FROM IMAGERY TO MAP:

digital photogrammetric technologies

15th International Scientific and Technical Conference

Conference Proceedings

Organizer

Racurs
(Moscow, Russia)

Partner

Galantis
(California, USA)

Supported by

- **International** Society for Photogrammetry and Remote Sensing (ISPRS)
- **Russian** Federal Space Agency
- **National Committee** for Cooperation with Latin American Countries (CN-CEPLA)
- **Moscow** State University of Geodesy and Cartography
- GIS-Association **Russia**

Dear colleagues!

We present to your attention the proceedings of the 15th International Scientific and Technical Conference "From imagery to map: digital photogrammetric technologies". Here are few words about the conference history. The first, second and third conferences were held in Russia, next ten in Europe. Since last year we have expanded conference geography and held the 14th conference in Asia, China. This year, the 15th conference will be held in Latin America, Mexico. Racurs Company has strong relationships with this region. Moreover, the very first Spanish localization of PHOTOMOD was done in Argentina. PHOTOMOD is widely used for RSD processing and education in Cuba, Mexico, Brazil, Colombia, Argentina, Chili, Nicaragua.

Traditionally, the main topic of the conference is photogrammetric processing of aerial and satellite images. The related issues also do not go unheeded. Undoubtedly, the proceedings will be useful and informative for you.

Sincerely yours,
the Scientific Committee of
the 15th International Scientific and Technical Conference
"From imagery to map: digital photogrammetric technologies"

15th International Scientific and Technical Conference
"From imagery to map: digital photogrammetric technologies"
October 26-29, 2015, Yucatan, Mexico.

RACURS

2015

CONTENT

Utilización De Photomod Lite Como Herramienta De Aprendizaje Del Método Fotogramétrico

Gabriela Alvarez Parma, Alejandro Munizaga, Walter Melian, Silvia López
Centro de Fotogrametría Cartografía y Catastro,
Facultad de Ingeniería - Universidad Nacional de San Juan (UNSJ), Argentina

RESUMEN

Las tendencias actuales, en cuanto a la gran disponibilidad de recursos de imágenes, la demanda creciente de datos geográficos para su utilización masiva en un amplio espectro de disciplinas, y las nuevas tecnologías que evolucionan día a día, imponen al Ingeniero Agrimensor su involucramiento directo con los métodos y técnicas más modernos utilizados para el relevamiento del terreno y la producción cartográfica, entre ellas la Fotogrametría.

A partir del año 2015 se propuso un cambio de enfoque pedagógico para el dictado de la cátedra de Fotogrametría, correspondiente al quinto año de la carrera de Ingeniería en Agrimensura de la Facultad de Ingeniería, de la UNSJ. Este cambio consistió en buscar el involucramiento directo de los estudiantes en la construcción activa y significativa del conocimiento, aplicando en las clases los conceptos pedagógicos de "Clase invertida" y "Aprender haciendo".

A modo de fortalecer esta iniciativa, se propuso la implementación de una práctica final integradora, de todos los contenidos dictados en la materia, a partir de la aplicación del método general de la fotogrametría, en un proyecto de pequeñas dimensiones, y utilizando como software de apoyo PHOTOMOD Lite 5.3.

Con el objetivo de compartir la idea de educar a futuros profesionales capaces y competentes, y no meros receptores de saberes y datos, se invitó a otras cátedras interrelacionadas con la fotogrametría, a pasar a ser parte de la iniciativa de brindar conocimientos y herramientas para que los alumnos sean capaces de resolver situaciones problemáticas diversas, trabajando r en proyectos reales, y asi puedan crear sus propios portfolios con sus alcances y aprendizajes.

Los resultados logrados son considerados como muy positivos, ya que se pudo verificar la participación activa de los alumnos en los conceptos teóricos generales de la materia, trabajando motivados, en equipo y vinculados con otras materias, propiciando la interrelación de contenidos, donde alumnos y profesores trabajaron juntos para evaluar y lograr un aprendizaje significativo.

PALABRAS CLAVE

Fotogrametría digital, software de aplicación fotogramétrico, Photomod, proceso fotogramétrico, clase invertida (flipp classroom) aprender haciendo, enseñanza universitaria.

OBJETIVO

El objetivo general del proyecto se enfocó en complementar y reforzar los conocimientos teóricos adquiridos durante el cursado de la materia a partir de la aplicación del método general de la fotogrametría en un proyecto de pequeñas dimensiones, aplicando en el dictado de clases los enfoques pedagógicos denominados "clases invertidas" y "aprender haciendo".

Para ello se propuso la realización de una práctica final integradora, cuyos objetivos particulares estaban dirigidos a relevar los distintos rasgos del terreno en estudio y elementos necesarios para la generación de productos cartográficos finales.

Los productos finales solicitados para el área de trabajo fueron los siguientes: Modelo digital de elevaciones; Cartografía digital; Ortofoto; Hoja Cartográfica; Informe final.

La precisión de los productos solicitados debían ajustarse a una escala 1:10000.

La realización y aprobación de la práctica, se consideró como condición de aprobación de la materia.

GRUPO DE TRABAJO

El grupo de trabajo para llevar a cabo esta propuesta, estuvo compuesto por tres docentes de la cátedra de Fotogrametría y personal de apoyo, involucrados directamente en la proyecto, y otro grupo de docentes del Departamento de Agrimensura y del Centro de Fotogrametría Cartografía y Catastro, que colaboraron con la iniciativa en la realización de trabajos relacionados con sus propias materias.

El grupo de alumnos que realizaron la práctica estuvo compuesto de 15 personas.

ÁREA DE TRABAJO

El área de trabajo seleccionada para la práctica se ubicó en las inmediaciones de la zona denominada Quebrada de Zonda, (Departamentos Rivadavia y Zonda) a 15 km al oeste de la Ciudad de San Juan, en la provincia de San Juan, República Argentina. El polígono definido involucró una superficie aproximada de 10 km2 según la figura.

El área de trabajo se dividió en sectores, que fueron abordados individualmente por 6 equipos de trabajo.

DATOS UTILIZADOS

Para la realización de la práctica se solicitó la colaboración del Instituto Geográfico Nacional de Argentina (IGN), ante quien se hicieron las gestiones necesarias para la adquisición del material fotográfico.

El IGN proveyó de 6 fotografías aéreas digitales, dispuestas en dos corridas sucesivas sobre el área de interés, con las siguientes características:

Sensor: Vecxel Ultracam XP

Calibración del sensor: Revisión 2.0

Tamaño de imagen: 11310 pixel x 17310 pixel

Tamaño de pixel: 6.000µm x 6.000µm

Distancia focal: 100.5mm ± 0.002mm

Punto principal: X ppa 0.000mm ±0.002mm; Y ppa 0.000mm ±0.002mm

Número de tomas que componen el sector: 1421

Tamaño del pixel: 0.50 m

Fecha de vuelo: 26/04/2014

Altura (snm) : 8970 m

Escala de foto: 1/83284

Bandas: 4 (Azul, verde, rojo, infrarrojo cercano).

Formato de imagen: Tiff standard.

Las imágenes originales fueron convertidas a un formato de menor tamaño para que puedan ser usadas en computadoras de características estándares.

HARDWARE UTILIZADO

Para la realización de las tareas que no requerían visualización estereoscópica, cada uno de los 6 grupo de trabajo, utilizaron un ordenador portátil (configuración típica: Procesador: Intel, i3, i5 SO: Windows Windows 7/8).

Luego para las tareas de digitalización estereoscópica se utilizaron las estaciones fotogramétricas del CEFOCCA, con el objetivo de mejorar las condiciones de visión e interpretación de los rasgos del terreno y de utilizar por parte del alumnado estaciones de trabajo actuales y posibles de utilizar en su ejercicio profesional. Se contó con dispositivos para visión estereoscópica de acuerdo a la configuración recomendada para PHOTOMOD en su licencia comercial (Tarjeta gráfica NVIDIA QUADRO FX580, pantalla nVidia 3D Vision Ready, anteojos Stereoglasses nVidia 3D Vision)

SOFTWARE UTILIZADO

Para la realización de la práctica se utilizó Photomod Lite 5.3. Los alumnos no tenían instrucción previa sobre el manejo y funcionamiento del software, la cual se fue dando en forma simultánea al avance de la práctica, utilizando de base los contenidos teóricos dictados. Como material de guía y manual de ayuda en el proceso, se tomó de referencia el documento publicado por el Ing. Carlos Lizana "Utilización de PHOTOMOD como estación fotogramétrica digital (DPS)", y manuales de Photomod.

APOYO TERRESTRE

Las tareas necesarias para el apoyo terrestre fueron realizadas en conjunto con las cátedras de Geodesia I y II y Cartografía Matemática, con el objetivo de propiciar una interrelación de contenidos y economizar tiempos de trabajo.

Se programó una campaña de medición con equipamiento GPS diferencial para el relevamiento de puntos de apoyo fotogramétrico post vuelo. Con anterioridad a la ejecución del mismo se evaluó la probable ubicación de los puntos en función del área de trabajo, características del terreno y accesos. La medición fue realizada en una jornada de trabajo dividiendo la medición de los puntos en grupos de trabajo.

El post proceso de los datos fue realizado como parte de las trabajos prácticos previstos en las Cátedra de Geodesia y Cartografía.

Con los resultados anteriores, se procedió a la elaboración de monografías de cada punto relevado para luego poder compartirlas con todos los grupos de trabajo.

ESQUEMA GENERAL DEL TRABAJO

La práctica fue organizada en etapas,

siguiendo el esquema lógico del cualquier proyecto fotogramétrico. Cada una de las etapas se cumplieron semanalmente, en un período de trabajo que abarcó poco más de dos meses con una dedicación horaria semanal de 8 a 10 horas por grupo. Para cada semana se preparó un documento indicando las tareas a realizar y entregables o obtener, según el detalle que se cita a continuación:

Etapa 1: Creación del proyecto fotogramétrico bajo el entorno del software de trabajo.

● Generación del Proyecto dentro del entorno de Photomod

● Armado del bloque

Etapa 2: Orientación interna

● Cargar datos de la cámara (ver certificado de calibración),

● Asociar la cámara a cada una de las imágenes

● Realizar proceso de orientación interna

● Generar reporte y analizar resultados

Etapa 3: Orientación externa

● Cargar coordenadas de puntos de apoyo terrestre (PAF)

● Identificación y medición de puntos de apoyo en las imágenes.

● Medición de puntos de enlace entre fotogramas.

● Medición de puntos de enlace entre corridas.

● Transferencia de puntos medidos en la zona de superposición lateral y de triple superposición a los pares contiguos.

● Generar reporte y analizar resultados.

Etapa 4: Ajuste de bloques (Aerotriangulación)

● Configurar método de ajuste.

● Configurar parámetros del reporte

● Establecer alguno de los puntos de chequeo

● Analizar los resultados obtenidos (residuos aceptables 50 cm planimetría y altimetría en los puntos de apoyo, y 75 cm en los puntos de chequeo)

● Generar reportes con parámetros del ajuste.

Etapa 5: Restitución tridimensional

● Digitalizar estereoscópicamente: Caminos principales (rutas), Caminos secundarios (huellas más destacadas), Drenajes principales, Rasgos para mejorar el modelo de elevaciones, Puntos acotados, construcciones.

● Exportar resultados para su posterior compilación cartográfica

Etapa 6: Generación del modelo de elevaciones y edición

● Crear una grilla de puntos regulares.

● Incorporar datos vectoriales

● Generar TIN

● Generar DEM

● Visualizar resultados y evaluar correspondencia con el terreno

● Evaluar posibles ediciones. Exportar resultados: Archivo de curvas de nivel, Modelo de elevaciones

Etapa 7: Generación de mosaico y ortofoto

● Configurar proyecto de mosaico

● Evaluar solapes, sitios de corte, balance de brillos.

● Generar Ortofoto

- Evaluar posibles desplazamientos
- Exportar resultados: ortofoto

Etapa 8: Producción cartográfica final

- Evaluar y seleccionar software para la compaginación cartográfica final.
- Diseñar esquema de hoja cartográfica conteniendo todos sus elementos.
- Volcar sobre la hoja los productos obtenidos a partir del proceso fotogramétrico
- Seleccionar simbología adecuada
- Exportar resultados e imprimir producto final.

Etapa 9: Elaboración de memoria final de resultados y exposición del trabajo realizado.

- Con la experiencia realizada a partir de la práctica elaborar un informe técnico conteniendo el resumen del material utilizado, tareas desarrolladas y productos obtenidos.
- Exposición y defensa del trabajo realizado

CONCLUSIONES Y EXPECTATIVAS A FUTURO

El enfoque pedagógico iniciado, buscó centrarse en la idea de educar a futuros profesionales capaces y competentes, y no meros receptores de saberes y datos, pasando a ser la base de una metodología del proceso de enseñanza-aprendizaje diferente, que brinda conocimientos y herramientas para que los alumnos sean capaces de resolver situaciones problemáticas y diversas en tiempo real. En lo que respecta a la fotogrametría; que trabajen en proyectos reales y puedan crear sus propios portfolios con sus alcances y aprendizajes, destacando la importancia y la necesidad de hacerlos sentirse protagonistas y constructores de su propio aprendizaje.

Se promovió en los alumnos el uso intensivo de material de lectura, videos y documentos ya existentes en internet relacionados con la materia, como así también la práctica con modernos equipamientos. Esto les permitió abordar la apropiación de nuevos conocimientos referidos al método general de la fotogrametría, de una forma significativa. Si sumamos la implementación de un proyecto real, aunque de pequeñas dimensiones, les permitió vivenciar el concepto de "aprender haciendo", potenciando el aprendizaje en el aula.

La utilización de Photomod Lite 5.3 como software fotogramétrico facilitó la aplicación del método general de la fotogrametría. Su esquema lógico permite al alumnado adoptar con mayor facilidad los conceptos teóricos adquiridos. Su versión en español y material de referencia ya

generado, facilitó la apropiación por parte de los alumnos, sumado a la facilidad de contar con el software en el idioma nativo de los alumnos.

Si bien Photomod Lite, es una versión liberada con algunas restricciones, para la ejecución de este proyecto superó las expectativas, por cuanto pudieron realizarse todas las tareas previstas y obtener verdaderos productos cartográficos de acuerdo a los requerimientos planteados.

Esta primera experiencia plantea a futuro, para el dictado de la materia, un desafío, ya que el dominio de una competencia y de herramientas tecnológicas no es algo lineal unidireccional, sino que requiere un proceso de aprendizaje apoyado en determinados conocimientos y en el desarrollo de contenidos aportando experiencias, debate de opiniones, iniciativas, proyectos, etc.

Por último, los resultados logrados son considerados como muy positivos, ya que se pudo verificar el involucramiento activo de los alumnos en los conceptos teóricos generales de la materia, trabajando motivados y en equipo y la vinculación con otras materias propiciando la interrelación de contenidos, donde alumnos y profesores trabajaron juntos para evaluar y lograr un aprendizaje significativo.

Colaboradores: Ing. Dario Terluk, Ing. Hernán Alvis Rojas, Lic. Ricardo Velázquez, Ing. Eduardo Marquez, Ing. José Maraz, Ing. Guillermo Garcés, Ing. Osvaldo Estevez.

PHOTOMOD

Digital photogrammetric system

Spatial aerial triangulation

Digital terrain models

2D and 3D-vectorization

Orthorectification and mosaic creation

Map making

3D-modeling

RACURS

› UniScan™

real-time satellite monitoring

A multi-mission UniScan™ ground station is capable of receiving Earth observation data from polar-orbiting remote sensing satellites in X-band. One UniScan™ station covers an area of about 20 million sq. km. and can receive images from optical and radar satellites in real time. The UniScan™ system includes software and hardware components for data acquisition, storage and processing. As of today there are more than 80 UniScan™ stations deployed worldwide, including Russia, Ukraine, Kazakhstan, Uzbekistan, Vietnam, Spain, USA, etc.

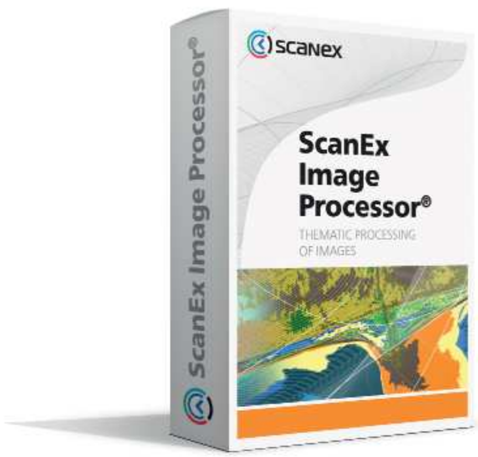
info@scanex.ru

+7 (495) 739-73-85 • www.scanex.com

› SIP

ScanEx Image Processor®

High-performance remote sensing software for photogrammetric processing and thematic mapping



The main features of the software include support of all major remote sensing data formats, user-friendly and intuitive interface, paralleled computing, ability to work with large volumes of data, automation and a 64-bit architecture. The software provides all functionality that is necessary to perform basic and advanced image processing on an industrial scale for a variety of applications. The modular structure of the SIP provides an exceptional level of flexibility and scalability to end-users.

software@scanex.ru

XV Años De Experiencias En El Uso Del Programa Digital Fotogramétrico PHOTOMOD En El Ámbito Profesional, Investigativo Y Docente En La Universidad Autónoma De Sinaloa; Campus Los Mochis, México

Ciro de la C. Díaz
Universidad Autónoma de Sinaloa, Mexico

El Uso del Programa Photomod se ha difundido en América Latina, en ello ha jugado un papel predomínate los egresados de los centros de enseñanzas de la Federación rusa, y las generosas facilidades, que ha mostrado la Empresa RACURS. Conocemos del uso del Software en versiones de trabajo y demo en Chile, Argentina, Colombia, Cuba y por su puesto en México.

Desde el año 2000 en la Universidad Autónoma de Sinaloa, México se ha venido usando el programa Digital Photomod, versión de trabajo y demos (desde la Ver2.11 hasta la última actualización de 5.3). Nos ha servido como herramienta insustituible en el aprendizaje e instrucción de los estudiantes en los cursos de fotogrametría, y en la posibilidad de poder convertir las imágenes terrestres aéreas y satelitales en cartas topográficas, catastrales y para GIS.

En el campo de la investigación ha permitido poder procesar imágenes tomadas por nuestros propios medios desde aviones ligeros y ultraligeros de ciudades, litorales, islas, minas, estudios de ecosistemas, vegetación, monumentos históricos, objetos metrados en 3d, entre otros. Lo más importante poder demostrar para la docencia y la investigación ciclos tecnológicos cerrados.

Ortomosaico Mochis, México

Ortofotoplano UAS Campus Mochis

Plano topográfico UAS Campus Mochis

The Measuring Qualities of Archival Aerial Photographs as A Function of Time

Ireneusz Ewiak, Paulina Brodowska
Military University of Technology, Faculty of Civil Engineering and Geodesy, Warsaw, Poland

In the process of aging the usable properties of the material change over time. Aging is detrimental for a lot of materials and results in the deterioration of their properties. In case of aerial photographs, elapsed time predominantly dictates their interpretative and measuring value, which, while linked to physical properties of the photographs, depends on external factors as well. Supposing the physical properties of aerial photographs do not change, the process of aging may only be considered with regard to the degree of changes of the depicted topography, and such an aspect of the aging process is the subject of the present research. The degree of aging of aerial photo may be indicated through evaluating the possibility to project and measure the ground control points, which comply with the required criteria of completeness and layout, within the block is a part of. It was agreed the points should be clearly identified in archival aerial photographs, and directly measured, taking current topography into account.

The purpose of this research was to determine the time resolution of the aerial photographs block, for which the block could be prepared in compliance with the Polish quality standards. In order to determine the indicator, aerial triangulations of 10 blocks of aerial photographs obtained in different time periods between 1972 and 2013 were elaborated. The photographs taken with analogue cameras, scale from 1:5000 to 1:30000, and digital cameras of GSD spatial resolution between 10 and 15 cm, were used in the research. The arranged blocks included from 60 to 4000 aerial photographs with standard overlaps of 60% and 30% in flight and cross flight direction taken analogue images respectively, and 70% and 50% for digital images. The images covered approximately the same urban area, with minor height difference, spreading circa 900 km2. In order to examine the aging degree of an aerial photograph, the requirements for measuring control and tie points of the block, and the accuracy of the aerial triangulation results, were determined. Derogations from these requirements dictated the value of the aging degree of aerial photograph coefficient. Two tie points had to be measured in each Gruber position, assuming they are measured in all photographs. For the image coordinates measured with standard deviation of more than 5 micrometres, three binding points had to be measured in the position of six-fold photo coverage. It was also agreed that the tie points measured in at least 4 photographs, should be no less than 35% of all tie points. The number and placement of the control points in the block, and their position in the aerial photograph, were to assure the required accuracy of the result and its homogeneity.

The project of control points included individual properties of the block, such as shape, the measuring hindrance resulting from the topography and possible inconsistencies in the lateral overlap. It was agreed that when measuring the perspective centres for all photographs in a block, one had to measure two control points in the angular models of the block and eight bases on its edges, along the fly direction. If there were no measurements of the perspective for some photographs in a block, it was agreed that an additional control points will be measured, which has to be closest possible equivalent of the missing measurement, particularly with regard to accuracy of the determine of altitude of tie pints. It was agreed that due to the determination of additional adjustment parameters and to systematic errors of absolute orientation elements of the photographs, the number of ground control points should not be less than 1 control point for every 17 photographs.

For unsuccessful measurements of the perspective centres for all photographs in the block, the control points network had to be rearranged in such a way so as to place the points on the edges of the block and in every second lateral overlap, not less frequently than every 4 bases. It was agreed that the photo control points at the end of strips have to be placed in lateral overlap so as to enable their measuring on 4 photographs, and that control points on the edges of the block, along the axis of strips, have to be placed in triple coverage, with the exclusion of the points in angular models of the block. The ground control points were placed in such a way to enable semi-automatic measurements on all photographs with the particular control point.

The photo-measurements and adjustments of individual aerial triangulations were obtained and conducted with the software module Match-AT by Inpho. The accuracy measure of the aerial triangulation result was the average root mean square error of determining the ground coordinates of the tie point. The error was calculated as a root mean square of all root mean square error of the coordinates of the tie points in the block. The value of the error was in strict correlation with the scale of the aerial photograph, its spatial resolution, and the focal length of the photogrammetric camera lens. As a result of the analyses conducted the ranges for the indicator of the aging of aerial photographs, in relation to the completeness of the ground control points network and the maximum value of the average root mean square error of the coordinates of the tie point defined for individual aerial triangulations, were determined. The indicator equalled 0 if all ground control points in the block were projected and measured, and the root mean square error of determining the ground coordinates of the tie point did not exceed half of the value of the maximum error. The indicator equalled 0.1 if all required control points of the photogrammetric network in the block were measured and the root mean square error of determining the ground coordinates of the tie point was close to the value of the maximum error. If more than 80% of the nominal value of the control points were planed and measured, and the criterion for the root mean square error of determining the ground coordinates of the tie point was met, the indicator of the aging of aerial photographs equalled 0.2. For other values of planned ground control points within general required scores of 70%, 60%,...,10%, the indicator equalled 0.3, 0.4,...., 0.9 respectively.

The criterion for the root mean square error was met if the indicator was more than 0.4. It was determined, on the basis of the analysis, that for the aerial photographs with time resolution less than 6 years, the value of the indicator was within the number range of <0.0-0.1). It was determined, on the basis of the analysis that for the aerial photographs with time resolution less than 8 years, the value of the indicator was within the number range of <0.1-0.2).

Increasing the time resolution of the block of aerial photographs to 11, 15 and 21 years resulted in the increase of the indicator of aging of aerial photographs to more than 0.2, 0.3 and 0.4 respectively, which means that it is impossible for more than 21-year-old aerial photographs to obtain the results of aerial triangulation meets the accuracy criterion. It is justifiable to investigate the possibility to adopt a sequential measurement of control points of archival aerial photographs on the basis of the aerial triangulation developed for other archival blocks with lesser time resolution.

The present research was conducted as part of the research project no. PBS3/B9/39/2015, co-financed by the Ministry of Science and Higher Education under the Applicable Research Programmes of the National Centre for Research and Development.

Cadastral Mapping Based on UAV Imagery

Michał Kędzierski, Anna Fryśkowska, Damian Wierzbicki, Paulina Deliś
Department of Remote Sensing and Photogrammetry,
Institute of Geodesy, Faculty of Civil Engineering and Geodesy,
Military University of Technology, Warsaw, Poland

1. Introduction

The recent evolution of non-metric high resolution digital cameras and miniaturization of UAVs has promoted development of low-altitude aerial photogrammetry. Considering cost-effectiveness of the flight time of UAVs vs. conventional airplanes, the use of the former is advantageous in many photogrammetric and remote sensing applications including the up-dating of cadastral maps.

As the primary mapping resource for many legal and business uses, including land management, development planning and project location, cadastral maps should be kept up to date.

An increasing number of government agencies worldwide use photogrammetric data from both aerial and satellite imagery for developing and updating cadastral maps. A good example is Bolivia, where cadastral map is produced based on aerial photos [1]. Also Japan used archival aerial imagery for reproducing the limits of cadastral plots as they existed before natural disasters (the earthquake and tsunami of 2011) [2]. In Poland, in order to cadastral maps updating, orthoimage on scale 1: 26 000 developed within the framework of the PHARE (Poland and Hungary: Assistance for Restructuring their Economies) system and LPIS (Land Parcel Identyfication System) are used [3].

The study by Corlazzoli and Fernandez [4] can exemplify the use of satellite imagery for the development of cadastral maps. In this case, orthoimages produced based on high-resolution images from the SPOT 5 satellite were the main source of data for plot limit identi-fication. In certain cases, cadastral maps are plotted based on both airborne and satellite im-agery [5].

However, because of the large scale, low-altitude UAV images serve this purpose much better than the conventional aerial or satellite imagery. UAV images are used for updat-ing cadastral maps [6], [7]. Further, UAV data can help to evaluate up-to-dateness and accu-racy of cadastral maps [8]. The study described in this paper evaluated the suitability of UAV orthoimagery for updating cadastral maps.

2. Data capture

To capture low-altitude aerial photos, the researchers used a Trimble UX5 UAV equipped with a compact SONY NEX5R camera with a wide-angle fixed-focus lens. The platform has a single-frequency GPS receiver and IMU, which enables registration of ap-proximate components of the external reference for each image. The UAV can fly at the alti-tude of 75-750 m and the design overlap of pictures it can take ranges from 60 to 90 percent.

The tests were carried out for the surroundings of the Chrzęsne village (Poland). The land is flat, agricultural, partially forested. The flights were flown in good weather, with no cloud cover. The pictures were taken with the 1/2,500 seconds exposure time, from an altitude of 200 m.

Fig. 1: Orthoimage of Chrzęsne based on UAV imagery

The test package consisted of 3,625 digital photos taken by 3 independent flights within a single mission. The study measured coordinates of the 21 signalized points (16 con-trol and 5 check points). The coordinates of the points were measured with an RTK GPS in-strument. The mean error of the coordinates was approx. 3 cm. The package was processed using the INPHO UASMaster software suite.

Table 1: Test package features

Parameter	Test package
Number of rows	37
Camera / focal length [mm]	NEX 5/ 15.51
overlap (along / across-track direction) [%]	80/ 70
Flight altitude [m]	200
Camera matrix pixel size [µm]	4,75

3. Data processing

After adjustment of the test package, the mean error of a typical observation was 6.9 µm (1.4 px). This large value could be a result of significant rotation angles (ω and φ < 3°). See Table 2 for the package adjustment specifications.

Table 2: Results of the test block adjustment

σ0 [µm]/[pix]	6.9/1.4
Number of control points	16
Number of check points	5
RMS error for control points (X, Y, Z) [m]	0.03; 0.03; 0.09
RMS error for check points (X, Y, Z) [m]	0.11; 0.04; 0.13
mX0 [m] / mY0 [m] / mZ0 [m]	0.10 / 0.08 / 0.09
mω [°] / mφ [°] / mκ [°]	0.020 / 0.026 / 0.007

The values of root mean square errors (calculated from the adjustment) in the X,Y positioning of the signalized control points ranged from 0.03 to 0.09 m. For the independent control points, the RMS errors (calculated as differences between the coordinates set by the ad-justment and the on-ground survey coordinates) ranged from 0.04 to 0.13 m.

The adjustment provided very good results for the determination of coordinates of the centers of perspectives (X0, Y0 and Z0). The values of standard deviations ranged from 0.08 to 0.10 m. The accuracy of determination of the rotation angles (ω, φ and κ) ranged from 0.007° to 0.026°.

The processes of creation of DTM and orthorectification used the Surface and Ortho Generation module of the UASMaster software suite. The creation of a DTM starts from the genera-tion of a point cloud based on stereo. The minimizing of the function of costs is the measure of similarity of features in the adjustment algorithm used to generate the point cloud. The al-gorithm is called "Cost Based Matching" (CBM) [9]. The resulting point cloud was filtered by removing points located underground. The quality of the DTM used to generate the ortho-imagery is critical to the accuracy of the final product. The modification of DTM was fol-lowed by orthorectification and automatic tessellation. A very important aspect of teaseling orthoimagery taken from a low altitude is the merging and adjusting of image radiometry. The automatic tessellation produced a uniform digital orthoimage with 6 cm spatial resolution.

To verify the quality of the geometric orthoimage, its accuracy was evaluated in abso-lute terms by reference to an independent control measurement. This accuracy can be ex-pressed as the root mean square error [10]:

$$m_{orto} = \sqrt{\frac{d}{n}}$$

where:

d – deviation meaning the length of the control point offset vector found on the orthoimages in reference to the position determined with the independent control measurement.

n – number of points

The evaluation used the check points not involved in the adjustment. The accuracy of the resulting orthoimage generated for the test area based on the UAV imagery with a 6.4 cm GSD was about 2 pixels, which means an accuracy of approx. 10-12 cm.

4. Orthoimage vs. cadastral map

Depending on urban development density, Polish cadastral maps are produced at the 1:500, 1:1,000, 1:2,000 and 1:5,000 scales. The accuracy of cadastral maps corresponds to the accuracy of the underlying master maps. The scale used for rural area mapping is 1:2,000 or smaller. It was agreed for rural areas that the acceptable error of point positioning on a cadas-tral map is equal to the accuracy of the 1:2,000 master map (2 m).

To check whether the geometric accuracy and interpretative advantages of the result-ing orthoimages are sufficient to justify investing in desk studies for the update of land and building registers of rural municipalities, the orthoimages were compared to existing cadastral maps. Vector cadastral maps were used as the reference. The review evaluated buildings, plots, roads and single-purpose land stretches.

Fig. 2. Orthoimage based on UAV imagery with vector layers of cadastral maps: buildings and plots

These items were checked for accuracy and in terms of identification on the orthoimages. The check determined the mean error of positioning of the outlines of buildings, plots, roads and single-use land stretches. See Table 3 for the results.

Table 3: Comparison results

	number of objects	**Identification of objects [%]**	**m0 [m]**
Buildings	75	91	0.80
Plots	40	80	0.51
Roads	15	95	1.02
Land stretches	20	80	0.40

Looking at the table, all of the checked master map items meet the accuracy require-ment. It means that the orthoimages developed from UAV are suitable for the updating cadas-tral maps.

5. Summary and conclusions

The recent rapid development of low-altitude photogrammetry made it possible to add a high level of automation to the capturing and processing of high-resolution images.

In the paper, the accuracy of orthoimage generated based on UAV imagery, acquired from non-metric SONY NEX 5R camera and the accuracy of the fragment of cadastral map were compared. The analysis included buildings, plots, roads and single-purpose land stretches. The conclusion from the foregoing study is that the geometric accuracy and interpretative advantages of the resulting orthoimages allow to updating the cadastral map in rural areas. The ability of identifying objects was over 90% (buildings, roads), more than 80% (plots and land stretches). The interpretive possibilities of orthoimages is influenced by the flight altitude pixel size, spectral and radiometric resolution of a sensor. It is estimated that such an update of cadastral maps based on UAV imagery can be approx. 50% less costly than on-ground measurements.

The purpose of the further study will give an answer if it is possible to update cadastral maps concern based on orthoimages developed from UAV data in urban areas.

This paper was developed based on research conducted as part of the Statutory Research Work of the Institute of Geodesy by the personnel of the Department of Remote Sensing and Photogrammetry.

6. References

[1] Jaramillo J., Mathematical Rectification of aerial photographs for cadastral mapping in Bolivia, International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B4. Amsterdam 2000, pp. 394-399

[2] Hasegawa H., Imase T., Cadastre 2014 Japan – Initiative for Restoring Original Boundaries by Using Past Aerial Photos, Engaging the Challenges – Enhancing the Relevance, Kuala Lumpur, Malaysia 16-21 June 2014

[3] Kaczyński, R., Ziobro J., Ewiak I., Dokładność poszczególnych etapów generowania ortofotomap cyfrowych ze zdjęć Phare 1:26.000. Archiwum Fotogrametrii, Kartografii i Teledetekcji, Vol. 9,1999, pp. 57-60.

[4] Corlazzoli M., Fernandez, O.L., SPOT 5 Cadastral validation project in Izabal, Guatemala, International Archives of Photogrammetry, Remote

Sensing and Spatial Information Sciences, vol. 35, pp. pp. 291-296.

[5] Farzaneh, A., 2010, Cadastral mapping of Agricultural lands and Natural Resources by using image and non-image data, ISPRS Commission I Mid-Term Symposium, Image Data Acquisition - Sensors & Platforms, Calgary, Canada 2010

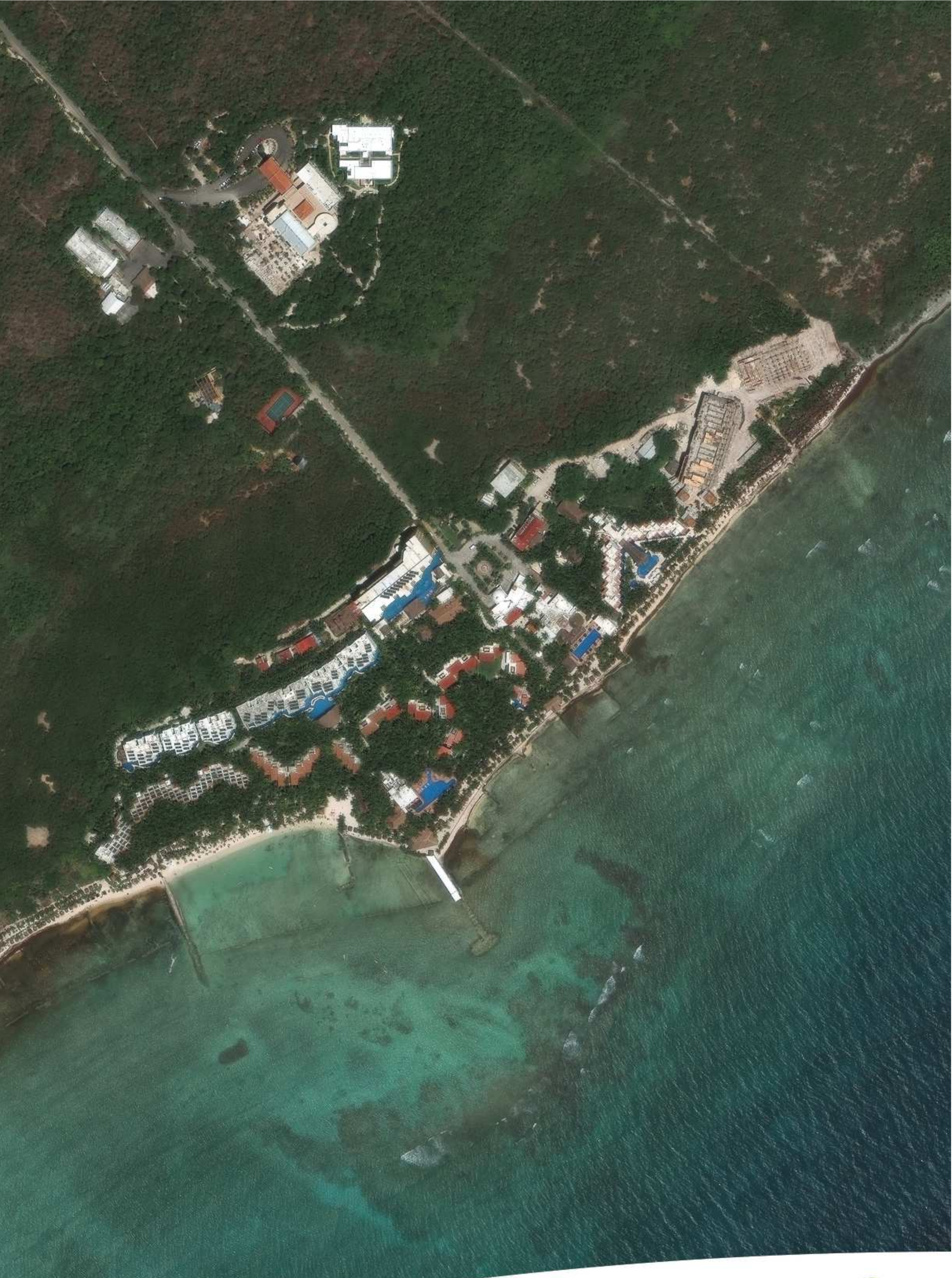
[6] Manyoky, M. Theiler P., Steudler D., Eisenbeiss H., Unmanned aerial vehicle in cadastral applications, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII-1/C22, UAV-g 2011, Conference on Unmanned Aerial Vehicle in Geomatics, Zurich, Switzerland

[7] Volkmann W., Barnes G., Virtual Surveying: Mapping and Modeling Cadastral Boundaries Using Unmanned Aerial Systems, Engaging the Challenges – Enhancing the Relevance, Kuala Lumpur, Malaysia 16-21 June 2014

[8] Cunningham, K. Walker, G., Stahlke E., Wilson, Cadastral Audit And Assessments Using Unmanned Aerial Systems, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII-1/C22, UAV-g 2011, Conference on Unmanned Aerial Vehicle in Geomatics, Zurich, Switzerland

[9] Saile J., High Performance Photogrammetric Production, Photogrammetric Week 2011, pp.21-27;

[10] Kędzierski M., Fryśkowska A., Wierzbicki D., Opracowania fotogrametryczne z niskiego pułapu, Redakcja Wydawnictw Wojskowej Akademii Technicznej, Warszawa 2014, ISBN 978-83-7938-047-3



El Dorado Casitas Royale
Riviera Maya
Mexico

May 28, 2015
WorldView-3
30 cm resolution

DigitalGlobe

Technological Capabilities of DPW PHOTOMOD 6.0: Practice Implementation In the Cartographic Production

Dinara M. Khaydukova
JSC Uralgeoinform, Ekaterinburg, Russia

In October 2014 came the full 64-bit digital photogrammetry system PHOTOMOD 6.0. JSC Uralgeoinform successfully works with PHOTOMOD more than ten years, so already 10 October 2014, the company introduced a new software system to work. At that time, it assumed active use PHOTOMOD 6.0 for the creation of digital orthophotos for satellite images.

In the first part of the report referred to the composition of the professional and technical capabilities of the Department of digital photogrammetry. The main advantage of 64-bit version of the system is complete and optimal use of computer memory, so the company acquired a new modern fleet of workstations. Server distributed processing made an eight-processor computer with Intel (R) Core (TM) 2 3.40GGts i7-3770 CPU, RAM and 16 GB Windows 7 x64. Clients were 7 computers with 4 core processor 4 nuclear Intel (R) Core (TM) 2 3.40GGts i5-3570 CPU, RAM and 16 GB Windows 7 x64. The total number of customers - 9 threads - 28.

The second part describes the experiment posed of "Uralgeoinform" based on the project on creation of digital orthophotos for satellite images. The total area of the captured territory 698000 km2. The number of satellite images: 5139, obtained from spacecraft TH-1, TH-2 and ZY-3. The total size image 1400.832 GB. The resulting volume of digital orthophoto 3000 nomenclature sheets. For the main work in PHOTOMOD 6.0 was allocated two jobs for engineers photogrammetry, the other computers involved only as clients distributed processing and is mainly used by specialists cartographers to work on other projects the company.

Additionally, the report will examine some interesting thematic projects implemented in the enterprise.

In conclusion, the report will draw attention to the positive and negative conditions affecting the speed of the work will be the analysis of the benefits of using PHOTOMOD 6.0, estimated profitability of using DPS PHOTOMOD 6.0 when creating large mapping projects limited number of specialists.

My Latin American Experience

Em. Prof. Dr.mult. Gottfried Konecny
Leibniz University Hannover, Germany

From 1959 to 1971 I was employed by the University of New Brunswick (UNB) in Canada, where we started the first English language Geomatics program in Canada. As part of my University activities I participated in a Canadian Research Council led activity of the Pan American Institute of Geography and History (PAIGH) to introduce cadastral land registration in Latin American countries. At PAIGH we had annual meetings in Mexico City between 1968 and 1970. At UNB we had a guest professor in geodesy from 1967 to 1970 from Tucuman in Argentina. After my move from Canada to Hannover in 1971 my Argentine friend had become Dean at his University in Argentina, and he invited me to hold a short course in analytical photogrammetry to the Argentine photogrammetric community in 1971, which up till then had an analog orientation. At that time the group of about 30 participants founded the Argentine Society for Photogrammetry. The course was repeated in 1973.

During my activities in Hannover I continued my interest in establishing cadastral land registration systems in the developing countries of the globe. We founded a group of German academic, commercial and governmental representatives, the BEV, of which I became chair in 1975. We held workshops supported by the German Ministry of Economic Cooperation on surveying and mapping in 1975 in Berlin and later in Hannover and Hamburg. We cooperated with the UN Secretariat in New York and with the German national technical cooperation agency GTZ (now GIZ).

This brought me as a member of the German delegation to the UN Cartographic Conferences for the Americas to Panama in 1976, to Mexico in 1979 and since 1983 to the UN Headquarters to New York where we had interchanges with the Latin American countries in geodesy, land surveying, cadastre, photogrammetric mapping and remote sensing.

In this context I became involved in the educational effort for surveying and mapping at the University of Heredia in Costa Rica in 1976, at the University of Los Andes in Merida, Venezuela in 1982 and at the University of Zulia in Maracaibo, Venezuela in 1983. I gave a short in analytical photogrammetry in Spanish at the Universidad Nacional de Mexico in the same year and I gave lectures at the University of Curitiba in Brazil in 1984.

In the 1990´s I was involved in a technical cooperation project at the Instituto Geografico Nacional in Guatemala.

Through my ISPRS activities as President I had good contacts with visits in the 1980´s to Brazil, Uruguay, Chile and Cuba.

Latin America has traditionally very close relations to the U.S. This was facilitated by the Interamerican Geodetic Survey organized by the American Military. Accordingly access to hardware and software is traditional from the US except for Cuba, which had relations with the Sovjet Union. It is only handicapped by cost. But even German technical cooperation agencies have included American software into their projects because of service considerations. However,

European hardware suppliers, like formerly Wild, Zeiss and Kern traditionally had a high esteem, even though only Hexagon is on the global market from Europe. Brazil´s activities of their space agency INPE by providing imagery and software for image processing free of charge or at low cost have enhanced uses of geospatial products.

In the geoinformatics field Latin America has a very unique position. The Latin American countries gained independence in the early 19th century, when mapping was globally not yet well developed. In Asia and Africa mapping was introduced in the late 19th century and in the early 20th century by the colonial powers. In the early 20th century the Soviet Union introduced mapping as a national priority. So it happened in North America, Australia and Japan as well.

In Latin America Mexico followed the developments in the USA, while in most Latin American Countries in the South mapping was mostly a military activity. The UN Secretariat studies of 1960 to 1986 show, that the areas mapped at large and medium scales in Latin America had a much lower percentage than areas mapped in Africa and Asia, and this is still so. Brazil has only a complete coverage at the scale 1:250 000. This means, that the demand for large scale mapping is immense, considering the existing low map coverage and considering at the same time the rapid increase in population in the Latin American urban centers. This demand cannot be satisfied by government alone. This is a great challenge for the private sector, particularly when it can cooperate with the government.

International events and conferences, such as the Racurs Conference, are opportunities for network creation. Organizers of such conferences have it in their hand to invite papers of persons, who are responsible for soliciting, financing and conducting large scale mapping projects:

1) national mapping agencies, such as INEGI in Aguascalientes in Mexico, which plans and finances national activities at medium scales. The same is the case in Guatemala by the Instuto Geografico Nacional. The Municipalities in Mexico and Guatemala may have their own budgets for large scale mapping, but their activities are coordinated by the national mapping agencies.

2) some of the poorer states in Central America rely on donors, such as the World Bank, Latin American Division in Washington D.C. or the Interamerican Bank to finance urban, land management and cadastral projects, which need large scale mapping. The World Bank and the Interamerican Bank provides loans to governments. Other bilateral arrangements for smaller projects are usually made by national donors, such as the Canadian International Development Agency CIDA in Ottawa, USAID in Washington, D.C., the German Technical Cooperation Agency in Eschborn near Frankfurt, and other agencies funded by their national governments, such as Dutch Cadastre, Swedesurvey, Norwegian Development Agency NORAD, the Danish Agency DANIDA or IGN France. JICA Japan has not been very active in Latin America, as well as China.

3) all such agencies generally outsource their projects by international or national tender to a mapping company. In Mexico GeoAir with Wolfgang Kost as CEO, who also works by tenders in Central America and even South American countries should have an excellent knowledge about the national and international competitors in the region. Maybe you might want to talk to him or ask him to present a paper on the private mapping sector in Latin America, if you cannot attract all competitors together.

4) all Latin American mapping agencies are networked in two organizations:

a) the Pan American Institute of Geography and History PAIGH, established in Mexico in 1928, with is present General Secretary Santiago Borrero from Colombia. PAIGH meets annually and has many working group activities with members of all Americas.

b) out of the former United Nations Cartographic Conferences for the Americas established in 1976 a regional group was created by the name PC-IDEA in the 1990´s. Santiago Borrero was the first President of PC-IDEA. In 2009 UN ECOSOC has established UNGGIM in New York, which meets globally every year. The next global conference is scheduled from August 3 to 7, 2015 at UN Headquarters in New York. Current Vice Chair of UNGGIM is INEGi, Mexico President Eduardo Sojo Caza-Adape.

However, UNGGIM has created regional chapters for the establishment of regional activities by working groups. UNGGIM-Americas has become the successor of PC-IDEA.

President of UNGGIM-Americas is currently Rolando Ocampo Alcantanar, Vice President of INEGI, Mexico. PAIGH and UNGGIM-Americas also discuss mapping activities.

5) As noted, the next UNGGIM global conference UNGGIM5 is scheduled from August 3 to 7, 2015 at UN Headquarters in New York. The German government has nominated me as member of the German delegation. Our delegation consists of BKG President Kutterer from Frankfurt, the representative of the Cadastral administrations of Germany Mr. Wandinger, the President of the German Survey Society, Karl Friedrich Thöne, who organizes Intergeo and myself.

Applying of Space Remote Sensing Data in Urban Development

Victor A. Panarin[1], Olga N. Kolesnikova[2], Roman V. Panarin[3]
[1]*Municipal Budget Institution "Urban development", Dzerzhinsk, Russia*
[2]*Sovzond, Moscow, Russia*
[3]*SCANEX Research and Development Center, Moscow, Russia*

As of today in the urban self-governance architecture structure the space imaging as one of the types of urban development documentation, or at least as a source for preparation of this documentation, is not clearly understood and underestimated by staff and even the developers of the documentation. In the best case the images are used for visual clarification of a particular location or to recognition of objects of urban development. However these images can provide a significant amount of information for correction and further control of urban development documentation and allow to econom significant fonds during the documentation development.

First step during as part of a try to use the image as a base for further work was the image coordinates binding to the coordinate system used in urban self-governance architecture structure. The binding was done using land anchor points with binding accuracy check by 10 pivot control points. To achieve acceptable results it is enough that binding is done using 4-5 points and the rule that 3-4 of the points are chosen close to the image corners area and one point is located in central area to adjust offsets is followed.

Having image translated into urban coordinate system it is possible to use the image to clarify information about urban development objects and urban territories sensing. Having images from different time periods and from different satellites gives the possibility of correct and quality comparison of given calculated results (most importantly object areas and object locations) from different sources, such as: images, maps, schemes, general plan of a city, rules of land tenure and housing, planning projects, territories and land lots surveying, etc.

Vectorization of sensed territory boundaries from an image is needed to get the digital estimation of territory sensing. Digitizing was done using spectral analysis with visual adjustment.

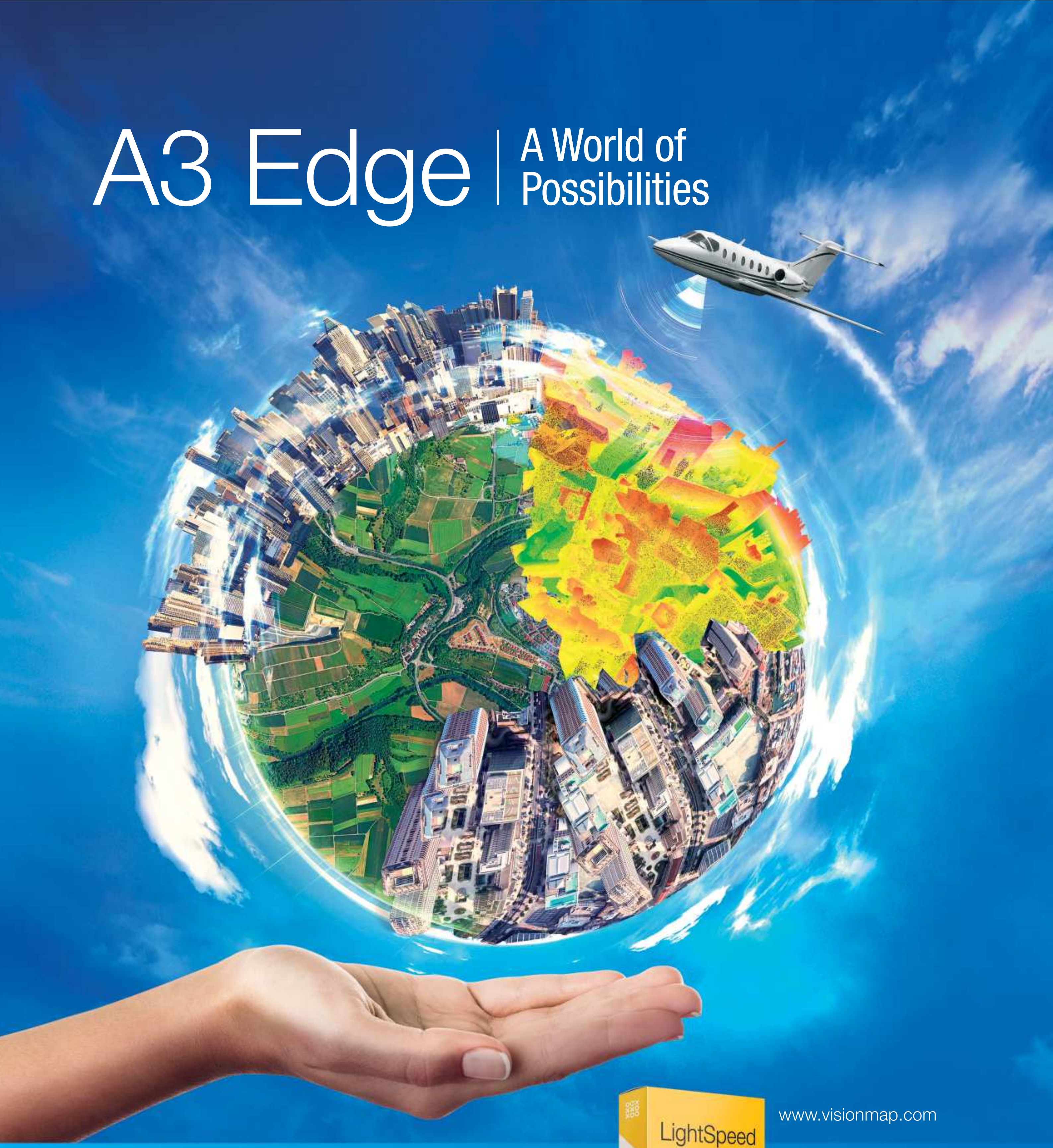
First and widely used application of the images is monitoring of urban territory. City housing boundaries, water objects, roads, natural and artificial landscapes can be vectorized automatically and with high quality using the image. Processing of high-detailed images requires adjustment and clarification by generalization of images of objects fragmentary which impacts area of vectorized polygon. Swamps, meadow vegetation, various grounds, landscaping elements are much more laborious and require manual adjustment. It is close to impossible to digitize buildings, especially the ones with gable roofs. The only reliable method is manual digitizing of the buildings.

General plan of a city and rules of land tenure and housing are prepared using maps with 1:10 000 scale according to standards, but at the same time rules of land tenure and housing have to be fulfilled with land lots boundaries which have accuracy equal or more detailed than 1:2 000. Fulfillment of such requirements and combining it with images in such scales is very laborious and expensive which is why it is not used in development of rules of land tenure and housing, thus reducing development cost. However partly the issue is solved by using space image for boundaries adjustments.

Territory balancing is a very important element of territory planning and sensing. Space images usage allows estimate with very high precision areas of water objects, green spaces (noticeably the real boundaries instead of assumed boundaries), landscaping, etc.

To conclude, usage of high-detailed space images with high definition during development of urban development documentation, especially documents of territorial planning and sensing, allows (even using old maps as sources) to get an accurate and quality data, adjust boundaries of territories and reduce cost of development and further correction of urban development documentation.

Provided with step by step instructions and corresponding software the methods for binding and processing (including vectorization) of space images can be utilized by regular staff of urban self-governance architecture structure. Additional expenses for development of the instructions, acquiring of specialized software and education of personnel pays off in a very short time period. Urban development documents with high quality are popular and allow to increase the investment attractiveness of urban territories. The return of spent fonds is done by providing paid details from information systems supporting urban development activities and development of territories by investors.



www.visionmap.com

An Edge over the rest.

A3 Edge is VisionMap's all-in-one digital mapping system that completes your mapping and oblique projects 2-5 times faster than other mapping systems.

Coupled with the fully-automatic LightSpeed processing system, A3 Edge provides final photogrammetric products at sub-pixel accuracy, with the highest processing productivity.

VISIONMAP

Creation of Digita l Surface Models using Resurs-P Stereo Pairs

Alexey A. Peshkun
The Research Center for Earth Operative Monitoring
JSC "Russian Space Systems", Moscow, Russia

Two spacecrafts of Resurs-P"type (spacecraft №1 was launched on June 25, 2013, spacecraft №2 was launched on December 26, 2014) are operated currently. These spacecrafts are manufactured for a wide range of tasks (map updating, supporting of activity of different federal, regional, municipal departments and other consumers) as well as for receiving information concerning control and protection of the environment.

The Resurs-P spacecrafts stereopairs are the input data for creating DSM.

The key characteristic of a stereo pair is the B / H ratio. The convergence angle is approximately 54 degrees for values of the B / H ratio close to 1. If stereo imaging is performed with equal deviations in pitch, the deflection angles will be about 27 degrees in this case. Pros of such parameters of stereo imaging are: a large angle of convergence allows to improve the measurement accuracy of a stereo pair, a larger area of a stereo pair. Cons are: shadow zones of mountainous areas and areas with storied buildings, additional imaging with a small angle of deviation from the nadir or use of image of a stereo pair with a deviation from the nadir more than 20 degrees is to be performed for creating orthophoto

Normally B/H ratio is in the range from 0.3 to 0.5. This ration should be reduced for mountain areas , and increased for flat areas. Thus, the convergence angles range is from 30 to 45 degrees. To create orthophoto stereo imagery can be performed with different angles of deflection of the optical axis from the nadir in pitch (for example, +20 and -10 degrees) for the purpose of using image with a lesser angle of deviation from the nadir for orthorectification.

To create a DSM stereo imaging by spacecraft Resurs-P №1 sensor GEOTON-L1 in the panchromatic band with different angles of deviations in pitch were performed.

7 images were used For creating stereo pairs . The main stereo pairs (by the imaging on the same orbit pass) and additional (matched to the angle of convergence). The result was 8 stereo pairs for the same territory, but with different angles of convergence and B/H ratio. Data processing level 1A and 2A was used for photogrammetric processing .

Photogrammetric processing was performed by using the PHOTOMOD v.6. The block of 7 images was formed during processing. To perform the block adjustment 7 controls and 76 check points were used.

7 DSM were created after adjustment . 5 DSM were created using data processing level 1A and 2 DSM were created using data processing level 2A. Amond them 2 DSM were built using the new algorithm of PHOTOMOD — dense DSM creation (using multiple overlapping).

The results of data processing showed that images of data processing level 2A are the best for photogrammetric processing, including the creating DTM and DSM . Images of data processing level 2A have better geometric properties and lead to the DTM precision (standard deviation by height up to 3 meters).

GIS-Sofia Data Base

Vanya Petrova
GIS-Sofia Ltd., Sofia, Bulgaria

Founded seven thousand years ago, Sofia is the second oldest city in Europe. It has been given several names in the course of history and the remains of the old Thracian and Roman cities can still be seen today. The city became known as Sofia from the beginning of the 15th century. In 1879 Sofia became capital of Bulgaria.

Nowadays the territory of Sofia Municipality is 1349 sq. km and includes the areas of 4 towns — City of Sofia (around 200 sq. km), three other towns: Bankya, Novi Iskar, Buhovo and 34 villages. The City of Sofia with 1.3 million population includes 24 administrative and territorial districts.

The main function of creation and maintenance of the cadastral information system of Sofia Municipality is in charge of GIS SOFIA Ltd. (Geographical Information System – Sofia), established in 1999, as a Sofia Municipality company. Starting with 25 persons the staff of GIS SOFIA has grown to 130 highly qualified, proven specialists in the field of geodesy, cadastre, spatial planning, photogrammetry, cartography and a team of lawyers, specialized in the field of property relationships. GIS SOFIA Ltd. is one of the largest surveying companies in Bulgaria. The company is certified according to International Standard ISO 9001:2008.

GIS SOFIA Ltd. has created own geographic information system - SOFCAR - including cadastral and urban plans, as well as other geographical data also orthophotoplans, from aerial and satellite images, over the territory of the municipality. The SOFCAR information system meets all modern requirements and trends in this area, allowing efficient use and management of the data. This is the most significant project and achievement of the company.

There is an internet application on our site through which you get reliable real-time information about the cadastral plan of Sofia — IsofMap. For the territory or property you have chosen the system enables you to load additional thematic maps with information on regulation, spatial development zones, noise sources, cultural monuments, orthophotoplan also data on the location, boundaries and features of the property.

In the family of geographical information system one of the main positions holds photogrammetry — the fastest and the most modern way to acquire up-to-date information of the Earth's surface. Photogrammetry Department at GIS SOFIA applies digital photogrammetric software PHOTOMOD in projects based on aerial and satellite images. During the years 2000-2013 different kind of sources were used — analogue film cameras (RMK A 15/23, RMK TOP 30), digital cameras (DMC, UltraCamXp), various high resolution satellite sensors (IKONOS, QuickBird, KOMPSAT, GeoEye-1).

The first of its kind, in Bulgaria, orthophotoatlas of Sofia Municipality at a scale of 1:5000 was printed, using aerial images with 10 cm GSD — a luxurious, limited edition. In 2013 on the celebrating of the World GIS Day in Bulgaria, GIS SOFIA Ltd. was awarded in category of successful GIS projects within local authorities for "Applying of innovative GIS approach in the development of an Ortophotoatlas of Sofia Municipality".

Cartography Department at GIS SOFIA produces cartographic products in various formats, size and content for the territory of Sofia and Sofia Municipality. There are lots of interesting thematic maps - map of polling stations and voting sections within an administrative area; with the location of sirens for warning of the population; with stations for protection of the population in case of disasters or emergencies; with places for walking pets etc.

One of the recent activities in GIS SOFIA is the Professional Training Centre, established in 2010. The Centre organizes courses and seminars for increasing qualification levels in the several occupational areas - Cadastre, Regulation Planning, Digital Photogrammetry, Remote Sensing, Cartography and Legislation related to geodesy. The main goal of the centre is to organize very specialized training that meets the specific needs and requirements of participants. The center is licensed by the National Agency for Vocational Education and Training.

Photogrammetry and Parallel Computing — Software and Hardware

Andrey Yu. Sechin
Racurs, Moscow, Russia

We have currently a rapid growth of remote sensing satellites and aerial cameras productivity. For example European Pleiades-1A and Pleiades-1B satellites have acquisition capacity of 2,000,000 km2 per day. Visionmap A3 Edge aerial camera produces 5000 km2/hour of images with 20 см GSD. Total size of acquired aerial or satellite images is enormous and requires a lot of CPU processing time on a modern workstation. If one needs fast photogrammetric image processing he should use modern parallel computer capabilities. Today computer clusters are cheap enough and allow fast photogrammetric processing.

This paper considers high computer performance technologies and algorithms for parallel seamless photogrammetric mosaic building for aerial and satellite images with the given DTM. Different methods and algorithms are analyzed. Some estimates are made. The second part of the paper is dedicated to storage systems that should hold initial, temporary and final images. These storage systems must be properly designed for high scalability on clusters.

Updating the Thematic Content of Touristic Maps Using Satellite Images

Roman Shevchenko
Kyiv National University of Trade and Economics, The Tourism Department, Ukraine

Most national touristic maps in Ukraine are old, outdated, and largely exist in analogue form. Due to the high cost of aerial photography, these maps have not been updated for many years and as such are not useful for planning and navigation purposes in tourism. Therefore, there is an urgent need to produce new maps or update existing ones. The National Centre for Mapping of Touristic Objects for Development of Ukraine (NCMTD) has a wide experience in rapid and cost-effective updating of touristic maps using high resolution satellite data. The method entails: undertaking preliminary interpretation of georeferenced satellite imagery based on predefined classification and aided by secondary; ancillary data; identification of sample points that prompt Wikimapia Geoportal facilitated ”ground truthing”; conducting the final image interpretation; development of database driven thematic map layers; mosaicing of all the thematic touristic layers to form country-level thematic maps; integration of these datasets with administrative boundaries.

In this thesis, the updating of the National Touristic map of the Ukraine using the 20 by 20 meter resolution OKEAN-O satellite imagery is given as a case study. The successful completion of the project not only demonstrates the capabilities and potential of satellite remote sensing in modern day mapping but also illustrates the flexibility and dynamism of GIS generated map databases in the provision of value-added products for quality planning and decision making.

In Ukraine the first commercial high-resolution satellite sensors were heralded in the mid 2000s, mapping agencies have shown a keen interest in the possible use of satellite imagery in their data collection programmes. Since as long ago as 2006 (reported in Ridley et al, 2007) Ordnance Survey has been investigating this potential, initially using images synthesized from aerial photography, more recently using satellite imagery from the DNIPRO-1, IKONOS and QuickBird sensors. A recently-published OEEPE (now EuroSDR) report presented findings of an investigation into the potential of IKONOS data for touristic mapping, undertaken by several European mapping agencies and institutions (Holland et al. 2013). The results suggested that there is potential in this field, especially in rural areas at scales between 1:10 000 and 1:50 000.

The results of this project were as follows:

I) A cost-effective and rapidly updated National Touristic Map of the Ukraine was produced using SPOT satellite imagery at the scale of 1:250000. The map carried eight land touristic cover classes, touristic-hydrological features, the transportation infrastructure, sacred towns, and the administrative boundaries.

II) A rich GIS database containing both spatial and aspatial information was developed. From the flexibility of scale and thematic overlays, scalable thematic Touristic Maps of the Ukraine can be generated at fairly short notice from the massive database.

III) Despite various limitations, the appropriateness of this mapping methodology was tested, refined and is thus suitable for Nation wide mapping of East-European countries especially considering the socio-economic inadequacies perpetually inherent in this countries.

IV) The satellite image interpretation accuracy was about 80% indicating that the methodology is robust and reliable if well executed.

The results of this project indicate that high resolution data can be reliably and rapidly used to update touristic maps at both National and Regional Levels. However, it should be noted that use of remote sensing data has certain limitations. These include:

I) Geometric inaccuracies and errors: satellite mapping carries high possibilities of inheriting and cumulatively propagating inaccuracies and errors through both the source data and methodology. It is therefore important that potential users are aware of these limitations and thus use the Touristic Maps as a general information source and not for site specific studies. As with any earth resource issue, regulatory and policy decisions demanding the most accurate and precise information will require more detailed data, especially those from ground observations.

It should also be recognized that the spatial properties of the final land touristic cover data are a combination of the geometries of the individual source data layers i.e (a) different paths and rows of DNIPRO-2 data; (b) the use of geocoded and in-house geometrically-corrected data; and (c) the integration of ancillary data whose geometry has been altered somewhat in the raster-to-vector conversion. However the geometric fidelity of each dataset, combination of datasets, and products derived through image processing operations in this case were carefully scrutinized at each stage of the mapping project to maintain the highest level of co-registration possible.

II) Effect of cloud cover: The use of satellite touristic mapping is sometimes limited by various atmospheric noises of which cloud cover especially in the coastal regions is the most significant. In such cases there tend to be an excessive reliance on collateral data majority of which are usually old.

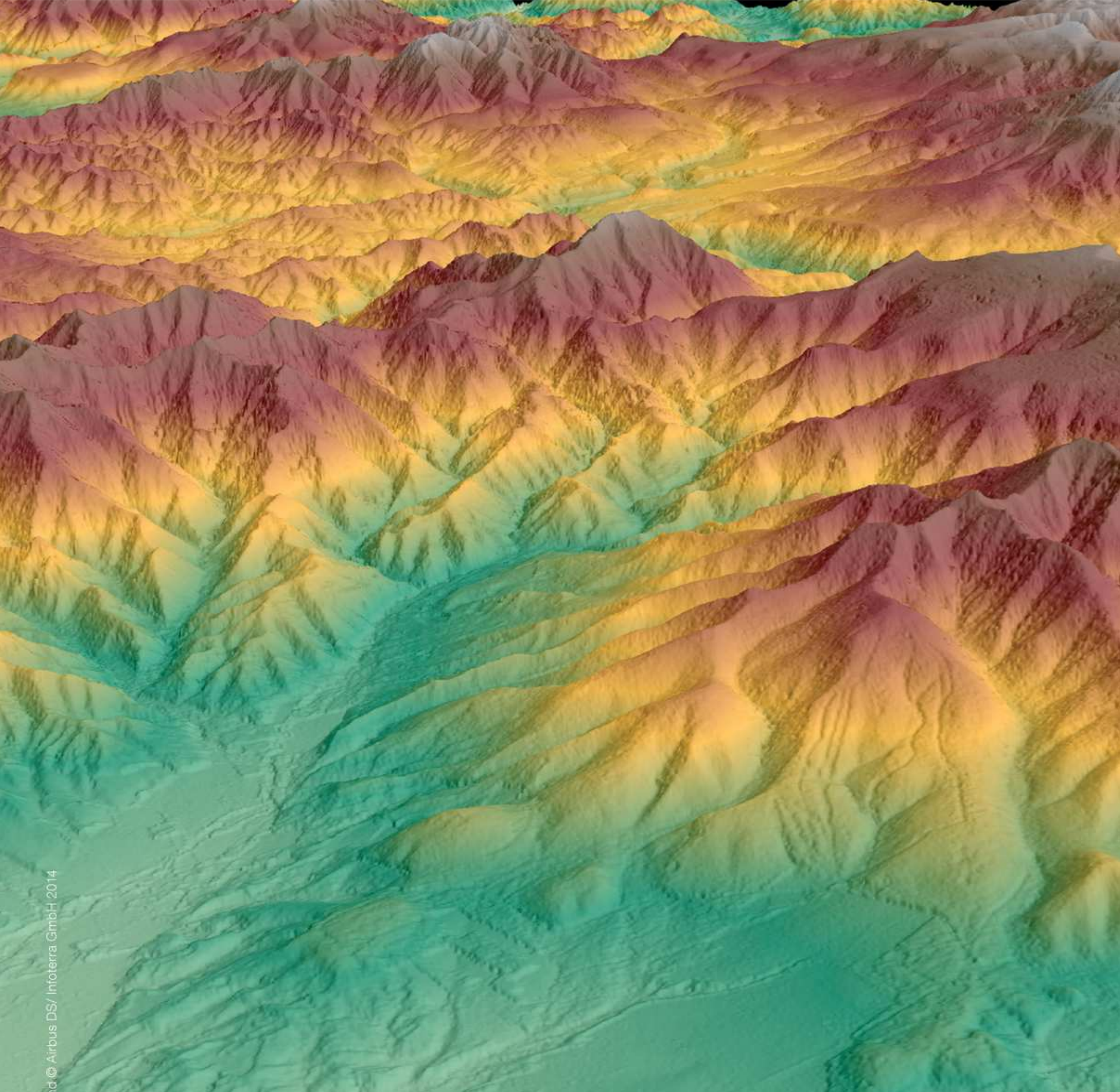
Field observation in this case is most suitable but is usually confined to the more accessible areas. On the other hand aerial photography, though expensive, may also be used. Despite the limitations, high resolution satellite data can be used effectively and rapidly to update old touristic maps. The resulting touristic maps provide useful and general information that is necessary for planning and decision-making at National and Regional Levels. Digitization of the final touristic interpretation was done on a scene by scene and theme by theme basis using Arc/Info and ArcView GIS software. Touristic cover polygons, rafting-hydrological features and the road network were thus digitized as independent thematic layers. Each thematic touristic layer was then edited to eliminate digitization errors and thereafter coded and georeferenced. Prints of the preliminary digitization were then made at the same scale as the original images so as to allow direct 1:1 overlay evaluation of the quality and accuracy of the digitization and coding. Whenever errors were identified, the necessary correction was made. Additional feature information was then input and appended to the GIS database. Following approval of the quality of the digitized themes, adjacent digital themes were edge-matched and joined together to produce single nationwide thematic mosaics of the entire Touristic Regions of the Ukraine. Using ArcView, all the different National map layers were overlaid to produce a single multi-thematic map of Ukraine Touristic View at the scale of 1:250000.

Summary. The results of this project are encouraging and confirm the utility of SPOT & SICH-3 satellite data (and indeed other high resolution satellite data like Landsat TM, Ikonos, Eros, etc) in updating statewide GPS-touristic maps and monitoring change.

Since the successful launch of DNIPRO-3 in 2009, a new source of imagery has been available to the touristic user. In many parts of the world high resolution satellite imagery from IKONOS, QuickBird and, more recently, ORBVIEW 3, has proved to be auseful data source for the creation of ort horectified images and associated touristic mapping products. One of the great advantages of satellite imagery is the ease of access to areas which have previously been too remote or too dangerous to reach using conventional aerial photography. However, for areas of the Earth which are not difficult to reach, and which have a tradition of high resolution mapping from aerial photography, this advantage is of rather limited importance. Ordnance Survey, Ukrainian National Mapping Agency, currently makes extensive use of aerial imagery in the collection of large scale geospatial data.

In 2015, a project was initiated which would determine whether satellite imagery could replace, or complement, aerial photography in this data collection process; or could be used in other ways within a production tourism environment to make the process more efficient. Interim results of this research are presented in this thesis. The results described in this paper have indicated that QuickBird Imagery can play a role in all the processes investigated.

Imagery of this resolution can be used to update mid-scale touristic maps (1:6 000 to 1:10 000 scale) as long as small linear features are excluded from the touristic mapping specification. This imagery can also be used in the detection of change, and in the quality checking of existing map data. However, in each case there are disadvantages, which indicate that QuickBird imagery should be used in a supplementary way, rather than as the main source of data. For example, QuickBird could be used to obtain frequent snapshots of rapidly changing urban areas, enabling change to be detected more readily than is possible by other methods.


© DLR e.V. 2014 and © Airbus DS/ Infoterra GmbH 2014

Creation of a 3D Model of the City of Krasnoyarsk as Part of Cartographic Support of Urban Planning and Property Complex Management

Aleksandr Voitenko, Igor Koshechkin
KADASTRSYOMKA, Irkutsk, Russia

Over the period since fall 2013 to spring 2015, our company performed a set of work for update of cartographic information related to the territory of Krasnoyarsk, developed digital aerial survey maps of the city's territory in scale 1:500, 3D topographical maps in scale 1:2000, and plotted TrueOrtho maps in scale 1:500 based on the city's vector 3D model, as well as developed a vector 3D photorealistic model of the city of Krasnoyarsk. This work has been performed with the purpose to create an up-to-date, consolidated, highly accurate cartographic basis required to develop the new general layout of the city of Krasnoyarsk, which is scheduled to host the 29th World Winter Student Games in 2019.

Krasnoyarsk is a city in Russia with population of over one, one of the largest cultural, economic, industrial and educational centers of the Central and East Siberia. Total area of the city is 353.9 sq.m. Elevation about sea level - 287 m. The terrain of the city and its surroundings is diverse. The city is predominantly composed of 5 to 9-storied buildings.

The first stage of work was create a single geodetic basis for the city of homogeneous accuracy, which included 452 reference points (on the basis of triangulation network, elevation references and the city's polygonal network). The created reference geodetic network enables to utilize its points as reference in performance of geodetic work both by classical methods – with electronic tachymeters, and using GLONASS/GPS technologies.

The second stage to obtain a digital cartographic basis was digital aerial survey and aerial laser scanning. Aerial laser scanning was performed with a Leica ALS60 set of equipment. Digital aerial survey with RCD30 camera was performed simultaneously. Total surveyed area amounted to 633.59 sq.m.

During the third stage of works, we created digital orthophotomaps in the local coordinates system in scale 1:500, with terrain resolution of 6 cm, using TerraSolid and PHOTOMOD software. TerraSolid was required to calculate the parameters of external image orientation and classification of laser reflection points, while PHOTOMOD was used to remedy cuts, to compensate color palette and plot digital orthophotomaps. Coverage with digital orthophotomaps amounted to 382 square kilometers.

Laser survey parameters

Flight speed: 150 km/h

Flight height: 550-600 m

Scanning angle, scanning rate: 56°, 120000 Hz

Average point density per 1 sq.m. of surface: 30 points

Average point density per 1 sq.m. of terrain surface : ~ 5 points

Accuracy of plan point position: 0.09 cm

Elevation scanning accuracy: 0.07 cm

Transverse overlap of laser scanning runs: 35%

Key technical parameters of aerial photo camera and survey mode:

Flight height: 550-600 m

Image size: 8956px*6708px

Lens focal distance: 52 mm

Camera pixel size: 6 µm

Acquisition interval: 4.8 sec

Calibration: RCD30 incorporates photogrammetric calibration data

Average pixel size on terrain (GSD): 0.068 m

Total number of images: 32559

Longitudinal image overlap: 80%

Transversal image overlap: 70%

During the third stage of works, we created digital orthophotomaps in the local coordinates system in scale 1:500, with terrain resolution of 6 cm, using TerraSolid and PHOTOMOD software. TerraSolid was required to calculate the parameters of external image orientation and classification of laser reflection points, while PHOTOMOD was used to remedy cuts, to compensate color palette and plot digital orthophotomaps. Coverage with digital orthophotomaps amounted to 382 square

kilometers.

The fourth stage was the creation of the digital cartographic basis. Digital topographic maps in scale 1:2000 with terrain interval of 1 m were developed on the basis of digital orthophotomaps in scale 1:500 and laser reflection points, while field identification data were used as additional cartographic material. The technology of photo fixation produced by 8 photo cameras operating simultaneously and pointed in different directions was used for field identification. The photo fixation technology can also be used for monitoring of territories, condition of terrain, including the following: road structures, road signs, rating of motor roads and for other purposes. (Fig. 1)

model, methods of its further use and customer's budget, a particular technology for 3D model creation must be used.

In this given case, the city's 3D model was required to satisfy the following requirements:

• model scale: 1:500;

• coordinates system MSC No.2, Baltic elevations system;

• the model is required to contain the following elements: terrain, buildings, tree vegetation;

• buildings images with texture and real roofing (LOD 2);

• rendering in nomenclature sheets sized 1*1 km in Microstation software package;

• total area 265 sq.m.;

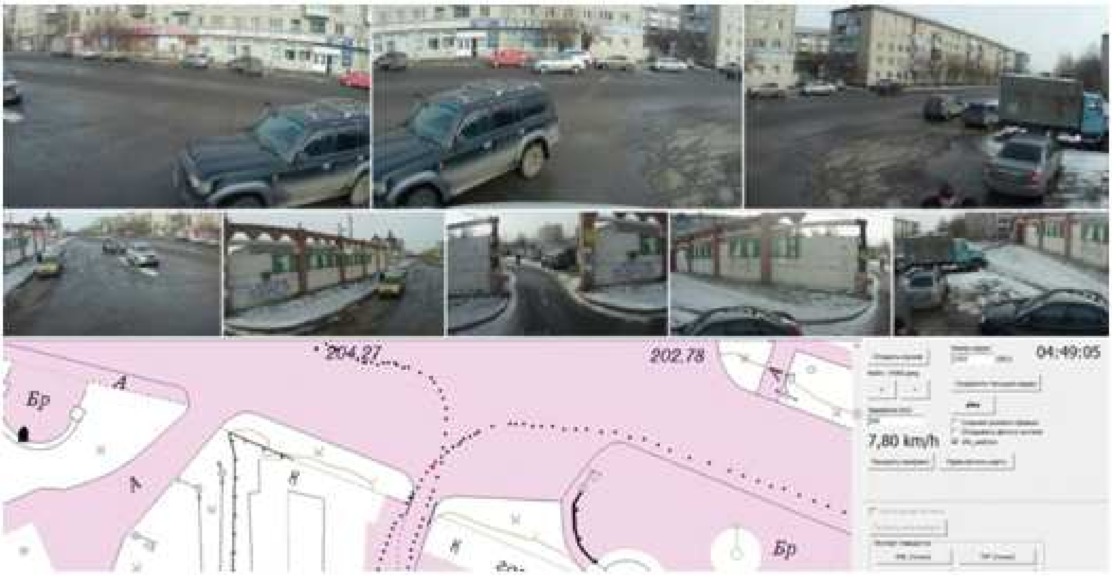


Fig. 1

The last stage included building a 3D model of the city's developed areas. 3D terrain models are a relatively new product in the Russian market. They continue to enjoy ever greater demand among potential consumers as equipment and technologies improve, and as potential of their use is understood by a wider audience. Each model needs to meet its own set of demands. For some customers, it will suffice to produce a "surface" model, while others may require an object-by-object model. Sometimes it is sufficient to only show 3D buildings, while others may need other elements of content. In certain cases it is enough to represent buildings as blocks (LOD 1), and in other cases, a detailed architectural model with internal interior (LOD 4) is necessary. Accordingly, different requirements may be raised to the model's accuracy as well. Depending on features of the 3D

The terrain of the underlying ground surface was obtained on the basis of aerial laser scanning and after classification of laser reflection points. Buildings were produced by projection of buildings roofs surfaces vectorized in stereoscopic mode in PHOTOMOD onto the terrain's surface. Buildings' facades were confirmed by vectorization of laser scanning data. RPC models of trees were plotted and automatically scaled in cloud shape according to laser scanning points class "trees". Dimensions of vector trees correspond to dimensions of the real trees. Following this, the model's texture was processed in automatic mode based on aerial photo survey data. (Fig. 2). In addition, the 3D model was used to plot "true" orthophotomaps on its basis (TrueOrtho), where foundations and elevated elements of objects are displaced to their true position, without buildings tilt or omitted zones.

TrueOrtho resolution on terrain amounted to 6 cm (Fig. 3).

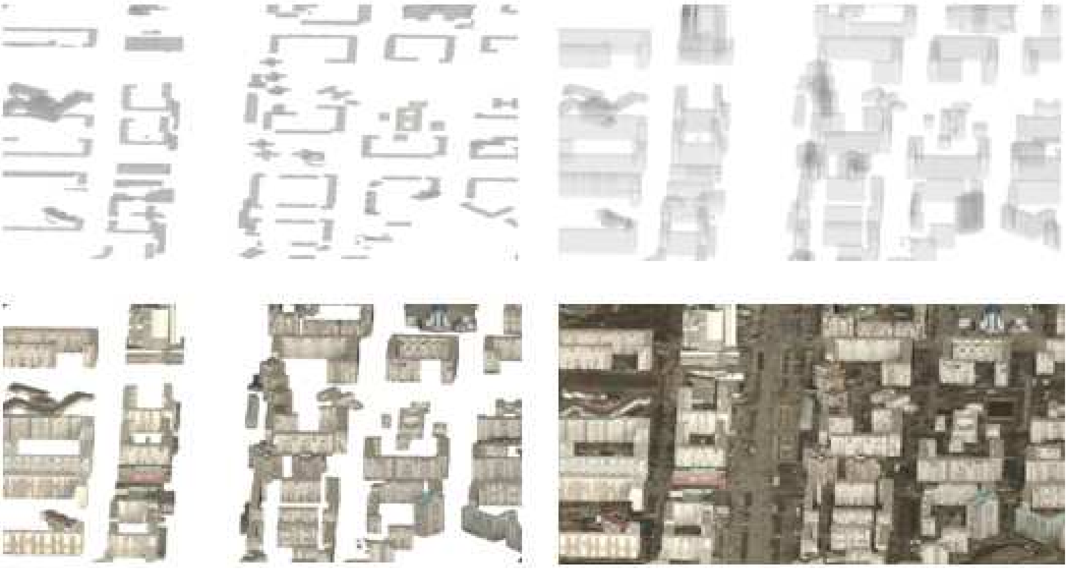


Fig. 2

Fig. 2.1

Fig. 3

Real World Information Addressing Global Challenges

Ilya Yudin
DigitalGlobe, USA

We live in an age of unprecedented challenges to our world and opportunities to safeguard it. Our growing needs for food, water, and energy are driving a rapidly changing global dynamic upon which natural diversity, human health, and prosperity depends. When it comes to improving lives around the world, DigitalGlobe provides you with a unique opportunity to address the key global challenges of our time. This presentation will showcase the latest in base layer information, rapid three dimensional visualization, the highest quality satellite imagery at 30cm and the potential application for SWIR.

Comité Nacional para la Cooperación Económica con los Países Latinoamericanos

(CN CEPLA)

Nuestros servicios:

- **Buscar en los países de América Latina y el Caribe y Rusia socios comerciales;**
- **Promoción de los productos y servicios de socios rusos y latinoamericanos;**
- **Facilitar el establecimiento de los contactos, organización del proceso de negocios y realización de proyectos;**
- **Organización y realización de conferencias, videoconferencias, seminarios y “mesas redondas”;**
- **Organización de misiones comerciales a los países de América Latina y Rusia;**
- **Apoyo informativo y organizativo de los empresarios-miembros del CN CEPLA;**
- ***(nuevo) Preparación de los materiales informativos y analíticos de acuerdo con las solicitudes concretas.***

SOBRE NOSOTROS

El Comité Nacional para la Cooperación Económica con los Países Latinoamericanos (CN CEPLA) es una organización sin fines de lucro creada en Moscú el 10 de febrero de 1998 con el apoyo de la Cámara de Comercio e Industria y el Ministerio de Relaciones Exteriores de la Federación de Rusia.

El Comité tiene mucha experiencia en trabajar con los representantes de las esferas diplomáticas y empresariales de los países latinoamericanos y mantiene contactos con las Embajadas y Repsentaciones Comerciales de los países de América Latina en Rusia y en los países latinoamericanos.

El Comité colabora activamente con las Cámaras de Comercio e Industria, asosiaciones de empresarios, empresas y estructuras de los países latinoamericanos y Rusia.

El Comité participa en las actividades de las Comisiones intergubernamentales de cooperación económico-comercial y científico-técnica con los países de América Latina, y también en los seminarios regionales y misiones de negocio.

El Comité trabaja a nivel regional (estados, provincias, departamentos) de los países de América Latina.

OBJETIVOS DEL COMITÉ:

- Promoción de los productos, tecnologías y servicios de socios rusos y latinoamericanos;
- Promoción de realización de los proyectos conjuntos en ámbito económico y la cooperación técnico-cientifica y cultural;
- Desarollo de las relaciones interregionales;
- Promoción de la cooperación en la ciencia y educación.

CONTACTOS

Para mayor información:

Teléfono:
+7 (499) 702-83-05

Correo electronico:
cncepla@inevm.ru

Sitio web:
http://www.cepla.ru

Dirección:
123557, Moscú, Presnenskiy val, 19

PRESIDENCIA

La Presidencia del CN CEPLA está compuesta por los jefes de:

- Ministerio de Relaciones Exteriores de Rusia,
- Ministerio de Desarrollo Económico y Comercio de Rusia,
- Ministerio de Industria y Comercio,
- Cámara de Comercio e Industria,
- Instituto de América Latina de la Academia de Ciencias de Rusia

Y otros instituciones estatales y comerciales de Rusia, directamente empleados en el trabajo de la orientacion de cooperación rusa-latinoamericana

MIEMBROS DEL CN CEPLA

Más de 100 compañías-miembros, incluido:

- ROSTEKH;
- ROSEKSIMBANK
- POWER MACHINES;
- INTER RAO EES;
- KAMAZ;
- UNIVERSIDAD ESTATAL DEL SUDOESTE;
- RUSSKIE AVTOBUSY – GRUPO GAZ;
- SOYUZSPEZSTROY;
- INEVM;
- RADIOKOMSISTEMA;
- AVTOVAZ;
- NEGUS EXPO INT;

Asosiaciones-miembros:

- Cámara de Comercio de Perú en Moscú;
- Gazprom Int;
- ProNicaragua;

Real World Information Addressing Global Challenges

Ilya Yudin
DigitalGlobe, USA

We live in an age of unprecedented challenges to our world and opportunities to safeguard it. Our growing needs for food, water, and energy are driving a rapidly changing global dynamic upon which natural diversity, human health, and prosperity depends. When it comes to improving lives around the world, DigitalGlobe provides you with a unique opportunity to address the key global challenges of our time. This presentation will showcase the latest in base layer information, rapid three dimensional visualization, the highest quality satellite imagery at 30cm and the potential application for SWIR.

ESCANEO LIDAR Y FOTOGRAMÉTRICO CON CÁMARA DIGITAL DE BARRIDO, UN AVANCE TECNOLÓGICO EN LA AEROTOPOGRAFÍA

SCANNING LIDAR AND PHOTOGRAMMETRYC WITH IMAGE PUSHBROOM SENSOR, AS TECHNOLOGICAL ADVANCE IN AEROTOPOGRAPHY

Elena Mozgovaya - elena@sap.mx
Tamara Freire Cuesta - tamara@sap.mx, Krassimir Iankov - iankov@sap.mx
Sistemas Avanzados y Proyectos S.A. de C.V.
Ciudad de México - México

RESUMEN

La demanda de datos topográficos exactos crece cada vez más, ya que el diseño de proyectos de ingeniería como los viales, líneas de transmisión, cálculos volumétricos y detección de cambios, etc. requieren que estos sean de alta fiabilidad y calidad. Por otro lado, no se cuenta con el tiempo y presupuesto suficientes para ejecutar un levantamiento topográfico tradicional con la cantidad de información suficiente que permita detectar todos los detalles del terreno y de los objetos sobre este. La tecnología LiDAR y los levantamientos fotogramétricos aéreos permiten la adquisición de datos topográficos y la creación de mapas y modelos de terreno más rápidamente.

El LiDAR aerotransportado se compara favorablemente con varias tecnologías, ante todo debido a su exactitud, cualidad de sensor activo y capacidad de penetrar el dosel forestal; brindando tres características esenciales a los levantamientos topográficos: exactitud, rapidez y detalle (cantidad de información). La exactitud que provee el levantamiento LiDAR puede llegar a menos de 10 cm.

Este artículo se enfoca en la innovación tecnológica del escaneo simultáneo con LiDAR, cámara fotogramétrica digital de barrido (push-broom camera) y sistema GPS/IMU, formando un sistema integrado eficiente que permite obtener datos de alta calidad con el mismo ancho y largo de franja del escaneo. Lo anterior evita la multiplicidad de fotografías que tomaría una cámara digital convencional por cada franja de LiDAR, lo que obliga a disponer de gran cantidad de puntos de control tomados en campo para el proceso de aerotriangulación, implicando tiempo y costos adicionales. Con este sistema, se obtienen además otro tipo de productos como estéreopares sintéticos creados a partir de los datos LiDAR y ortofotos, logrando con ello un alto grado de precisión para el proceso de restitución fotogramétrica.

La empresa Sistemas Avanzados y Proyectos se implemento esta tecnología de punta para los proyectos de alta precisión e importancia para el país desde el año 2012, realizando primer proyecto relevante con esta tecnología en los meses agosto – diciembre del 2012 para la empresa DCR Consultoría Y Construcción S.A. de C.V. denominado "Levantamiento Topográfico Mediante Láser Aerotransportado (LIDAR) e imagen aérea para obtener la cartografía básica de 636.72 Km lineales de las carreteras: Magdalena-Nogales, Cananea-Imuris, Altar-Caborca, Caborca-Sonoyta, Sonoyta-San Luis Rio Colorado Y Sonoyta-Puerto Peñasco, en el estado de Sonora"

<u>Palabras Clave:</u> *Aerotopografía, LiDAR, cámara digital de barrido, GPS/IMU, modelo digital de superficie, imágenes estéreo sintéticas, restitución fotogramétrica, precisión topográfica.*

ABSTRACT

The demand for accurate topographic data grows increasingly; because of the engineering design projects such as roads, power lines, volumetric calculations, change detection, etc. They require land information with high reliability and quality. In the other hand, it does not have the time and budget enough to run a traditional surveying with a sufficient amount of information to detect all the details on the ground.

The LiDAR and aerial photogrammetric surveys allow the acquisition of topographic data and creating maps and terrain models faster.

The airborne LiDAR compares favorably with several technologies, primarily due to its accuracy, quality of active sensor and ability to penetrate the forest canopy; providing three essential characteristics to topographic survey: accuracy, speed and detail (quantity of information). The accuracy provided by the LiDAR survey can reach less than 10 cm.

This article focuses on technological innovation of simultaneous scanning with LiDAR, digital photogrammetric camera (push-broom camera) and GPS / IMU system, forming an integrated efficient system for obtaining high-quality data with the same width and length scanning strip. This prevents the multiplicity of photographs take a conventional digital camera for each strip of LiDAR, which requires the availability of a large number of control points taken in the field for the triangulation process, involving additional time and costs. With this system, it's the possible also obtained other products as synthetic stereopairs created from LiDAR data and orthophoto, thereby achieving a high degree of accuracy for photogrammetric restitution process.

Keywords: *Aero-topography, LiDAR, image pushbroom scanner, GPS/IMU, digital surface model, synthetic stereo images, photogrammetric mapping, topographic accuracy.*

1. INTRODUCCIÓN

Sistemas Avanzados y Proyectos S.A. de C.V. (SAP) es una empresa mexicana que cuenta con una amplia experiencia en levantamientos fotogramétricos y aerotopográficos y capacidad instalada con aeronaves Cessna, escáneres LiDAR, cámaras digitales de barrido (*image pushbroom sensors*) y vehículos aéreos no tripulados de origen ruso.

El LiDAR (*Light Detection and Ranging*) es una técnica que utiliza la luz de láser para obtener una muestra densa de la superficie de la tierra produciendo mediciones exactas de coordenadas geográficas en X, Y, Z (ESRI, 2013).

Los escáneres de barrido producen tiras continuas (*strips)* de imágenes del terreno y se basan en arreglos lineales. La cobertura de estos escáneres depende de la longitud del arreglo y tienen como elementos básicos dispositivos de carga acoplada (CCD *Charge-Coupled Device*). Un CCD consiste en una matriz de celdas sensibles a la luz, cada una de las cuales corresponde a un píxel (Petry, Walker, 2007).

Los levantamientos aéreos con sensores LiDAR y cámaras digitales permiten la adquisición de datos topográficos e imágenes de la superficie de la tierra con gran detalle y precisión *(figura 1)*. Con estos datos se pueden crear entre otros productos mapas y Modelos Digitales de Terreno (MDT) de forma rápida y económicamente factible para una gran cantidad de aplicaciones.

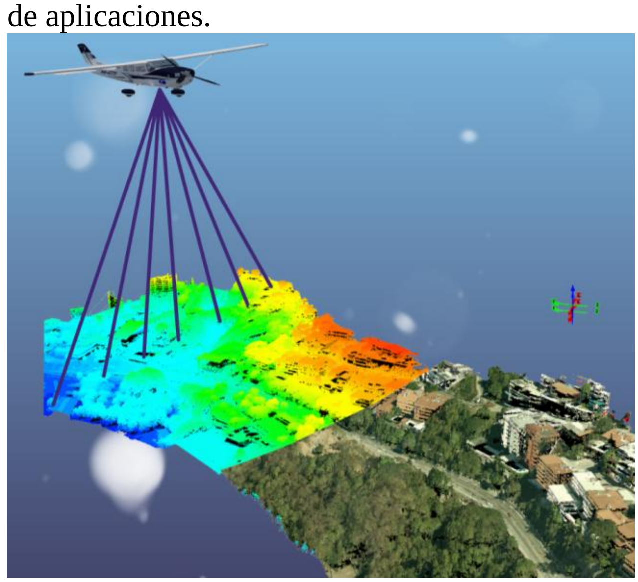


Figura 1: Escaneo del terreno con LiDAR y cámara digital de barrido

El objetivo de este documento es dar a conocer un innovador sistema integrado por un escáner LiDAR y un sensor aéreo de barrido para la obtención simultánea de líneas de vuelo (*strips)* de nubes de puntos e imágenes digitales a color con ancho de franja y longitud similares (figura 2), permitiendo una toma eficiente de los datos con el consiguiente ahorro de tiempo y recursos, ya que no se necesitan realizar dos tipos de vuelo para captar los datos provenientes de estos sensores. Por otro lado con una imagen de barrido el número de puntos de control para el proceso de aerotriangulación (alineación), se reduce considerablemente (en un 90% aproximadamente), ya que se necesitan puntos solamente para la alineación entre *strips* y no para un ajuste transversal (figura 3).

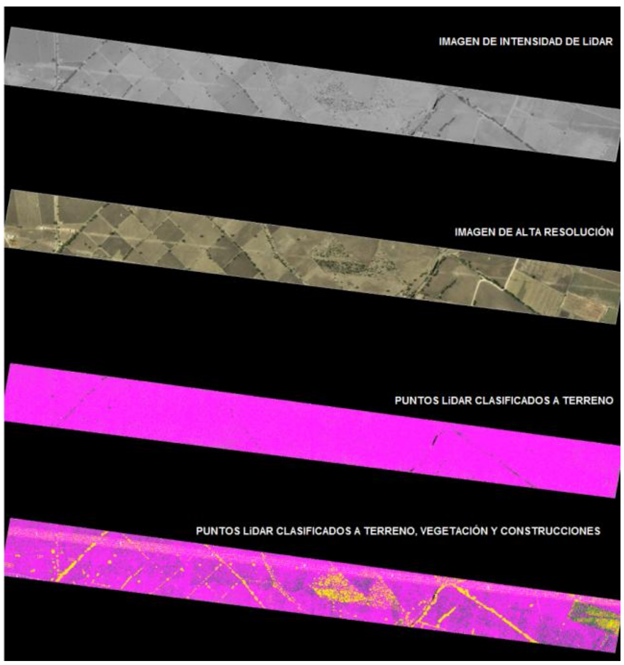


Figura 2: Productos obtenidos con el sistema LiDAR, cámara fotogramétrica de barrido y GPS / IMU

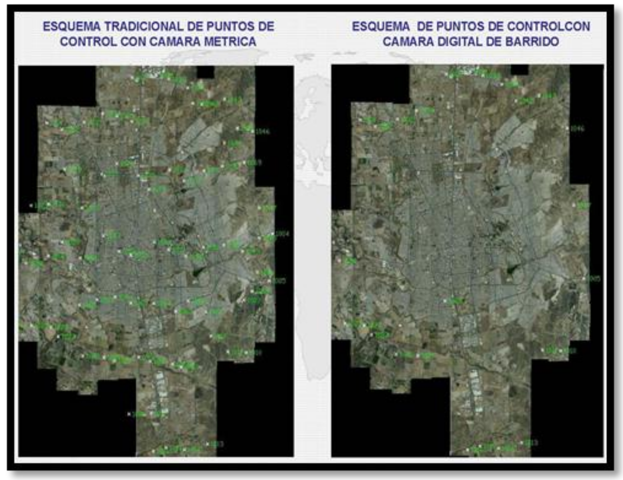


Figura 3: Puntos de control para aerotriangulación (fotografías de cámara) y alineación (imágenes de barrido)

Durante el período que se ha trabajado con este sistema ha dado excelentes resultados en cuanto a reducción de tiempo y costos con un valor agregado importante como la obtención de productos finales de alta calidad y precisión, pues la precisión de los datos LiDAR ha llegado inclusive a menos de 10 cm, lo que también beneficia el proceso de restitución fotogramétrica, ya que éste se realiza en un ambiente tridimensional, utilizando un estéreopar sintético que se crea a partir de la nube de puntos LiDAR.

2. SISTEMA INTEGRADO PARA ESCANEO SIMULTÁNEO DE LIDAR E SENSOR DE IMÁGENES DE BARRIDO

Para la integración del sistema se consideraron los siguientes equipos:

- Cámara digital de barrido (sistema pushbroom) de mediano formato del fabricante Geosystem™, modelo 1-DAS-1, que consta de una matriz lineal fija de muchos sensores que se barre a través de un área por el movimiento de la plataforma, de tal modo construyendo una imagen. Se basa en sensores cuya respuesta y lectura es casi instantáneo (CCD), de modo que la franja de imagen puede segmentarse en píxeles.

Figura 4: Cámara 1-DAS-1

En la Tabla 1 se muestran las características técnicas de la cámara 1-DAS-1.

Cantidad de módulos RGB (camera channels)	1 (nadir)
Cantidad de bandas	1 (1x3)
Altura de vuelo	550 m – 5,500 m
Velocidad de vuelo	110 – 400 Km/h
Ancho de franja	360 m – 3,600 m
Distancia focal	65.53 mm
CCD línea	8,000 píxeles
CCD tamaño de píxel	9 nm
Tamaño de píxel	4.5 a 45 cm
Resolución radiogramétrica (por banda)	14 bit
Campo de visión (Field of View o FOV)	36 º

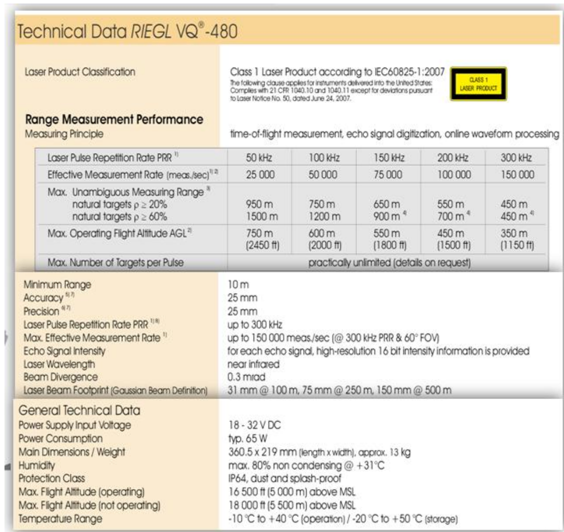
Tabla 1: Características de la cámara 1-DAS-1

La cámara fue modificada a requerimientos específicos del sistema para que abarque el mismo ancho de la franja de escaneo de LiDAR, es decir se adaptó un lente con distancia focal adecuada de 65.53 mm.

- Sensores LiDAR del fabricante RIEGL que permiten un rango de altitud de operación sobre el terreno entre 350 – 5,600 m con el pulso de repetición (PRR) de hasta 400 KHz; velocidad de escaneo de hasta 200 líneas/segundo; y ángulo de escaneo de 60º en total (+/- 30º).
El sistema se configura de acuerdo a las necesitadas de cada proyecto en particular acoplando el sistema LiDAR diferente. En la actualidad se desarrollan los proyectos con los modelos de equipos: VQ-480 y Q-780.

Figura 5: LiDAR modelo VQ-480 y Q-780

En la Tabla 2 se presentan principales características de LiDAR VQ-480.



Technical Data *RIEGL* VQ®-480

Laser Product Classification: Class 1 Laser Product according to IEC60825-1:2007
The following clause applies for instruments delivered into the United States: Complies with 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.
CLASS 1 LASER PRODUCT

Range Measurement Performance
Measuring Principle: time-of-flight measurement, echo signal digitization, online waveform processing

Laser Pulse Repetition Rate PRR 1)	50 kHz	100 kHz	150 kHz	200 kHz	300 kHz
Effective Measurement Rate (meas./sec) 1) 2)	25 000	50 000	75 000	100 000	150 000
Max. Unambiguous Measuring Range 3) natural targets ρ ≥ 20% / natural targets ρ ≥ 60%	950 m / 1500 m	750 m / 1200 m	650 m / 900 m 4)	550 m / 700 m 4)	450 m / 450 m 4)
Max. Operating Flight Altitude AGL 2)	750 m (2450 ft)	600 m (2000 ft)	550 m (1800 ft)	450 m (1500 ft)	350 m (1150 ft)
Max. Number of Targets per Pulse	practically unlimited (details on request)				

Minimum Range	10 m
Accuracy 5) 7)	25 mm
Precision 6) 7)	25 mm
Laser Pulse Repetition Rate PRR 1) 8)	up to 300 kHz
Max. Effective Measurement Rate 1)	up to 150 000 meas./sec (@ 300 kHz PRR & 60° FOV)
Echo Signal Intensity	for each echo signal, high-resolution 16 bit intensity information is provided
Laser Wavelength	near infrared
Beam Divergence	0.3 mrad
Laser Beam Footprint (Gaussian Beam Definition)	31 mm @ 100 m, 75 mm @ 250 m, 150 mm @ 500 m

General Technical Data

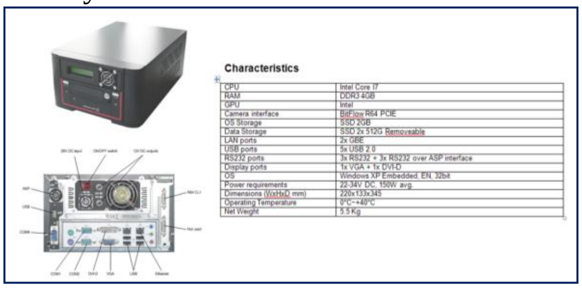
Power Supply Input Voltage	18 - 32 V DC
Power Consumption	typ. 65 W
Main Dimensions / Weight	360.5 x 219 mm (length x width), approx. 13 kg
Humidity	max. 80% non condensing @ +31°C
Protection Class	IP64, dust and splash-proof
Max. Flight Altitude (operating)	16 500 ft (5 000 m) above MSL
Max. Flight Altitude (not operating)	18 000 ft (5 500 m) above MSL
Temperature Range	-10 °C to +40 °C (operation) / -20 °C to +50 °C (storage)

Figura 6: Características del LiDAR VQ-480

- Los dos equipos comparten un mismo sistema GPS/IMU SPAN-SE del fabricante Novatel, con el IMU del modelo LN-200 (figura 7), con lo cual se garantiza la precisión alta en la captura de los datos.

Figura 7: Sistema SPAN-SE

- El sistema esta soportado por el centro de grabación de datos a bordo que consiste en una CPU con dos discos sólidos para el almacenamiento de imágenes y datos LiDAR y cuatro monitores para el control de vuelo y de foto navegación, fabricante GeoSystem.



Characteristics

CPU	Intel Core I7
RAM	DDR3 4GB
GPU	Intel
Camera interface	BitFlow R64 PCIE
OS Storage	SSD 2GB
Data Storage	SSD 2x 512G Removeable
LAN ports	2x GBE
USB ports	5x USB 2.0
RS232 ports	3x RS232 + 3x RS232 over ASP interface
Display ports	1x VGA + 1x DVI-D
OS	Windows XP Embedded. EN. 32bit
Power requirements	22-34V DC. 150W avg.
Dimensions (WxHxD mm)	220x133x345
Operating Temperature	0°C~+40°C
Net Weight	5.5 Kg

Figura 8: Sistema de almacenamiento de datos

La configuración del sistema se adapta a las necesidades de cada cliente de un proyecto determinado.

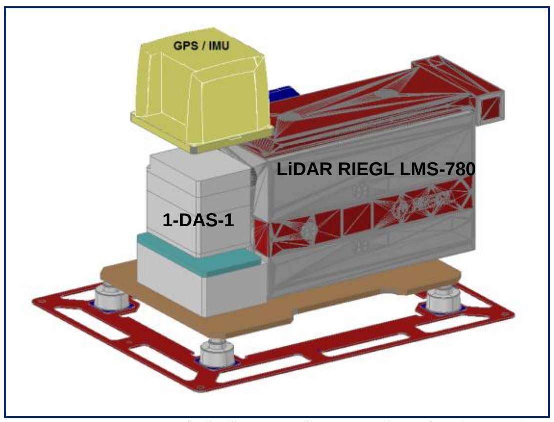


Figura 9: Esquema del sistema integrado LiDAR, cámara fotogramétrica de barrido y GPS/IMU

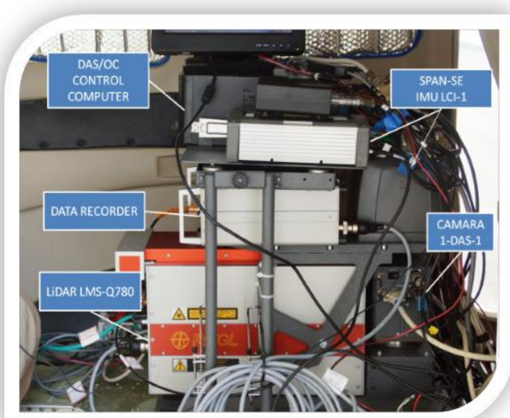


Figura 10: Sistema integrado colocado al interior de la aeronave

El funcionamiento del sistema integrado es el siguiente: la cámara digital captura la imagen con sensores de alta frecuencia, mediante un proceso denominado "pushbroom", la frecuencia de lectura varía con la velocidad y la altura de vuelo, pero este habitualmente está en el intervalo de 200 a 800 Hz. Por su parte el LiDAR en la misma dirección del vuelo recolecta datos del rebote de pulsos con una frecuencia más alta. Al mismo tiempo el GPS e IMU registran lecturas a cada cierto intervalo, en caso del IMU LN-200 son 200 lecturas por segundo de los movimientos angulares del avión (roll, pitch, yaw). Todos los datos son grabados en el dispositivo de almacenamiento con discos sólidos. En resultado y en el post proceso se calcula la única trayectoria del vuelo con la orientación absoluta en cada punto (X, Y, Z, phi, capa, omega) con el software Inertial Explorer del fabricante Novatel.

De acuerdo a este análisis aproximado, para una velocidad promedio de la aeronave de 80 millas náuticas por hora, se tendrían datos directos de orientación absoluta precisa a cada 20 cm. Esto significa que el funcionamiento integrado entre el sistema GPS/IMU y los sensores remotos (láser y cámara) es óptimo.

La ventaja de utilizar el sistema antes descrito es procesamiento homogéneo de datos de cámara y de LiDAR con una sola trayectoria de vuelo, lo que elimina en su mayor parte los errores de incompatibilidad de datos grabados en diferentes tiempos.

Lo anterior permite obtener una imagen ortogonal proveniente de la cámara de barrido con una alta precisión, debido al ángulo de la visión reducido cual está ajustado al ángulo del LiDAR (60º), se disminuye la distorsión de la perspectiva en la imagen y gracias a la integración con el sistema GPS/IMU.

3. FASES DE LA METODOLOGÍA DE ESCANEO

Para la ejecución de un proyecto se sigue los pasos siguientes:

- *Análisis de requerimientos y elaboración del plan de vuelo*
- *Ejecución de vuelos*

- *Trabajo de campo*
- *Cálculo de trayectorias de vuelo*
- *Procesamiento de los datos LiDAR*
- *Clasificación de la nube de puntos LiDAR*
- *Procesamiento de imágenes digitales*
- *Generación del estéreopar sintético*
- *Restitución planimétrica*

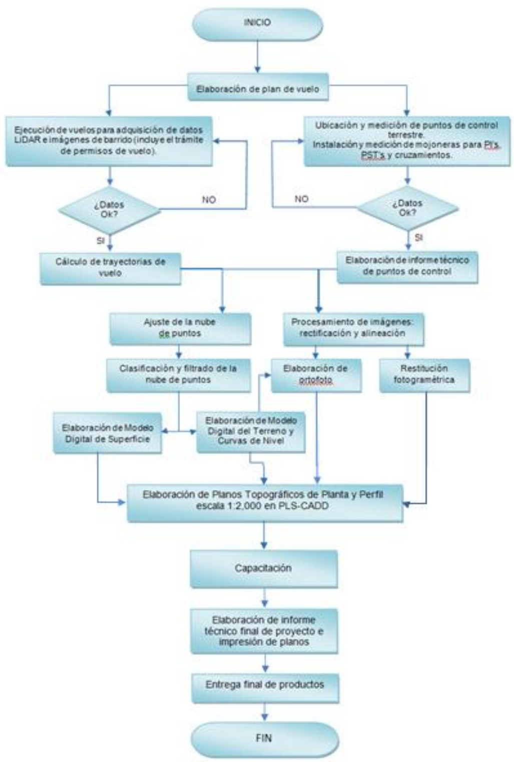


Figura 11: Flujo de trabajo para un proyecto de Líneas de Transmisión

4. VENTAJAS

Con lo antes descrito, se puede vislumbrar la multiplicidad de ventajas de la aplicación de la tecnología LiDAR y de las imágenes de barrido, y la potenciación y ahorro de recursos cuando se utilizan en forma conjunta. A continuación se mencionan algunas de ellas:

- Configuración precisa del terreno, facilitando la proyección de alternativas para proyectos viales, de líneas de transmisión, gasoductos, detección de cambios, etc.; incluso en aquellas zonas donde existe vegetación alta y densa.
- Plazos de entrega cortos, comparado con levantamientos topográficos terrestres, puesto que se trata de un sistema aerotransportado capaz de adquirir datos sobre cientos de km^2 en un solo día.
- La información generada se puede utilizar para otros fines, como por ejemplo modelar bosques, edificios y otros elementos antropogénicos; permitiendo identificar inclusive zonas arqueológicas, suelos con carsticidad y realizar cálculos de biomasa; datos que sin duda ofrecen una importante aportación para determinar la factibilidad total o parcial de un proyecto.
- Esta tecnología ofrece el beneficio de no requerir acceso directo por tierra a la zona de interés, lo que conlleva ventajas tanto de seguridad como de reducción de costos en zonas inaccesibles o de mucho tránsito.
- Al combinar el LiDAR con fotogrametría, la extracción de la planimetría es mucho más fácil y exacta porque el operador de fotogrametría sigue los elementos visibles y puede compilar con gran exactitud las líneas de ruptura donde existen cambios topográficos abruptos.

5. DESVENTAJAS

La tecnología LiDAR, por sí sola, es costosa para proyectos con extensiones de terreno muy pequeñas.

Para aplicaciones con requerimientos de precisión milimétrica es preferible un levantamiento terrestre, sobre todo en terrenos con pendientes abruptas.

6. CONCLUSIONES

La tecnología del sensor LiDAR combinada con cámara digital de barrido, asegura obtener productos adicionales para complementar el levantamiento aerotopográfico de grandes extensiones de terreno, reduciendo costos y tiempo de ejecución. Por otro lado, la fotogrametría se beneficia de la precisión de los datos LiDAR, permitiendo generar productos fotogramétricos de altísima calidad y precisión centimétrica (en algunos casos menores a 10 cm.)

El levantamiento de la topografía del terreno con LiDAR e imágenes de barrido, de manera simultánea, reduce considerablemente los

costos y permite un acople perfecto de los datos, dando lugar a productos adicionales muy interesantes desde el punto de vista tecnológico y de valor agregado a los proyectos, ya que la creación de un par estereoscópico sintético originado de los datos LiDAR ofrece un mejoramiento significativo en la precisión, al proceso de restitución fotogramétrica.

REFERENCIAS

AUTODESK, Manual de Autocad y Civil 3D, 2015.

ESRI, Manual de ArcGIS 10.1, Diciembre 2013.

Fricker, P., Gervaix, F., Roth, R., Llorens, P., Delgado, J., and Cardenal, J., 2002, Utilización de sensores aerotransportados para la generación de MDT y ortofotografías: LH ADS40 Y LH ALS40, *XIV Congreso Internacional de Ingeniería Gráfica*. Santander: Universidad de Cantabria, 1-10.

Forlani, G., Nardinocchi, C., Scaioni, M., and Zingaretti, P., Enero 2006, Complete classification of raw LIDAR data and 3D reconstruction of buildings, *Pattern Analysis and Applications*, **8**, 357–374.

Petrie, Gordon; Walker, Stewart. Airbone Digital Imaging Technology: A New Overview. The Photogrammetric Record 22(119): 2003-225.