-spatial data". In view of this, it is "a special case of information systems where the database consists of observation of spatially distributed features, activities, or events, which are definable in space as points, lines or areas. A GIS manipulate data about these points, line or areas to retrieve data for ad hoc queries and analyses". And, it is also "a database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database". In lieu of this, it is "an automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation and display of geographically located data". Often, it is summaries as "a decision support system involving the integration of spatially referenced data in a problem solving environment" (Cowen, 1988) [21]. And, it is "a system with advanced geo-modelling capabilities". And, also, it is "a form of management information system (MIS) that allow map display of the general information".

Although, all these above described definitions covered wide range of subjects and activities for the best refer to geographical information. Occasionally, it is also termed as Spatial Information Systems because it deals with locational data, for objects positioned in any geographical space (Worrall, 1990) [70]. Similarly, the term 'a spatial data' is often used as a synonym for attribute data. For instance, the local weather is constituted by the rainfall, temperature, pressure, wind direction etc. attributes. So, the commonly used technical terms in spatial data handling are the Geographic Information Systems (GIS), Geo-information System, Spatial Information System (SIS), Land Information System (LIS), and Multi-purpose Cadastre System (Worboys, 1998) [68]. Hence, the geographic information systems is used and applied for various geospatial analyses by different disciplines as a tool for spatial data handling in the geoinformatics environment.

In GIS environment, the locations on the earth's surface are described by points, lines, and polygons which are defined by a series of x, y coordinates. The coordinate system can be self-described or in axiomatic units with reference to the real world. For instance, the decimal degrees in form of the degrees, minutes, seconds; meters; and feet are the examples of units of measure in a coordinate system. So, the Geographic Information Systems is a relational database whose notable feature is the use of a common coordinate system for accessing both spatial data and descriptive or attribute data (Clarke and Stillwell, 2006) [18]. The attribute data can be stored in form of the tables, graphs or plain texts which is containing information defining the object or feature. The Real world objects are stored in form of the points, lines, and polygons. While these information are accessed through the system, the spatial objects can appear with their linked attribute data on any part of the world. Such distinctive features make GIS an ideal for storing, analysis and display information for making and understanding maps (Burrough, 2000) [13].

A GIS possesses facilities for various forms of analyses of the spatial and non-spatial data linked by the system to the objects. Such important features assist in creating maps interactively as well as more useful in understanding the objects relationship in context to the real world scenario. The GIS stores data like any other database. The database can also be stored, up-dated and retrieved as and when required for the explanation purpose (Decker, 2001) [25]. So, a GIS can serve as a powerful tool for monitoring change in quantities and relationships, over time and space. Generally, a GIS is helpful for handling maps of one kind or another. The maps might be represented by several different layers in which each layer contains data about a particular kind of feature. Each feature is linked to a position on the graphical image on a map which is attached to a record in an attribute table. The most significant feature of the GIS is that it can relate on the basis of common geography by revealing the unseen patterns, relationships, and trends which are not readily apparent in case of the spreadsheets or statistical packages, often used for creating new information from existing databases.

GIS is practiced to perform a diversity of geospatial analyses, comprising overlaying combinations of features and recording resulting conditions, studying movements or other characteristics of networks as well as by proximity analysis in which the buffer zones are defined in terms of spatial criteria (Fotheringham and Wegener, 2000) [28]. So, there are various fields in which it is applied like the facility management, environmental monitoring, population census analysis, insurance assessment, and health service provision, hazards and risks mapping and many more applications. Apart from these application areas, there are enormous potential of GIS in which it can be applied for solutions of the real world problems (Goodchild and Longley, 1999) [31]. For instance, the agricultural development, land evaluation analysis, change detection of vegetated areas, analysis of deforestation and associated environmental hazards, monitoring vegetation health, mapping vegetation cover for the management of land, crop acreage degradation and production estimation, wasteland mapping, soil resources mapping, groundwater potential mapping, geological and mineral exploration, snow-melt, run-off forecasting, monitoring forest fire, monitoring ocean productivity (Ripple, 1994) [61] and so on are the applications areas for solutions of the problems of the reals worlds.

In this context, the GIS is playing an important role in various fields as the effective utilisation of natural resources for sustainable development, natural disaster management, selecting suitable site for waste disposal, finding an optimum route alignment and solutions for many local problems. So, GIS is a powerful tool to create maps, integrate information, visualize scenarios, solve complicated problems, present potential ideas, and develop effective solutions like never before for the real world problems (Cope and Elwood, 2009) [20]. In essence, the GIS can be described as supporting tool for decision making process. The process of map making and geographic analysis are not new, but the GIS performs these tasks better and faster than performed by old manual methods

(Davis, 2000) [24]. At present, the GIS is a multi-billion dollar industry employing millions of people in different parts of the countries around the world.

Global Positioning Systems

Global Positioning Systems is used to deliver the three dimensional position of static or moving objects, in space and time, underneath any meteorological circumstances and in real time scenario all over the earth's. The Global Positioning System is consisted by the constellation of 24 satellites orbiting to the earth (Xu, 2007; Langley, 1991a) [71, 44]. So, for global positioning of an object, there must be at least 4 definite satellites above the horizon for any point and time on earth. By and large, there are normally 8 or so satellites which are usually visible to a GPS receiver at any given moment on earth's surface (Arradondo-Perry, 1992) [3]. Each of the satellite is configured to contain an atomic clock. The satellites functioning is based on the radio signals which are continuously sent to the receivers. The receivers have in-built capability to find out how far away each satellites. Sometimes their positions can be with millimetres precision at a given time and place (Kaplan, 1996; Langley, 1991b) [38, 45]. The satellites are having a constellation a distance of 11,000 miles overhead and orbiting to the earth. The satellite signals are normally weak by the time reach to a receiver on the earth. So, it requires an open condition for the receiver to collect satellite signals for real time positioning, surveying and mapping. In the recent past, there have been wide usability of the GPS not only for positioning for latitude and longitude information; but also for tracking and mapping in the real time on the earth surface.

There are two functioning constellations of global positioning satellites which were planned and launched in earth's orbit during the 1970's and 1980's by the two former political blocs the United States and Soviet Unions (earlier USSR). The NAVSTAR (NAVigation Satellite Timing and Ranging Global Positioning System) GPS was developed by the America (Parkinson, 1994) [56]. Whereas, the GLONASS (Global' naya Navigatsionnaya Sputnikovaya Sistema) currently managed by the Russia. Besides this, the Europe Unions is also working on an alternative constellation for global positioning with the aim of reducing dependence on American and Russian systems (Hofmann-Wellenhof, Lichtenberger and Wasle, 2008) [36]. This is based on the latest technology which would provide more reliable and multifunctional system with wide strategic and economic benefits to the Europe. On July 19, 1999, the European Union council approved a resolution that the Galileo system to be developed in cooperation with the European Space Agency (ESA). This Galileo System is planned to have complete complementarity with the existing GPS and GLONASS systems of the world. Likewise, there have also been developed the regional, continental and global positioning systems as the COMPASS by the China and the GAGAN by the India. These systems are consequential of the technological marvellous advancements in the Asian giants which are economically emerging and developing countries of the world, China and India.

Laser Scanning System

The laser scanning system is particularly significant for precision surveying and is important one among the other survey disciplines. Because it is characterised by the ability to produce complete information and achieve high precision. It is having a considerable level of automation responsible for productivity. The laser scanning system survey is "starting from a laser source, fixed or in motion, ground based or aerial, through the polar detection of a very large number of points surrounding the laser source and the radiometric measure of each of them, it is possible to recreate, nearly continuously, the three-dimensional image of the object or the surface of interest" (James, 1996) [16]. Practically, the Laser scanning system is used to pinpoint objects and measure their distance by means of the incident radiation in the optical frequencies ranging from 0.3–15 μm of the electromagnetic spectrum.

Apart from this, the laser scanning techniques are also contributing meaningfully in the development of some aspects of photogrammetry for obtaining aerial photograph of the objects located on surface of the earth. In this way, it is directly providing data for generation of three-dimensional surface model. Whereas, it was cumbersome through traditionally technique in which the information was obtained from the stereoscopic elaboration of bidimensional images. So with the wide application of the laser scanning system in this manner reducing the involvement of expert interpreters and approaching the total automation of the process for generation of three-dimensional surface model of the earth (Jenson, 2009) [37]. However, with the advancement in the technology and computer science offers multiple applications in ground and aerial surveys. One of the significant weakness of this system is represented by the complex and ill-defined filtering operations which are necessary to reduce redundant data. So, laser scanning system used to collect the enormous amount of data by the laser system surveying which is necessary to recreate the digital surface models for various purposes.

Decision Support Systems

In the recent past, there have been the evolution of "a Decision Support System (DSS) is a powerful set of tools for collecting, storing, retrieving at will, processing, transforming and displaying georeferenced spatial data in adequate scenarios of the real world so as to supply the decision makers" with objective elements of evaluation of environmental problems (Burrough, 1986 and Cowen, 1988) [11, 21]. The DSS directly contribute in positional situation mitigation and prevention as well as to foresee territorial and environmental phenomena and to discover several situations to obtain a summary of their possible significances (Densham and Rushton, 1998). For instance, it has an ability to foresee in case a volcanic eruption or a flood occurrence takes place, its intensity, and the extension of the area involved, may be useful in the delineation of a plan for evacuating people from disasters and risks prone areas. The decision support systems (DSS) is used to implement complex geographical information systems intended to create possible real world scenarios by modelling of the ground truth and to offer a set of solutions to the problems (Armstrong and Densham, 1990) [1]. So, in this decision making system, the expert system is used to consider instruments capable of emulating the expert's cognitive processes and their ability to manage the complexity of reality by means of interdependent processes of abstraction, generalization, and approximation for the real world problem solutions more effectively to the policy makers and planners for development.

So, the on-line widespread application of geographical information systems resulting into production of many more maps by many more people. The Web Cartography can handle the geospatial database remotely. The Cartographic Geovisualisation process is considered to be the efficient translation or transformation of geospatial database into map like products. This process is directed by the proverb that "How do I say what to whom, and is it effective?" (Kraak and Ormeling, 1997 & 2003; Kraak and Allen, 2001) [42, 43, 41].

The Web map designing and creation is a challenging task. The cartographer must have greater role in order to consider the limitations, opportunities and characteristics of the web. Like merging functionality with a high level of attractive designing and visualisation which suits to attract the users are the real challenges for the cartographer. For instance, as a matter of fact, the leading role of National Mapping Organisations (NMOs) is becoming less noticeable as a result of inevitable changes taking place in their environment. One of the important aspect of these changes is the emergent awareness in linking and dissemination of databases by means of a geospatial data infrastructure (GDI) web portals. At present, there are many NMOs in Europe, America, Southeast Asia and Oceania appear to be active at some extent on the WWW (Bernard, *et al*., 2005). The web maps in practise are all without exemption either 'static, view only' or 'static, interactive'. Side by side, there have also been a lots of development in the creation of the dynamic maps for the various purposes.

By and large, the web map application is focused mainly for use in exploring the area and planning outdoor activities. The web map user interface objective is at providing a complete tool to interact with the maps. In reality, the actual business of map making is gathering spatial data and visualization without the assistance of the experts. Even a layman have a capability to make a map, with a spectacular interactive 3-D map. This is now feasible with a home computer and an internet connection to the masses. So, the cartography's latest "technological transition" (Monmonier, 1985; Perkins, 2003) [55, 58] is not so greatly a question of novel mapping software; but a combination of "open source" collective tools, mobile mapping applications and geotagging with the world. In fact, the cartography as a way of perceptive to the world has continuously struggled with the prominence of its knowledge in a fashion comparable to that of the geographical discipline (Livingstone 1992) [49].

Web-GIS

The Web-GIS is emerging an effective tools for geospatial analysis and mapping in real time through internet. The Internet is an international consortium based on the wide area networks at the regional and the global levels. It is an outcome of a Defence Advanced Research Projects Agency (DARPA) research project took place in the early 1970's. Later on, additional regional, private, and public networks have been joined to the internet over periods. It is noteworthy to mention that it has an ease-of-use and multimedia capabilities which attracted most of the mass market attention and resultant increase in usage of the World Wide Web (WWW). It has developed into a unique source for numerous application areas such as the web publishing, electronic voice mail, online interactive teaching and training, telnet applications, online library information system and online advertising and shopping. So, such an advancement over time, the world wide web developed into new internet protocols such as the hypertext text transfer protocol (HTTP), as well as easily customisable interface browsers, tools and languages as hypertext markup language (HTML), and an extensible mark-up language (XML) and Java. The various internet applications and Web-GIS are the systems of future.

Since late 1993, the internet-based World Wide Web (WWW) has emerged as a powerful medium for accessing, viewing and distributing geospatial information. In other words, the www web is the most recent new medium to present and disseminate geospatial information (Van and Kok, 2004; Masser, 2005) [65, 54]. In this connection, the map play an important role, in terms of multiple functionality. Because, the map not only play the traditional role of providing perception into geospatial patterns and relations. The most common form of map found on the web is the static view only map. So, the World Wide Web is a relatively new way of electronically publishing maps. Although, at present there are millions of people have its applicability in everyday life. All these users are even not aware that how it actually works in the real time scenario.

At present, the Web-GIS is latest development for geospatial analysis and visualisation of the geographic data which is remotely stored on dedicated machines and is accessible through the complex network architectures. In Web-GIS, the results are derived by integrating on-line query capabilities on the basis of commercial DBMS and GIS software packages which are working in the background (Kraak and Allen, 2001) [41]. By virtue of this, the research findings are available on the internet for browsing to the whole world. In fact, today's web-based analysis and mapping products are spatially enabling indefinite number of web sites accessible by the peoples around the world.

In the past, the cartography played a significant role in the exploration of the world. It was used to map the unknown territories. It is a new phase in mapping of the unknown territories which has recently started very recently (Monmonier, 1985) [55]. It is primarily dealing with the mapping of cyberspace. So, kind of Web Cartography can be considered a new trend in cartography. Such and the other recent trends have large affect in developing of web cartography. These have to look after with the impression of visualisation and the necessity for interactivity and dynamics.

Ontology

It origin dates back to the early stages of development of knowledge with particular reference to the view of science which is considered as a historical fact and as an expression of human wisdom. The Ontology is used to specify a conceptuality which is the description of concepts and relationships existing for an element or among various elements of a group, entity, or class (Gruber, 1993) [33]. The conceptualization is an intellectual simplified vision of the world to be signified for a given application. More recently, there have been growing interest and is attracting especially within the spatial information domain. Because, it is playing an important role in contributing in organisation of terminologies and definitions. These are often inadequately used as a consequence of the rapid development of geoinformatics.

The term ontology is often controversial in considerations to artificial intelligence on the one hand. And, the term ontology is very often confused with the term epistemology. It is noteworthy of distinguish between them in context to the philosophical meaning of the epistemology and the ontology. The epistemology is the study of nature and of the value of scientific knowledge through the continued critical examination. Whereas, the ontology is recognised as metaphysics that is a philosophical dogma related to the universal characters of the Supreme Being (God), prior to the Aristotelian philosophy. So, the ontology is the description of conceptuality and the explanation of concepts and the interactions existing for an element or between elements of a group, class or entity.

Besides this, the ontology provides the account of philosophies of knowledge commencing with the history of scientific knowledge and with the expansion and consequent influence on society and the planet earth (Ton and Sticklen, 1991) [64]. In context to geomatics, the ontology implies the explanation of diverse ontologies which are involved with sharing and reprocessing knowledge, so as to assist to define ontological norms. On the other hand, in the context of artificial intelligence, it is promising to describe the ontology of a program through describing a group of illustrative terms for that application. In this kind of an ontology, the explanations associated with the labels of entities in the universe of dialogue. For instance, the classes, relationships, functions, other objects, etc. with an expressive script presenting the meticulous connotation of the terms, supposing formal axioms or restraining imaginable explanations and usage of such expressions.

Computer Science

Computer science approach is currently wide spreading, not only concerning as electronic equipments; but also in context to methods, models, and systems that contribute in improving scientific research and developmental activities in various fields. Informatics, as a discipline, comprises by the computer technology, both in form of the physical as well as the software components (Longley, *et al*., 2001) [51]. So, the computer science is applied to represent and process applicable information through the development of technological equipments as the computer hardwares and the methods, models, and systems as application softwares.

There is found exits a close relationship between the possibility of data representation and data processing. The informatics is defined as "…systematic study of the algorithms which describe and transform information: their theory, analysis, plan, efficiency, realization and application…" by the Association for Computing Machinery (ACM). The application software is comprised by the sets of algorithms which are precise sequences of comprehensible operations, performable by an automatic electronic equipment. Programs define the arrangement of operations to be performed by expressing them in a language interpretable by the electronic equipment i.e. the calculator or computer.

In the present information technology age, there are two most commonly used terms are the data and the information which are often used synonymously. Whereas these two terms individual meaning is in reality totally different. Data are the basis of information and in general characterise for the measurement of the external world. The procurement of information drives through the cognitive process centred on data (Masser, 2005) [54]. For instance, a raw satellite imagery represents to digital data. While the digital imagery is processed into different land use land cover classification then that becomes information. Likewise, the GPS data are a measure of time; the resulting information is a location in geographic space. So, the records of an electronic documentation or database are data. And, the response obtained for a question using data from a database produces information.

Geoinformatics: Developments and Advantages

There have been an ever-growing understanding and recognition that the earth functions as a complex system composed of innumerable interconnected mechanisms have made earth scientists to apprehend that prevailing information systems and techniques used are over and over again insufficient. At present, the unmanaged dissemination of available data sets, nonexistence of documentation about them, and the lack of easy-to use access tools are most important difficulties for scientists as well as educators. All these kinds of hindrances have slowed down scientists and educators in the access and full utilisation of available data and information which is resultantly perceptible in the scientific productivity and the excellence of education. More recently, due to the technological advancement such hindrances have practically been overwhelmed, at large (Yang, *et al*., 2011) [72]. For instance, the advances in computer design, software, disk storage systems as well as the progression in deployment of the world wide web nowadays gives authorisation for the first time for the management of gigabytes to terabytes of data on the one hand and the easy dissemination of information to general public, students and more particularly to educators and scientists, on the other hand.

The ultimate objective of the geography science is a completely integrated data system occupied with high quality, easily accessible data, as well as, a robust set of software for analysis and interpretation of the data for the solution of the real world problems (Atkinson and Nicholas, 2013) [4]. Such database system would supplement to convenient accessibility to the researchers. Such competences of database are required to attract researchers for solutions of a variety of elementary and practical earth sciences problems. So, the solution resting in the data analysis which is far more complex than the solutions provided by geospatial analysis worked out through traditional geographic information systems (GIS). Besides this, sometime the extent, intricacy, and the existing data sets and databases are not up-to-date. So, there is a need for the optimization of the collection of new data sets which requires a large, cooperative, well-coordinated and sustained efforts, in order to allow the scientific community to attain their desired scientific goals. With such a robust emphasis on ease accessibility and use of database, the resultant data system would be a precise and powerful scientific tool to conceal novel connections between space and time. Such database would be an assets as an important resource for the layman, students, researchers, and teachers as well as to the industry and several governmental organisations.

The major scientific new discoveries requires the availability of databases which encompass to a diversity of spatial and temporal scales. Because there is a need to integrate heterogeneous data sets and tools to analyse them. In this connection, the geoinformatics technology provides the emphasis for community involvement on a large scale for testing to enhance and retain earth sciences research for the betterment of the humanity (Worrall, 1990) [70]. This also promotes for the creation of a global database system. So, the spatial and non-spatial information storage into digital form and the interlinkages between them can be made on the basis of geographic proximity. The data availability from different geographical regions can often proposes for new insights and explanations of the world. Such interconnection are often possible with the help of Geoinformatics which is playing a vital role in understanding and managing earth resources for sustainable development.

Accordingly, the geoinformatics provides in a systematic way the complex topics and techniques namely, geodesy, cartography, photogrammetry, remote sensing, informatics, acquisition systems, global positioning systems, digital image processing, geographic information systems, decision support systems, and Web-GIS (Yang, *et al*., 2011) [72]. The geoinformatics describes in detail and at an easy to get to the state of current knowledge. In this context, it will serve as a working tools and technology not only to the geographers and geoscientists; but also to the architects and engineers, computer scientists and urban developers and planners. Besides this, to the specialists in remote sensing, geographical information systems, forestry, agricultural science, environmental scientists and managers for the solutions of the problems of the real world.

Geoinformatics: Applications and Professionals

The Geoinfromatics is an emerging field enabling to yield profits from the exceptional amount of digital geodatabase and exception computing power available through electronic networks at global levels. Geoinformatics also able to harness the enormous potential available from the World Wide Web. Such network computing and database resources provides opportunity to revolutionise from observational and computational geodata into knowledge. The Geoiformatics facilitates collaborative multidisciplinary research and escalate capacity to understand the earth as a vibrant and multifaceted system in the universe. Besides this, the geoinformatics is extensively operational as the geospatial tools not only to geographers and geoscientists; but also to the engineers, architects, computer scientists, urban planners. In addition to this, to the remote sensing, forestry, agricultural science, environmental scientists, and managers and specialists in geographical information systems (Buiten and Clevers, 1993) [10]. It is having a variety of applications like it is applied in security, risk management, monitoring, info-mobility, geo-positioning, food security and so on. So, the applications of geoinformatics are primarily oriented to solutions to the real world management problems which are pertaining to natural and manmade environments.

The applications and expertise of geoinformatics are far wider from one field to another which includes as environmental modelling and analysis, land use management, transport network planning and management, urban development and regional planning, military, telecommunications, agriculture, meteorology, climate change and so on at the regional and global levels. In the recent past, the new technological revolution impacted to the functionality of geoinformatics especially in the many disciplines which were progressed rapidly over recent past like from spatial geodesy to precision topography, from photogrammetry to remote sensing, and from numerical cartography to the processing of observations and to the GIS, DSS, and expert systems (Cracknell and Hayes, 2009) [22]. In lieu of this, not only the surveying disciplines; but also several international cartographic institutions have taken responsibility and increasingly extended their supports for the problem of quality certification. There are wide opportunities and professional prospects for the geoinformatics experts in surveying and monitoring which are therefore increasing endlessly and progressively. So, the high-quality education and professional oriented training in geoinformatics will definitely open large avenues for job opportunities at the local, regional and global levels for the regional development and planning.

Conclusions

Geoinformatics technology provides the emphasis for community involvement on a large scale for testing to enhance and retain earth sciences research for the betterment of the humanity at the regional and global levels. So, the spatial and non-spatial information storage into digital form and the interlinkages between them can be made on the basis of geographic proximity. The data availability from different geographical regions can often proposes for new insights and explanations of the world. Such interconnection are often possible with the help of Geoinformatics which is playing a vital role in understanding and managing earth resources for sustainable development. The geoinformatics describes in detail and at an easy to get to the state of current knowledge. In this context, it will serve as a working tools and technology not only to the geographers and geoscientists; but also to the architects and engineers, computer scientists and urban planners. Besides this, to the specialists in remote sensing, geographical information systems, forestry, agricultural science, environmental scientists and managers. The applications and expertise of geoinformatics are far wider from one field to another which includes as environmental modelling and analysis, land use management, transport network planning and management, urban development and regional planning, military, telecommunications, agriculture, meteorology, climate change and so on at the regional and global levels. So, there are wide opportunities and professional prospects for the geoinformatics experts which are therefore increasing endlessly and progressively all around the world.

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