Digital Mapping as an Emerging Technology in Surveying and Mapping in Urban Areas

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ABSTRACT

Surveying, the way we measure the earth constants, has changed in the recent years with the rapid technological evolution. The time of surveying with purely optical and mechanical instruments (steel meter, levels, theodolites, etc) has rapidly been replaced with more sophisticated surveying techniques and equipment like motorized total stations, GPS, etc. Digital technology has also penetrated in all aspects of the mapping process, from raw data collection through map compilation and design to final production. Advancement in mapping technology has replaced the conventional stereo plotters with digital imaging systems. The technological advancements has made map making more efficient and accurate.

To cope up with the challenges in the urban environment due to the rapid rate of urbanization, needs proper planning and management, which in turn requires up-to date digital spatial information. Remote Sensing technology ensures the free flow of unlimited stream of data to be used for multifaceted applications. The advent of high-resolution satellite data coupled with stereo capabilities has resulted in better mapping with higher accuracy. The recent launches of high-resolution (less than 1m) satellite systems have opened up new vistas for digital mapping at a large scale for cartographic applications.

In addition to this, new technologies, such as advanced digital image processing, Global Positioning System (GPS) providing positional information within cm accuracy and Geographic Information Systems (GIS), LIDAR, InSAR, etc can be used to integrate and process spatial data for applications ranging from basic mapping to supporting resource exploration and development; from environmental management to the planning and administration of transportation and telecommunications systems, utility infrastructures, urban development and land use.

These advanced technologies can very effectively be used to handle the present day complex urban problems related to optimum utilization of available resources and infrastructure management.

The paper presents the recent trends in digital technologies in mapping urban areas and a case study demonstrating the use of these new technologies for creation of a digital database for generating an urban resource information system.

INTRODUCTION

During the last three decades, the global spread of information technologies has not only led to a flood of information in almost all areas of application but also has made the majority of this information available in digital form. Digital technology has penetrated all aspects of the mapping process, from raw data collection (total stations, GPS and remote sensing, LIDAR,) through map compilation and design to final production. Advancement in mapping technology has replaced the conventional stereoplotters with digital imaging systems. More significantly, the uses of digital cartographic data have changed fundamentally because of the widespread diffusion and adoption of GIS technology in applications as varied as city planning, utilities management etc.

Specially in the field of urban management the dramatic increase in all kinds of geographic data is closely associated with the start of operational high resolution remote sensing satellites, GPS, LIDAR and digital image processing as well as the development of computer-assisted cartography and geographic information systems.

Digital mapping i.e. the making of maps using computerized data and procedures is a logical response to the public's evolving demand for the rapid delivery of up-to-date information, especially in forms that are amenable to spatial and statistical analysis. In the past, when information was available only in paper form, the public's expectation for information delivery was tempered by the time-consuming process of conventional printing and distribution. The adoption of advanced digital techniques in mapping is due in part to the increased functionality and decreasing costs for Geographic Information System (GIS) and map production software, and for computers that are capable of supporting these software's. Further, with the availability of information in digital form has enhanced its utility.

ADVANTAGES OF DIGITAL MAPPING

Digital map once developed can demonstrate the spatial distribution of any area for more than one purpose because it has super imposed layer; Digital map can be manipulated and beautified. As a result it will attract the user to use it at any level of census and survey operations. Thus, digital map will ensure better quality and better dissemination.

A typical urban GIS might let users view an aerial photograph of every building in the city by simply clicking on a lot number in a digital map. The lot number can also be linked to a database of census data, zoning classifications, tax assessments, traffic patterns and crime reports related to that building's block. Armed with that kind of information, city administrators can make informed decisions about where to beef up police patrols, expand subway service, or authorize the construction of new clinics, schools or hotels, to name just a few applications.

EMERGING TECHNOLOGIES FOR DIGITAL MAPPING

EARTH OBSERVATION SATELLITES

Satellite Remote Sensing, with repetitive and synoptic viewing capabilities as well as multi-spectral capabilities is a powerful tool to map and monitor the emerging changes in the urban core as well as in the peripheral areas of any urban entity. The growing demand for the utilization of remote sensing data in map production, due to the following benefits provided by them: stereo coverage, frequent revisits, timely delivery, wide area coverage, virtually global coverage, and storage in digital format to facilitate subsequent updating and compatibility with current GIS technology with the advent of a number of commercial satellites providing data with a spatial resolution as fine as 1m.

Mapping applications of remote sensing include the following:

1. Planimetry
2. Digital Elevation Models (DEM's)
3. Baseline Thematic Mapping / Topographic Mapping

The high quality data available from new remote sensing systems can be used for preparing detailed digital maps. These digital maps and databases can be easily mosaiced to generate a seamless database and map for the region, country and continent. Also 3-D visualization of the entire earth surface can be achieved i.e. creation of virtual earth

The current and future high-resolution earth observation satellites (table 1) having a spatial resolution of 1m & less and stereo capabilities will go a long way in the field of mapping in terms of cost, time and accuracy.

Table 1 : CURRENT AND FUTURE HIGH RESOLUTION SENSORS

SENSOR	LAUNCH DATE	RESOLUTION
IRS-1C	28-DEC-95	(Panchromatic): 5.8 m
IRS-1D	29-SEP-97	(Panchromatic): 5.8 m
Ikonos	24-SEP-1999	(Panchromatic): 1 m (Multispectral): 4 m
QuickBird	18 October 2001	Panchromatic): .61 m (Multispectral): 2.44 m
EROS A1	05-DEC-2000	1.8m
CBERS 3	2003	(Panchromatic): 5 m
EROS B1	2003	(Panchromatic): .81 m
EROS B2	2003	(Panchromatic): .81 m (Multispectral): 3.3 m
CARTOSAT-1	2004	(Panchromatic): 2.5 m
CARTOSAT-2	2005	(Panchromatic): 1 m

HYPER SPECTRAL REMOTE SENSING

Intricate mixtures of materials ranging from concrete, wood, tiles, bitumen, metal, sand and stone typify urban areas. The spatial distribution of these materials is not regular and is compounded by rapid temporal changes, which leads to errors in the multispectral classification. Hyperspectral sensors with their high spectral resolutions have the potential for mapping complex urban ecosystems. The creation of spectral library for urban surface materials can assist in the sub-pixel analysis and has the potential to diminish some of the limitations posed due to spatial resolution.

GPS

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. It provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Basically GPS works by using four GPS satellite signals to compute positions in three dimensions (and the time offset) in the receiver clock. So by very accurately measuring our distance from these satellites a user can triangulate their position anywhere on earth. Global Positioning Systems (GPS) technology is affordable because of its low cost and provides accuracy up to cm level and with the help of newer and enhanced forms of GPS, such as Differential GPS and Carrier-Phase GPS, one can theoretically achieve the accuracy up to 3 or 4 mm. The integration of GIS and GPS in the fields urban planning will provide insights into land planning.

GPS technology has matured into a resource that goes far beyond its original design goals. There are five main uses of GPS today (http://www.palowireless.com/gps/tutorial4.asp)

1. Location- *determining a basic position.*
2. Navigation - *getting from one location to another.*
3. Tracking - *monitoring the movement of people and things.*
4. Mapping- *creating maps.*
5. Timing - *providing precise timing.*

GPS today is being used to survey and map the earth surface precisely, saving time and money. It can help generate maps and models of everything in the world. Cities everywhere are facing similar problems - increasing traffic congestion, it can transmit the location of traffic congestion to the vehicles and suggest alternate routes for better traffic management in urban cities

SAR and INSAR

Radar remote sensing has the capability to make observations independent of the meteorological conditions and cloud coverage. The Synthetic Aperture Radar (SAR) collects maps of the backscattering coefficient and has the capability to detect urban extension and urban changes.

Using the INSAR technique, it is possible to produce directly from SAR image data, detailed and accurate three-dimensional relief maps of the Earth's surface. In addition, an extension of the basic technique, known as Differential INSAR, allows the detection of very small (centimetre-scale) movement of land surface features. Furthermore, recent research has established the potential of INSAR to monitor changes in time of the Earth's surface scattering properties.

A first quantitative estimate of the height accuracy associated with ERS-1 INSAR has come from a comparison with Global Positioning System (GPS) measurements. These initial results are very encouraging and show excellent agreement with differences in terrain height of approximately 10 m. (http://earth.esrin.esa.it/rootcollection/sysutil/00e72.html).

The Spaceborne Imaging Radar (SIR, 1994, www.jpl.nasa.gov/radar/sircxsar/sirc-pkt.html) and Shuttle Radar Topography Mission (SRTM, Feb 2000, www.jpl.nasa.gov/srtm/) are two of the publicized SAR projects and produced elevation models at about 30 m resolution for a large part of the globe. In recent years ERS-1, 2 and ENVISAT of ESA have contributed significantly in deriving height information from RADAR.

GEOGRAPHIC INFORMATION SYSTEM

Geographic Information Systems (GIS) have evolved over the last 20 years - from simple mapping systems into an essential information systems technology for modeling and decision support. Urban Planning in particular has benefited from the increasing sophistication of GIS capabilities. It has revolutionized the collection, coalition, analysis and interpretation of data for planning and decision making process especially in urban and regional planning activities. The data storage, updating, retrieving and manipulating capabilities of GIS have facilitated in developing strategies for urban management and planning.

MULTIMEDIA GIS & WEB GIS

Viewing information in three dimensions is a natural way for a human to view data representing a three-dimension world. (http://www.envstudies.brown.edu/thesis/2001/james/mmgis.html). Multimedia/hypermedia GIS allow the user to access a wide range of georeferenced multimedia data (e.g., simulations, sounds and videos) by selecting resources from a georeferenced image map base. A map serving as the primary index to multimedia data in a multimedia geo-representation is termed as hypermap. They are highly interactive, live, and they attractively present the hot links to the information associated to any geographic feature.

Since the inception of Internet technology, there has been widespread usage of WWW, and the ubiquity of browsers and the available geographic information has made it possible to develop new forms of multimedia geo-representations on the Web. Internet technology has grown to incorporate multimedia technology as audio, video and 3D-graphics. These new media technologies can result into new representation and presentation methods that can enrich traditional GIS systems and create new aspects of reusing of geographical data in the planning process. With the integration of internet-technology and multimedia-elements into GIS-applications the user has a choice for any-time, any-where access to the geography related information vital to many critical needs.

A web based urban information system would aid town planners, bureaucrats, corporators and commissioners in the day-to-day functioning of all departments and ward offices of Municipal Corporation. Sitting on his desktop and through the browser, any authorized user of corporation will be able to get a visual display of all day-to-day queries, maps and maintenance reports.

GROUND PENETRATING RADAR (GPR)

Ground Penetrating Radar (GPR) is a technology that uses radio waves to non-invasively locate objects beneath the surface. In a manner analogous to sonar, the radio waves enter the earth, and then reflect back to the surface at varying velocities depending on differences in the properties of the materials making up the objects to be located.

GPR technology uses high frequency electromagnetic waves (RADAR). The signal is directed into the material and the partial reflection of the waves occurs from layer boundaries and objects or features that have contrasting electrical properties to the stock material. The reflected waves that return to the surface are used to create the 2D and 3D images, in a similar manner as an ultrasound device works

Ground penetrating radar is a widely accepted field screening technology for characterizing and imaging subsurface conditions. Ground Penetration Radar (GPR) is most commonly used for locating buried objects such as tanks, pipes, and drums etc. It can also be used to map the depth of a shallow water table, identify soil horizons and the bedrock subsurface. GPR can also detect plastic, glass, concrete, or wood. It is an effective tool for utility locating because non-metallic features may be identified. A common application is the thickness measurement of pavements and underlying materials. The data may be obtained more rapidly and unobtrusively versus the traditional method of coring. Since the pavement is not penetrated, utility clearances are not required and in most cases, traffic control is also not required because the GPR operator simply walks across the road. Other potential uses are assisting with archaeology and forensics and many more.

LIDAR

LIDAR is an acronym for Light Detection and Ranging. It is a rapidly emerging technology for determining the shape of the ground surface plus natural and man-made features. A Lidar system is an aircraft mounted laser system designed to measure the 3D coordinates of features on the earth's surface. LIDAR technology offers one of the most accurate, expedient and cost-effective ways to capture wide-area elevation information to produce highly detailed Digital Elevation Models (DEMs).

An infrared laser beam is pulsed at high frequencies, ranging from 4,000 to 30,000 pulses per second (quantified in kHz) or more, onto a mirror and projected downward to the ground from a fixed-wing aircraft (or helicopter). The laser beam hits an object on the ground and is reflected back to the scan mirror into a telescope receiver. Based on the known speed of light, the time between emission of the laser beam and reception of the return signal, the distance travelled can be calculated. A higher ground sample distance (a greater point density collected) results in a more accurate depiction of the terrain. The advanced systems have the capability to establish a digital elevation model with point spacing from 1 to 15 m and vertical accuracy of 15 cm.

The advantage of LIDAR data is that they quickly and cost-effectively reveal a higher-resolution elevation model than can be practically be obtained with traditional mapping technology. Even in areas with dense vegetation or complex urban environments, a highly accurate map of the terrain can be produced with ease. LIDAR data can be seamlessly integrated with other data sets, including orthophotos, multispectral, hyperspectral and panchromatic imagery. LIDAR can be combined with Geographic Information System (GIS) data and other surveying information to generate building renderings, advanced three dimensional city models etc.

VIRTUAL REALITY

There are numerous ways of visualizing digital environments, which can facilitate planning and the simulation of processes, which affect the urban environment. Virtual Reality GIS have been developed to allow the creation, manipulation and exploration of geo-referenced virtual environments. Virtual Reality GIS can be also Web-based which include 3D simulation where one can generate different scenarios for planning and management aspects.

DIGITAL PHOTOGRAMMETRY

Digital photogrammetry is photogrammetry with digital images. There are several advantages connected with using digital images:

- Digital softcopy workstations running on standard computers can be used rather than expensive plotting devices requiring special hardware.
- Digital image processing techniques can be used for image enhancement.
- Digital image processing techniques render possible the automation of photogrammetric measurement tasks.
- Easy integration of data into a GIS.

The point selection, point transfer, point measurement and final block adjustment have to be performed sequentially and manually using point mark/transfer instruments and analytical plotters. Digital aerotriangulation combines these steps into one integral procedure. The key technique is the application of matching procedures to digitized images, enabling a substantial automation of aerial triangulation (AT) (Heutchel, 1996).

One of the main applications of Photogrammetry is the generation of ortho photo/ image, which makes a photograph/ image function more like a map. To provide a photograph/ image the geometric accuracy of a map, relief distortion and other artifacts of the optical process are removed by using a Digital Elevation Model (DEM) as an independent source of information on height. Various urban projects require detailed terrain and land cover maps for planning, environmental assessment and engineering design. The applications are so diverse in their requirements that mapping has to be repeated at a number of different scales, from 1:600 for design to 1:50,000. Traditional field survey methods have given way to digital photogrammetry, using either traditional analytical stereo-plotters or modern soft-copy photogrammetry.

The research in the area of automatic feature extraction has shown promising results and is a step in the automation process of feature extraction.

CASE STUDY

The Institute has taken up one pilot project for generation of digital maps as well as plotted maps at a scale of 1:2,500 using digital photogrammetric techniques. The project area is a small township in the state of Punjab with an area of approximately 50 sq. Km. A digital database of the city comprising of features like, different categories of roads, settlements, water bodies, railway line, agricultural areas etc along with proper annotation and attributes was generated. This database will be used by the town and country planning department for developing a urban resource information system for urban resource management. Digital elevation model along with contours was also generated. The uniqueness of the project being that contours at an interval of 1m was generated using digital photogrammetric techniques, which would have not been possible to generate through conventional photogrammetric technique in shorter time.

The generated datasets will be integrated into an Urban Resource Information System, which will provide with an effective management tool for utilization of the urban resources

1. Urban planning, including town planning;
2. Regulation of land use and construction of buildings;
3. Planning for economic and social development;
4. Roads and bridges;
5. Water supply for domestic, industrial, and commercial purposes;
6. Public health, sanitation, conservancy and solid waste management;
7. Fire services;
8. Provision of urban amenities and facilities such as parks, gardens and playgrounds;
9. Promotion of cultural, educational and aesthetic aspects;
10. Burials and burial grounds; cremation grounds and electric crematoria;
11. Public amenities including street lighting, parking lots, bus-stop and public conveniences;

This facility will aid management of public utilities like water supply, drainage, sewerage system, roads, storm-water drains, streetlights etc. This facility would also cater to town planning schemes, urban and estate management and property tax-related matters. The more important components of the new maps will be the precise pinpointing of the water supply pipes; sewage drains that cover the city. It will also help in better transport management of the city.

The urban resource information system is a step towards helping public in a big way. Fire and Health departments find it useful during emergency services since all information is brought around the hot spots with the click of a button. The most beneficial amongst all departments are the roads and building and town planning. The search for maps and documents seems to be over. Where hours are counted to locate maps, now that uncertainty is over.

CONCLUSION

In view of the rapid urbanization and changing scenarios, it is imperative to have a digital maps and databases to support decision-making and futuristic planning. The advanced technologies like Remote Sensing coupled with GPS, LIDAR etc have made it possible for surveyors to locate their position anywhere on the earth and has also enabled towards the generation of precise and updated maps in a cost-effective and timely manner. The digital maps generated will allow the user to study the urban environment; digital surface models of urban areas can be used to generate accurate and up-to-date 3D city models for urban planning and management.

Digital mapping is a logical response to the public's evolving demand for the rapid delivery of information, especially in forms that are amenable to spatial and statistical analysis. This information in digital form can be made available quickly and in many cases without cost across the Internet which can be utilized for variety of applications.

The Digital databases will improve the functioning of the municipal departments by enabling the prompt decision-making by analysis, easy information retrieval and timely, accurate, complete and updated information.

Map making and geographic analysis are not new but a GIS performs these tasks faster and with more sophistication than traditional manual methods do. This technique is likely to reduce large amount of paper work in the day-to-day transactions in the municipalities. The public dealings such as water and electricity bill and related maintenance services would become much faster and more efficient and thus provide a better quality of life in the urban cities.

Hence these advanced technologies for production of digital maps can very effectively be used to handle the present day-to-day complex urban problems related to optimum utilization of available resources and infrastructure management

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