New developments of SOCET SET®[1], ORIMA and PRO600

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ABSTRACT

Geographic information generated by photogrammetry is originating from a growing range of sensors. Both LIDAR and IFSAR systems and the recently introduced digital airborne sensors will be particularly significant. Organizations producing such information encounter increasing competitive pressure as commerce becomes more global. Productivity is the universal key. Modern requirements for photogrammetric systems, therefore, emphasize data fusion and automation. The evolution of software products available from LH Systems reflects these twin goals and considerable progress can be reported: throughputs from digital photogrammetric production are on the increase. Nevertheless, rather little has been achieved in certain critical areas of automation, a situation that must urgently be addressed.

1. INTRODUCTION

The recent addition of new digital aerial sensors, satellites, LIDAR and IFSAR systems are generating ever larger volumes of data and increasing possibilities for data fusion with the hope of increased automation. By introducing these new devices into the production flow line, we must strive to handle the widening data types and quantities and build efficient data flows and algorithms that will yield increased automation in photogrammetric data production.

LH Systems, LLC, combined inside Leica Geosystems with new partners such as ERDAS, Inc., is studying the smoothest methods of increasing data production when using a variety of these new devices. Our remote sensing and photogrammetric data production products are being adapted to new digital data collection systems such as the recently introduced ADS40 Airborne Digital Sensor and the ALS40 Airborne Laser Scanner systems. These new collection devices yield additional data types and massive quantities of data and thus require improved data handling and processing systems. In particular, our digital photogrammetric products are being adapted to process these new data types more efficiently.

The new image sources from the ADS40 include improved dynamic range and improved spectral range over traditional film systems. This yields potential for new product generation and improved automation. Care must be taken to build reasonable data processing methods to achieve the promise of more automation. The dense DTMs that are scanned in seconds from LIDAR systems such as the ALS40 must be adjusted and edited efficiently to fulfill the needs for dense 3D modeling while still being affordable.

This paper reviews these new data sources, discusses recent changes in our products to better handle these new data sources, and alludes to new modules for improved automation and data processing.

1.1. Review of the products

Three products fall within the scope of this paper. SOCET SET is an extensive package for digital photogrammetric workstations. First launched on the commercial market in 1990, it performs all the

[1] SOCET SET is a registered trade mark of BAE SYSTEMS Mission Solutions Inc.

frequently required operations of digital photogrammetry and is particularly flexible in terms of image types, formats, coordinate systems and map projections. ORIMA, an acronym for orientation management, is a product for orientation and triangulation. It has been the standard software on SD-line analytical plotters and upgraded legacy systems since 1995 and has been offered with SOCET SET since 1998. Its strengths are sophisticated bundle adjustment followed by interactive graphics to assess results, identify weaknesses, supervise remeasurement, etc. PRO600 is LH Systems' standard offering for feature collection and editing, operating in Bentley Systems MicroStation GeoGraphics® environment. Developed in the late 1980s, PRO600 runs on analog and analytical workstations but has been especially closely integrated with SOCET SET. All these software products except ORIMA run on Solaris® and IRIX® platforms as well as Windows NT/2000®. This paper is focused on recent and ongoing developments of these products.

2. NEW DIGITAL DATA TYPES

We begin with a review of the two new sensors introduced above. There are also other important data sources that have recently begun to be used in LH Systems photogrammetric software products.

2.1. LH Systems ADS40 Airborne Digital Sensor

The ADS40 (R. Sandau *et al*., 2000) is a 12-bit, three-line "pushbroom" sensor that typically produces seven channels of data during a single flight line or project. These channels deliver forward, backward and nadir panchromatic, RGB, and near infrared data. The data is collected directly on to removable hard disks in a somewhat specialized 16-bit compressed format. This format allows for a compression level of about 4x over the original 16-bit/pixel representations. This facilitates more efficient recording and data transfer and a cost benefit due to reduced disk requirements. The data volume collected over time is very large and can be in the range of 400 GB of uncompressed data per hour. Typical ground resolution depends on flying height and would commonly be in the 10-30 cm range per pixel.

2.2. LH Systems ALS40 Airborne Laser Scanner

The ALS40 is a scanning "pushbroom" sensor that generates large quantities of elevation points and intensity values over the terrain surface. After initial GPS and IMU post-processing, there are two main data types: a point cloud of dense elevations and a point cloud of intensity. Typical point spacing on the ground depends on flying height and other factors and is commonly in the 1-10 meter range. Thus very dense and highly precise data is collected. This data is usually processed further into dense DTMs of 1 to 50 million points. The elevation point cloud can also contain multiple elevations per laser return. This yields added information of the ground objects and permits further automated processing.

2.3. Other new data types

SOCET SET continues to undergo expansion to handle a variety of other data types. Those added recently or currently in work include the ERS-1, ERS-2 and Radarsat satellite data. IKONOS imagery is read together with the Rational Polynomial Coefficients provided by Space Imaging: SOCET SET copes with this using sensor models already written for US government imagery. It is planned that data from the forthcoming Earth Watch high-resolution satellite sensor can be processed as soon as it is available. TerraSource® imagery from the ImageAmerica DDP-2 (Direct Digital Panoramic) sensor and SPOT 4 satellite imagery can be processed as well.

3. UPDATES IN DIGITAL PHOTOGRAMMETRY PRODUCTS

Once again, the focus is on modifications to the products to accommodate data from LH Systems' new ADS40 and ALS40 sensors. Even earlier in the flowline, however, a requirement that has become critical to more and more customers is an archiving system.

3.1. Digital Data Archiving

Digital data is immediately at risk after collection: there is no film in a storeroom as a last resort. One of the first challenges in dealing with these new data volumes is to archive them safely. LH Systems has introduced the GDM100 GeoVault Data Manger for cataloguing and archiving spatial data. The GDM100 increases productivity by providing an automated archive and retrieval system. Massive quantities of data can be redundantly archived without user intervention using automatic tape libraries. Subsequent retrieval of data for production processing is also automatic, thus relieving congestion and human effort when performing data handling during production. The use of metadata to catalogue the data into a standard RDBMS permits rapid and simplified queries and retrieval decision making. Whilst specific clients for GDM100, for example for SOCET SET or ADS40, are available, generic clients have been written too and this product is designed for a wide client base.

3.2. Updates in SOCET SET and ORIMA to support ADS40 imagery

Since the ADS40 is a pushbroom sensor that exploits the high frequency attitude output from the Applanix POS system (R. Sandau *et al.*, *ibid.*), a specialized photogrammetric sensor model has been implemented which models the imaging events (U. Tempelmann *et al.*, 2000). This sensor model is used for most photogrammetric operations with the imagery and is further implemented into the triangulation process of ORIMA. The software has been augmented for self-calibration and boresight alignment of the ADS40 system as well. The use of triangulation yields reliability and additional accuracy over the direct orientation provided from the GPS/IMU system alone. This gives flexibility for datum and GPS error sources as well.

With the addition of this new sensor model, and the implementation of direct image access to the 16-bit JPEG compression, SOCET SET further exploits the ADS40 imagery for DTM extraction, feature extraction, orthophoto production and other classical photogrammetric tasks. The addition of forward, backward, and nadir stereo coverage combined with higher signal to noise ratio will increase the efficacy of automatic DTM extraction.

The image types and mathematical models used for the ADS40 are readily available and will be published for other users wishing to implement this software.

With ERDAS, we are implementing the sensor model in the IMAGINE product for classical remote sensing algorithms such as classifiers, image rectification, band merging, etc. This will allow improved band combinations between panchromatic, RGB, and near infrared channels. Thus the entire IMAGINE functionality can be fully exploited with ADS40 imagery.

3.3. Updates in SOCET SET and PRO600 for LIDAR data processing

The increased demand for editing and processing of LIDAR data combined with our support for the ALS40 system is driving the development of improved tools for handling large DTMs. These will include the efficient import of LIDAR binary files. These tools will give users new processes for filtering, thinning, grid or TIN generation, and intensity image generation at import time.

Furthermore, the new tools allow subdivision of the LIDAR strips into smaller working units. After import of the LIDAR intensity image as an orthophoto, orthophoto stereomates can be generated in batch to provide stereo visualization of the DTMs. Within the DTM display and edit tools, enhancements are in work to allow tiled access to very large DTMs in order to reduce memory overuse and increase algorithm efficiencies. Additional third party tools such as TerraScan, from the Helsinki firm Terrasolid Oy, are being used for more advanced filtering, thinning, vegetation filtering, and visualization through MicroStation®. LH Systems' PRODTM functions on top of MicroStation and also fosters the smooth dataflow between TerraScan, SOCET SET and MicroStation.

Most of these tools are augmentations of existing ones and will yield smoother dataflow and editing. The addition of break lines into the LIDAR DTMs can be done interactively or in batch modes using either SOCET SET or PRO600. These breaklines can be added using classical stereo film imagery, satellite imagery, ADS40 imagery, and even the LIDAR intensity stereo model created from the ALS40 itself.

4. FURTHER ASPECTS OF DATA FUSION AND AUTOMATION

Since digital imagery obviates the film processing and scanning phases of the workflow, and LIDAR data is supplied as DTMs already of good quality, the level of automation is increased *de facto*. Though the processing of these data types and their fusion with other sources already capable of being processed in SOCET SET, ORIMA and PRO600 is the most exciting development currently unfolding, many other aspects are worth brief comment.

4.1. Data fusion elsewhere in the flowline

Recently added image sources have been discussed above. Equally useful for many customers are developments aimed at increasing the compatibility between their existing projects and the digital photogrammetric workflow. For example, import of imagery in ERDAS, MrSID and ECW formats is widely welcome. ORIMA has been enhanced to support the same coordinate systems and map projections as SOCET SET, and PRO600 now operates with data in geographical as well as Cartesian coordinate systems. Customers from the GIS community are provided with bi-directional, three-dimensional interfaces between SOCET SET and Laser-Scan LAMPS2 or ESRI® ArcSDE™. Improved links between PRO600 and the ESRI world are under consideration.

4.2. Notes on automation

To some extent, the current situation with automation is disappointing. The big advances that digital photogrammetry promised, for example totally automatic generation of DTMs or extraction of features, have not been achieved. LH Systems' packages are not so different from those of its competitors, perhaps, in that success tends to be represented by incremental improvements to algorithms for automatic point matching in triangulation, automatic terrain extraction using area matching, semi-automated feature extraction, automatic seamline placement for mosaicking, or image balancing and dodging. Similarly, incremental improvements continue to be made in the blunder detection and interactive editing processes that must necessarily accompany the fully automatic steps. Further elements of "mundane automation", arguably rather sterile intellectually yet of not insignificant value to the customer, include batch processing functions for all the major operations of the photogrammetric flow, and the TopoMouse™ control device, which offers not only ergonomic control of measurement in the stereo model but also completely programmable

buttons and rocker switches, which when properly used offer worthwhile acceleration in routine operations such as feature collection or DTM editing.

Indeed, there may be a realization that the dramatic increases in automation that we have anticipated for so long will not arise from algorithmic development, at least for production systems as opposed to the research and development environment, but have been awaiting the new data sources on which this paper has been centered. Airborne digital sensors offer linear response, together with greater radiometric range and signal-to-noise ratios than scanned film imagery. Multispectral and panchromatic imagery are available from a single flight with a single sensor. Matching algorithms are certain to work more effectively with this improved input. The three-line design of the ADS40, moreover, enables triple matching throughout a strip, certainly a more robust process than pairwise matching. Finally, the combined processing of imagery and LIDAR data is surely a significant key to automatic feature extraction, whereby LIDAR gives the clues to buildings, trees or other discontinuities in the surface, guiding tomorrow's sophisticated algorithms to accurate, high resolution matching in a second phase.

5. CONCLUSIONS

Digital photogrammetric production, as exemplified in this paper by three LH Systems software products, seems certain of a rosy future. Products exist already that can make data fusion a reality, with the result that customers can use photogrammetric processes with data from those sensors that are most suitable for their applications. Digital airborne sensors, LIDAR and IFSAR are the most exciting debutantes in this respect, but the overall range of image types and formats that can be processed continues to increase in response to demand. These sensors, too, may be the key to big increases in automation that have heretofore proved elusive. Incremental algorithmic development may soon be superseded in production tools by rapid leaps in development. Elsewhere in the flowline, customers' options are enlarged by increasing choices of coordinate systems and map projections, by direct import of GPS and IMU data, by wider ranges of environments for feature collection and editing and by more widespread batch processing and workflow tools.

These changes result from investment in science and engineering in response to customers' requests. Yet the commercial developments of the few months before the Photogrammetric Week may prove equally important to our future! LH Systems' acquisition of Azimuth Corporation has necessitated acceleration in the development of tools for LIDAR processing. And the coexistence of LH Systems, ERDAS and two GIS business units under the Leica Geosystems roof is an exciting thrust towards integrated photogrammetric and remote sensing tools tuned for vertical applications in the overall GIS environment.

Data fusion and automation, therefore, have cranked to the top of a photogrammetric roller coaster. A massive, breathtaking acceleration of development is perhaps imminent, providing customers with remarkable new levels of productivity.

6. REFERENCES

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