How India May Benefit from Airborne Laser-Altimetry

Geo-Information from LiDAR

The need for geo-information in tackling a wide variety of nation-wide problems has grown rapidly. Over the last decade new remote sensing techniques have emerged which provide a response to these demands. In particular, Airborne Laser-Altimetry (LiDAR) demonstrates many beneficial properties in this respect. Why is it, then, that India - with its emerging economy - remains reluctant to adopt this advanced IT technology: a technology able to support solutions to the many infrastructure and disaster management problems the country faces today? Basing their reflections on papers presented earlier this year at Map India and discussions which emerged there, the authors elaborate upon this question. They also provide suggestions for what needs to be done to surmount the impasse.

By Mathias Lemmens, Delft University of Technology, The Netherlands and Bharat Lohani, Banaras Hindu University, India

India is emerging as an important player in today's global economy, particularly in the field of Information Technology (IT). India's pool of highly skilled IT human resources attracts a substantial portion of the service sector of the world to its shores. However, the full exploitation of these opportunities requires a strong infrastructure.

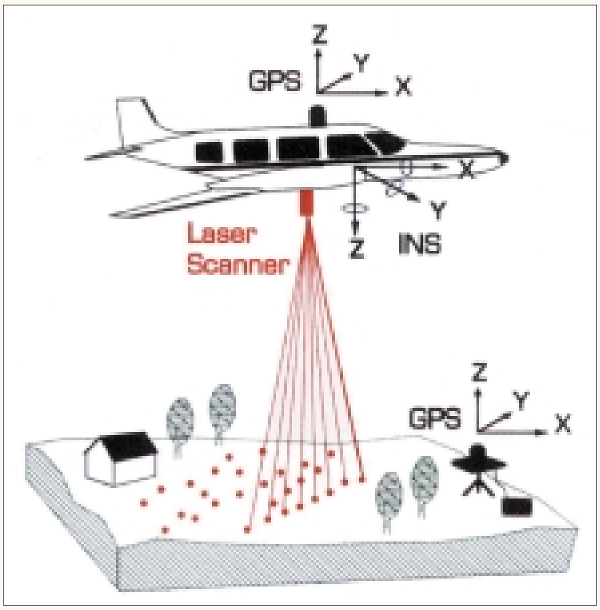

Figure 1, *Principles of Laser-Altimetry (Courtesy: Survey Department Rijkswaterstaat, Netherlands)*

Infrastructure and Urban Planning

In this respect, India still has a long way to go. It has to launch major projects concerning roads, railways, oil and gas pipelines, electric transmission lines, communication networks, and ports and harbours. The availability of accurate, timely geo-information significantly reduces the cost of such projects.
In addition, many urban areas in India are characterised by the clustered growth of housing, streets and other infrastructural works. This is partly due to the long existence of these cities and partly to unregulated growth. The management of drainage, sewerage, telephone networks, electricity and disaster mitigation represents a great challenge to local governments. Geo-data forms a major and indispensable contribution to all these projects which aim at infrastructure improvement and, more generally, the overall development of the country.

Airborne Remote Sensing

The acquisition of geo-data has long been, and continues to be, a cumbersome, labour-intensive and expensive task. The past decade has been witness to a favourable development, which is the rise of new airborne remote sensing techniques able to collect geo-data in an automated manner. In particular, techniques enabling the highly automated collection of 3D geo-data in the form of Digital Elevation Models (DEMs) have rapidly emerged and are now at the leading edge. These include Airborne Laser-altimetry Systems (LiDAR), softcopy photogrammetry and interferometric SAR (INSAR).
Desirable properties for the operational attractiveness of such systems include:

- High data capture rates
- High degree of automation of the entire process, up to the creation of the desired 3D terrain surface
- Low cost per point
- Final solution largely independent of terrain type and terrain characteristics

LiDAR

LiDAR stands at the forefront of these new techniques. The automation rate is substantial, whilst data capture rates of 100 km^2/h are possible. Consequently, time-efficiency and cost effectiveness are prohibitive. Densities of up to various dozens of height points per square meter can be acquired, depending upon the system, the flying height, the speed of the platform and the merging of data stemming from multiple fly-overs. Helicopters are better suited for high-resolution coverage because they can easily limit their speed. Weather and visibility conditions only slightly affect flight surveys, making the technique fairly independent of season and daytime. The number of accompanying ground surveys is usually modest. Less accessible areas can be mapped relatively easily.

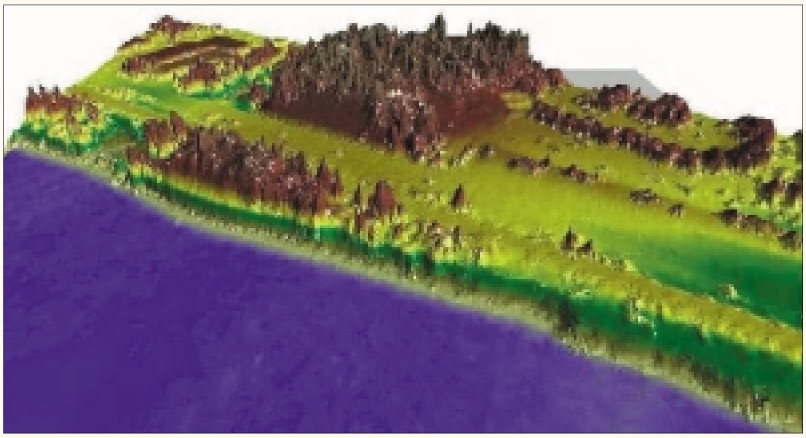

***Figure 2**, This shoreline height map with beach details and trees, size 500 x 700 m, consists of 50,000 points. This site in Toronto, Canada, was mapped with an Optech ALTM 1020, within 15 seconds, from an altitude of 700 m. (Courtesy: Optech Canada).*

Status of Laser Altimetry in India

No LiDAR surveys have yet been conducted in India. The reasons for this are many. High investment costs (US$ 1M) discourage initial purchasing of the basic instruments. Another reason is lack of awareness of the opportunities offered by LiDAR. Basic to the situation too is governmental policy which, with respect to airborne remote sensing, is characterised by protectionism. A few government departments enjoy a complete monopoly while regulations prevent the entry of others. This high level of protection results in a low participation rate on the part of the private sector and academia, which in turn leads to a disproportionally low growth rate for this technology, especially in comparison with general IT sectors. What efforts should be undertaken to make the benefits of LiDAR available for the support of infrastructure improvement and, more generally, national overall development? There follows an attempt to identify the necessary roles to be played by the three major players: government, private sector and academia.

Government

- Identify application domains and organisations (users: both governmental and private) which may benefit from LiDAR technology and identify these benefits
- Select a limited number of critical application domains, like flood risk management, for carrying out pilot projects to arrive at a more quantitative insight into the benefits, also in terms of savings in lives and property
- Modify the airborne remote sensing data collection and distribution policy to ensure broader involvement of the private sector and academia. The involvement of the latter is crucial for the independent and scientific guidance of any introduction process, which will in evitably be accompanied by complications and growing pains
- Initiate regulations to stimulate the involvement of the private sector by subsidies and tax measurements, and the participation of academia by making available LiDAR research budgets
- Make the use of LiDAR data mandatory in critical application areas where compromise in data standards leads to loss of both life and property (e.g. floods)

Private Sector

- The producer side of the private sector should raise awareness among the users about the benefits of LiDAR technology
- The user community should make the government aware of the untenability of the present repulsive policy with respect to airborne remote sensing data
- Producers, in co-operation with users, should outline pilot pro-

Principles of LiDAR

LiDAR systems, operating from an aircraft or a helicopter, are multisensor systems consisting of a reflectorless laser range system and a positioning system. The laser ranger determines the distances from the platform to arbitrary points on the earth's surface by measuring the time interval between transmission of a train of pulses (up to 80,000 per second!) and the return of the signals (Figure 1). A rotating or nutating mirror enables high resolution scanning perpendicular to the direction of flight. The resulting swath width usually lies in the order of half the flying height of the platform. A flying height of 1,000 metre is typically used during operational flights. The positioning system determines the position and attitude of the laser ranger. This is necessary for geo-referencing purposes, i.e. to determine the coordinates of the sensed points on the terrain surface in a local or national system. Differential GPS is usually used for position determination and an Inertial Navigation Unit (INU) for the determination of the roll, pitch and yaw of the platform. The final accuracy depends on many factors, including the properties of the entire measuring system, flying height, resolution, terrain characteristics and applied processing software. During typical operational airborne surveys, the accuracy values to be achieved are five centimetre systematic error and ±15 centimetres random (root mean square) error.

jects and convince government that the expected gains of these projects make them deserving of financial support
- Identify the market and consequently the value-added services necessary to transfer the raw LiDAR data to services from which users may benefit

Academia

- Carry out research to optimise LiDAR technology for the particular needs of the country
- Develop special courses to bring LiDAR technology into the knowledge domain of both data producers and consumers and current students
- Promote the technology during workshops and conferences in order to make a broader audience aware of its possibilities

Attempts have been made at several forums recently to generate awareness concerning LiDAR. The present authors presented papers on LiDAR technology at Asia's largest GIS conference, MapIndia2001, in New Dehli. The presence of Optech Inc. at this conference was also an encouraging sign. The second author is active in generating awareness about the benefits of LiDAR in several other arenas The remainder of this article provides an indicative list of possible fields of application so as to arrive at awareness of its opportunities.

Infrastructure Applications

In many countries LiDAR has already found its way to a wide variety of applications. It is beneficial for purposes of planning, design, inspection and maintenance of infrastructural works. In the planning process, corridor planning and environmental impact simulations can be carried out. LiDAR provides accurate terrain information for optimisation of the construction process and logistics such as those presented by the optimal movement of earth works. Major road surface, runway surface and railroad track deformation may be traced on the fly. Large obstructions, like fallen trees after storms, can be detected and registered. In built-up areas, reliable, accurate and detailed 3D digital city models can be constructed as input for, amongst others, infrastructure planning purposes and the design of cellular networks. Such detailed mapping capabilities enable the monitoring of electric power-lines from the air. Another application in built-up areas includes change detection e.g. for detection of unauthorised expansion of existing buildings and property tax purposes.

Natural Environment

The terrain surface of forest areas can be captured accurately and with a high level of detail, whilst canopy height can also be determined and forest biomass estimated. Dunes and beaches can be captured accurately and with a high level of detail, enabling coastal erosion modelling, monitoring and flood risk management (Figure 2). When water-bodies are hit, a proportion of the pulses may penetrate the water and be reflected by the bottom of the water-body, enabling bathymetric measurements. Other applications include: flood hazard zoning, river flood modelling (Figure 3), and assessment of damages after a disaster (earthquake, flood). The accuracy and resolution of LiDAR are so high that it appears that geo-scientists are forced to readjust their erosion and floodplain models. As with so many remote sensing techniques, the value of LiDAR appears to full advantage when the data is combined with other datasets, such as aerial and satellite imagery, cadastral information and topographic data.

Concluding Remarks

Much geo-information crucial to national development can be acquired by means of LiDAR. The technology has passed through a rapid and successful history of development. At present, it has reached the stage of being an established, although still rapidly emerging, technique. The only restriction on new applications seems to be unfamiliarity and unawareness among users about its full potential. The viability of the technique depends upon a balanced involvement on the part of governmental, private and academic parties. Crucial to its success is liberalisation of India's airborne remote sensing policy. The Indian Department of Science and Technology and the Department of Space have already shown interest in the technology, which may result in the initiation of pilot campaigns in the near future.◆

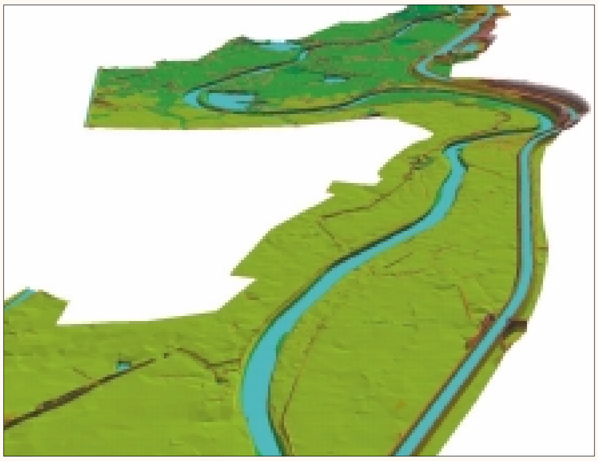

***Figure 3**, One of the important applications of laser-altimetry is river flood management. Shown here is a part of the river IJssel in The Netherlands. (Courtesy: Survey Department Rijkswaterstaat)*

Biography of the Authors

Dr. Mathias Lemmens is Assistant Professor in GIS Technology at the Department of Geodesy, Delft University of Technology. Since 1996 he has been involved in research on LiDAR.

Dr. Bharat Lohani is Assistant Professor at the Department of Civil Engineering of the Institute of Technology, Banaras Hindu University. In 1999 he completed his Ph.D. thesis at the University of Reading, UK, on the application of airborne remote sensing to the study of inter-tidal geomorphology.

Mathias Lemmens, Faculty of Civil Engineering and Geosciences, Department of Geodesy, Delft University of Technology, Thijsseweg 11, 2629 JA Delft, The Netherlands, E-mail: m.j.p.m.lemmens@geo. tudelft. nl

Bharat Lohani, Department of Civil Engineering, Institute of Technology, Banaras Hindu University, Varanasi - 221 005, India, E-mail: bharat_lohani@rediffmail. com