PICTURE PERFECT!

WITH AERIAL PHOTOGRAPHIC SURVEYS YIELDING IMAGES OF EVER GREATER ACCURACY AND CLARITY, AND WITH CORRESPONDING ADVANCES IN IMAGE MANIPULATION TECHNIQUES, NEAR-PERFECT 3D LANDSCAPE AND CITY MODELS – AVAILABLE ONLINE AND IN REAL-TIME – ARE OPENING UP NEW APPLICATIONS EVERYWHERE. FLORIAN SIEGERT AND FRANK LEHMANN OUTLINE THE TECHNOLOGIES AND TECHNIQUES THAT MAKE FOR THE PERFECT PICTURE

Until now, the data necessary for developing a Digital Elevation Model (DEM) have largely been acquired with airborne LiDAR (Light Detection And Ranging) technologies. The high cost and limited flight capacity associated with such systems make them ill-suited to the mass production of elevation data. The technology is also at the brink of its effectiveness, especially in alpine regions with extreme relief differences.

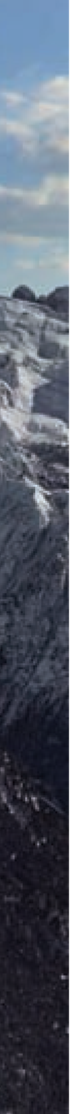
Over recent years an alternative technology has been developed based on the automatic stereo-analysis of aerial imagery acquired by digital aerial cameras. The technology was originally developed at the German Aerospace Center (DLR) within the framework of the European Space Agency's Mars-Express Mission. With the so-called High Resolution Stereo Camera (HRSC), a large part of the Martian surface has been mapped in colour 3D.

New levels of accuracy

Stereo image analysis was developed further at the DLR's Institute of Robotics and Mechatronics (RMC) and, together with other technical innovations such as the airborne Inertial Measurement Unit (IMU combined with GPS), has achieved unprecedented levels of accuracy. An IMU measures and documents the exact speed and direction of the onboard camera and allows for largely automatic photogrammetric stereo analysis of the digital imagery.

The Semi Global Matching (SGM) algorithms, developed by the DLR, calculate highly accurate digital elevation models based on data captured by not only by the modern DLR camera but also by a variety of commercial aerial cameras such as the UltraCam from Vexcel, the DMC from Zeiss and the ADS40 from Leica.

The stereo analysis of aerial imagery delivers – depending on the resolution - between 16 (at 25 cm resolution) and 200 (at 5 cm resolution) elevation points per square meter. A highly accurate, sharp-edged DEM calculation requires a large amount of image overlap - 80% in the flight direction and at least 40% between neighboring flight paths. Since the overlap in the flight direction



does not affect the flying time, large areas can be captured at high resolution in a single day.

With a resolution of 20-30 cm sufficient for landscapes, an area greater than 1500 km^2 can be captured per day with, for example, the Vexcel UltraCam Xp camera. For the production of 3D city models, a resolution of at least 10 cm is needed, whereby the overlap between neighboring flight paths should be 70% to provide an optimal quality for building reconstruction and façade texture. This makes the use of digital aerial cameras the preferred method for acquiring elevation data and True Ortho images if extremely high data quality are required at moderate cost.

Comparisons

A comparison shows that the accuracy of optical aerial imagery is of a similar order to that of LiDAR data. Height deviations of 30-50 cm are hardly relevant for the 3D-visualisation of cities and landscapes. Affordable LiDAR systems currently deliver fewer than eight elevation points per square meter and data acquisition is significantly more costly. That said, LiDAR systems are irreplaceable if the goal of the analysis is to measure ground elevations under tree canopies.

An additional advantage of the aerial image technology is that the DEM and aerial image are perfectly aligned. After calculating the DEM from individually triangulated aerial images, a so-called True Ortho aerial image mosaic is generated. This mosaic can be used to texturise the elevation model to achieve a near-perfect lifelike landscape and city model (Fig.1).

Photo-realistic city models are enjoying increased popularity for a variety of applications. The majority call for a cost-effective solution that LiDAR is unable to deliver. For this reason, Munich-based 3D RealityMaps has developed a procedure to extract façade textures from oblique aerial image segments and to automatically associate them with the corresponding 3D building surface. Fig.1 shows a 3D city model of Munich in which the façade textures were extracted directly from an original UltraCam Xp aerial image and projected onto the buildings.

New camera technology

Qualitatively superior results are achieved with oblique-looking aerial cameras now on offer from several manufacturers. One has been developed at the DLR's RMC-Center in Berlin that is so precise that it can be used for automatic stereo analysis.

For this purpose, 3D RealityMaps has developed a procedure that automatically texturises buildings captured and reconstructed in 3D from oblique imagery captured by the DLR camera or a commercial aerial camera such as the Quattro DigiCam Oblique from IGI. Fig. 2 shows the results: the quality of the façade representation is superior to that achieved by extracting the textures from vertical aerial images.

In the near future the results will be even better: procedures are currently being developed to calculate an elevation model of the vertical façade structure based on the stereo analysis of oblique images, so that roof overhang as well as balconies and bays on buildings can be visualised precisely down to the last centimeter. 3D city models will then no longer be a collection of block-like structures; rather, digitally-accurate building façades will be generated.

Data from high resolution, accurately-positioned satellites can also be utilised for 3D processing. This is particularly relevant in remote areas or regions and for which it is difficult or impossible to obtain flight permits.

A procedure for the processing of satellite data was also developed at the DLRs RMC-Center. 3D RealityMaps has developed software that allows for the interactive online use of these extremely high resolution datasets. The most current and prominent example is an online 3D-visualisation of Mount Everest – a joint research project of 3D RealityMaps, the RMC-Center, and the U.S. satellite operator DigitalGlobe.

For this project, 3D RealityMaps used 0.54 meter ground resolution (highest resolution) satellite images from DigitalGlobe. The virtual 3D-model of the Mount Everest can be accessed and navigated online using the powerful, easy-to-use 3D-software from 3D RealityMaps.

3D-visualisation on the Internet

The software from 3D RealityMaps is the first of its kind to provide top quality visualisations of 3D datasets without limit of size, resolution

Fig.1: Photo-realistic 3D-citiy model of Munich automatically generated from stereo aerial imagery.

Fig.2: Texturised 3D city model of Braunschweig in Lower Saxony, automatically generated from stereo aerial photographs captured by IGI's Quattro DigiCam Oblique camera. *Couresy of 3D RealityMaps/AeroWest*

3D models provide an efficient tool for urban planners, whether for entire cities or individual structures

or level of detail and can be downloaded for free from the company's website at www. realitymaps.de

Thanks to the technologies and techniques described here, the production of photo-realistic 3D-city and landscape models are being made more cost-effective and dramatically expanding the range of potential applications. City models, in particular, have a multitude of possible applications such as urban planning, emergency planning, energy efficiency planning, and tourism.

Risk reduction in mission planning: The deployment of emergency services in crisis situations must be well planned to minimise risk. This is particularly so when the terrain and its challenges are well known and where 3D city or landscape visualisations can help personnel from outside the area evaluate potential dangers.

Urban planning – insight for all: Urban planners must, of necessity, inform and often convince citizens of their intentions. A 3D model is an essential tool for this purpose and an ideal instrument for more efficient decision-making. A classic example was the planning of a sports venue for Munich's 2018 Olympic bid. The International Olympic Committee was able to examine the snow covered Alps and the planned Olympic ski courses, ski jumps and cross country trails, as well as venues in the city, within a 3D visualisation from 3D RealityMaps.

Energy efficiency: With energy suppliers and municipalities eager to establish roof areas suitable for solar panel installation, 3D RealityMaps has worked with the Steinbeis Research Centre (SFZ) to develop new algorithms that automate the extraction of roof area from surface models

Online destination marketing: 3D RealityMaps technology has been employed by the tourism industry for a number of years and is used increasingly in marketing

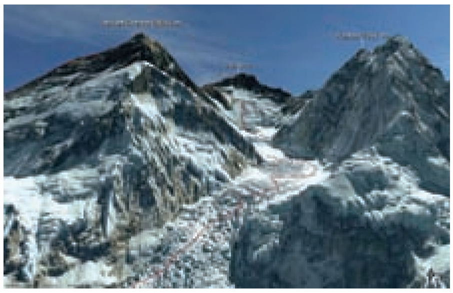


Fig.3: Photo-realistic 3D-model of Mount Everest developed from stereo-satellite images from DigitalGlobe's Worldview-1 satellite. The model is available in an interactive format at www.everest3d.

holiday destinations. Tourist regions are making themselves increasingly popular through the use of photo-realistic maps and spatially-based accommodation search tools. The 3D maps are made available to tourist board Internet sites free of charge to help intending travellers access all relevant information in advance. Once everything is comfortably researched, online direct booking is available.

Those who have chosen to adopt this 3D solution for their marketing activity, receive a complete package from 3D RealityMaps: from data acquisition and processing to 3D-visualisations of landscape and city models, plus integration with existing geodata.

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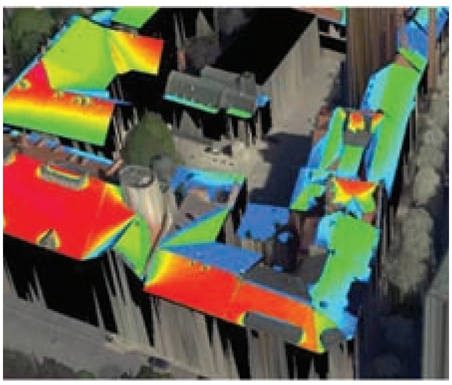

Above and right: Solar energy potential visualisations