Real-time cartography technologies based on ALTM

Evgeny Medvedev | Daina Vagners

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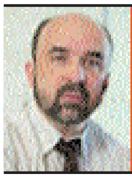

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THIS YEAR there had been more than 1,000 hours of aerial survey missions with the ALTM 2050 system all over the territory of the Russian Federation. A huge amount of data has been collected and processed. Geokosmos, a privately owned and operated topographical and surveying company based in Moscow has been involved in this along with Canada-based Optech, a manufacturer of Lidar instruments for the surveying industry. Geokosmos created a complete technology of its own for 'real time mapping' based on laser scanning with ALTM.

The technology comprises of a set of auxiliary aerial survey tools (digital aerial cameras, GPS and GLONASS receivers, data recorders, mounting system and so on), ALTEXIS software and methodology. The technology proposed by Geokosmos is already the national standard in Russia.

ALTM BASICS

The ALTM is a compact laser instrument that is mounted onto an airborne platform, and flown over the survey area. It efficiently and accurately obtains 3-D digital topographic data in a very short period of time. With typical fixed-wing aircraft speeds of 70 m/s and 1-km flight altitude, data can be collected at a rate of 3 sq km/min.

It can also be installed in helicopter platforms for low-speed surveys. As the laser is an active sensor, data collection can be conducted even at night. It can also penetrate forest canopy, making it possible for you to produce bare earth Digital Elevation Models of the forested land. All these qualities make the ALTM ideal for applications such as:

- Natural resources inventory (e.g. canopy heights, biomass estimates, other forestry applications, open pit mine volume estimates)
- Large topographic surveys
- Urban mapping
- Terrain mapping / GIS applications
- Disaster prevention/assessment
- Environmental assessment (e.g. coastal engineering, tidal flat monitoring, dune/beach erosion, wetlands mapping)
- Corridor or route surveys (e.g. monitoring of electrical power lines/towers, gas/oil pipeline, road constructions, urban canyons, urban infrastructure and development

The speed at which data can be acquired makes the ALTM substantially more cost-effective than standard photogrammetry methods. It is also compatible with most photogrammetric camera mounts.

To summarize the technology's distinct advantages over more conventional survey and aerial mapping methods, one may enlist:

- Day or night operation: No need for sunlight or a particular sun angle
- Totally digital: No intermediate steps to generate digital X,Y,Z data points
- Dense data
- Accurate: Typical 15 cm elevation accuracy
- Airborne: Easy installation in multiple platforms (fixed-wing, rotary, UAV)
- Non-intrusive: Capable of rapid access to and from remote areas
- Rapid turnaround: 'Overnight' processing

CONCEPT OF REAL-TIME MAPPING

LiDAR technology has today completely proven its effectiveness. Application like Digital Terrain Model (DTM) production and power-line corridor mapping are already classical. The technology is still progressing, its main advantage first of all lies in its combination with other airborne remote sensing data, such as aerial photography.

The '3D nature' of laser data allows fully, automatic spatial orientation, orthorectification and geopositioning of imagery. It is obvious from practical perspective that the simultaneous recording and combined processing of LiDAR data, aerial imagery and some other kinds of remote sensing data accelerate the processing cycle and increase data accuracy and reliability. Such an approach encapsulates the concept of real-time mapping.

THEORETICAL ASPECTS

The progress in LiDAR technology and its numerous topographical application are rather impressive for the last few years. On the one hand the development of sophisticated algorithms for geomorphological analysis is still ongoing, enabling improved recognition and detailed description of objects. On the other hand, fusion with other datasets results in augmented information.

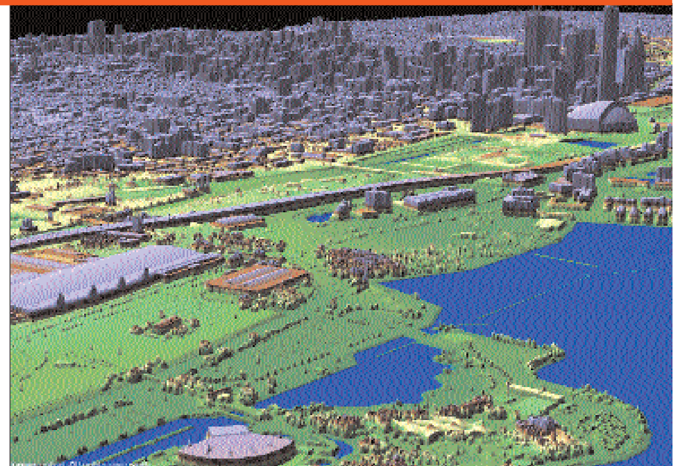
In this respect, LiDAR and digital imagery data perfectly supplemented each other. LiDAR allows the effective generation of a DTM while enabling automatic recognition of many classes of objects having a clear geomorphological structure. Digital imagery provides the most natural kind of scene representation, including complete information concerning surface texture.

In some cases, this pure visual information may be supplemented with infrared or multi-spectral data. LiDAR data and appropriate processing technology enable the following:

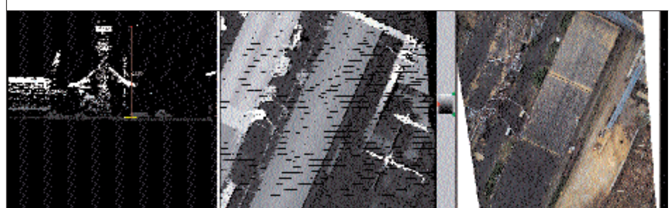
- Avoidance of terrain work for the collection of geodetic support for both corridor and area survey
- Use of laser-derived DTM for ortho-image rectification
- Creation of new procedures for aerial triangulation in particular, and frames georeferencing in general, by combined geomorphological analysis of laser data and imagery

Simultaneous recording of LiDAR data and digital imagery requires joint operation of the two sensors on board of the aircraft, which apparently is associated with the solving of a number of technological problems.

Generally speaking from practical point of view the concept of real-time mapping proposed by Optech and Geokosmos may be regarded to be some alternative for a classical stereotopographical method in cartography, though it would be more accurate to declare that this technology is derived from wide variety of classical geodetic and photogrammetry methods.



▲ Fig 1 The laser image of Toronto water front. The data is collected by means of the latest Optech ALTM 30/70 with 70 kHz laser scanner

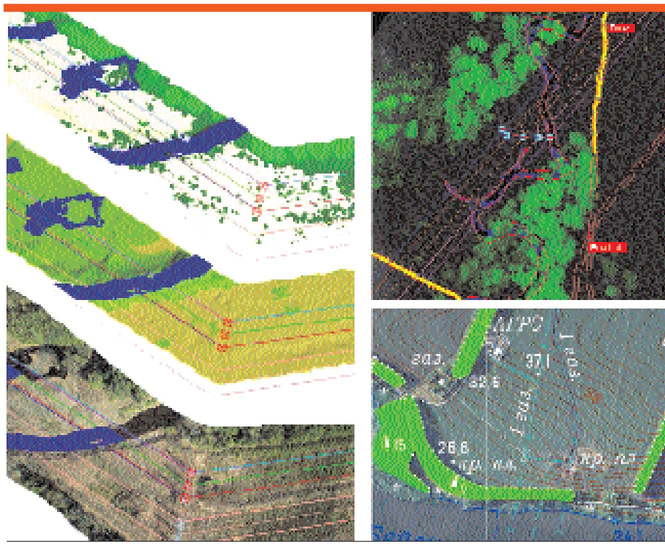


▲ Fig 2 Simultaneous recording of ALTM laser data and aerial imagery. The complete processing of both data sets, in particular automatic photo rectification, is carried out by Geokosmos software packages

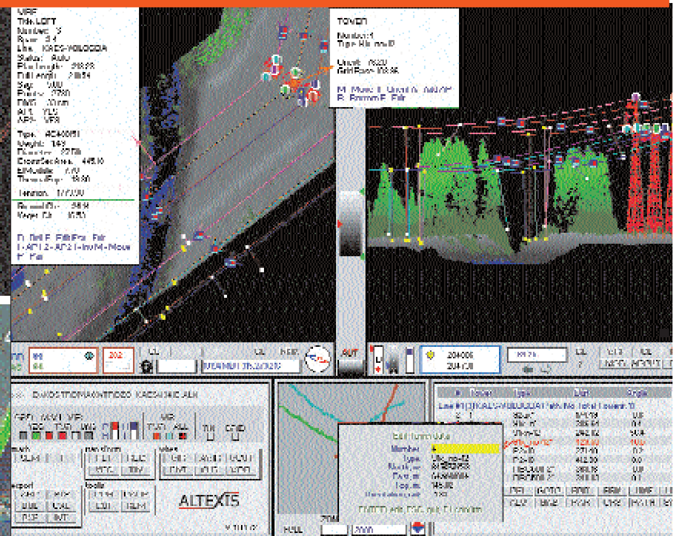
LIMITATIONS

The problems of such nature are quite diverse in their characters, but they all are in general tied with issue of points correlation on stereopair. In certain cases this leads to complete inapplicability of the method, for instance in snowed or sanded landscapes with a full absence of visual texture. In other cases this problem puts the results' quality in dependence on the number of the factors like average forest elevation and density when surveying forestry, or buildings shape when mapping city landscapes.

The mentioned above limitation of the stereophotogrammetry method emerges mostly in the most practically meaning applications connected with survey of complex and full of objects scenes. Particularly due to this reason, large-scale mapping of city landscapes with significant share of multilevel buildings can not be done by exclusively aerial survey methods, thus forcing massive involvement for this goal carrying out of on-ground topographic survey, extremely expensive in city conditions. Besides, there are season limitations restricting aerial surveys in presence of significant snow cover or vegetation with leaves. For most part of the Russian Federation for example such limitations only leave 1.5 - 2 months a year for aerial survey. Practically, such problems often lead to the serious deformation of technology that causes doubts about results correctness. Thus, production of DTM of a big city area considered as compulsory within the stereotopography method, is deemed



▲ Fig 3 The stages of topography map production under Optech & Geokosmos technology of real time mapping



▲ Fig 4 The semantic power line model within Geokosmos' specialised software module ALTEXIS

such a labor consuming and expensive task affecting the overall cost of project that a 'compromise' is offered to use a relief model taken from existing topographic map of appropriate scale. Given the extremely low metrologic quality of existing topography basis in Russia, it is only left to guess what consequences in future would be caused by such decisions when doing, for example, a cadastre system to regulate real estate relations.

It would be reasonable to note here that the main value of the real time mapping technology is that it is next to free from all the limitations mentioned above. This explains its great attractiveness for potential customers engaged in various kinds of topographic activity.

The proposed digital technology of mapping in real time has overcome the major disadvantages of the classical stereotopography method which as already mentioned are a necessity of on-ground geodetic support, inevitable manual labour on stages of frames mutual orientation, DTM production and correct combination of orthorectified photos.

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SOME PRACTICAL RESULTS

The proposed technology of real time mapping assumes carrying out the aerial survey mission for desired territory with ALTM and other aerial survey equipment. The aerial data is to be processed according to the following scheme:

Logically the first is a procedure of true DTM separation from full cloud of laser points. As it was mentioned, implementation of such procedure is a sophisticated task. Solution is reached upon application of special topologic analysis algorithms classifying laser point per criteria 'belong/not belong' to true ground. Such algorithms are built upon two obvious postulates:

- True ground point has minimal value of geodetic elevation in comparing with ones in its vicinity
- Spectrum of spatial frequencies of true ground surface has no high frequencies

Particular realisation of such algorithms is normally carried out by modelling mathematical surface, which delineates the laser point cloud from beneath. Spectral selection for the given surface is expressed by limiting the values of the first and second differentials of the surface regarding as a two-dimensional function of planar coordinates. In practice such an approach provides quite satisfactory results.

The next step is the procedure of aerial photos automatic mutual orientation:

- The special DTM processing is implemented with a goal to detect the DTM fragments for which the correlation algorithms of point matching can be applied effectively. It means that such fragments must be smooth enough and be free from vegetation, buildings, etc.
- The aim of the next operation is a transfer of selected 'favorable' fragments (their mathematical representation) to the coordinate system of each aerial photo taking into

account their visibility (these fragment may be shielded with a relief or on-ground objects).

- Using only selected 'favorable' fragments (more accurate their projections into the photo plans) the stereo model is produced, which now is free from miscorrelation problems. Of course such a model is not full, because it is made up from the fragments. But it is not a problem within this real time mapping approach, because the created model has only auxiliary meaning contrary to the classical stereotopography method.
- After that the model produced during the previous stages is finally orientated relatively laser-derived DTM, that corresponds with its orientation in geodetic space. Naturally, the orientation of each frame is implemented also.

The presence of GPS principal point coordinates for each photos is strictly determines the stereo pair position in space with only one degree of freedom - angle of turning around survey basis vector. So the final true stereo model orientation relatively to DTM may be done by minimisation of spatial misalignment function for both laser-derived and photogrammetrical surfaces of terrain. This may be done with R.M.S. method, for example. Besides the topography survey and DTM making which are definitely the main kinds of companies activity, there are some other important application where this technology is successfully used. Among them are:

- Power lines inspection
- GIS and land use systems
- Forestry
- Coastal mapping and monitoring
- Avalanche and flood prediction

The technology perhaps proved its applicability for wide range of topography and non-topography application where it can be used instead of combinating with classical photogrammetrical and geodetic methods. ■

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