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Point Clouds and Smart Cities

The Need for 3D Geodata and Geomatics Specialists

WHICH PHOTOGRAMMETRY SOLUTIONS ARE SURVEYORS WAITING FOR?

USE OF GIS IN SMART CITY PROJECTS

THE SEARCH FOR THE ECONOMIC VALUE OF 3D GEOINFORMATION

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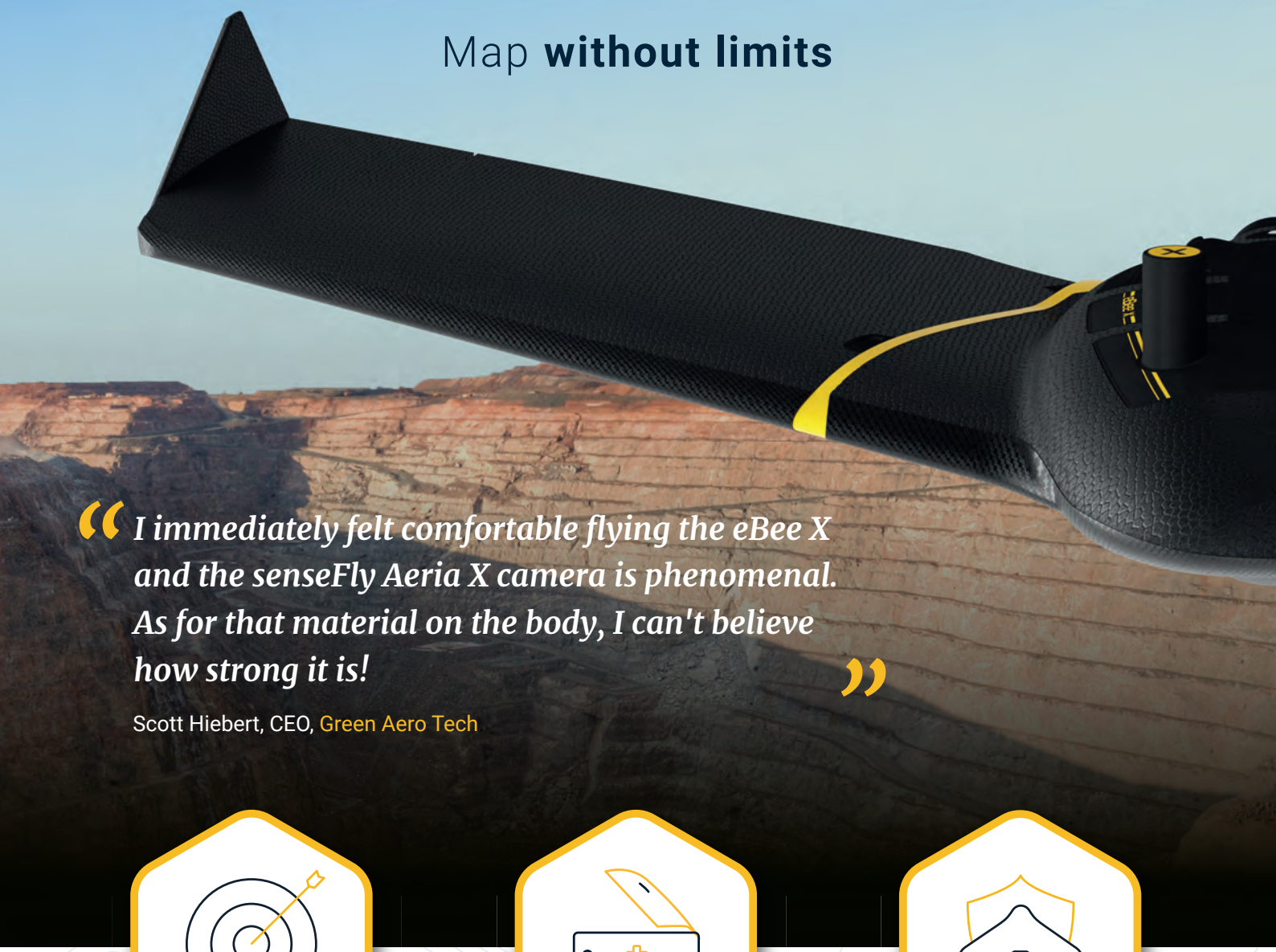

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COVER STORY

This September/October issue is focused on the largest annual trade show for the geospatial industry, Intergeo. One of the key themes of both Intergeo and this edition of *GIM International* is smart cities. 3D geospatial data plays a crucial role in the smart city concept. The image on the front cover shows high-resolution geodata displayed in the Vricon Telco Suite, a software solution that enables companies to analyse urban, suburban and rural areas precisely and quickly. Courtesy: Vricon (www.vricon.com)

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Investment

Economies in large parts of the world are currently doing better than they have been doing for the past ten years. Nevertheless, economists are warning that the upturn could still be in danger due to climate change, trade wars, crises in the once-so-promising BRICS countries and turmoil in international politics – with the impending Brexit causing substantial uncertainty in Europe, for example. Now would be a good time for governments to invest in technology and human capital that will make our societies more resistant to future threats. Our senior editor, Mathias Lemmens, has written a feature article on point clouds and smart cities for this Intergeo-preview issue of *GIM International* (see page 24).
I strongly support his advocacy for investment in geomatics technology to reinforce the concept of smart cities and to better prepare us all for the above-mentioned dangers. I also echo his call for investment in technological human capital: new geomatics specialists. Because the technology is pretty useless without them, and we will be left with ineffective models that do little to safeguard us.

This issue is certainly a very full one. Besides the article by Mathias Lemmens, there's much more to bring you up to speed on what to expect at Intergeo in Frankfurt (from 16-18 October) and everything else going on in the industry. I hope you enjoy reading it – and, if you are in Frankfurt, stop by to meet me and the rest of the *GIM International* team (Hall 12.1, Stand D.135)!

Durk Haarsma, director strategy & business development

The future role of geoinformation

I recently attended a seminar on the application of 3D, virtual reality (VR) and augmented reality (AR) for local authorities in The Netherlands. A couple of years ago, VR and AR were announced to much fanfare as the next big thing that would revolutionise the surveying profession. But not much has actually happened since then. Well, maybe I am exaggerating a little, but the proclaimed transformation to an immersive or interactive environment has not taken place on such a scale as to send massive shock waves through the geospatial industry. However, the event I attended highlighted a surprisingly large number of applications for implementing these technologies – and not just for the sake of being a front runner and demonstrating how slickly your organisation has entered the modern era. Instead, 3D and VR/AR techniques are being used to inform citizens about the impact of the installation of new wind turbines, for example. 3D modelling is already widely used by geomatics professionals, of course. However, it is now increasingly becoming a tool used by local governments too. Obviously, 3D models are very suitable for visualising development plans, and they help to involve citizens in the planning process. How will the direct vicinity – their local neighbourhood – look after it has undergone major restructuring? 3D models, AR and VR offer tremendous possibilities for smoothing this process in completely new and innovative ways. Participatory spatial planning has only just begun! And with smart cities as one of the key topics in the geospatial debate, it seems like everything is falling into place at the right time. VR and AR are important elements to support the implementation of the smart city concept. All of this requires huge volumes of data, so superfast mobile internet is absolutely crucial. 5G will bring the solution, as it will interconnect and control machines, objects and devices in a fast and smart way. Combining 5G with 3D, VR and AR will catapult the smart city concept so that these technologies will finally deliver on their promises. And as for geomatics, a smart city won't be smart without it!

Wim van Wegen, content manager

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Indoor Mapping: We Have Only Seen the Beginning

Indoor mapping is often associated with the rise in location-based services, but over the past few years there has been a growing demand for indoor mapping for a much wider range of use cases. In fact, it is fair to say that the evolution of indoor mapping has only just got started.

The biggest trend is that mobile indoor mapping is taking on more of the work traditionally performed by static laser scanners. Some of the earliest adopters of simultaneous localisation and mapping (SLAM) technology were surveyors and engineers. Faced with growing demand for 'scan-to-BIM' projects, this group in particular appreciated the speed and mobility that a mobile indoor mapping system could provide.

But the past year has marked a turning point, setting the stage for this emerging trend to become a real game-changer – in terms of both how indoor spaces are scanned and how that scan data is delivered and consumed. Three key developments have paved the way for what could be a monumental shift: improvement in the quality of the data, new deliverables, and new use cases.

First, the evolution and improvement of SLAM technology means that data captured by mobile devices is in some cases already achieving survey-grade results. SLAM originated in robotics and is one of the core technologies powering self-driving cars and augmented reality applications. Big names in tech like Apple, Google and Facebook have invested heavily in developing SLAM; analysts estimate that the global market for SLAM will be worth over US$8 billion in the next decade.

SLAM is also being used to improve mobile indoor mapping. The enhancement in data quality as a result of improvements in SLAM technology means that surveyors can use mobile devices for an even greater number of applications. Static scanners will continue to play an important complementary role, but an increasing portion of scanning projects will be done by mobile devices that can deliver high-quality data.

The second development is that indoor mapping offers surveyors not just faster data capture, but also rich new deliverables. Point clouds tend to be limited to professionals who are tasked with creating floor plans and BIM models. The new generation of software tools delivers this valuable scan data as HD maps and realistic, interactive 'digital twins'. This type of web-based deliverable lets users interact with the scan data as if they were walking around the site, making it far more intuitive. The cumulative effect is that a much broader customer base can make use of this valuable scan data, not just those who know how to use CAD software.

That brings us on to the third development, which is that realistic, interactive digital twins open up a myriad of new use cases. Laser scanning captures incredibly valuable details. Making that detailed data available in a format that can be consumed by a broader customer base is going to increase demand for this technology. We have already started to see this happen; for professionals ranging from factory planners to facility managers, high-definition, detailed visualisations provide them with valuable spatial intelligence that can be used on its own or integrated into existing software systems. The benefits are also increasing along with the applications, and have resulted in significant time and cost savings by reducing international travel, facilitating the remote sharing of best practices and increasing collaboration.

▲ *Felix Reinshagen.*

Therefore, as indoor mapping technology continues to advance, it will result in many more stakeholders benefiting from a digital version of their buildings. ◀

ABOUT THE AUTHOR

Felix Reinshagen is co-founder and CEO of NavVis, a company specialised in indoor mapping. In April 2018 the company launched a new version of its indoor mobile mapping system, which is powered by next-generation 6D SLAM.

Xsens Presents Upgraded Versions of MTi 1-series Modules

UAVs and agriculture machinery equipped with the MTi 1-series.

Xsens has released the upgraded versions of the successful MTi 1-series of motion-sensing inertial measurement unit (IMU) modules, offering improved roll, pitch and yaw measurement accuracy and higher tolerance of mechanical stress than the first generation of the product. The company has integrated into the new modules the latest, best-in-class accelerometer and gyroscope ICs alongside its high-performance sensor fusion algorithms. The modules synthesise the inputs from multiple motion sensors at very high speed to provide synchronised data on an object's heading, orientation, acceleration and position. The Xsens sensor fusion technology produces accurate measurements of high-frequency motion, ideal for stabilisation of handheld laser scanners and of professional unmanned aerial vehicles (UAVs).

▸ **https://bit.ly/2xtrKUz**

Airbus and Orbital Insight Announce Geospatial Analytics Partnership

Airbus OneAtlas provides worldwide coverage.

Airbus Defence and Space has entered into a partnership with Orbital Insight, a US-based geospatial analytics company, to build a suite of geospatial analytics services and tools. The agreement will provide Orbital Insight with access to Pleiades and SPOT satellite imagery at scale and provide Airbus with analytics services. This makes Orbital Insight the first analytics partner for the Airbus digital platform, 'OneAtlas'. The OneAtlas platform is a collaborative environment enabling users to easily access constantly updated satellite imagery, perform large-scale image processing, extract industry-specific insights, and benefit from Airbus assets to develop tailored solutions for a wide range of markets in both commercial and government sectors.

▸ **https://bit.ly/2MKADP8**

New Investor Fuels CycloMedia's Growth Ambitions

CycloMedia mobile mapping system.

Dutch high-end street imagery specialist CycloMedia is changing hands. After owning the mapping company for the past ten years, Avedon Capital Partners is selling it to British investor Volpi Capital. This is good news in terms of CycloMedia's ambitious future plans, since an environment of new financial perspectives will foster significant growth in Europe and the USA, the further development of data analytics capabilities and the development of a next-generation image-capture and sensor system. According to CycloMedia, this transfer of ownership to a new investor comes at precisely the right time. The takeover is first and foremost aimed at ensuring business continuity, so no significant changes will be noticeable in the short term. The company's main focus will still be on providing a cloud-based solution for street-level imagery and Lidar data with GIS accuracy, captured with an advanced five-camera panoramic image capture system. Behind the scenes, however, the wheels are already in motion to support the Dutch company's aim of extending its leadership position in high-end capturing of public spaces and related data analytics.

▸ **https://bit.ly/2xgiuUo**

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The Delair R&D team has developed the UX11, next generation drone for surveyors, topographers, and GIS (Geographic Information System) experts . Launched in April 2018, it is more compact, faster and more economical. It has a flight duration of 59 minutes with the highest coverage and resolution in its class, at 120m above ground.

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DELAIR

3DR Launches Site Scan Esri Edition

Site Scan Esri Edition.

3DR, the maker of Site Scan, has partnered with Esri, a global leader in location intelligence, to develop Site Scan Esri Edition. This is a custom version of 3DR's iOS app for drone flight planning and data capture that works seamlessly with Esri's ArcGIS Online and Drone2Map for ArcGIS. The Site Scan Esri Edition app will complement Esri's Drone2Map for ArcGIS software by providing full drone project mission planning and a simple workflow for transferring drone-captured data into the Esri ArcGIS ecosystem. Users will be able to connect to ArcGIS Online with an Esri sign-in. The app will allow users to directly use Esri data layers from ArcGIS Online – including custom data layers from the user's FedRAMP-authorised ArcGIS Online organisation account – as base and reference data for their drone flight planning missions.

▸ **https://bit.ly/2pehbkt**

Gaming Technology Brings 3D and VR Data Visualisation to Mining Industry

Mining technology developer Maptek and augmented reality expert LlamaZOO are teaming up together to bring digital twinning and advanced 3D data visualisation to the mining industry. LlamaZOO Interactive is an award-winning software studio developing 3D interactive data visualisation solutions for enterprise and industry 4.0. LlamaZOO specialises in centralising disparate spatial datasets and making the information actionable for all stakeholders through real-time engaging 3D and virtual reality (VR)/augmented reality (AR). Maptek stakeholders within customer networks will be able to interact with the spatial data in high-resolution 3D, in a format typically only seen with high-end video games, but with actionable real-world data.

MineLife VR LlamaZOO data layers.

▸ **https://bit.ly/2PL5JYR**

Siemens and Bentley Systems Strengthen Strategic Alliance

Bentley Systems and Siemens have decided to further strengthen their strategic alliance. The two companies will extend their existing agreement and further develop their joint business cooperation and commercial initiatives. Therefore, the joint innovation investment programme will be increased from the initial €50 million of funding to €100 million. In addition, as a result of Siemens' continuous investment into secondary shares of Bentley's common stock, the Siemens stake in Bentley Systems now exceeds 9%. Now Siemens is investing in the next collaboration level with Bentley; for instance, the engineering and project management tools will be strengthened with Siemens' enterprise-wide collaboration platform Teamcenter to create a full digital twin for the engineering and construction world.

▸ **https://bit.ly/2xqq0Ah**

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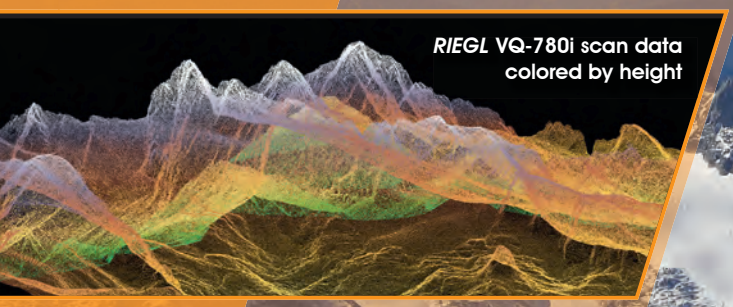

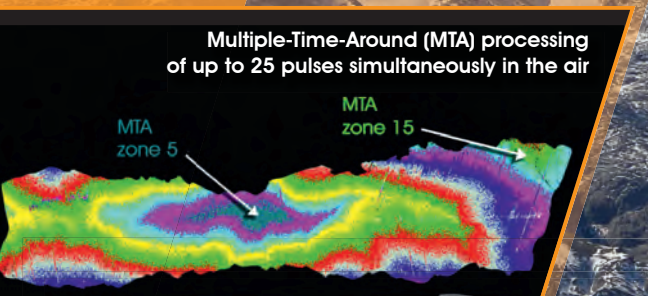

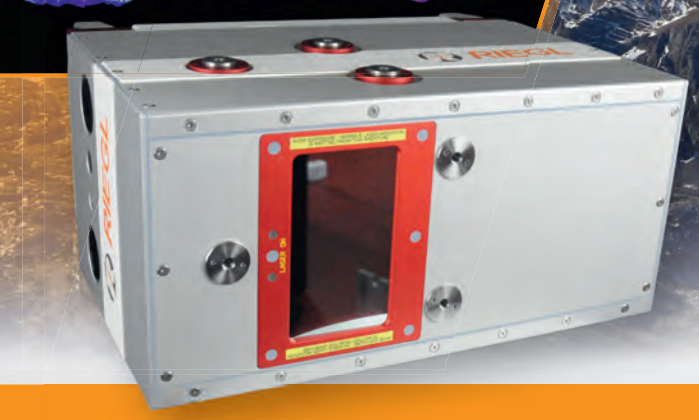

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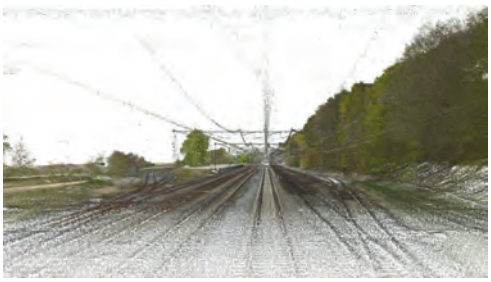
Dutch 3D Aerial Scanning Project to Reduce Rail Travel Delays



Point cloud of a 3D Lidar scan.

ProRail, the company in charge of managing and maintaining the Netherlands' railways, is using 3D aerial imagery to reduce travel disruption. The company has scanned more than 7,000km of railway tracks over recent months, and the imaging project is due to be completed this summer. The resulting Lidar images will be used to produce a detailed 3D map which will help to minimise delays by enabling ProRail employees to see areas of track that need replacing or where trees need to be cut down. According to ProRail, tree branches falling on the overhead lines or leaves on the track already cause disruption to the rail service on a weekly basis, and even more frequently in the case of stormy weather. It can take up to six hours to clear a tree from the tracks, so the company is keen to take preventative action wherever possible.

▸ **https://bit.ly/2phUUCw**

3D Laser Mapping and GeoSLAM Merge as One Company

Leading UK laser scanning and monitoring companies 3D Laser Mapping Ltd and GeoSLAM Ltd have merged to create one mobile mapping and monitoring technology provider. 3D Laser Mapping is a world-leading geospatial technology supplier and innovator that works alongside governments, universities, blue-chip firms and operators of highways, power lines and railways, helping customers to capture and understand the world in 3D. GeoSLAM is a global market leader in 3D handheld mobile mapping technology solutions. Its 'go-anywhere' technology is adaptable to all environments especially spaces that are indoor, underground or difficult to access, providing accurate 3D mobile mapping without the need for GPS.

▸ **https://bit.ly/201b9yG**

Delair Receives Funding from Intel for Data-driven Drone Software Solutions

Delair UX11 mapping UAV.

Delair, a leading global supplier of commercial unmanned aerial vehicle (UAV or 'drone') solutions, has recently closed its expansion round with an investment from Intel Capital. For the past year, Delair and Intel have been collaborating on the Intel Insight Platform. This is a cloud-based digital asset management solution that leverages Delair's extensive suite of industry-optimised software analytics to speed Intel's efforts to transform how businesses in key verticals work using data captured from UAVs for actionable analytics. The funding will be used to further accelerate the development and adoption of the Intel Insight Platform – a data processing, visualisation, analytics and reporting service that allows customers to , organise, share and harness the rich data provided by commercial drone systems. The platform integrates Delair's deep customer experience and vertical expertise with Intel's expertise in developing customer-focused, easy-to-use cloud-based solutions and tools.

▸ **https://bit.ly/2NjAk35**

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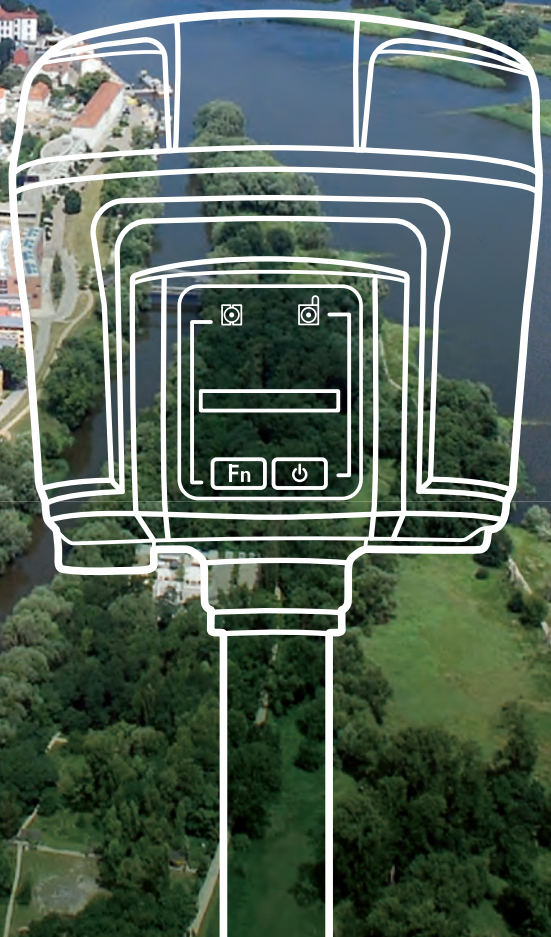

CHCNAV

DroneDeploy Launches Machine Learning-driven Cloud Photogrammetry Software

DroneDeploy Map Engine.

DroneDeploy, a leading cloud software platform for commercial unmanned aerial vehicles (UAVs or 'drones'), has announced the release of Map Engine – the industry's first machine learning-driven photogrammetry software. The release came after a successful beta period where it processed 30,000 maps per month for more than 4,000 clients across 180 countries. The software solution generates high-resolution maps and 3D models from UAV imagery collected in the construction, energy, agriculture and surveying sectors. The new processing engine leverages the latest cloud infrastructure and machine learning technology to deliver high-quality results and to help customers reduce costs.

▸ **https://bit.ly/2xiEqh0**

Bluesky Captures Ultra-high-resolution Aerial Survey of Dublin

Aerial mapping company Bluesky Ireland has captured the first-ever 12.5cm-resolution aerial photography coverage of the whole of the Greater Dublin area. Covering a total of 1,850 square kilometres, the imagery is so detailed that road markings, street furniture and property boundaries are all easily visible and it is accurate for use in GIS and desktop mapping software. In another first for the Republic of Ireland, the data is also being made available through a dedicated web mapping service (WMS), allowing users to stream the imagery directly into their GIS or other compatible software.

Ultra-high-resolution imagery of Dublin.

▸ **https://bit.ly/2PJqm7G**

Phase One Launches 150MP Metric Camera and New Aerial Systems

Phase One iXM-RS metric camera.

Phase One has launched the iXM-RS metric camera series and new aerial systems. The flagship iXM-RS150F camera is full frame with 150 megapixels and available in RGB and achromatic models. Its ultra-high-resolution (14,204 x10,652) backside-illuminated CMOS sensor, fast capture speed (2 fps) and enhanced light sensitivity enable increased productivity in a wide range of aerial image acquisition projects. The iXM-RS camera is the imaging heart of Phase One Industrial's aerial system: a fully integrated solution for mapping and surveying. The two new 150-megapixel and 100-megapixel iXM-RS cameras feature Phase One Industrial's proven RS lens series with seven field-replaceable focal length options, ranging from 32mm to 150mm. Designed and built for aerial photography by Rodenstock and Schneider Kreuznach, these lenses are factory calibrated for infinity focus and each is equipped with a central 1/2,500 sec. leaf shutter.

▸ **https://bit.ly/2D3qH3H**

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Artificial Intelligence for Smart Cities and Sustainable Urban Systems

Urbanisation is undoubtedly one of the most fundamental trends of the past two centuries. Between 1950 and 2014, the share of the global population living in urban areas increased from 30% to 54%, and by 2050 it is projected to expand by an additional 2.5 billion urban dwellers. Urbanisation yields many benefits for society, including enhanced opportunities for education, improved job prospects, better access to healthcare and cleaner water. Yet it is also associated with immense societal and environmental challenges. Inefficient planning and management practices lead to unsustainable settlements that do not enable people to advance personally, socially or economically.

Smart and innovative technologies are revolutionising the way cities address the challenges associated with urban growth. These technologies help cities to utilise existing assets more effectively, allocate resources more efficiently and improve how data and information are managed and shared across systems. According to the International Data Corporation (IDC), worldwide spending on smart city technologies is forecast to reach US$80 billion in 2018, of which US$22 billion will be spent in the US alone. Investment in smart city technologies can potentially improve the sustainability of cities. The McKinsey Global Institute (MGI) suggests that such technologies could cut emissions by 10-15%, reduce water consumption by 20-30% and decrease the average commute time by 15-20%. Whether these are mobile apps that provide real-time information on public transportation delays, intelligent GIS systems that propose the shortest route to a destination or systems that track the sources of air pollution or determine electricity pricing dynamically according to demand peaks, smart city technologies have the potential to not only foster economic growth, but also to improve people's quality of life.

Increasingly, satellite data is becoming a fundamental component of smart cities and an essential tool for city management and governance. From understanding connectivity between cities to measuring economic growth, detecting power outages or identifying where resources should be allocated after disasters, the increasing availability of satellite data is transforming how cities are managed and helping to improve their functionality.

From the point of view of urban governance, machine learning and artificial intelligence (AI) provide near-real-time information on how cities change in practice, e.g. through the conversion of green spaces into built-up structures. By 'teaching' computers what to look for in satellite images, rapidly expanding sources of satellite data are leveraged in combination with machine learning algorithms to quickly reveal how actual city development aligns with planning and zoning or which communities are most prone to flooding. Machine learning techniques help to automatically detect and map different types of land cover and land use across space and time, and generate important insights, analytics and visualisations.

In the past, expensive satellite imagery and limited computational power only allowed analysis of small geographical areas. This model is being replaced thanks to the wealth of publicly available and free satellite data about every location on Earth, captured every few days and in a spatial resolution of a few metres. This data is brought to the cloud and, using machine learning algorithms, analysed on various cloud-based platforms without the need to download and upload large volumes of data. This new model provides cities and governments with accessible solutions for satellite data analysis, decision-making and data sharing.

▲ *Ran Goldblatt.*

Today, AI is almost a buzzword, a kind of magic formula, based on some 'intelligent agents' and sophisticated algorithms that make decisions and take action for humans. But AI will never replace human validation or effective governance on the ground. 'Smart' technologies that collect data on the ground or from space must be leveraged to monitor and manage urban systems and to provide guidance and recommendations for better decision-making, which will in turn make cities more sustainable. ◀

ABOUT THE AUTHOR

Ran Goldblatt is a GIS and remote sensing analyst with more than 20 years of experience in geospatial analysis and geospatial data management. He currently works as a remote sensing scientist and senior consultant at New Light Technologies, a company that provides comprehensive information technology solutions for clients in the public, private and non-profit sectors.

✉ ran.goldblatt@newlighttechnologies.com

GIM INTERNATIONAL INTERVIEWS THE RIEGL TEAM

Leading Four Decades of **Innovation in Lidar Technology**

Whenever anyone talks about Lidar technology in the geospatial sector, it is only a matter of time before the name RIEGL is mentioned. Thanks to its renowned R&D department, the Austrian provider of innovative Waveform Lidar technology has a rich history of proven innovations in 3D. Today, RIEGL provides mapping and surveying professionals with airborne, mobile, terrestrial, industrial and unmanned laser scanning solutions. To tie in with the company's 40th anniversary, *GIM International* interviewed founder Dr Johannes Riegl and three of his staff members.

Dr Riegl, your company is celebrating its 40th anniversary this year, congratulations! How did it all start back in 1978? And what were your main reasons for starting your own company?

Dr Riegl: The true idea behind starting the company, after ten years of research and development activity at Technical University Vienna, was my desire to find a tangible, practical use for the fruits of those research activities. Another thing that motivated me were the comments of some of my colleagues back in 1978, such as "Yes, Johannes, it's probably best that you've founded your own company, as the topic has no real scientific future," or my professor, who literally said "Of course you can try it, Dr Riegl, but it won't work out, you'll see". Of course, this was 40 years ago, but it all served as an excellent additional motivator for me to succeed.

▲ *Dr Riegl unveiling the new RIEGL VZ-400i terrestrial laser scanner during Intergeo 2016.*

▲ *Dr Riegl personally giving an insight into the production of airborne laser scanners during a guided tour at the RIEGL LIDAR 2013 User Conference.*

The first working laser was built in 1960 by Maiman. What stage had the technology reached when you founded RIEGL Laser Measurement Systems?

Dr Riegl: When I started working with lasers in 1968, ten years before founding RIEGL, there were only a few types of lasers available and they were in a very embryonic stage. In the visible range, for instance, the helium-neon (HeNe) laser was the latest state of the art, but it wasn't yet commercially available. For us to build our own HeNe lasers, we first had to learn the science of glass blowing so that we could fabricate the long tubes – with the additional glass bodies for anode and cathode – ourselves. Meanwhile, semiconductor lasers had to be cooled down by liquid nitrogen to -77°C, which is certainly not the ideal situation for developing handy, lightweight laser distance meters. It wasn't possible to gain access to uncooled semiconductor lasers, the indispensable key transmitter component for portable devices, until at least 1970.

How has the application of your company's measurement and surveying systems changed over the past decades?

Dr Riegl: In our early years, the main field of application for our single point laser products was short-range distance measurement and rangefinding over long distances. Then in the late 1990s we started producing our 2D and 3D laser scanners, and a wide range of new application areas emerged. Applications for these sensors and systems truly cover the entire spectrum: archaeology, agriculture, corridor mapping, glacier and snowfield mapping, forestry, mapping of complex urban environments, mining, topography, road surface measurements, surveying, monitoring, civil engineering, ulta-wide-area/high-altitude mapping, power-line mapping, railway inspection, crash-scene investigation, GIS mapping, BIM, asset management, emergency management planning, pipeline inspection, coastline mapping, transportation infrastructure mapping, cultural heritage documentation and so much more. It is incredible and makes me really proud to see RIEGL products used in so many different fields.

What do you regard as the key milestones in your company's history so far?

Dr Riegl: Achieving many milestones and industry innovations is of the utmost importance for our success. To keep things brief, I'd like to mention just a few product-related ones here. In 1982, for example, we developed the first handheld laser binoculars for hydrography. Then, in the 1980s and 1990s, we introduced ever-evolving distance and speed meters. 1996 saw the market launch of our first 2D airborne scanner, and in 1998 came the first 3D laser scanner for terrestrial (static) applications. The year 2004 marked the introduction of the world's first compact airborne laser scanner, LMS-Q560, with purely digital signal processing. In 2008 we introduced the VZ-400, the first 3D laser scanner using purely digital signal processing, which was a remarkable breakthrough – we were miles ahead of the competition at that time. In 2014, as one of the established Lidar developers and producers, RIEGL was an early visionary in recognising and accepting the rising importance of unmanned aerial vehicles (UAVs) in surveying. We designed and developed the first surveying-grade laser scanners for UAV applications, and even our own UAV platform, the RiCOPTER, as the basis for complete turnkey UAV Lidar systems from a single source.

With regards to research & development (R&D), what is your strategy to stay on top in this field and how do you handle your intellectual property (IP)?

Martin Pfennigbauer: As a technology-driven

company from the very beginning, it has always been the mindset of RIEGL to rely on in-house know-how as a solid ground to stand on. Thus we have the capability to push the state of the art in Lidar technology on many levels. Another important asset to us is the strong interaction with our partners in both academia and industry. Many of our innovations have stemmed from the inspiring work with a network of specialists. Fostering these relationships and having an open mind for new and novel requirements and applications helps to shape our developments and motivates us to further push the boundaries.

What are the key factors that help your company to remain a frontrunner in Lidar technology?

Dr Ullrich: There are a lot of factors that go into our company being at the cutting edge of Lidar technology. We have a highly motivated team of engineers from various disciplines with impressive backgrounds, striving to contribute everyone's excellence into the progression of Waveform Lidar. In addition there is constant vigilance on our side in monitoring the rapid development in fields of technology such as electronics, signal processing, IT and laser technology, and in utilising valuable achievements to further Lidar progress. Our customer base and partner base have also played a large role in optimising our portfolio. With their input and feedback, we are able to fine-tune the sensors and systems to their needs to meet both their requirements and those of the market.

Numerous customers from all over the world rely on the high performance of RIEGL's Lidar products, including for large-scale aerial measurements. Which inspiring examples are you particularly proud of?

Dr Riegl: We are proud and excited about each and every one of our customers. Every RIEGL user is working on unique and exciting projects throughout the world, for applications that we would not have thought possible when we first started the company. I can't mention all of our customers here, of course, but one exciting example is NOAA in North America – a long-time user of RIEGL airborne sensors and systems – which utilises airborne Lidar for a multitude of purposes. One of those purposes is the use of RIEGL topo-bathymetric Lidar to extend the survey into the water, capturing data from both land and sea with shallow-water bathymetry, and to lay the foundation for sound decision-making. The data NOAA uses helps it to view potential impacts of sea-level rise along the coast, see flood forecasts in a visual format, and see pre- and post-effects of natural occurrences along coastlines. There are many prestigious names in the geospatial world we are proud to call our customers, such as Fugro in The Netherlands, Quantum Spatial in the USA, Alibaba in China, Nakanihon in Japan, and Land Survey in Australia, to name but a few.

How do you expect Lidar technology to develop over the coming years?

Dr Ullrich: Lidar is a prominent technology in such a broad spectrum of applications, ranging from autonomously driving and flying vehicles to atmospheric applications like global wind measurements, surveillance and reconnaissance, precision farming and, of course, surveying. I'm sure that the technology will develop in different directions in these distinct applications, and in others too. There is still plenty of room for further improvement in the technology we believe in: Waveform Lidar. We expect to make considerable progress in the future in

TODAY RIEGL SOLUTIONS ARE USED THROUGHOUT THE WORLD, FOR APPLICATIONS THAT WE WOULD NOT HAVE THOUGHT POSSIBLE IN OUR EARLY DAYS

▲ *Lidar imagery of Michaelerplatz in Vienna, captured by a RIEGL VZ-400i terrestrial laser scanner.*

acquisition speed, range accuracy, size and weight, and for smoothing the data processing workflow.

In view of the current wave of mergers and acquisitions, and the increasing concentration of power amongst a handful of industry giants, how is RIEGL managing to remain an independent family business?

Johannes Riegl Jr: RIEGL has positioned itself over the years as one of the key innovation drivers in the industry, and I believe we have the necessary recognition in the market to sustain our strong position. As a main innovation leader we are also striving to support industry growth overall. Along with 20 other companies such as Esri, Oracle, Trimble and Autodesk, we have recently been a founding member of the new World Geospatial Industry Council (WGIC) – an organisation aimed at helping improve industry collaboration and raising awareness of the need for global geospatial data availability.

You have long-standing relationships with Esri and a number of other companies in the geospatial industry. What are they built on?

Johannes Riegl Jr: Within each of our partnerships with other companies in the geospatial industry, we focus on fostering bonds that offer substantial benefits for our mutual customers. Using our partnership with Esri as an example, it enables our customers to deploy a more complete solution, which improves efficiencies and productivity. Through partnering with another industry leader such as Esri, RIEGL is able to provide mutual customers with additional options to improve their results and advance their use of Lidar technology in their GIS applications. Earlier this year we received the 3D Impact Award at the Esri User Conference, which is extra recognition that we are on the right path in terms of collaboration. Industry partnerships are critical to our success.

Lidar technology for drones is sometimes described as 'the next geospatial frontier'. What is your view on the current status of UAS-Lidar?

Dr Riegl: The availability of both high-performance UAV carrier platforms and matching sensors for challenging professional surveying tasks has increased considerably over the last few years. At first, UAVs were considered a nice-to-have gap filler between high-altitude airborne sensing for large-area mapping and terrestrial scanning. In fact, UAV-Lidar has proved to be a real solution for those areas that would be difficult, dangerous or impossible to access by traditional means of surveying. But maybe even more importantly, new applications have emerged that initially seemed very exotic to established surveying. It became evident that UAV-borne sensors also permitted a new class of data quality thanks to the unrivalled perspective from which they can capture the surface or object of interest and the closeness that provides very high resolution, accuracy and completeness of the data.
Today, the importance of the UAV surveying market and its future growth potential are undisputed. Currently, we're seeing both the further miniaturisation of all kinds of sensors for integration on small UAVs or multi-system-setups, and at the same time the endeavour to make UAVs more efficient with regard to both payload capability and airworthiness. These developments go hand in hand with the layout of a legal context regulating step-by-step integration of professional UAVs into non-segregated airspace.
It is exciting to have been an active participant in the rise of the UAV sector, from the so-called hype of commercial professional UAVs to the broad acceptance that we have reached nowadays. We're continuously improving and enlarging our product range in this area, since we are convinced that the field of remotely piloted systems is not yet fully explored.

Lastly, is there anything else you would like to say to our readers – mapping and surveying professionals around the world?

Dr Riegl: We would like to thank our customers and partners worldwide who have not only trusted in us but have also encouraged us, from the earliest beginnings to the present day. Through their feedback and positive criticism, they have spurred us on to persist with our hard work to fine-tune our products and services and pursue new developments. We would also like to assure them all that we will always strive to best satisfy their needs, now and in the future. We want to not only maintain our position in the market but also continue to fortify and expand upon it. You can count on that, for sure! And, last but not least, we should also take a moment to thank our highly regarded competitors who have not allowed us to take a breather for a second. With their own hard work and dedication to the industry, they have helped to ensure that our ever-lasting quest for innovation must never stop and that we must always strive for more. ◀

BIOGRAPHIES

Dr Johannes Riegl founded RIEGL Laser Measurement Systems GmbH in 1978 (originally called Dr. Johannes Riegl, Radartechnik und Elektrooptik until 1989) and has been the company's CEO and managing director ever since. He holds a Dipl-Ing degree in communications engineering and a PhD from Vienna University of Technology, and wrote his thesis on 'Optical Short Distance Measurement'. From 1972 to 2002 Dr Riegl served as a lecturer at the Vienna University of Technology's Institute of Communications and Radio-Frequency Engineering on topics covering radar technology and optoelectronics.

Johannes Riegl, Jr has been a member of the RIEGL executive team since 2012. He serves as the president of the company's US operations based in Orlando, Florida, handling the company's North American market. He is also president of RIEGL International, the division responsible for worldwide marketing activities and the development, support and expansion of the global RIEGL Distribution Partner Network. His position reflects a unique role within the company: to coordinate strategic business development and marketing between the international RIEGL locations. He holds a master's degree in business management from the University of Applied Sciences in Vienna.

Dr Andreas Ullrich holds a PhD in electrical engineering from Vienna University of Technology and is author of the thesis on 'High-Resolution Optical Doppler Radar' (1987-1990). Since 2001 he has been a lecturer on radar technology at the Vienna University of Technology's Institute of Communications and Radio-Frequency Engineering. In 2004 he was awarded the Wilhelm Exner Medal for excellence in research and science. From 1984 to 1991 Dr Ullrich was an assistant professor at the Vienna University of Technology's Institute of Communications and Radio-Frequency Engineering. Having held various positions since joining RIEGL Laser Measurement Systems in 1991, he has been CTO and managing director of RIEGL since 2006.

Dr Martin Pfennigbauer holds a PhD in engineering from Vienna University of Technology. He has been with RIEGL Laser Measurement Systems since 2005, presently as the director of research and intellectual property. He manages research projects funded by the European Space Agency, the European Union and Austrian national funds. He is the product manager for hydrographic airborne laser scanning systems. His area of special interest is the design and development of Lidar instruments for surveying applications, with a focus on rangefinder design, waveform processing and point cloud analysis.

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MANAGING AND VISUALISING GEOSPATIAL DATA IN A USER-FRIENDLY ENVIRONMENT

Use of GIS in **Smart City Projects**

The smart city concept is developing very quickly around the world, because it provides a comprehensive digital environment that improves the efficiency and security of urban systems and reinforces the involvement of citizens in urban development. This concept is based on the use of geospatial data concerning the urban built environment, the natural environment and urban services. The successful implementation of a smart city project requires the development of a digital system that can manage and visualise the geospatial data in a user-friendly environment. The geographic information system (GIS) offers advanced and user-friendly capabilities for smart city projects. This article shows how a GIS could help in the implementation of smart city projects and describes its use in the construction of a large-scale model of the smart city.

The 'smart city' concept aims at developing a comprehensive system that uses geospatial data to enhance the understanding of complex urban systems and to improve the efficiency and security of these systems. This geospatial data concerns (i) the urban built environment such as infrastructure, buildings and public spaces, (ii) the natural environment such as biodiversity, green spaces, air quality, soil and water, and (iii) urban services such as transport, municipal waste, water, energy, health and education. The smart city concept also aims at transforming the 'silo-based' management of cities into a 'shared' system that involves urban stakeholders in the design, realisation and evaluation of urban projects.

The emergent technology enables cities to achieve more agile management that improves the quality of life for citizens, enhances the economic development, improves the attractiveness of the city and reinforces the involvement of citizens in the city government. Indeed, the smart city concept provides the city managers with pertinent information about the performance of urban infrastructure and services, as well as users' feedback. Analysis of this data allows policymakers and city managers to improve the efficiency of the urban system as well as the quality of urban services. This concept is particularly pertinent for the security and resilience of the city. It allows collection of data concerning how the city infrastructure and stakeholders respond to urban hazards. Analysis of this data provides greater understanding of the behaviour of urban systems (infrastructure, public services, emergency response, etc.) during urban crises or disasters, and consequently enables improvements to the city's capacity to address the resiliency challenges. The smart city concept offers the possibility to confine a local fault and to prevent its spread to larger areas.

USE OF GIS IN SMART CITY PROJECTS

The implementation of smart city projects is based on a number of steps (Figure 1) including the construction of the urban digital model, data collection using the sensing layer, then data analysis, interactive data visualisation and system control. GIS plays a role in these steps, as described below.

CONSTRUCTION OF THE URBAN DIGITAL MODEL

The first step in the implementation of smart city projects concerns the construction of the urban digital model that describes the components of the urban built and natural environments. For each urban component, the digital model provides the geolocalisation and characteristics (attributes). GIS is generally used for the construction of the digital model of urban 'horizontal components' such as urban networks, transport facilities and natural environment, while building information modelling (BIM) is used for the description of 'vertical components' such as buildings. The combination of GIS and BIM provides a powerful tool for the construction of the urban digital model with georeferenced data and the visualisation of this data in a user-friendly environment.

SENSING LAYER

The second step in smart city projects concerns the construction of the sensing layer that transfers urban operating data to the smart city information system. This layer includes sensors used for monitoring urban networks and infrastructures. Data could also be enhanced by images, videos and audio

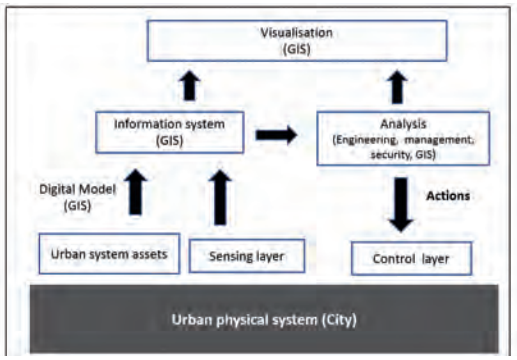
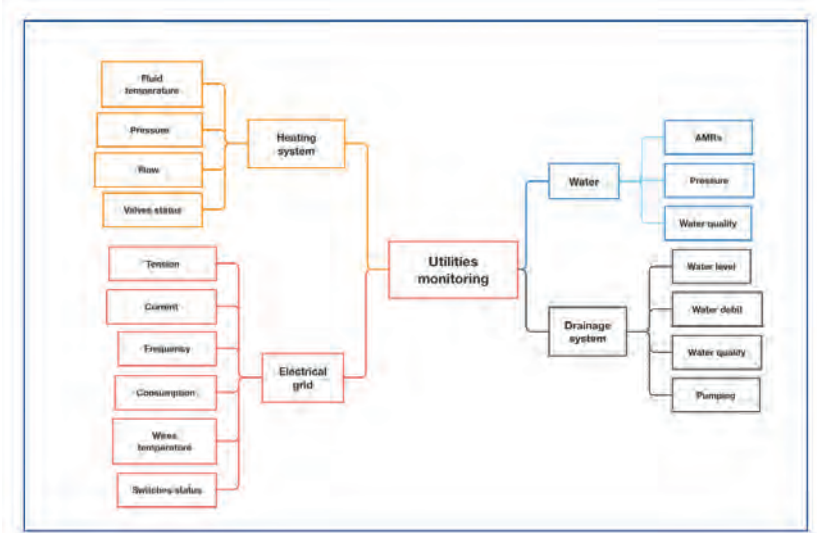
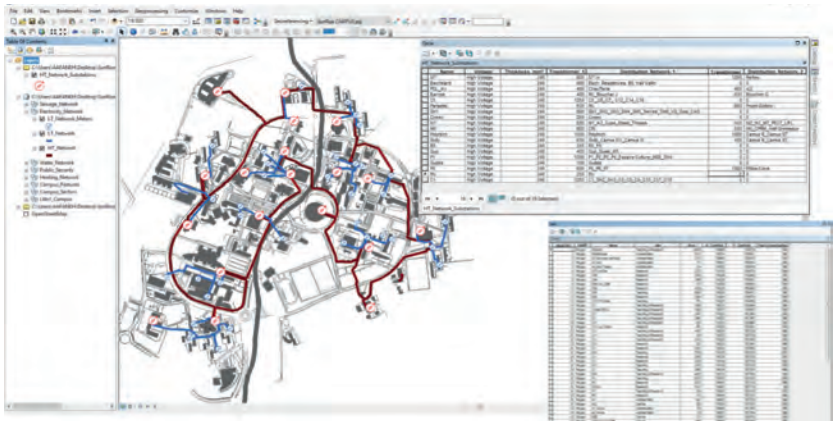


Figure 1: Steps for the implementation of smart city projects.



▲ *Figure 2: Sensors used in water and energy utilities monitoring.*



▲ *Figure 3: GIS system of the electrical grid (red: high-tension line, blue: low-tension line).*

▲ *Figure 4: Use of GIS to visualise the equipment of the storm-water system in the SunRise project.*

files resulting in the construction of urban big data. Figure 2 shows examples of sensors used in monitoring water and energy utilities. The drinking water system uses automatic meter readers (AMRs) to record water consumption, pressure sensors to record water pressure and water quality devices to track the water quality (turbidity, pH, chlorine, conductivity). The drainage system uses sensors to monitor the water level and flow, water quality (turbidity, temperature, pH, etc.) and pumping equipment. It allows early detection of flood and faults in pumping equipment. The electrical grid uses sensors to measure the electrical tension, current and frequency. It allows early detection of faults in the electrical grid. The district heating system is monitored by sensors to record fluid temperature, pressure and flow as well as the state of the valve. It allows early fault detection and the improvement of the system performance. GIS offers the possibility to visualise the monitoring system as well as the sensors' characteristics and status. It also provides the possibility to visualise real-time and historical data on GIS maps.

DATA ANALYSIS

The third step in implementing a smart city project concerns the development of the analytic environment, which converts real-time and historical data into operational data that improves the security, efficiency and quality of urban systems. The analytic environment includes engineering, management and safety software for urban systems as well as advanced digital tools such as artificial intelligence (AI). In smart city projects, GIS provides tools for (i) geospatial data analysis (distance and directional analysis, geometrical processing, grid models), (ii) spatiotemporal analysis, (iii) spatial statistics (spatial autocorrelation and egression), (iv) surface analysis (surface form and flow analysis, gridding and interpolation methods) and, (v) location analysis (shortest path calculation, facility location).

INTERACTIVE DATA VISUALISATION

Interactive data visualisation allows users to interact with the smart city's components and the stakeholders in a user-friendly environment. Web applications are used to create this interactive environment. The use of HTML popups enables users to access web-based content such as graphics referenced by URLs. The interactive GIS graphic environment allows the visualisation of urban components and sensors maps. Users and managers can utilise these maps to access static and dynamic data concerning urban systems as well as to update the data.

CONTROL LAYER

Data analysis of historical and real-time data results in commands for the optimal and safe management of urban systems. These commands are transmitted to the control layer, which includes different electronic devices such as smart valves, pumps, motors, switches, breakers and locks. The GIS system allows real-time visualisation of these devices

as well as their status. It could also visualise faults in device command.

SUNRISE SMART CITY PROJECT

The SunRise smart city project was aimed at the construction of a large-scale model of the smart city at Lille University's scientific campus. The campus is equivalent to a small town, with 145 buildings, about 25,000 users and 100km of urban utilities.

The first step of the SunRise project included the collection of asset data about the campus utilities and integration in the SunRise GIS system. The data concerned linear components such as pipes and lines and their attributes (diameter, material, age, etc.) as well as utilities-related equipment such as valves, hydrants, pumps, substations, manholes and tanks. Figure 3 shows the use of GIS for the electrical grid of the campus. The GIS map provides the grid architecture as well as attributes of the grid components including the electrical lines and substations. Figure 4 shows the GIS map of the storm-water system and the relevant equipment (valves, flow regulator, retention tank and lifting station).

The SunRise GIS system also included inspection and maintenance data. Figure 5 shows images of the video inspection of the sanitation system. For each component of this system, the management team can gain access to the maintenance history and reports including images and videos. The team can also conduct geospatial analysis of maintenance data for the optimisation of renovation and maintenance costs.

The monitoring system was also integrated in the SunRise GIS system. Figure 6 shows the smart monitoring of the drinking water network. It includes automatic reading meters (AMRs) for the water supply and consumption as well as pressure meters. The team manager can directly access information about the sensors and visualise the consumption history. The team can also compare the consumption of buildings and use data analysis to show abnormal consumption levels.

CONCLUSION

This article has presented the use of the GIS in the implementation of smart city projects. Since smart city projects are based on the collection, analysis, sharing and visualisation of data concerning urban systems and services, GIS provides powerful capacities for a successful implementation of such projects. GIS allows smart city managers to utilise a user-friendly and widely used digital system in the management of urban systems. GIS was used in the construction of the SunRise smart city demonstrator at the Lille University campus. The use of GIS facilitated effective cooperation between around 20 young researchers and the campus team management. GIS was used to store, share and analyse data concerning the campus utilities as well as their maintenance and monitoring.

ACKNOWLEDGEMENT

The author would like to thank Nitivat Voraditee from Lille University for his contribution to this article.

Figure 5: Use of GIS to visualise the maintenance of the sanitation system in the SunRise project.

Figure 6: Use of GIS to visualise the monitoring system of the drinking water network in the SunRise project.

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ABOUT THE AUTHOR

Isam Shahrour is a distinguished professor at Lille University in France. He is the founder and director of the SunRise smart city project, which consists of building a large-scale model of the smart city. He conducts various smart city projects with local authorities and companies. Shahrour has written more than 120 papers for journals and he is regularly invited to give academic and public keynotes on issues related to the smart city, sustainable city and resiliency.

THE NEED FOR 3D GEODATA AND GEOMATICS SPECIALISTS

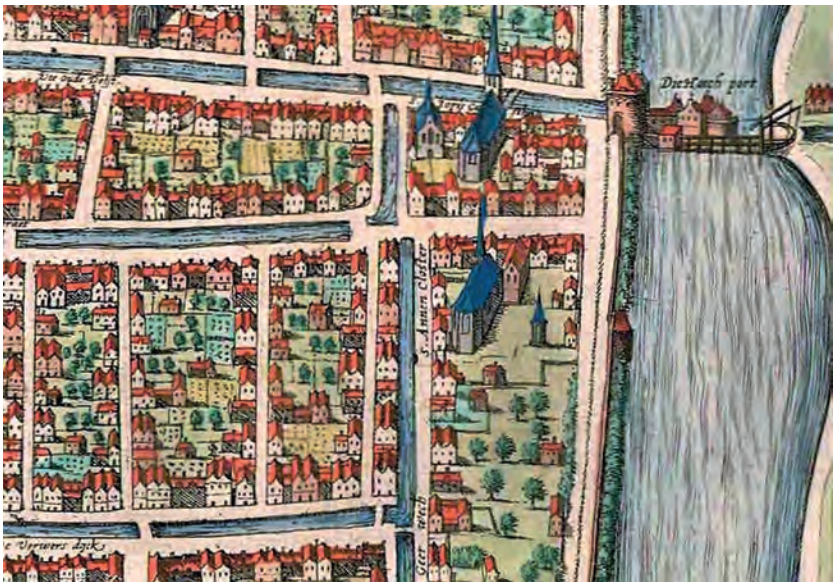
Point Clouds and Smart Cities

The 'smart city' concept entirely relies on a permanent stream of massive amounts of data acquired by a great variety of sensors distributed throughout the city. Smart use of all this data requires integration with 3D city maps for which point clouds, acquired by laser scanning or photogrammetry, are the main sources. The author of this article identifies the abilities of point clouds to support the smart city concept.

The benefits of point clouds for monitoring urban processes were recognised quite early on. Back in the early 1990s, airborne Lidar could accurately provide the height component which is so important for many urban needs. Not only the geometric accuracy appeared to be amazingly high, but also the point density. The needs include design and inspection of utilities such as water mains, sewer systems, tunnels, bridges, roads, railways and power lines, and the creation of 3D city maps in which the shapes of buildings and other objects have been reconstructed with high spatial detail. One prerequisite is the availability of geodata, which represents the environment in its full spatial and time dimensions at a highly detailed level. Before being ready for use, geodata has to be acquired. This seems trivial, but is far from it. Thanks to tools like Google Maps, too many laymen take the existence of geodata for granted. The desire of many local authorities to implement the smart city concept will result in a strong need for increasing the acquisition of geodata. Since geodata acquisition is time-consuming, labour-intensive and associated with a number of technological issues and costs, it may be readily envisaged that the creation of smart cities will be associated with a bothersome burden.

SMART CITY CONCEPT

People continue to move to cities. Population growth within the limited boundaries of a megapolis increases traffic, housing, utility density and the risk of calamities, and puts a strain on scarce resources. As a result, the economic, social and environmental impacts are tremendous. Added to this, nearly one billion people live in cities which may be hit by floods, droughts, cyclones, earthquakes or other natural disasters. Humans, power, water, gas, wastewater, bits and bytes – they all are transported through a labyrinth of roads, tunnels, pipes and cables. Flood, fire or other shocks can disrupt these arteries and veins of the city. To cope with these threats and optimise the use of scarce resources, many city authorities want to exploit the opportunities offered by today's technology; they want their city to become 'smart'.



▲ *Figure 1: Bird's-eye view of a part of Delft, The Netherlands, drawn in 1580.*

▲ *Figure 2: 3D map of the commercial centre of Frankfurt, Germany, created from free and open-source Lidar data and satellite images; buildings, ground and streets consist of one textured mesh (source: Turbosquid.com).*

In the smart city concept, information and communication technology (ICT) is fully exploited to increase the efficiency of mobility, retail and delivery services, to minimise energy consumption and air pollution, and to reduce the response time to casualties and hazard sites. The goals are often formulated in abstract terms such as liveability, economic progress, quality of life, sustainable development or attractiveness. In the smart city concept, decisions are not made ad hoc or based on political beliefs or preoccupations. Instead, decision-making is informed, based on the plethora of data obtained from sensors and analysed using smart algorithms – possibly based on machine-learning principles – running on high-performance computers. A city cannot be smart without the permanent availability of data collected by sensors mounted on static or moving objects. To illustrate this, the importance of point clouds for water management is discussed below.

▲ *Figure 3: A RIEGL VMX-250 mobile scanning system scanning the historic market square of Krakow, Poland (source: RIEGL, Austria).*

WATER MANAGEMENT

Flood threats are increasing due to rising sea levels and rapid urbanisation. Flooding is caused by an accumulation of water which may result from heavy rainfall, swollen rivers or dike breaches. Flooding causes degradation of assets, economic losses, injuries and health risks. Renovation of dikes, creation of water overflow areas and protection of vulnerable dunes are essential for urbanised lowlands such as the Mississippi River area and the Rhine/Meuse Delta. For these purposes, detailed and accurate knowledge is required on the variations in elevation of the river bed and the surrounding area, height of dikes, flood waves, along-track and across-track slope of the river and the water resistance associated with land use. The use of a digital elevation model (DEM) or, even better, a 3D map derived from point clouds as input for flood models provides insight into areas at a high risk of inundation. The development of a new urbanised area will affect the flow of water. Is the sewerage system still able to drain off the water after heavy rainfall? Does the rainwater still flow in the direction of the river or reservoirs? Should the drainage layout be improved? These are all questions a smart city should be able to answer, and the solutions lie in the expert analysis of 3D geodata by geomatics professionals.

GEODATA

Essential in the smart city concept is the availability and continuous production of digital data, which may be collected dynamically or statically, continuously or intermittently. Smartphones and social media channels such as Twitter deliver real-time data on human movements and how people use the city's space, either by public transport or their own methods, and other facilities. Static sensors distributed over the city produce data on particulate matter, noise pollution, temperature, groundwater level and so on. Cameras can detect traffic accidents and enable rescue workers to assess injuries while still rushing to the scene of a disaster. The permanent stream of real-time data captured by a dense sensor network needs to be processed, analysed, used in decision-making and disseminated to stakeholders. For this, the location of each sensor, whether static or dynamic (such as a smartphone in a cyclist's pocket), must be known in a uniform coordinate system. To guarantee the smart use of all sensor data, the skeleton of a

PUBLIC AUTHORITIES OFTEN UNDERESTIMATE THE NECESSARY COSTS OF UPDATING TO PRESERVE THE VALUE OF THE 3D MAPS

▲ *Figure 4: 3D map at LoD1 of a part of Rotterdam automatically created by combining building footprints with airborne Lidar point clouds (source: Municipality of Rotterdam).*

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smart city consists of cadastral maps, master plans, utility maps (containing the location of underground pipelines, cables, sewerage systems, manholes and much more), as-built plans, maps outlining buildings and roads, and 3D maps at the necessary level of detail.

3D CITY MAPS

3D maps include the height dimension which is essential for many smart city applications such as flood risk monitoring, emergency response, viewpoint analysis and calculation of the solar energy potential of parcels and roofs. Making a city really smart starts with the creation of an accurate 3D map covering the entire city. Of course, such a 3D city map should be precise, detailed and up to date. Positional or thematic inaccuracies and outdatedness will impair proper decision-making. The very nature of geoinformation means that damage originating from substandard products may not be immediately recognisable. Mistakes made today may – a decade or two later – cause society significant losses, not only moneywise, but also in terms of injuries, accidents, demolished houses, and human suffering. Accurate 3D mapping is therefore an important, even essential, asset underpinning the smart city concept. Capturing and representing the 3D space of a city is challenging because of the level of detail required. 3D mapping requires the right data, the right software tools and geomatics professionals with the right knowledge.

▲ *Figure 5: 3D map of a part of London manually created from high-resolution aerial images, covering 6km² (source: AccuCities, London).*

DIM IS HELPING TO AUTOMATE THE CREATION OF 3D CITY MAPS

IMPORTANCE OF UPDATING

The advantages of 3D city maps were first recognised many centuries ago. Armed with only pencil and paper, surveyors and cartographers in the 16th and 17th centuries exploited their craftsmanship to produce bird's-eye views which combined a 2D map with perspective views of buildings (Figure 1). Hundreds of years later, aerial images processed with digital photogrammetric workstations enabled extraction of 3D coordinates of corners of buildings and other key points, albeit in a labour intensive process. Apart from various types of imagery (satellite, aerial and terrestrial), today other data sources are available for creating 3D city maps, including airborne, mobile and terrestrial Lidar and topographic and cadastral 2D maps. Using a mix of these data sources allows a 3D city model to be created highly automatically (Figure 2). As airborne Lidar – and, later on, mobile laser scanning (MLS) systems (see Figure 3) – became more mainstream, this boosted the research into automated 3D mapping. For example, airborne Lidar enabled Rotterdam to generate a 3D map of buildings which was made openly available in 2011. The basic data source was a detailed map with footprints of buildings. The airborne Lidar point cloud was acquired by Fugro's Fli-Map system in 2010. The accuracy and point density of 30 points/m² enabled the automatic extrusion of the footprints resulting in a Level of Detail 1 (LoD1) representation of Rotterdam in CityGML (Figure 4). Manual editing was required to eliminate anomalies, some caused by time shifts in the acquisition of the map and point cloud. Since this is now outdated, Rotterdam is currently at an advanced stage of releasing a much more detailed 3D map in close consultation with a broad spectrum of prospective users. Regular updating is a necessity. Indeed, public authorities often become enthusiastic about the smart city concept initiated by one or more city department and release financial resources, but underestimate the necessary costs of the annual or biannual updating to preserve the value of the 3D maps. Despite all the photogrammetric methods and laser

▲ *Figure 6: Faro handheld scanner.*

▲ *Figure 7: GeoSLAM ZEB-REVO mobile 3D scanner.*

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scanning research, automated 3D mapping has not yet materialised; today's detailed 3D city maps are created manually. For example, AccuCities, based in London, UK, commercially offers detailed 3D maps based on the manual processing of high-resolution aerial images (Figure 5).

DIM AND SLAM

Since 2010, the acquisition capabilities of both photogrammetric and laser scanning sensors have been tremendously improved, but so too have the geodata processing methods thanks to innovative advancements such as dense image matching (DIM) and simultaneous location and mapping (SLAM). DIM enables the creation of dense point clouds from overlapping images. Meanwhile, SLAM has been one of the most prominent successes in robotics and enables a robot to move autonomously through an unknown space. No map is needed, and no GNSS; the solution is based on 'guessing' the position by exploiting all sensor data. The guesses are iteratively refined using data, which is collected while the robot is moving, and the iterative closest point (ICP) algorithm aimed at minimising the difference between successive scans. Landmarks – features which are distinct from the background – are central in the SLAM approach. SLAM solutions are also beneficial for 3D mapping of indoor and subsurface spaces using trolleys, hand-held sticks (Figures 6 and 7) or backpacks (Figure 8). On trolleys, the main positioning and orientation sensors are odometers, inertial navigation sensors and lasers. Odometers count wheel spins enabling computation of the speed and distance covered. When mounted on two wheels, odometers indicate directional changes. SLAM does not consist of a particular algorithm, but is rather an approach in which a diversity of solutions are employed depending on on-board sensors, the nature of the environment and possibilities to connect the trajectories with ground control points.

▲ *Figure 8: Leica Pegasus:Backpack consisting of five cameras and two laser scanners mounted on a carbon-fibre chassis.*

▲ *Figure 9: Green village sustainable building on Delft University of Technology campus, imaged from a UAS.*

Today's photogrammetric software enables high automation of the chain, from flight planning, self-calibration of consumer-grade cameras and aerotriangulation to the creation of DEMs and orthomosaics as well as their confluence: 3D landscape and city models. However, the creation of detailed 3D maps of cities still requires considerable human intervention. DIM is one of the technological innovations contributing to the automation of the process. DIM is based on semi-global matching, the basics and potentials of which have been developed and demonstrated by Hirschmüller (2008). DIM enables the computation of a height value for each pixel, thus producing high-resolution digital surface models (DSMs) and – by filtering out points reflected on buildings and vegetation – DEMs in (semi-)automatic workflows.
To demonstrate the capabilities of DIM implemented in commercial software, the section below presents a project comparing feature-based matching software, developed by students, with commercial software.

PHOTOGRAMMETRIC POINT CLOUDS

During a project carried out in the last quarter of their first year, students at the Delft University of Technology (TU Delft) working towards a master's in geomatics developed the 'NARUX3D' software to automatically extract textured mesh models from images captured by unmanned aerial systems (UASs). The software features three main modules which run in succession: image matching, sparse and dense point-cloud generation, and mesh generation. The scale-invariant feature transform (SIFT) was used to detect tie points in overlaps for co-registration of images, resulting in the camera

Figure 10: Point clouds and meshes generated by SP software (left) and Pix4Dmapper.

orientations and an initial sparse point cloud using structure from motion (SfM). The sparse point cloud was then densified using a multi-view stereo (MVS) algorithm. To reconstruct a 3D mesh from the dense point cloud, two methods were developed. The first – Poisson surface reconstruction – worked well for smooth surfaces. The second method – PolyFit – was effective for creating compact mesh models from piece-wise planar objects. The performance of NARUX3D was tested at two sites located on the TU Delft campus. During a UAS flight, images of a building (see Figure 9) were taken every two seconds, resulting in 99 images.

Providing that the overlaps were sufficiently high, the software was able to create point clouds even when the facades consisted of a variety of materials with complex textures. The resulting dense point cloud and mesh shown in Figure 10 (on the left) have been compared with the results from Pix4Dmapper commercial software (Figure 10, on the right). In general, point clouds generated by the latter were much denser, while the meshes were less noisy and had a more realistic appearance.

The SIFT matching approach uses feature-based image matching. Distinctive points are detected in the overlaps of images to which descriptors are assigned. Corresponding points in overlaps are then sought based on similarities between descriptors. When little or no texture is present, no reliable matches can be found. This was the case at the second TU Delft site, a white cottage (Figure 11). The roof and facades were coated white, and Pix4Dmapper dealt well with that. However, NARUX3D also extracted points on corners, ribbings and other locations with sufficient contrast. Considering the price of commercial software, the results the students obtained in just two months were quite impressive. Semi-global matching is now a regular part of many commercial photogrammetric mapping software solutions including Pix4Dmapper, SimActive's Correlator3D, Racurs' Photomod, Bentley's ContextCapture, SURE of nFrames, Trimble's Inpho and others.

GEOMATICS PROFESSIONALS

Most local governments do not have enough skilled personnel to implement the smart city concept. The private sector is eager to fill the gap, but companies often lack geomatics expertise too. No geodata or geoICT has much value unless it is in the hands of professionals who have the knowledge and craftsmanship to transform the data into information which supports the local authorities' goals and needs. And the best-qualified people to do this – experts who can set geodata to work for the benefit of the masses – are the geomatics specialists. Unfortunately, in and around the year 2000, many institutes of higher education experienced a low influx of new geomatics students and some universities abandoned their geomatics programmes altogether. Today, society is confronted with a shortage of skilled, experienced and knowledgeable geomatics professionals. Universities and local governments should join forces to fuel young people's enthusiasm for a career in geomatics. They are badly needed. ◀

FURTHER READING

Hirschmüller, H. (2008) Stereo Processing by Semiglobal Matching and Mutual Information. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 30(2), pp. 328-341.

McKinsey & Company (2018) *Smart Cities: Digital solutions for a more livable future.*

ABOUT THE AUTHOR

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Figure 11: Building with little texture (left), point cloud generated by NARUX3D software (middle), and point cloud generated by Pix4Dmapper.

Vegetation Management for Utilities Using Lidar Data

Vegetation and utility management of distribution and transmission lines has become one of the key applications related to Lidar and photogrammetry. The infrastructure sector, and especially the power line industry, has seen exponential growth in airborne surveys in recent years. Helicopters and aeroplanes are collecting thousands of kilometres' worth of corridors of Lidar and imagery data for analysis every day. And their 'little brother', the unmanned aerial vehicle (UAV or 'drone'), is starting to become a reliable alternative (albeit with limitations) for less accessible areas and small-scale surveys.

Laser scanning is the most accurate and efficient solution for collecting geospatial information in 3D as it is even able to collect information under tree canopies or in shaded areas. This information holds great potential for surveyors, but in some cases data remains underused meaning that much of that potential goes to waste.

DATA HANDLING

The problem starts as soon as the survey generates data. Some companies are unaware just how precious the data they have collected is. Especially since UAVs have arrived on the scene, some clients merely want to offer their customers 'something beautiful in 3D'. For the generation of technicians and geospatial analysts who have witnessed the evolution from low-resolution satellite acquisition and expensive private flights to high-resolution imagery (like Google) and Lidar, this seems like sheer madness, because there are unlimited applications and possibilities of Lidar data on any platform (whether helicopter, aeroplane or drone). For example, thanks to the most advanced and 100%-customised analysis and accurate 3D models, we can now do our work better in our offices than we could in the field… so how valuable does that sound?

Today, companies like utilities that are involved in infrastructure management – often with hundreds or even thousands of kilometres to manage – seem to better understand the value of Lidar data and how it can help them in their daily work… maybe because they understand how beneficial it is to be able to host their complete electricity network in a database and to evaluate every single span or structure with it, anytime, anywhere; or maybe because they have to monitor risks and avoid potential problems in the network that could cause huge financial loses (power cuts, indemnities, etc.). Whatever the reason, they are not only looking for a 'nice' 3D model, but they also need to know the exact condition of their network, where their problems are and at what level, an accurate estimate of the actions to be taken and which ones should be taken first… in other words, how much time and money they have to invest to make their power lines safer and comply with the regulations and laws in each country.

KNOWLEDGE IS POWER

It is all about the need to own a realistic and accurate virtual environment. Not too long ago, one had to go out into the field and measure. Today, the Lidar data is displayed in such a realistic way that it almost equals what you would see in reality – that is the power of point clouds! And with deep knowledge and the appropriate tools, any analysis and measurements will be as accurate as when performing an on-site survey. Together with customised analysis in line with the priorities and risks (offending vegetation areas, clearance distances, tree fall risk, etc.), this gives network owners the power of understanding and monitoring what is being done and what will be done. Every single action can be reported and evaluated, and the budget can be negotiated depending on the accuracy with which the job was completed (i.e. checks on vegetation trimming patrols).

CONTINUED INNOVATION

However, the benefits of Lidar data combined with other geospatial sources do not stop there. While vegetation analysis and clearance is today helping utilities to control and manage their networks, further innovation is already being implemented to allow data owners to also manage and control the related tasks done by third parties. Thanks to Lidar data analysis and custom algorithms, vegetation growth rates and safety distances can be combined to estimate potential risk areas and to set priorities, not only for this year but also for the years to come.

▲ *Rafa Torró.*

From our experience in analysing more than 120,000km of power lines, we have learned lots of things from our clients, but two things always hold true: 1) No two utilities work in the same way, and 2) All the complex analysis to be done and beautiful 3D models to be designed must fit into traditional outputs such as an Excel file or a PDF sheet… and from now on, that information must be in the cloud! ◀

ABOUT THE AUTHOR

Rafa Torró is a GIS analyst at Dielmo 3D, where he is responsible for international business development. His specialisations are remote sensing, in particular Lidar. He holds a bachelor's degree in geography and a master's degree in both geographic education as well as GIS and remote sensing technologies.

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MARLYN: THE GO-ANYWHERE MAPPING SOLUTION MADE BY SURVEYORS, FOR SURVEYORS

Fulfilling the **Land Surveyor's Wants and Needs**

Geospatial information gathered by unmanned aerial vehicles/systems (UAVs/UASs or 'drones') is now the driver for business success across many industries and applications. To develop the right tool for this data collection, Atmos UAV had a different approach compared to other commercial drone manufacturers. Rather than focusing just on the product itself, the team was mostly interested in the product fit. After conducting more than 500 interviews with end users, company owners and project managers during the last six years, the company developed Marlyn, a mapping and land surveying solution that meets the industry's wants and needs.

THE NECESSITY OF VTOL AND THE DESIRE FOR HIGH WIND RESISTANCE

Up until recently, professional end users could choose from two different UAV categories: multirotors and fixed-wing drones. Although fixed-wing solutions offer faster and longer flights, according to operators the damaging belly landings make them a no-go. Furthermore, the availability of space for such a landing is considered a luxury most of the time. On the other hand, multirotors are more flexible with their vertical take-off and landing (VTOL) ability, but they lack endurance and speed. As a result, developing a combination of the two proved to be necessary in order to meet the modern land surveying requirements.

Originating from TU Delft and its highly recognised faculties of aerospace engineering and applied Earth sciences, the founders of Atmos had all the resources needed for this challenge. The team not only focused on designing a robust cross-over by taking the best of both worlds, but did so by considering one of the most demanding desires of end users: wind resistance. The end result, Marlyn, takes off and lands vertically, even in confined spaces, while flying quickly and efficiently like an aeroplane (Figure 1), thus offering an unprecedented speed of operations. The unique design of the patented hardware enables the drone to withstand wind speeds of up to 6Bft (45km/h), with its four electric motors ensuring controlled and steady hovering.

▲ *Figure 1: Marlyn takes off vertically.*

▲ *Figure 2: Orthophoto from the Seychelles use case.*

THE NEED FOR HIGH ACCURACY AND PRECISION

There was a strong consensus among all the professionals interviewed regarding the need for high-quality data that will make the post-processing easier and the outputs (such as digital elevation/surface models and orthophotos) more accurate (Figure 2). After all, for most of the end users, their work is not finished when the drone has landed. Capturing high-resolution images and having precise geotagging is of the utmost importance when converting the aerial imagery into point clouds, ideally as quickly as possible. To that end, and by taking account of the fact that the optimal integration of payload components and platform is essential, the Atmos engineering team tested multiple sensors before eventually deciding to equip Marlyn with the SONY QX1. The QX1 is an industrial-grade camera that combines an APS-C-sized Exmor CMOS image sensor with a BIONZ X processor to produce high-resolution images (5,456 x 3,632 pixels). The balanced trade-off between resolution and light sensitivity gives the advantage of a longer operational window so that professionals can map without limits. The team is also working on integrating multispectral and thermal cameras for agricultural, environmental and thermal inspection applications.

With regards to geotagging, using ground control points (GCPs) often appears to be the least appealing option for surveyors as the process requires a lot of time in the field and more complex post-processing. To reduce costs and save time, post-processed kinematics (PPK) was chosen over both GCPs and real-time kinematics (RTK), as PPK is a more reliable solution that does not require an extra data link. A full-PPK module guarantees accurate image georeferencing as the satellite positioning is fully augmented with supportive base station/VRS information. By integrating Septentrio's high-end PPK module, all the GNSS bands are stored and used to achieve full-PPK accuracy, resulting in centimetre-level accuracies.

THE DEMAND FOR RELIABILITY AND EFFICIENCY

According to UAV operators, reliability and efficiency are major concerns when selecting the right tool for a mapping project. Professionals across industries are seeking a solution that can offer them peace of mind and full control during operations. To satisfy these demands, Atmos put a lot of effort into its in-house- developed autopilot, the flight planning and control suite MarLynk (Figure 3), and its dedicated smart battery system. The autopilot software makes the planning intuitive and straightforward, and provides the user with real-time information during the flight, such as position, altitude, battery consumption, wind speeds, project progress and more. After completing a quick checklist, the land surveyor defines the boundaries of the region he/she wants to map, specifies ground resolution and overlap, and takes off safely with the push of a button. Users can now enjoy the hands-off experience of a fully autonomous flight from take-off to landing. To further increase the efficiency and reliability of the drone, a dual-battery system is used in which one battery functions as a failsafe for the other. The two redundant smart batteries are closely monitored in terms of remaining energy capacity, voltage and cell temperature. Marlyn's smart power board can recognise any inconsistency and initiate a predefined safety routine to land automatically.

THE DESIRE FOR A GO-ANYWHERE SOLUTION

Besides the reliability, many respondents also highlighted the desire for a land surveying tool that can be easily transported, deployed and handled. According to the feedback, depending on the project, the system must be suitable for shipping as air freight, fit into a small car and be easy to carry around in the field. Surveyors usually perform mapping projects in difficult-to-access areas so a safely portable UAV is necessary. With these goals in mind, Atmos focused its R&D and product design efforts on the product's portability using detachable wings and expanded polypropylene (EPP), a highly durable constructive foam, as a means to an end. EPP is a material with a unique range of properties including high energy absorption, thermal insulation and impact resistance. EPP has not only been used for the protective inlay of the flight case and the associated backpack (Figure 4), but also for the drone itself. This provides compact storage that results in increased endurance and certainty during projects and transportation.

CONCLUSION

When considering mapping and land surveying projects, a reliable and easily portable VTOL tool with full-PPK accuracy appears to be the best solution. A high-end combination of hardware and software is needed to fulfil today's requirements. Atmos is keen on building strong relationships with clients and partners based on mutual feedback, in an effort to continuously improve its offering and provide professionals with go-anywhere solutions tailored to their wants and needs. ◀

▲ *Figure 3: Screenshot from MarLynk.*

▲ *Figure 4: Marlyn and its backpack.*

Further Reading

Use-case: Marlyn provides crucial data for endangered wildlife research (https://www.atmosuav.com/news/mapping-silhouette-island)
Atmos raises capital for further expansion (https://www.atmosuav.com/news/atmos-raises-capital-for-further-expansion)

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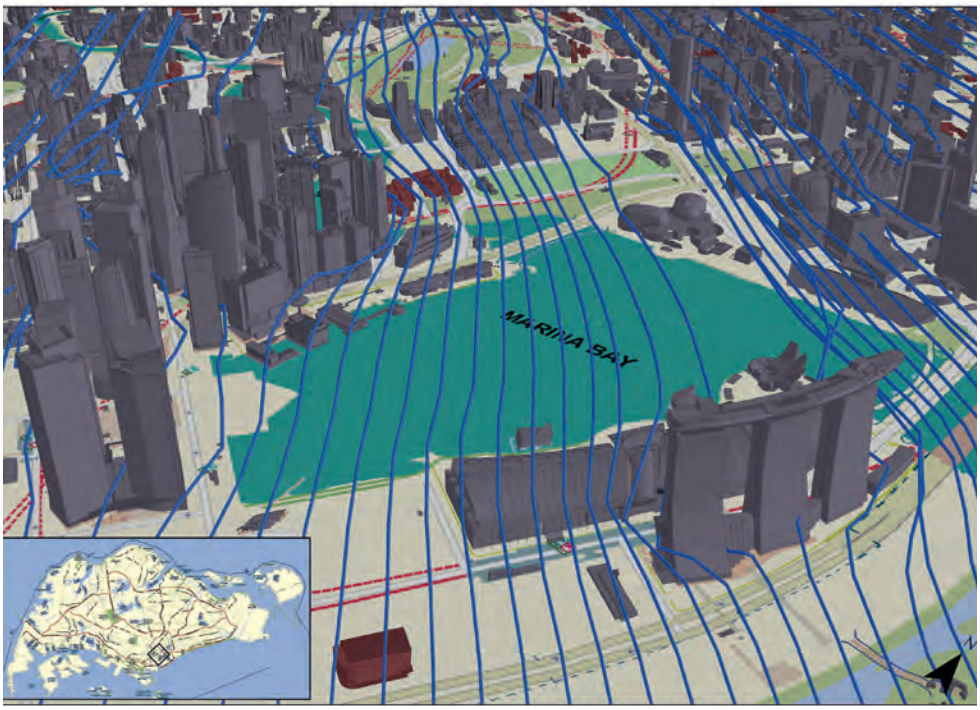
ADDING A THIRD DIMENSION TO THE MAPPING AGENCIES' DOMINANT DATA ENVIRONMENT

The Search for the **Economic Value** of **3D Geoinformation**

In 2017, 11 European public mapping agencies (PMAs) financed a EuroSDR project to explore the economic value of 3D geoinformation. They gained from being able to share knowledge with one another about the findings and their concerns. For the investigated cases, the cost-benefit ratio was found to be about 1:3. Since the calculated financial benefits were rather circumstantial, however, the academics involved in the project complemented the study with a scientific article in which they attempt to provide more nuance by focusing on the broader public value. They conclude that, in general, the use of 3D geoinformation is increasingly profitable. For PMAs, future research will be not so much about whether to make the transition to 3D, but more about how to do so.

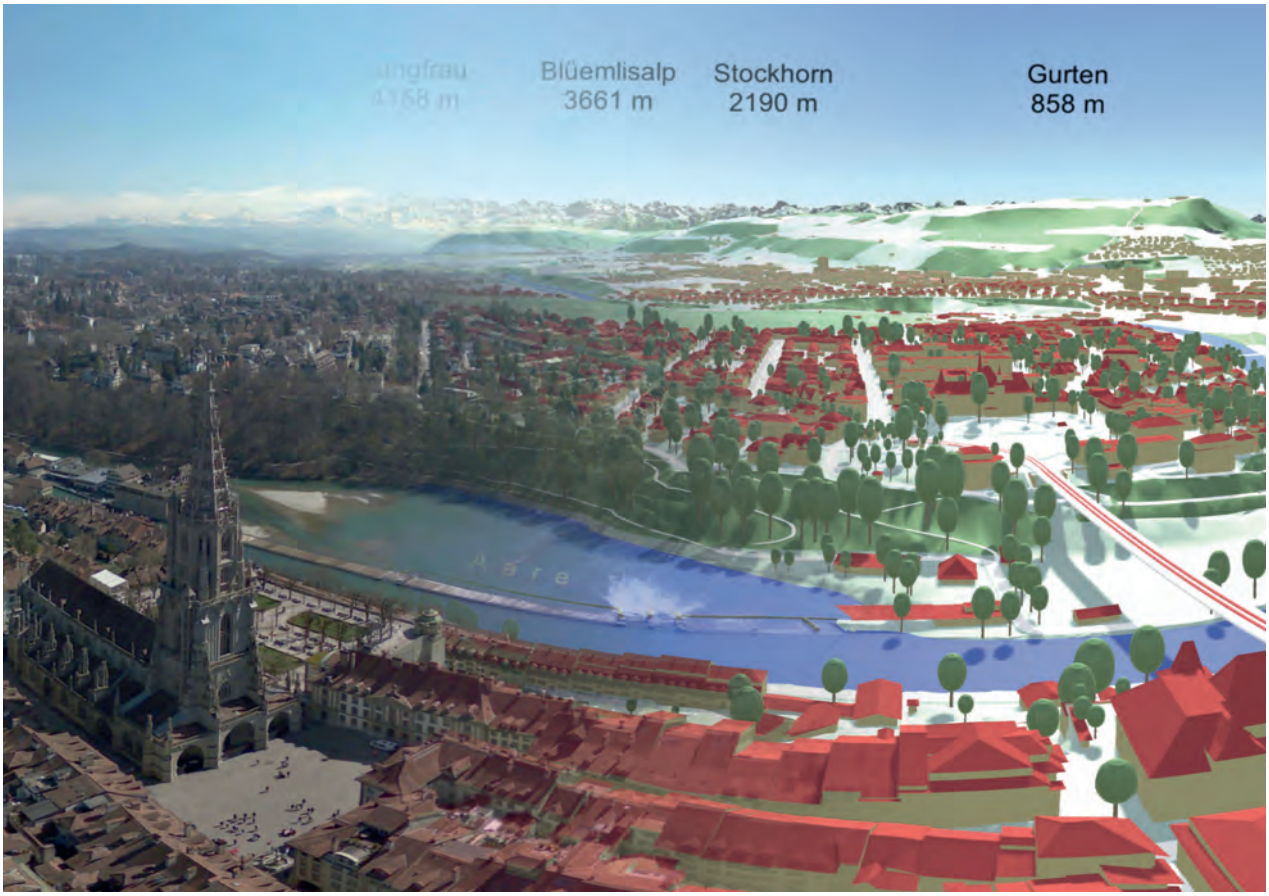
Public mapping agencies (PMAs) are in a difficult position. After 25 years the production processes for 2D mapping and GIS have finally reached a status of high efficiency, but now the market increasingly needs 3D data and information. New but here-to-stay applications like BIM, smart cities, augmented reality and climate change studies 'demand' it. Plus high-tech innovations and pretty 3D visualisations are more effective means of communicating data about the physical and built environments. But most PMAs are reluctant to invest in anything more than large pilots or individual projects. One of the problems is that the public authority that has to bear the costs is not usually the one that enjoys the most benefits. The core competence of PMAs is to produce all the highly reliable geographical data of the territory needed and distribute it in as client-friendly a way as possible within their imposed business model. If the clients' needs evolve to 3D, the PMAs have to follow, otherwise they risk losing their authoritative position – or do they? That is the key question for many European PMAs, which is why they participated in the EuroSDR project to investigate the economic value of 3D.



▲ *The Singapore Land Authority widely uses huge 3D models, such as for wind flow studies. (Source: SLA).*

COST-BENEFIT ANALYSIS

For the study – with involvement of the company ConsultingWhere – six application fields were selected: forest management, flood management, 3D cadastre and valuation,



▲ *Bern, the capital of Switzerland, in 3D. Swisstopo made a complete, national switch. (Source: swisstopo)*

civil contingency, asset management, and urban planning. Over the course of six different EuroSDR workshops, attended by representatives of the PMAs and the stakeholders of the application fields, value chain analysis was applied. Improved planning processes were a clear theme in all of the fields. Two application fields were selected for quantification using cost-benefit analysis: flood management, due to the ubiquity of the problem and its high political profile, and urban planning because 3D geoinformation has a significant potential to contribute to the problems of managing urban growth.

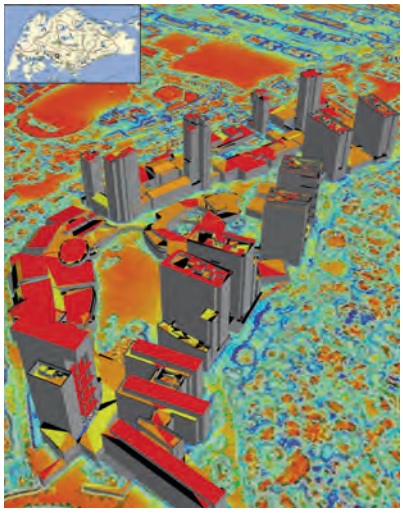
In urban planning, the costs and benefits were evaluated in detail by scaling up and comparing real-world cost estimates from Denmark, a country that uses 3D geoinformation in this field, with the Republic of Ireland (using the comparative land areas), which does not. The benefits are based on the financial impacts that are related to processes in the urban planning value chain:
- Local area planning (LAP) revision and the impact on the planning authority
- Visual impact assessment and the lower costs for developers
- Reduced time for citizens to make LAP submissions and major scheme objections
- General improvements to public-sector efficiency.

PROVING ECONOMIC VALUE IS VITAL, BUT THE CREATION OF PUBLIC VALUE IS EQUALLY OR MORE SIGNIFICANTLY A DRIVING FACTOR FOR INNOVATION

After the application of some correction factors, the net value of the cost-benefit analysis for a ten-year period was calculated as 1:2.1 and a net present value (NPV) of €22 million.

In flood management, the same financial model was applied but three approaches were taken to 'triangulate' the assessment. Firstly, a cost avoidance method used data from Switzerland, one of the few countries in Europe where the PMA has made a complete switch to 3D several years ago. Estimating the damage avoided since then thanks to the use of 3D geoinformation resulted in a cost-benefit ratio of 1:3.3 and an NPV after ten years of €8.9 million. Secondly, a case study was performed looking at an impact study in The Netherlands where high-resolution height data was published as open data some years back. The results of the Dutch study were compared with the cost-benefit potential of a similar high-resolution 3D digital terrain model in Denmark. The third method applied an adapted business case transfer from the USA's National Enhanced Elevation Assessment to Belgium. The results of the latter two methods were similar to the Swiss one.

The EuroSDR study concludes: "The cost-benefit analysis in both urban planning and flood management demonstrated that benefits outstrip costs by a multiple of two



▲ *Solar potential study in Singapore. (Source: SLA)*

to three times, even when considering each case in isolation. As further applications of 3D geoinformation are added, additional costs should rise more slowly, whilst benefits should accrue at a similar rate, thereby enhancing the overall rate of return." The PMAs were very content, both with the study outcome and also with the opportunity to share knowledge about the challenges they face in convincing decision-makers to invest in this innovation.

PUBLIC VALUE PERSPECTIVE

3D production and processing costs are approaching the same level as for 2D, but 3D innovations also require time and money to invest in technical infrastructure and in transforming business and operating models. In a climate of budgetary constraints, the economic feasibility of 3D innovation is "a point of consideration", states the report. Accordingly, to further assist public-sector managers making the case for change, two academics involved in the EuroSDR study – Professor Jantien Stoter (TU Delft, The Netherlands, specialised in 3D and 4D geoinformation) and Professor Joep Crompvoets (KU Leuven, Belgium, specialised in national spatial data infrastructures), both of whom have intimate knowledge of PMAs – sought other means to complement the findings. They collaborated with Dr Serene Ho (KU Leuven, specialised in institutional aspects of geospatial innovation) to explore 3D geoinformation innovation from a public value perspective. Such a perspective on innovation explores the value of it from the users' point of view. While acknowledging that traditional innovation ideals of effectiveness and efficiency matter, it draws attention to civic objectives like responsiveness to needs, liberty and participation, citizenship and transparency. Re-examining the data collected for the EuroSDR study, a qualitative analysis has been published as a scientific article (in *Land*, May 2018). It reveals that, in the authors' experience, proving economic value is vital, but the creation of public value is equally or more significantly a driving factor for transformative innovation "as this conveys social and political currency".

The article points out that moving towards a model where 3D geoinformation is the dominant data environment for PMAs will undoubtedly yield public value. 3D geoinformation enhances a government's ability to protect its citizens' quality of life by providing advanced analytical abilities that result in better living environments and avoiding damage to property. It improves the safety of emergency responders. It helps in planning and securing vital infrastructure. Also, it engenders greater trust in public organisations by fostering greater transparency, confidence and the ability to communicate decisions. The paper describes many examples from the 11 European countries.

AUTHORITATIVE GEODATA CUSTODIANS

Classification of the feedback from stakeholders demonstrates clear potential in financial and strategic aspects, mainly generated through mechanisms of improving the effectiveness of technical products (and, subsequently, various workflows and applications) and enhancing the data environment in which stakeholders operate. The potential for public value creation for PMAs could be even more significant, given the fundamental nature of cadastral data for all other development-related decision-making and the growing importance of sound urban planning. The authors conclude: "Innovation in 3D geoinformation would therefore likely consolidate and advance the PMAs' position as authoritative geodata custodians and emphasise the role PMAs play in fostering secure and sustainable development. The move to 3D is a better way to meet the evolving nature and scale of their public mandate".

"I have no doubt that 3D mapping is the near future in a fast-growing amount of applications," says Jantien Stoter. Joep Crompvoets agrees – albeit a little reluctantly, because he also believes that many so-called new applications function fine, and more simply, with 2D data: "A decision-maker's heart beats faster when they look at 3D visualisations, and this innovation is a logical evolution. So I agree that we will not get this genie back into the bottle again, although it comes at a price." In their scientific article they refer to the economic value outcome of the EuroSDR study by stating: "The study found that such innovation was potentially a viable return on investment, perhaps even profitable." This downplays the cost-benefit ratio of 1:3 actually presented in the study. Both professors explain: "We don't want to give the impression that the financial benefits for the national or regional mapping organisation are always that manifest, let alone achieve a certain cost-benefit ratio. And it makes a big difference whether the investors' perspective is aimed at obtaining benefits for the country as a whole, or

SINCE WE CAN'T CALCULATE THE PROFIT FOR NEW AND CURRENTLY UNKNOWN POSSIBILITIES, WE HAVE TO STOP CONCENTRATING ON THE DOUBTS

EUROSDR

EuroSDR is a not-for-profit organisation linking national mapping and cadastral agencies with research institutes and universities in Europe for the purpose of applied research in spatial data provision, management and delivery. Joep Crompvoets is EuroSDR's secretary-general and chairs the Business Models and Operation Commission. He is a professor of information management in the public sector, senior researcher/consultant and project manager at the Public Governance Institute of KU Leuven, Belgium. Jantien Stoter leads the EuroSDR 3D Special Interest Group. She is a professor of 3D geoinformation at The Netherlands' TU Delft, Faculty of the Built Environment & Architecture. Prof Stoter also works as an innovation researcher at both Kadaster and Geonovum.
www.eurosdr.net

whether the PMA has to sell the data to be profitable on its own. It certainly seems profitable, but the amount of scientific studies is too limited to be very specific. It is easier to prove that 3D geoinformation brings larger many similarities. They add: "An important difference is that back then the transition was made easy because the initial costs of the national large-scale digital mapping and GIS revolution had largely been paid by the utilities

WE WILL NOT GET THIS GENIE BACK INTO THE BOTTLE AGAIN, ALTHOUGH IT COMES AT A PRICE

effectiveness of policies, processes and operating environments within and between governments and businesses."

BACK TO THE FUTURE

This has echoes of an earlier time, when digital mapping and GIS found their way from the American defence industry to the national mapping authorities worldwide. There were not many convincing cost-benefit studies proving GIS was profitable, yet the PMAs still had to make the switch because everybody could see that it made so many processes more effective and the technology was here to stay. Stoter and Crompvoets recognise sector. Now the demand is so fragmented that there is no focus for a shared business model." Also, compared to the analogue way of working until then, GIS was a really disruptive technology; the market understood that serious investments and national coordination were needed. "But we passed the point of no return for the transition to 3D about five years ago," states Jantien Stoter. "Since we can't calculate the profit of new technology for new and currently unknown possibilities, we have to stop concentrating on the doubts. Look at examples such as Singapore and large cities in China or the PMA of Switzerland – they made the complete switch to 3D geoinformation and no longer want to be without it." Joep Crompvoets outlines the plans for future research: "Our investigations will concentrate on how – and not whether – to make the change. We think that mapping of base data in 3D is the most efficient for a country when it is centralised, harmonised and quality controlled by the national mapping agencies. Which steps can be taken? Which priorities work best? And how should it be financed?". His colleague concludes: "It is about the production of correct, up-to-date 3D data at different levels of detail for different applications, without every user group producing and paying for its own snapshot of reality. We'd better get going – back to the future!" ◀

ABOUT THE AUTHOR

Frédérique Coumans lives in Belgium and is contributing editor for *GIM International*. For more than 25 years she has covered all aspects of spatial data infrastructures as editor-in-chief of magazines on GIS and on data mining and GIS-in-business.

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5 Questions to... Thomas Stuiver and Peter Tapken, Geo-matching

Thomas Stuiver and Peter Tapken.

Surveying and mapping projects require tailor-made approaches. Every application demands its own specific solutions. All the necessary geospatial solutions are available in a single place: Geo-matching.com. We asked Thomas Stuiver and Peter Tapken, the driving forces behind this geospatial product platform, to explain the role of Geo-matching.

How would you describe Geo-matching?

Geo-matching is the world's largest product platform for surveying, positioning and machine guidance, listing more than 2,000 products from 500 manufacturers and attracting more than 250,000 users in 2017. With our product platform, we provide an overview of all the products and solutions in the geospatial market. On Geo-matching, users can make detailed product comparisons and view the latest videos, case studies and helpful articles.

What is the role of the platform in the geospatial industry?

Our mission is to inspire our users about geospatial technology and connect them with product manufacturers worldwide. Staying up to date on the latest geospatial product developments is difficult and time-consuming. Every day, new products and applications emerge that can help geospatial professionals do their jobs even better and faster. By centralising all the product information on one platform, we have become the linking pin between users and manufacturers worldwide.

Can you give us an idea how Geo-matching is being used?

Many manufacturers perceive us mainly as a lead generation tool, but getting in touch with manufacturers directly is not the key functionality for our users. User surveys show that Geo-matching is primarily used for product research and for inspiration/education about geospatial technology. Various users have mentioned that, for product research purposes, they need to create spreadsheets with product information from multiple manufacturers' websites. Geo-matching saves geospatial professionals valuable research time and helps them find better product solutions faster for their upcoming projects. With over 250,000 users researching products, our platform certainly plays a key role in the product evaluation and decision-making stages.

If you zoom in on the behaviour of your website visitors, what are the main trends?

One important trend is the strong increase in website traffic and enquiries from fast-growing regions such as the Asia-Pacific region, Eastern Europe, various African regions and South America. Furthermore, we have seen that applications for geospatial products have become more diverse. Enquiries have come from infrastructure companies (e.g. road survey, corridor mapping, etc.), maritime companies (monitoring of harbour walls), forensics (crime mapping and traffic accident investigation), mining (open-pit survey, etc.) and even some surprising sources such as New York City's Metropolitan Opera House (indoor mapping for maintenance and monitoring purposes).

Geo-matching has already developed into the largest product platform for mapping and surveying professionals. How do you expect it to evolve in the coming years?

Over 500 manufacturers are now involved in the Geo-matching platform, but products are constantly evolving and new types of products are being introduced. For the UAV market, for example, things are moving so fast that we need to update our specification list every six months to keep the information relevant. We are also constantly adding new product categories. We are currently looking at adding BIM and virtual reality, for example, because these technologies are becoming increasingly important for the geospatial sector. Also, with so many new users entering the geospatial market, inspiring and educating professionals will play a crucial role. This means that we need to better explain how the technology works and how it can be used. We will continue to be guided by our mission: to inspire our users about geospatial technology and connect them with product manufacturers worldwide. Our goal is not only to provide product information but also to help geospatial professionals when searching for products. So far we have received lots of positive feedback and are very eager to further expand the Geo-matching platform!

THE QUEST FOR THE BIG PICTURE

Characterising Activities in 3D City Modelling

3D city models have become common geospatial data assets for cities, and can be utilised for tasks including planning, visualisation and decision-making. The field of 3D city modelling is diverse, with a multitude of technical solutions. Even the definition of what constitutes a 3D city model still remains ambiguous. Yet, surprisingly few studies have focused on reviewing the existing activities and assembling the big picture. This article presents some of the key findings from a recent study reviewing major 3D city modelling activities in Finland.

3D city models can be seen as an enabler in the smart city paradigm, operating as a user interface to the modern urban environment and acting as a platform for cooperation and services. Therefore, a high degree of interoperability is expected from city models and from the information systems that host them. Also, 3D city models are expected to support a multitude of applications. This remains a challenging task, still hindered by many issues, such as ambiguities and differences in modelling, differences in perspectives, missing guidelines, challenges in data conversion and georeferencing, and problems in data quality.

QUEST FOR DATA INTEGRATION

Data integration is an inherent component in city modelling. 3D city models are commonly built through 3D reconstruction and data integration, by merging photogrammetry or laser scanning data with GIS data such as building footprints and IDs. Also, the use of highly detailed building information models (BIM) as a source of as-planned data remains a significant development topic. Another development direction is the integration of time series and sensor data to the objects in a city model. Rather than being static representations of the environment, inclusion

▲ *Figure 1: Different types of 3D city models. Helsinki Energy and Climate Atlas (left, courtesy City of Helsinki), BIM visualisation in Espoo (middle, courtesy City of Espoo), and Virtual Oulu (right, courtesy University of Oulu).*

City	Project	Used platform(s)	Data accessibility		Full city data coverage	Utilization of as-planned information
			Data publicly viewable	Data publicly downloadable		
Espoo	3D city model data	Locus	-	X	X	-
	Mission Leppävaara	CityPlanner	X	-	-	X
	Otaniemi lighting simulation	Unity	X	-	-	X
	Tapiola	Unity	X	-	-	X
Helsinki	Helsinki 3D+ information model	Cesium	X	X	X	-
	Helsinki 3D+ mesh model	Cesium	X	X	X	-
	3D city model data	Microstation	-	X	X	-
	Oulunkylä 2030	Unity	X	-	-	X
Oulu	3D city model data	Locus	-	X	X	-
	VirtualOulu	Unity, Unreal Engine	X	X	-	-
	Hiukkavaara 3D model	Unity	X	-	-	X
	SmartOulu	MAPGETS	X	-	X	X
Tampere	3D city model data	Novapoint, Quadri, AutoCAD, Viasys VDC	X	X	X	-
Turku	3D city model data	Locus	-	-	X	-
	3D model of Turku campus and science park area	Sova3D	X	X	-	-
Vantaa	3D city model data	Microstation	-	X	X	-
	Kivistö	Unity	X	-	-	X
	Minecraft	Minecraft	-	X	X	-
	Myyrmäki	Unity	X	-	-	X
Total	19	13	13	10	10	8

▲ *Table 1: A summary of the analysed 3D city modelling activities.*

of live data is turning city models into increasingly dynamic artefacts and towards the concept of a 'digital twin' of the city.

EXPANDING FIELD OF APPLICATIONS

The application space of 3D city models has expanded hand in hand with the technical development. In addition to the 'traditional' use cases in urban planning and zoning, 3D city models are expected to facilitate energy analysis, detailed architectural visualisation, interactive and immersive applications development, and participatory GIS. All this places challenging requirements on the platforms of the 3D city models.

The discussion on 3D city models is further complicated by the amount of different platforms used for 3D city model applications. In addition to the professional GIS/CAD tools, 3D city models are used on game engines and various web-based 3D viewers, such as virtual globes.

REVIEWING THE MAJOR 3D CITY MODELLING PROJECTS IN FINLAND

In a recent study, the authors took a closer look at some of the 3D city modelling projects in the six largest cities in Finland, using project descriptions maintained by the cities to obtain an overview of the current activities. To support further understanding, local city representatives in the studied cities were interviewed. A summary of the analysed projects is presented in Table 1.

EXCESS OF PLATFORMS

Firstly, the studied 3D city models utilised a great variety of platforms. In the 19 studied projects, a total of 13 different platforms were discovered for hosting the models. These included GIS/CAD software (e.g. Trimble Locus and Bentley Microstation), virtual globes (e.g. Cesium, CityPlanner, Sova3D, MAPGETS) and game engines (e.g. Unity, Unreal Engine). Some of the software solutions applied in Finland were more or less unique and have not seen wide adoption globally.

Secondly, the authors noted that in each studied city the maintenance and upkeep of the 3D city models was tied to the statutory base mapping process that heavily relies on the chosen GIS/CAD software. In many cases, the 3D model data maintained by the city itself was used as an input or reference data for virtual globes and 3D game engine-based projects, which focused on specific applications often aimed at broader audiences.

DATA QUALITY AND ACCESSIBILITY

The studied 3D city modelling projects contained a variety of different levels of detail, ranging from simple block models to highly photorealistic models containing facades modelled in great detail. Fewer than half of the models utilised as-planned information such as BIM or architectural plans. More than half of the city models covered the full regional area of the city.

In addition to data quality, accessibility plays a vital role in 3D city modelling, especially when models are to be used as a basis for developing new applications. Almost two-thirds of the studied city models could be freely viewed via a web-based viewer. This was realised either via separate viewer utility or, in the case of virtual globes, natively by the platform itself. More than half of the city models studied were offered for download over the internet. However, none of the cities offered any original raw data such as Lidar point clouds. This hinders possibilities to freely edit the models or to run additional analysis.

THE IDEAL OF A GENERAL MODEL

Producing and maintaining a 3D city model requires an interplay of several technical solutions and stakeholders, both of which vary from project to project. Many of the studied cases were likely to serve only a limited number of purposes or to pilot 3D modelling in a limited area. However, the interviews showed that this had not been the original intention in the cities. On the contrary, the common vision was close to the ideal of 3D city models serving as general platforms, including the capability to re-use the gathered data and models.

Further, an increased degree of realism in visualisations, attained with 3D models, was seen as a key element in enhancing the interaction and trust between different stakeholders. This includes the notion of demonstrating impact as well as including all relevant stakeholders in the co-design and decision-making processes.

Stakeholders inside and outside city organisations are a heterogeneous group of users that have varying needs, expectations and views of 3D city modelling. The city interviewees stated that up-to-date guidelines and policies were missing or that the existing guidelines were not followed. Ambiguous terminology, lack of coordination and leadership, and the slow adaptation of standards frequently crippled communication and collaboration. Additionally, the lack of expertise was said to result in an incapacity to recognise the need for 3D city modelling and hence to define the requirements for the modelling projects.

UNDERSTANDING THE BIG PICTURE

By looking at the characteristics of the studied 3D city modelling projects and literature, it was possible to identify three partially overlapping operational cultures in the 3D city modelling scene: 3D GIS, BIM, and computer graphics. Each of these operational cultures (Figure 2) has a unique

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3D GIS	BIM	Computer Graphics
Focus in real world data	Focus in as-planned data	Real world and as-planned data
Simplified model complexity (geometry and semantics)	High model complexity (geometry and semantics)	Intermediate model complexity (geometry)
Citywide data coverage	Local data coverage	Local data coverage
Global coordinate systems	Limited use of coordinate systems	Limited use of coordinate systems
Database approach (maintained models)	Life-cycle approach	Flexible application development approach
Automated or semi-automated modeling (geometry)	Manual modeling	Manual modeling
		User engagement (immersion, interactivity and multi-user environments)
		Visual realism (real-time rendering)

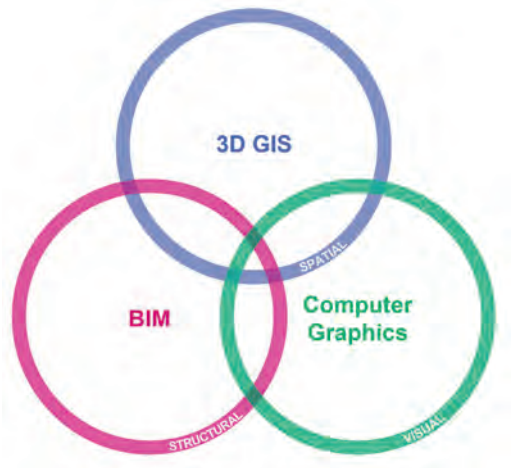
▲ *Table 2: The characteristics of the operational cultures in 3D city modelling.*

perspective on 3D city modelling and they often lead to differing realisations (Table 2).

In the 3D GIS category, the modelling projects typically have a large regional coverage but a limited level of detail in 3D reconstruction. Further, the role of semantic data and connection to the existing city GIS data is emphasised over mere geometric reconstruction. Most of the applications focus on professional uses like city planning, mapping and various geospatial analysis. Projects in the BIM category focus on integrating as-planned data from individual buildings to models of limited regions. Understandably, aspects like model conversion and inclusion of interiors are pronounced. Typical applications in this category include urban planning, building permit processes and architectural visualisation. The projects in the computer graphics category are based on game engines, offering the highest level of photorealism facilitated by advanced real-time rendering. At the same time, models are typically limited to local coordinate systems and they rarely utilise semantic information. Also, the 3D game engine-based models have a clear emphasis on game-like interaction and immersion, with the goal of engaging users to collaborate in and explore the models, even on a pedestrian level.

In the big picture, 3D city modelling is revealed to be a diverse and multidisciplinary field with steadily increasing interest and demand. It is often accompanied with visions of a high degree of interoperability and platform-like characteristics. However, when reviewing the modelling activities more closely, they appear fragmented and fail to reach the broad applicability envisioned.

This is, to some extent, explained by the complexity of the situation. Modelling projects are carried out by people from different fields, using varying tools and aiming for different outcomes. Further, the future uses for 3D city models can be hard to predict – and not only because the user group is heterogeneous with different levels and types of expertise. As an outcome, the quest for a single, completely harmonised 3D city model becomes demanding and laborious. Improving the interplay and communication between people and technologies across these three operational cultures is a key element in advancing the interoperability and creating flexible, demand-driven 3D city models of the future. ◀



▶ *Figure 2: The three categories representing distinct operational cultures in 3D city modelling.*

FURTHER READING

Julin, A., Jaalama, K., Virtanen, J. P., Pouke, M., Ylipulli, J., Vaaja, M., Hyyppä, J., & Hyyppä, H. (2018). Characterizing 3D City Modeling Projects: Towards a Harmonized Interoperable System. *ISPRS International Journal of Geo-Information*, 7(2), 55. https://doi.org/10.3390/ijgi7020055

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GIM INTERNATIONAL INTERVIEWS CHRISTOPH STRECHA, CEO AND FOUNDER OF PIX4D

The Shifting World of **Professional Mapping**

Over the past decade, photogrammetry from unmanned aerial vehicle (UAV or 'drone') data has proven itself as an effective method to capture high-resolution aerial imagery, while drones have demonstrated their value for mapping and surveying professionals as platforms for carrying payloads that include a variety of sensors. One of the leading developers of software solutions to convert the imagery into high-end geospatial solutions is Pix4D, which has established itself as a leader in the business. Christoph Strecha, founder and CEO, talked to *GIM International* and revealed that he foresees big changes in the geospatial industry.

Your company was started in 2011 as a spin-off of the prestigious École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. How would you describe your company's journey since then?

We started based on a product that was the result of ten years of research. I think that we were one of the first to say that you could do automatic structure-from-motion (SfM) photogrammetry. In view of the hype around drones and their development, it was the perfect time to bring the product to market. From that point on, we've continued to grow, continued to receive good feedback and generate a high level of interest. We're doubling our team every year and I'm convinced that we have contributed a lot to the acceptance of drone mapping in the professional arena.

How would you describe the state of the geospatial industry at the moment?

There used to be a time when the geospatial industry was dominated by experts. They used very expensive high-level equipment to create maps and survey large areas that were just out of reach of smaller companies and communities. That has started to shift over the last three years, and it's an ongoing process. Now, survey equipment in the geospatial industry can be used by people who have much less experience – they can basically use technology as a tool to solve their problems. This opens up a lot of opportunities in new sectors of the industry, because as prices are coming down, things are getting easier and becoming more automated. I think a big change is happening. And while we like to think we're playing a part in disrupting the industry, the change is not just from coming Pix4D, but also from the big surveying companies as their equipment is getting cheaper and being used by a wider public.

You started to verticalise your products a couple of years ago. Which emerging markets is Pix4D focusing on today?

Today we are focusing on enterprise solutions. I think more and more large companies are keen to use photogrammetry in their workflows, because they've seen that this approach is something that will actually save them money. We're focusing on bigger clients, which means customised solutions that we integrate with their complex workflows. Another focus is agriculture, where drones can be a big help in terms of crop analysis. For farmers and agronomists, we're building solutions that are easy to use and will also save them money. We recently launched Pix4Dfields from our Berlin office, for example. Lastly we are focusing on construction, where surveying is already common practice but also very expensive and therefore not done on a regular basis. So with drones and 3D modelling we can help construction companies understand the progress of their construction sites, optimise workflows and use this information in their planning. Even if they cannot regularly fly a drone, as is the case in many situations, our Crane Camera solution can deliver aerial images with the same results.

As you mentioned, verticals are something we've been focusing more on in the last few years. The growth in verticals is proof of how the drone market has grown as a whole, as there is now a need for specialised software for each industry.

In view of the growing number of photogrammetry software solutions for drones, what are the main points surveyors should take into consideration before purchasing?

As I stated before, I believe that end users will be using these tools more frequently, so ease of use and good support are more important than ever. There is also an increase in the number of surveying companies using drones, but the growth among end users is considerably higher.

Surveyors will have a vast number of drones to choose from, fixed wing or copters, and they should know which one to use for which jobs to optimise their surveying. Having RTK on a drone also saves you from having to measure additional GCPs (*ground control points, Ed.*), for example, so surveyors should choose an RTK-equipped drone. That's a huge gain in efficiency. Solutions are quite easy to find these days, but there are a

number of things to take into account. Surveyors should look at not only the software, but also the solution surrounding it. What is the support like if something goes wrong? Has this software been used by others in the same field to get great results? Can an end user pick up and work with the software if need be? And, finally, does the software come from an established company, so the surveyor can expect updates and support in the years to come?

There is increasing focus on the payloads of UAVs. Which key trends do you foresee?

I think we can expect to see more optimised payloads with better cameras offering better resolution, rig systems and systems of combined-perspective cameras that increase the efficiency. Then we have the trend of multispectral sensors combined with thermal sensors and RGB. There's also a lot of hype about Lidar, but it still remains a niche part of the market. It reduces the flight time of the drone, but it also dramatically increases the price of the equipment and the complexity of the workflow, so it just doesn't have the same advantages as photogrammetry. I'm not sure that this technology will become mainstream in the workflow of surveyors and end users in the same way that rig systems and combined cameras will become mainstream over the next few years.

Pix4D is known for its R&D efforts in collaboration with EPFL's computer vision lab. Is this still an important pillar of your company?

As a tech company, at Pix4D we invest heavily in technology to improve our algorithms, and we collaborate with EPFL and many other universities. But we also push a lot internally for research to see how we can add more value for our users, so we've established a much larger R&D effort to serve our clients.

Artificial intelligence (AI) and machine learning are likely to play an essential role in the future of drone mapping. Is Pix4D ready for the future in this sense?

I don't think anybody is really ready today, but we are investing considerably in that direction and I'm hoping we can do much more in this area. We are very focused on increasing the AI capabilities of our algorithms in combination with the photogrammetry that Pix4D already handles very well. Regarding AI, we presented a desktop product at last year's Intergeo that uses machine learning to automatically classify point clouds into different classes. I believe we were the first company in this field to present the use of AI in that way. This is a very important topic that we will continue to explore, because actually it's not the 3D model itself that matters, but rather the automatically extracted information that creates much more value than the 3D data.

Drones are becoming cheaper all the time, so is this increasing the number of potential customers?

Definitely. As drones become cheaper they become a standard tool for end users in their workflow. We are also focusing on making the software easier to use, so it can be used by more people. We believe that the combination of easy and dedicated verticalised software with cheaper drones is key to market growth.

You once said "A drone should be seen as a device". So, turning our attention to another device, what are the latest developments with respect to Pix4D's Crane Camera solution?

A drone is a very handy way to get a camera in the air and to acquire images from positions that are needed in order to build 3D models from interesting viewpoints. But flying one can still be somewhat disruptive to a workflow, and of course it requires a pilot. At Pix4D we think it's not the drone that is most important, but rather the position of the sensor while acquiring images. The Crane Camera is a very nice illustration of that. The crane moves, taking images from different viewpoints, which is what the technology requires. It's a trend we're seeing more and more of: more cameras being used – both moving such as in cars and trains, and static such as in cities, stadiums, airports and so on – to extract information from reality. This is the core of Pix4D's business. It might not be the most important thing, but today a drone is a near-perfect tool to obtain the viewpoints needed in order to extract the information.

Building information modelling (BIM) is seen as an intriguing opportunity for surveyors. What are your thoughts on this?

This goes together with converting raw images, not only into point clouds or meshes but also into information. A mesh doesn't have much more value than the original images. Automatically understanding what this mesh represents – what is a simple structure, what are semantic structures – that's where the value lies, because it means there's no human operator needed to extract the semantic information from the 3D model. BIM is a good example of how this concept of converting images to information can be applied and is extremely useful.

Which next steps can we expect to see on the processing side?

As I mentioned, machine learning will be a huge change for the industry. Companies will put a lot of effort into analysing the data in a semantic way: not just presenting images, but really extracting information from them. The standard processing workflows are working really well, although there's always the need to process faster – it's important to keep updating that, which is a focus for us. But that won't be a revolutionary change, at least in the short term. What we can expect is to apply photogrammetry, machine learning, geometry and radiometry from images in particular industries. That's where we'll see most of the developments in image processing in the future.

Lastly, what would be your message to the community of mapping and surveying professionals?

I think it's very important that everyone who works professionally with UAVs embraces public opinion positions on privacy and security issues regarding flying with drones. All the companies in the sector, whether they are software companies, hardware companies or surveyors that use drones in their work, need to work together towards a clear public definition of drones as an essential professional tool – one that can be fundamental in emergency response situations like earthquakes, for example. Drones have many useful professional applications that have nothing to do with spying on your neighbours, flying for fun or military applications. The general public needs to be made aware of the pros and cons of drone usage so that legislation is put in place correctly, in order to allow drones to be used where they add value to our society. ◀

ABOUT CHRISTOPH STRECHA

Dr Christoph Strecha is the CEO and founder of Pix4D, a Swiss company which develops and markets professional photogrammetry software. Dr Strecha received a PhD from the Catholic University of Leuven (Belgium) in 2008, completing his thesis on multi-view stereo. He has authored numerous papers and in 2015 received the Carl Pulfrich Award for his work in computer vision and photogrammetry. He is recognised by the scientific community as an influencer, trendsetter and advocate of modern approaches to photogrammetry.

Q&A with Chris Andrews, senior product manager 3D at Esri

5 Questions about BIM and GIS

There has been much debate on the synergy of building information modelling (BIM) and GIS (geographic information systems). This makes for a potentially powerful combination, but what is the best way to maximise the advantages of the two? Not surprisingly, data plays a crucial role in delivering on the promise of transforming infrastructure design and construction. At *GIM International* we decided it was high time to ask a renowned expert from the field to share his views with our readers. Chris Andrews, senior product manager 3D at Esri, answers five key questions about the journey towards optimal integration.

BIM and GIS integration is often presented as the optimal solution for the movement of data throughout the asset lifecycle, but it is not so easy in practice. What are the biggest misconceptions?

One of the most obvious misconceptions when customers ask for the ability to use their design and construction data (BIM data) with GIS is that BIM models contain 'all' the data about assets. Typically, a BIM model is only a representation of what was built. Even the most accurate as-built BIM model will rarely contain the furniture and other unfixed assets that actually exist in the operational real-world structure. Another misconception is that BIM contains facility management information. For example, in architecture models we rarely see rooms, spaces or even a footprint of the building. These geometric properties are useful for building-asset management and space allocation, but they aren't necessary for building construction. From this perspective, the BIM is often missing information. Lastly, everyone – including many BIM practitioners – forgets that BIM applies to multiple, diverse industries. Architecture, civil transportation and utilities all use BIM processes, but have divergent data and construction needs.

What is needed to further enhance the combination of BIM and GIS?

Critical to more efficient, resilient data interoperability between BIM and GIS will be the establishment of lightweight exchange formats and interfaces for access to data across domains. GIS is largely open. There is a robust geospatial open standards community. Esri publishes interface and format specifications for access to just about anything a system integrator could want to access in ArcGIS Online, ArcGIS Enterprise or a geodatabase. While the BIM world has some similarities, we find that open-standard BIM exchange formats can be complicated and incomplete. There are also many proprietary BIM model formats that are black-box data stores with little or no ability to access their content. We understand that BIM content is complex, diverse and often contains proprietary algorithms or techniques, but the pressure to better enable use of BIM data in asset lifecycles is enormous and demands better access to BIM content.

Which steps could software vendors take in order to support GIS and BIM integration?

Software vendors on both sides can work together to provide better access to data, more transparent interfaces to connect systems, and even to use common access and authentication patterns so that customers can more easily combine and use the data that they already own. Customers want to do their work using the tools and platforms that were designed for specific tasks, and more open access to data eliminates attempts to do tasks using the wrong tools. We want customers to be successful with the right data in the right tools, knowing that 'the right data' is a task-appropriate view on the geospatial context and the design and construction detail that makes up our customers' assets.

Data is at the core of the digital transition, but BIM data is usually much more detailed than GIS data. How can BIM data be integrated into GIS data workably?

BIM is perceived to be more detailed than GIS because, to construct a building or bridge, the details have to be specified in the design documentation. With the emergence of 3D as a core capability of GIS, customers are now discovering that 3D technology enables them to have more accurate geospatial models of plans, proposals and the real world around us. Although what we find is that not all BIM information needs to be captured in a GIS for design and construction data to be used for mapping and spatial analysis, GIS technology also needs to be improved to support many orders of magnitude higher-density spatial information than was necessary in the past. We are not simply working on filters or better translations of BIM to get it into GIS, but – as an industry – we are inventing new technologies to support high-density 3D information about the built and natural worlds around us.

As two essential pillars of smart cities, how will BIM and GIS shape smart city-related developments in the coming years?

The preponderance of data about cities and their inhabitants presents an overwhelming problem for planning, analysis, monitoring and response to world events, environmental change and economic pressures. The key to enabling access to data for any urban problem in the future will be to identify the specific location, things and timing of events and programmes in cities related to the people who will be affected. Simplistically, GIS supplies location and BIM processes supply details about things. A more seamless flow of information about location and spatial characteristics and the design and behaviour of things will be essential to enable government leaders to manage the timing and impact of events and programmes on citizens in our increasingly densifying cities. ◀

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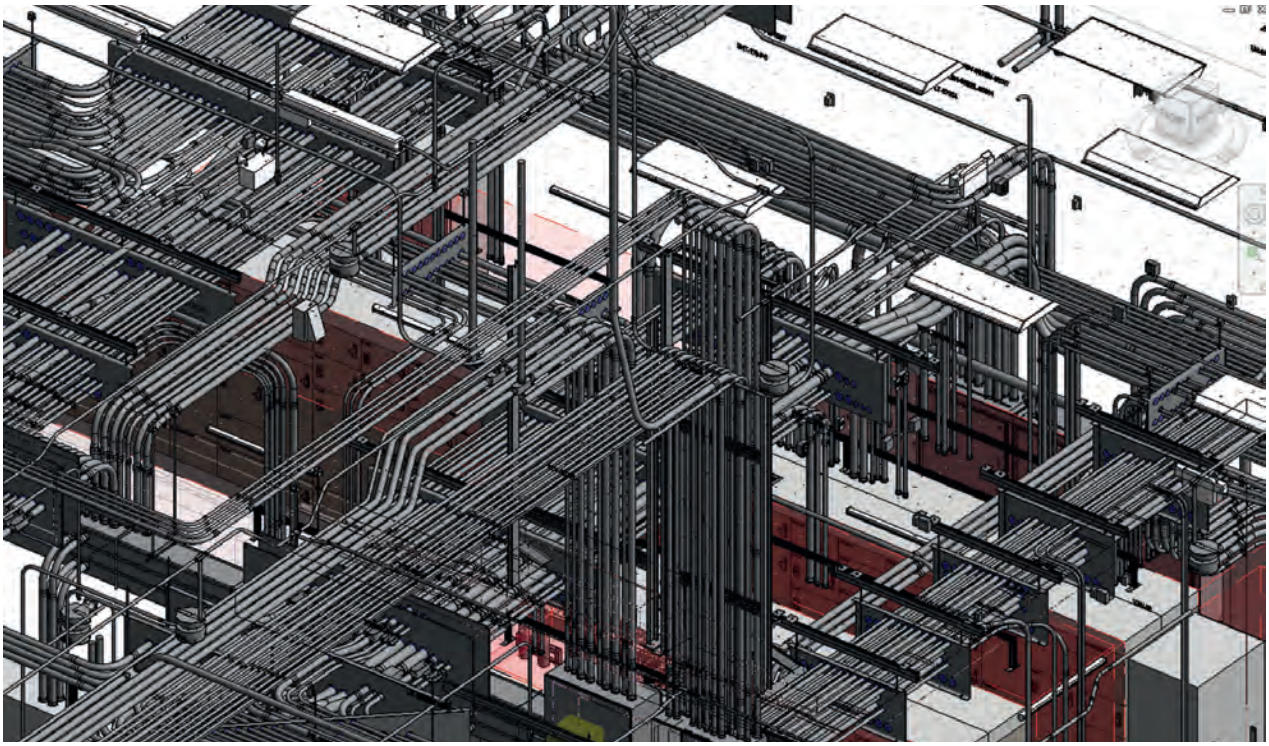
GREATER UTILISATION OF TECHNOLOGIES AT HAND

Chasing **BIM:** How **Surveyors** Can Shape the Future

While research shows that many organisations recognise the power of building information modelling (BIM) for streamlining construction and infrastructure projects in a seamless online environment, survey and geospatial professionals can do more to deliver value in the 3D environment. There have been countless presentations and papers on the definition of BIM. This article makes an attempt to provide some practical insights on how surveyors can leverage the BIM revolution to benefit their businesses.

The good news: there is a general consensus among geospatial thought leaders that the design and construction industry has reached a tipping point. The more that surveyors embrace BIM, the more it can positively impact their work. But for this scenario to play out to everyone's advantage, potential BIM adopters must shift their perspective and realise that BIM technology is not just intelligent 3D modelling; it also offers a centralised platform for sharing data to help partners communicate effectively in real time. When surveyors take advantage of BIM holistically, they are not only factoring in the traditional aspects of a building's design but are also creating rich data spanning the range of properties of a structure's components, construction and maintenance.

The challenge with BIM is not merely to ask surveyors to embrace technological changes



Geospatial professionals entering the world of BIM often discover a heightened level of project complexity.

as part of the way they work, but instead to start viewing it as more of a paradigm shift in the design and build process altogether. After all, at its core, BIM is meant to transform how project teams work together on a job, from start to finish.

TACKLING THE ISSUE OF LIMITED AWARENESS

In terms of a surveyor's scope, they typically measure property lines and record key assets such as utilities and topography to provide a base map of where a building will eventually be constructed. At this point, many surveyors conclude their role in the building lifecycle. However, this only provides a small sample of the information that everyone involved in a project needs in order to successfully transition from design to construction, and then to the operation stage. For example, additional data about a building's particularised components, such as specs, descriptions, sourcing, installation, maintenance and project management, are utilised by numerous parties involved in a building project.

One challenge preventing widespread BIM acceptance is that some surveyors have a limited understanding of the technology's range of capabilities, and not many stakeholders are using the technology to its fullest extent. For example, this scenario is evident in areas of the industry that deal with laser scanning of the built environment.

biggest obstacle is that they often mistakenly think the role of geospatial information in the context of building projects is limited to XYZ-type positioning data. Actually, surveyors should be talking more to other trades and parties working on a job site to determine

ONE CHALLENGE PREVENTING WIDESPREAD BIM ACCEPTANCE IS THAT SOME SURVEYORS HAVE A LIMITED UNDERSTANDING OF THE TECHNOLOGY'S RANGE OF CAPABILITIES

Many surveyors assume investing in a laser scanner automatically makes them 'BIM service providers'. However, a laser scanner is just another tool if it is not used properly. So, how can everyone involved in the process – and particularly surveyors – use BIM to stay relevant, enhance their business and become part of the so-called BIM revolution?

HOW SURVEYORS CAN PLAY A BIGGER ROLE

Surveyors worldwide are paying attention to BIM, and they see it as an opportunity to expand and enhance their operations. Their how – together – their deliverables can provide exponentially more value downstream.

Over the years, surveyors have traditionally 'left the rest to the client' when it comes to transforming point clouds into building information models. Very often, architects or land developers may still be working with 2D floor plans, building sections and facade elevations, and are not demanding 3D or BIM deliverables. However, BIM technology gives surveyors the opportunity and the capability to provide higher-quality services and deliver more value by creating intelligent models that promote a richer understanding of an entire scenario.

Moving forward, surveyors must come to realise that there is a role for them in every stage of the design and construction process. With BIM technology, they need to communicate with multiple disciplines, in real time, through a single project-management environment. Moreover, many BIM tools feature controls that can render extremely complex models in the field. So instead of staking out or listing data points, surveyors should work directly off live models. for instance, and as they place foundations or put stakes in the ground, other parties can receive immediate feedback no matter where they are located.

BUILDING LIFECYCLE PROCESS

Surveyors have opportunities to interface with BIM throughout all project stages, from pre-construction and design to construction, maintenance and operation. There are many ways surveyors can supplement their traditional offerings at various stages of the building lifecycle, including:

- **Pre-construction and design.** The project lifecycle begins way before the

construction starts and the first machines (or shovels) hit the ground. The processes in the pre-construction stage include planning, concept development, design and engineering, and bidding before the project is awarded to a general contractor. In each of these stages, surveyors are the key contributor. During the project planning, surveyors may be responsible for aerial photogrammetry or satellite imagery as well as building topographic maps and scanning to capture existing site conditions. Surveyors can provide more value with 3D visuals so they can illustrate the entire location in great detail, providing spatial awareness for a project including existing topography, precise documentation of as-built assets and historical records. Having feature-rich site documentation with existing site conditions in the proposal stage allows for more efficient architectural designs, compliance with legal controls and more accurate estimates and feasibility studies. In the design and engineering stage, the rich geospatial data generated by surveyors contributes to a more streamlined civil design process, enabling easier transition from a concept stage to a constructible model. Providing imaging panoramas, meshes, terrain models, utility (underground and above ground) locations and corresponding metadata ensures quality project design, minimising any potential rework and future requests for information (RFIs) in the construction stage, should discrepancies over pre-construction conditions arise or if damage to surrounding assets occurs. As the data collection is becoming more efficient and sensors more powerful, the emphasis is on the office software and feature extraction and modelling automation. A well-designed 3D model with the right initial information provided by a surveyor can speed up the construction process, save time and reduce waste on a job site.

- **Construction.** Surveyors play a critical role during construction in setting up the control network for the site, staking out the construction elements and performing the quality control, such as inspecting positional accuracies, performing verticality checks and doing real-time or campaign-based deformation monitoring. Using BIM models in the field can be an ideal source for extracting detailed prefabrication and work drawings. In fact, there are many ways in which data from the 3D model can be accessed to provide additional insights on a job site, using site workstations, tablets and mixed-reality devices. Surveyors can play a major role in improving and implementing virtual and augmented reality. Mixed reality combined with laser scanners or imaging instruments can make it possible to adjust a BIM or 3D model to just-taken scans in the field. Field connectivity and the concept of the 'connected site' can play a major role in getting the most up-to-date designs to the field, as well as closing the loop once an element has been properly placed and verification becomes standard practice.

- **Operation/maintenance.** In this phase, stakeholders can use BIM to manage and maintain a building efficiently. For example, a 3D model can be used to develop an annual maintenance plan or to locate parts that require repairs quickly. Any changes to installations in the 3D model can also be simulated and calculated before they are applied. Besides that, BIM allows surveyors to identify what should have been on a job site from the start and to better define a problem. For example, if a wall cracks, a surveyor might use the technology to precisely measure the point of the crack so team members can determine potential solutions. If an old building needs to be removed, the surveyor can measure the structural elements in order to enable the explosives placement study. Surveyors have the opportunity to be exceptional by providing additional as-built scan and imaging documentation services or by creating virtual tours – a collection of additional metadata that can be published and shared on a local intranet or web, providing additional value for facility managers, site occupants or potential buyers.

GATEKEEPERS IN THE BIM VALUE CHAIN

There is no denying that advances in technology influence how we use and interact with the built environment. We are living in an era of greater connectivity, especially among surveyors, designers, contractors and construction companies, and new tools are constantly emerging to support a shift towards widespread BIM adoption. Geospatial professionals must embrace technologies like BIM, not only to help with daily tasks but also to use it as a stepping stone to generate foresight and to gain a deeper understanding of design and construction as a whole.

BIM is already a clear winner – it delivers projects on schedule and under budget. It also enhances cooperation across a project team, improving both teamwork and communication. Survey and geospatial professionals are major stakeholders and often gatekeepers in the BIM value chain. They have the ability to move the industry forward, providing more rich and insightful information and deliverables to civil engineers, architects, land developers, owners and any other stakeholders. This not only ensures projects are delivered on time and under budget but, also and more importantly, allows survey and geospatial professionals to stand out in the sea of competition. ◀

ABOUT THE AUTHOR

Boris Skopljak is a market manager overseeing the development of survey and mapping office software at Trimble. Having been involved in the industry for more than 15 years, he has gained valuable insights through number of implementations of technology and data analytics, as well as management strategies in a number of public- and private-sector organisations internationally. He holds an engineering degree in geodesy from the University of Zagreb, Croatia, as well as a master's in geodetic science from the Ohio State University and a Master of Business Administration from the University of Denver.

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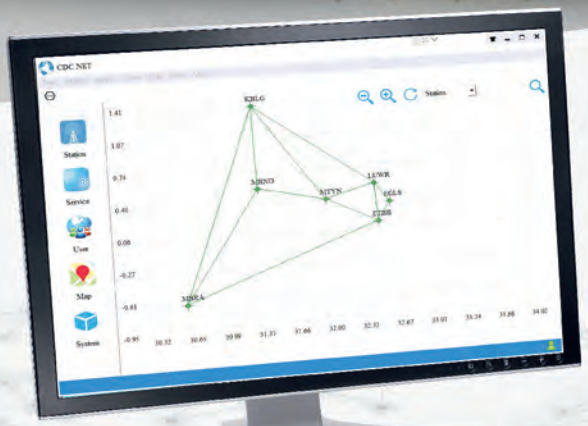

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CLASSIFICATION APPROACHES AND METHOD COMPARISON

Automatic Object Detection in Point Clouds

Point clouds are used as a data source for mapping tasks in various application fields. Before an object can be mapped, it needs to be detected in the point cloud, preferably by automatic means. The development of detection methods is a complex task due to the significant diversity of objects, the random structure of point clouds, and the different characteristics of point clouds created by airborne, mobile or static systems or image matching. This article introduces classification approaches for automatic object detection and highlights several challenges related to the topic.

Automatic object detection in point clouds is done by separating points into different classes in a process referred to as 'classification' or 'filtering'. The types of objects, and thus the classes, depend mainly on the application for which the point cloud was collected. For example, the classes for a power line maintenance project will be different from the classes of a road maintenance or a city mapping project. This article discusses two classification approaches: point-based and group-based classification. Point-based classification means that the software looks at one point at a time and analyses the attributes of the point, its connection with points in its closest environment or its relationship to a reference element. For group-based classification, points are first assigned to groups in a process that is sometimes also called 'segmentation'. Then, the software looks at the group and analyses the group geometry and attributes, the similarity to sample groups, or the relationship to other groups or a reference element.

POINT-BASED CLASSIFICATION

Classification based on single points uses attributes that are collected and stored for each point, such as the coordinate values, intensity, time stamp, scan angle or return type and number. Additional attributes may be derived during the processing workflow, for example a distance-from-ground value,

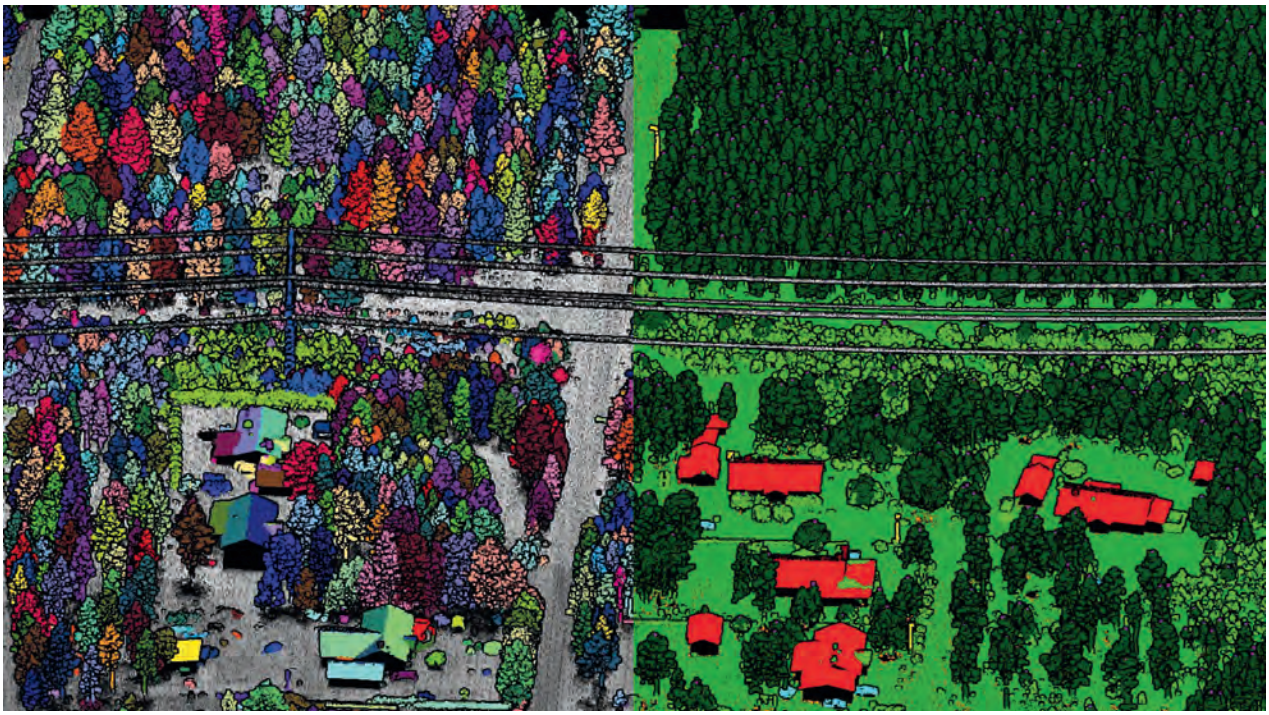
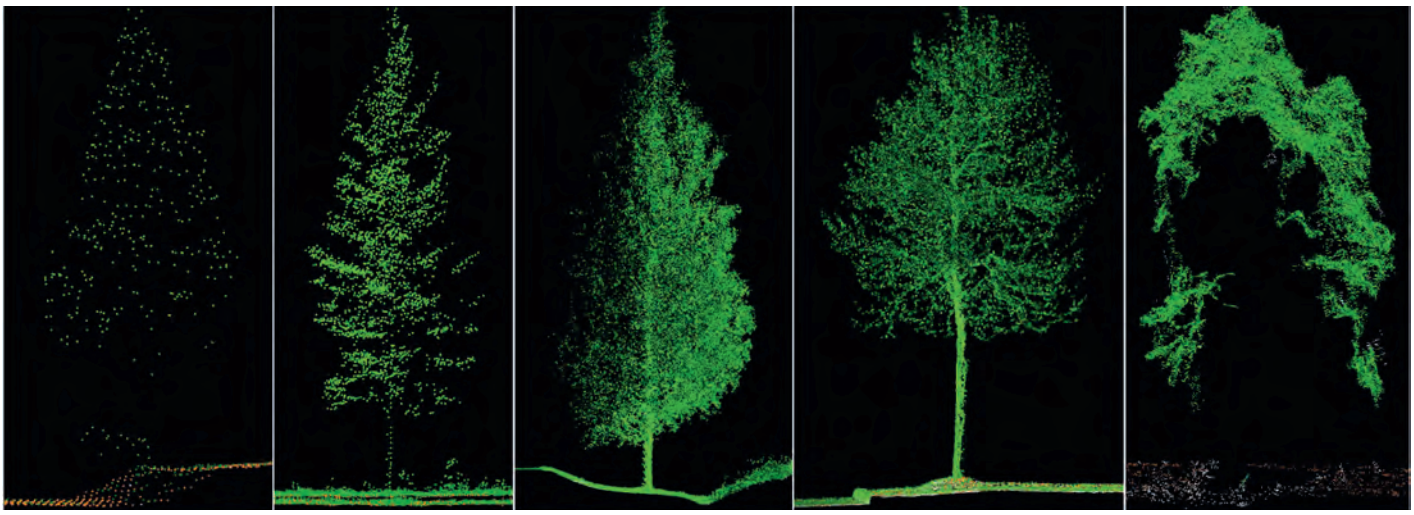
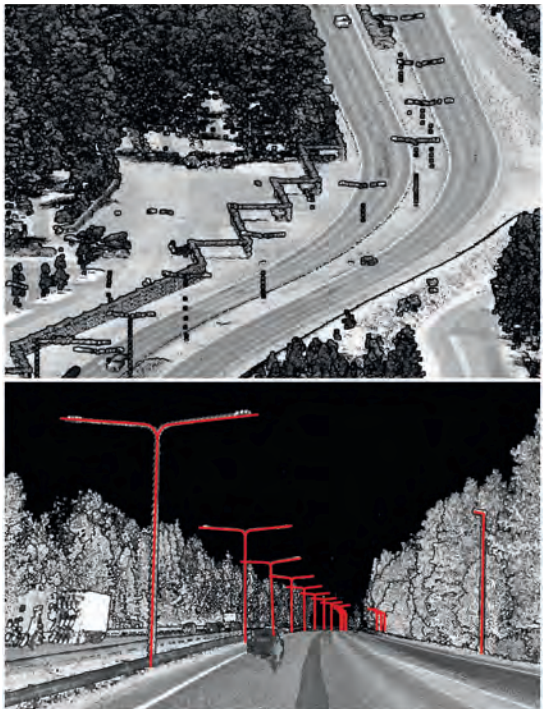


Figure 1: Group-based classification is used to detect above-ground objects and tree heights (magenta points at tree tips).



▲ *Figure 2: Trees in different types of point clouds (airborne Lidar, mobile Lidar, image matching point cloud).*



▲ *Figure 3: Poles are hardly detectable in sparse airborne point clouds (top) while they are well represented in mobile point clouds (bottom).*

normal vector, colour values extracted from images, or vegetation index. At a higher level of classification routines, the geometrical connections between points in the point cloud are considered. The analysis of point-to-point relationships determines whether a point belongs to a surface-like structure, such as the ground, or to linear structures, such as overhead wires. Single isolated points can also be detected by comparing a point to its closest environment.

Different types of reference elements can support the point cloud filtering task. The trajectory determines the scanner position at a certain point in time, which enables the classification of points based on their range or angle from the scanner. Cross sections of tunnels or clearance areas are used for detecting points falling inside or outside a section. Finally, vector data representing topographic objects allows a detailed classification of point clouds. Examples are boundary polygons for classifying points inside or outside of a specific area (e.g. water areas), and centre line elements of corridors for classifying points within a buffer area around the linear element (e.g. points along power lines, railways or roads).

GROUP-BASED CLASSIFICATION

The group-based classification approach goes further by analysing not only point-to-point relationships but also geometrical characteristics within and between point groups. The distance above the ground of a group, the planarity of points in a group, the shape and width-to-height ratio of a group, the point density and distribution within a group, and the distance between point groups all determine whether the group most likely represents a lamp post, a tree crown, a car, a building roof, a wall or another object of interest. The statistical analysis of point attribute values in a group leads to additional information for classification tasks. Specific object types may be represented with typical attributes in point clouds, such as dominating colour channel or intensity values. A common example is the separation of coniferous and deciduous trees by using near-infrared colour values.

The detection of objects in a point cloud can be supported by the use of group samples. The sample represents a typical entity of an object type, such as a street lamp or a pole. In the detection process, the software compares a group with samples stored in a library and assigns the corresponding class.

Reference elements can be used for the classification of point groups in a similar way as for single points. There are more options for defining the relationship between a group and the reference element. For example, inside a boundary polygon may be the entire group of points, the majority of them or just a number of points. The classification of key points in groups, such as the highest, lowest and/or centre point of a group, can be useful for analysis tasks. A typical example could be the detection of tree heights, which are mapped by the highest points of groups representing trees (Figure 1).

METHOD COMPARISON

The group-based classification approach has clear advantages for the automatic detection of above-ground objects in point clouds. Point groups provide information about the geometry and other characteristics of an object. By analysing the information, automatic filtering routines can directly assign a group to a specific object class. In addition, the comparison of groups to group samples enables the discovery of objects of the same type in the point cloud.

In contrast, the point-based classification approach seldom relates the points directly to an object type. Attributes of a single point are most often not object-specific due to the diverse and random nature of point clouds. Thus, the approach is suitable for

the detection of isolated points, surface-like and linear structures, but very limited for automatic above-ground object detection.

The processing effort is lower for point-based classification. It can be started directly after internal positional errors are corrected in the point cloud. The group-based approach relies on group assignment before the classification of the point cloud starts. Therefore, the classification result depends mainly on the quality of the grouping.

CHALLENGES

Point clouds collected with different scanner systems or created by image matching software represent the same object type in different ways regarding point density, viewing angle, sharpness and so on. For example, in an airborne point cloud a tree is mainly represented by its crown seen from above. Points from inside the tree crown and the ground around the tree may be included if the point cloud is dense enough and if the laser beam was able to penetrate the crown. In a mobile point cloud, a tree is seen from the side and from below the tree crown. Therefore, much more information is available about the tree trunk, limb and crown structure, but not necessarily about the top of the tree crown. In an image matching point cloud, most often only the outer layer of a tree is represented without clear information about the tree shape and structure (Figure 2). The smaller or thinner an object is, the more dependent the detection ability is on the point cloud density and viewing angle of the scanner. While poles along roads and railways are easy to detect in dense mobile point clouds, they are hardly detectable in less dense airborne point clouds where the scanner does not always capture the vertical part of a pole (Figure 3).

Another challenge for automatic object detection is the variety of object types that are present in point clouds of different application fields. Furthermore, the same object type may look very different in different countries and regions of the world. This applies not only to natural objects, such as trees, but also to man-made objects like buildings, road and railway furniture, power line towers and so on. Automatic detection algorithms therefore have to be flexible to cope with many different object types in various point cloud types. Predefined libraries with sample objects can only provide a starting point for country-specific, region-specific and application-specific extensions. Machine learning and artificial intelligence methods seem to be promising for improving the automatic object detection in point clouds in the future. ◂

FURTHER READING

http://www.terrasolid.com/download/presentations/2017/classification_using_groups.pdf

ABOUT THE AUTHOR

Friederike Schwarzbach is technical support assistant at Terrasolid, a leading software provider in the field of point cloud processing. She is a graduate of the University of Applied Sciences in Dresden, Germany, and her professional background is in GIS and cartography.
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5 Questions to... Gilles Labossière, CEO, senseFly

senseFly recently announced its brand-new UAV solution called eBee X, giving us a good excuse to pose a few questions to the company's CEO, Gilles Labossière, who joined senseFly earlier this year. What makes this new UAV different from the rest? What about the payloads and the point cloud processing software? And last but not least, what are Labossière's thoughts on the future of the professional drone market?

Why is the launch of the brand-new eBee X UAV solution such an important milestone for senseFly?

senseFly's team of expert engineers have been working diligently to develop a solution that meets the evolving needs of mapping professionals. Our goal, as ever, is to drive the industry forward. What we see as driving, and will continue to drive, the growth of the commercial UAV industry is the knowledge that it is largely not about the drone; first and foremost, it's about the user – the professional in fields such as agriculture, construction, real estate, mining and quarrying, public safety and more. For these professionals, drone adoption is about overcoming everyday business challenges while boosting the quality, efficiency and safety of geospatial data collection.

Can you tell us more about the payloads that accompany the eBee X?

Obtaining highly detailed, accurate insights is key for our customers. As such, we have developed a range of new camera options for the eBee X to suit every mapping job – from land surveying and topographic mapping to urban planning, crop mapping, thermal mapping and environmental monitoring. The senseFly S.O.D.A. 3D, for instance, uses a one-inch sensor to capture a wider field of view and can produce intricate, digital 3D reconstructions of vertically focused environments like urban areas or coastlines. To facilitate mapping in almost all light conditions, the new senseFly Aeria X camera features Smart Exposure technology that enables professionals to map for more hours per day than ever before, while also offering DSLR-standard image quality. Operators can also create geoaccurate thermal maps and digital surface models with the senseFly Duet T, a dual-camera thermal mapping rig which can be synchronised with Pix4Dmapper photogrammetry software to simplify the map reconstruction process. With these revolutionary new payloads, the our new UAV offers a multi-purpose, comprehensive mapping solution for a wide range of environments and verticals.

The new solution has been developed for a wide variety of applications. How does it benefit the 'traditional' surveyor?

Indeed, the eBee X is versatile. It can operate in several different environments and it is reliable enough to meet the exacting requirements of almost any project. In the surveying industry specifically, the UAV can be used for cadastral surveying, topographic mapping, construction surveying, corridor mapping and large-area mapping. The eBee X benefits 'traditional' surveyors in two key ways. Firstly, its Endurance Extension technology unlocks a flight time of up to 90 minutes and can achieve single-flight coverage of up to 500 hectares at 122m (400ft). Secondly, surveyors can activate the high-precision-on-demand (HPoD) built-in RTK/PPK when their project requires it. These two elements are unique to the eBee X and provide surveyors with unmatched efficiency and precision.

There is considerable demand for accurate and easy-to-use point cloud processing software for UAVs. Are there any plans for senseFly to capitalise on this opportunity?

senseFly's strong, ongoing relationship with Pix4D – a leading provider of photogrammetry software, fellow Parrot Group company, and another key player within the wider Parrot Business Solutions activity – has enabled us to provide best-in-class drone mapping solutions that produce highly precise, georeferenced 2D maps and 3D models using point cloud data. The seamless integration of this software with senseFly drone hardware has enabled our customers to quickly and easily incorporate drone technology into their everyday business operations and existing workflows. As UAVs continue their trajectory to becoming essential mapping tools, especially with the launch of the eBee X technology, we look forward to further building on this collaboration as the needs of geospatial professionals evolve.

How do you envision the future of the professional UAV market for the mapping and surveying industry?

With more surveying and mapping professionals using UAV technology than ever before, we anticipate that the demand for precision, accuracy and efficiency in end-to-end drone solutions will continue to grow. We believe our new solution is a major step forward for mapping technology and the geospatial market as a whole, and we are excited to play a part in setting new standards for our customers and the industry alike. ◂

Gilles Labossière is the executive vice president and COO of Parrot Group and recently became the CEO of senseFly, a commercial drone subsidiary of Parrot Group. He is focused on further boosting senseFly's growth and utilising his extensive professional expertise across Parrot's wider Business Solutions group to help drone operators make better decisions, faster.

EXPLORING THE DEMANDS OF GEOPROFESSIONALS

Which **Photogrammetry Solutions** Are Surveyors Waiting For?

Photogrammetry is a well-established technique for acquiring dense 3D geospatial information. In fact, the method is as old as modern photography, dating back to the mid-19th century. The science has continued to evolve over time, of course, and – especially in view of the recent advancements in computer vision and machine learning – the technology is no longer as simple as it may seem. Developers of photogrammetric equipment and software face the challenge of providing the mapping and surveying community with solutions that are sophisticated, yet also meet high customer expectations in terms of user-friendliness. At *GIM International*, we conducted a survey among our readers in the geospatial industry to gain insights aimed at helping manufacturers to further optimise the solutions on offer.

Before examining the results of the *GIM International* readers' survey on photogrammetry, let us first zoom in on the ongoing debate about photogrammetry versus Lidar. Is it fair to say that one mapping method is definitively better than the other? Or is the situation more nuanced than that?

▲ *Bentley's ContextCapture was frequently mentioned as the software of choice. (Courtesy: Bentley Systems)*

LIDAR

Data that is captured by either photogrammetric or Lidar mapping technology is gathered in a point cloud. An often-heard question is whether photogrammetric point clouds are superior to Lidar ones, or vice versa. The best answer is probably that there is no clear-cut answer; it depends on the application. Although Lidar mapping may deliver a higher level of detail, photogrammetry is usually sufficiently detailed for large areas, for example. The fairest conclusion is that each system has advantages and disadvantages. Our survey reveals that photogrammetry is a far more popular geodata acquisition technology for mapping projects than Lidar (photogrammetry 73%, Lidar 27%). The three most popular laser scanning processing software packages are Leica Cyclone, Terrasolid and CloudCompare. However, the demand for Lidar solutions is growing. About a third of the respondents indicate they are planning a major investment in laser scanning devices, and a similar number intend to purchase laser scanning processing software. Lidar in particular is an often-used method for the generation of digital elevation models (DEMs).

TOPOGRAPHIC MAPPING AND CADASTRAL SURVEYING

There are two categories in which photogrammetry is most popular by far. One is topographic mapping, for which 60% of surveyors indicate that they prefer this technique. Topographic maps are used for a wide variety of applications, such as construction, mining, land use surveys, urban planning and civil engineering. The traditional approach to updating topographical maps can be time-consuming and expensive, but a digital photogrammetric environment offers a way forward. Here, 3D point cloud data is created by applying image matching to overlapping digital images. Cadastral surveying is the second area in which photogrammetry is regarded as a highly effective method. The main advantage is that it can be just as accurate as a ground survey, yet much more affordable. However, when land is covered by obstacles such as trees, additional survey equipment such as a total station and GNSS receiver can be necessary.

COMBINING LIDAR AND PHOTOGRAMMETRY

Following on from the above, and perhaps only logically in view of the advantages and disadvantages of the two methods, there is a growing tendency to combine them both (Figure 1). More than half of the survey participants rely on photogrammetry plus Lidar for the creation of 3D city models, for instance, and archaeology and forestry are also high-ranking applications. When surveying an archaeological site, for example, UAV photogrammetry with both nadir and oblique cameras is often combined with the large-scale details acquired by terrestrial laser scanning of vast areas or complex objects. In forestry, Lidar-derived DEMs and photogrammetric canopy surface measurements are both suitable for providing relevant geospatial information relating to forest canopy structure. Contrary to Lidar, photogrammetry cannot penetrate vegetation canopy, but photogrammetric matching of digital aerial images is a cost-effective and reliable solution. So here, too, a combination seems to make perfect sense.

PHOTOGRAMMETRIC SOFTWARE

There are numerous software solutions available on the market for the photogrammetric processing of digital images and to generate 3D spatial data. Geoprofessionals can use the photogrammetric software to create orthomosaics, point clouds and models.

	PHOTOGRAMMETRY	LIDAR/TLS/MMS	COMBINATION OF BOTH
Topographic Mapping	60.34%	6.47%	33.19%
Generation of DEMs	27.50% 33	45.83%	26.67%
Cadastral Surveying	53.97%	19.05%	26.98%
Creation of 3D City Models	29.49%	19.23%	51.28%
Archeology	46.88%	9.38%	43.75%
Forestry	29.63%	25.93%	44.44%
Others	34.15%	21.95%	43.90%

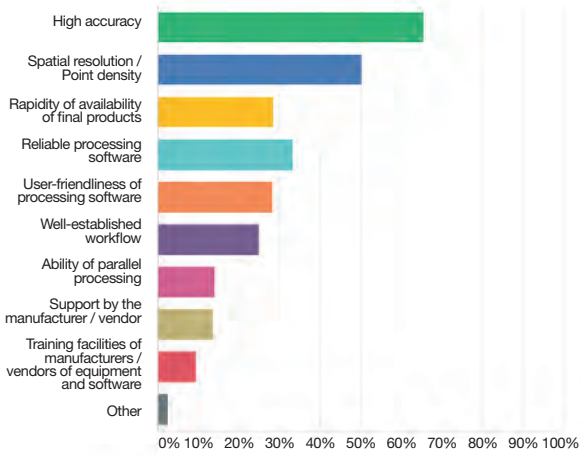
Figure 1: The key applications for which respondents are using photogrammetry/Lidar.

Some photogrammetric software solutions are suitable for large-format images from aerial cameras and satellite processing, while others are especially developed for small and medium-format digital images acquired by unmanned aerial vehicles (UAVs or 'drones'). The Pix4D and Agisoft PhotoScan software solutions are currently way out in front, according to our survey. In a thorough comparison of these two household names in the geospatial industry by Michael Schwind and Michael Starek in an edition of *GIM International* in 2017, they were both found to be very close in terms of density, spacing and number of points. Apart from Pix4D and PhotoScan, respondents frequently mentioned Inpho (Trimble), ContextCapture (Bentley), DroneDeploy, Photomod (Racurs) and SURE (nFrames) as their software of choice.

VALUED CHARACTERISTICS

We also asked our readers what they valued most about their chosen geodata acquisition method, and the answers will undoubtedly be of interest to providers of photogrammetric solutions. At the top of the list of priorities (Figure 2) is high accuracy (more than 65%), followed by spatial resolution/point density (just over 50%) and reliable processing software (33%). Other important aspects are the rapid availability of final products and a well-established workflow.

It is hardly surprising that accuracy is regarded as essential. However, accuracy is affected by several factors. PhotoModeler



ANSWER CHOICES	RESPONSES
High accuracy	65.50%
Spatial resolution / Point density	50.25%
Rapidity of availability of final products	28.50%
Reliable processing software	33.25%
User-friendliness of processing software	28.25%
Well-established workflow	25.00%
Ability of parallel processing	14.00%
Support by the manufacturer / vendor	13.50%
Training facilities of manufacturers / vendors of equipment and software	9.50%
Other (please specify)	2.50%

Figure 2: Overview of what respondents like most about the geodata acquisition method they use.

ANSWER CHOICES	RESPONSES
Need for expensive computer resources	40.26%
Use of equipment and / or software requires expensive export knowledge	22.31%
Subsequent editions of equipment and / or software are poorly interchangeable	16.92%
Limited data formats can be used	21.54%
Low accuracy	25.38%
Low spatial resolution / Point density	14.10%
Slow processing facilities	28.46%
Bugs in the software	26.41%
Support by the manufacturer / vendor	7.18%
Training facilities of manufacturers / vendors of equipment and software	6.92%
Other (please specify)	6.67%

▲ *Figure 3: Overview of surveyors' most frequent complaints with regard to the geodata acquisition method they use.*

▲ *The rise of UAVs in the surveying profession requires providers of photogrammetric solutions to adjust. (Courtesy: Wingtra)*

Technologies (also known as Eos Systems) published a relevant blog [1] titled analysing the various aspects of photogrammetric accuracy. According to the blog, high accuracy is related to photo resolution, camera calibration, angles, photo orientation quality, photo redundancy and targets/marking precision.

One particularly important aspect is knowledge of how to gather the best imagery. After all, of the various factors that affect the accuracy, the quality of the input imagery is crucial. Photogrammetric mapping companies are always working on optimising their solutions, but geospatial professionals themselves can also do a lot to improve the results. It may sound obvious, but high-quality inputs lead to high-quality outcomes.

WHAT GEOSPATIAL PROFESSIONALS DISLIKE

To gain a true picture of the photogrammetric market, we also asked our readers which characteristics of their chosen geodata acquisition method they dislike most. Their responses make it clear that suppliers of photogrammetric solutions still have some work to do. Common complaints range from discontentment about the need for expensive computer resources (40% of the respondents mention this) to slow processing facilities (28%) and bugs in the software (26%). The limited number of data formats that can be used (21%) and the fact that the use of equipment and/or software requires extensive export knowledge (22%) are also common annoyances of the survey participants. Hopefully this feedback will give manufacturers of photogrammetric solutions food for thought in their further development processes.

USER EXPERIENCES

To gain deeper insights into practical usage, we asked our readers to summarise their experiences, both pros and cons, with the photogrammetric products they are using. This resulted in a wide variety of reactions, but there are several recurring topics. One of the most frequently expressed hands-on experiences revolves around complications with image format processing during analysis. Another gripe by several respondents is the need to know photogrammetry in order to use the package appropriately. But it is not all bad news; there is also a lot of positive feedback, such as that, for academic purposes, the equipment and software programs are very useful in obtaining orthophoto maps and maps in the GIS structure. On another positive note, one experienced surveying professional comments that, over the years, photogrammetric methods of geodata collection and applications have achieved obvious improvements in the quality and also the rapidity of processing huge volumes of 3D geodata.

In general, the survey participants seem satisfied about the products they are using. However, there is still plenty of room for improvement. "Extensive training on equipment, workflows and delivered products to end customers are required," states one respondent. Another frequent complaint is that the hardware is expensive and the software has a limited licence. "There is a lack of consistent workflow between software packages," one reader notes. Needless to say, the specific application also plays a role in how software is rated. As one respondent puts it, although the chosen solution may not be best-in-class software, it provides the "fit-for-purpose" output that clients want at a cost-effective price.

OPTIMALLY MEETING USERS' NEEDS

The question that will probably spark the most interest among manufacturers and developers of photogrammetric equipment and software solutions is 'What would geospatial professionals suggest to manufacturers of photogrammetry solutions

FURTHER READING

Ahmad, F., Uddin, M. and Goparaju, L. (2018), 3D Mapping by Photogrammetry and LiDAR in Forest Studies, *World Scientific News*

Schwind, M. and Starek, M. (2017) Producing High-quality 3D Point Clouds from Structure-from-Motion Photogrammetry, *GIM International*

Blog: Factors Affecting Accuracy in Photogrammetry, [1] https://info.photomodeler.com/blog/kb/factors_affecting_accuracy_in_photogramm/

ABOUT THE AUTHOR

Wim van Wegen is content manager of *GIM International*. In his role, he is responsible for the print and online publications of one of the world's leading geomatics trade media brands. He is also a contributor of columns and feature articles, and often interviews renowned experts in the geospatial industry.

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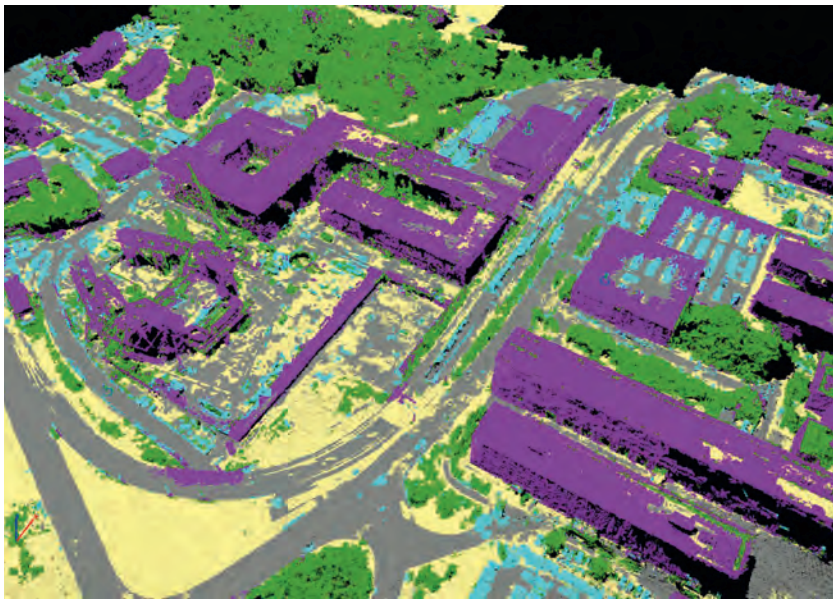


▲ *Pix4D's machine learning-driven process automatically classifies entire point clouds into five predefined groups: ground, road surface, high vegetation, building, and human-made object. (Courtesy: Pix4D)*

to help them ensure their products optimally suit their needs?' Our survey generated a wealth of information, of course, but the key insights can be summarised as follows. Firstly, automatic procedures to analyse and extract information from 3D point clouds are high on the wish list. Versatility, ease of use and low costs are also mentioned often. This will make photogrammetry accessible to a wider range of users, including non-traditional photogrammetry users, some of the respondents argue. There also seems to be a growing demand for software that is able work with Lidar, aerial photography and UAV data in a single-window environment. A significant number of respondents call for interoperability between data formats and/or sensor formats from different manufacturers. Several readers also indicate that the rise of UAVs in the geomatics field will require adjustments from providers of photogrammetric solutions.

WILLINGNESS TO INVEST IN PHOTOGRAMMETRY

In an attempt to assess the future of the industry, we asked the survey participants two questions with regard to their plans to buy new photogrammetry equipment and processing software. In response to the question 'When will be your next major investment in photogrammetric equipment?', almost half of the respondents indicate 'Before 2020'. On the other hand, around 30% still need to be convinced of the necessity to invest in new equipment as they currently seem unwilling to make a financial commitment.

In terms of their intention to make a major investment in processing software, 45% of the survey respondents state that they plan to do so before 2020, while 18% expect to make their next significant purchase between 2020 and 2022. Once again, approximately 30% have no plans to invest.

FUTURE OUTLOOK

Looking ahead to the future of photogrammetry, one respondent in our readers' survey made a particularly bold and thought-provoking statement: "Photogrammetry in the traditional sense will disappear in 5-7 years. The first such unnecessary process is the measurement of the heights of the points and the construction of the DEM. Real technologies can only be the construction of orthomaps and engineering photogrammetry". While we are not able to look into our crystal ball to see whether this is indeed true, there is certainly enough innovation in the industry for us to be able to predict that things will transform. Advancements in computer vision, artificial intelligence and machine learning are already adding new dimensions to photogrammetry. Bearing in mind that it is still very much early days for these technologies, we are in no doubt that exciting and inspiring times lie ahead! ◀

FACTORS AFFECTING ACCURACY IN PHOTOGRAMMETRY

Photo Resolution: This is the number of pixels in the image. The higher the resolution of the images, the better chance of achieving high accuracy because items can be more precisely located.

Camera Calibration: Calibration is the process of determining the camera's focal length, format size, principal point and lens distortion. There are several ways of obtaining this camera information. Associated with this are two sub-factors: a) certain cameras do not calibrate that well (very wide angle or fish-eye lenses), and b) certain cameras are unstable (calibration changes). In both cases, accuracy will be lower. Conversely, a high-quality lens and stable camera will produce better results.

Angles: Points and objects that appear only on photographs with very low subtended angles (for example, a point appears in only two photographs that were taken very close to each other) have much lower accuracy than points on photos that are closer to 90 degrees apart. Making sure the camera positions have good spread will provide the best results. For projects that have low angles between photos, it is the total angle across multiple photos that affect a point's accuracy (for example, if a point was marked on five photos, it is the angle between the pair of photos with greatest angle difference).

Photo Orientation Quality: During processing, the location and angle of the camera is computed for each photo – this is called 'orientation'. The orientation quality improves as the number of well-positioned points increases and as the points cover a greater percentage of the photograph area.

Photo Redundancy: The position of a point or object is usually more accurately computed when it appears on many photographs, rather than the minimum two photographs. For a given marking precision, more photos 'average' that error to provide higher output accuracy. A point that is precisely marked on several photos can also compensate for one mark that is not precise.

Targets /Marking Precision: The accuracy of a 3D point is tied to the precision of its locations in the images. This image positioning can be improved by using targets. Using the image data to sub-pixel mark the point increases the precision of its placement and hence the overall accuracy of the point's computed 3D location.

Source: PhotoModeler.

GeoVille – A Leader in Satellite-based Land Monitoring

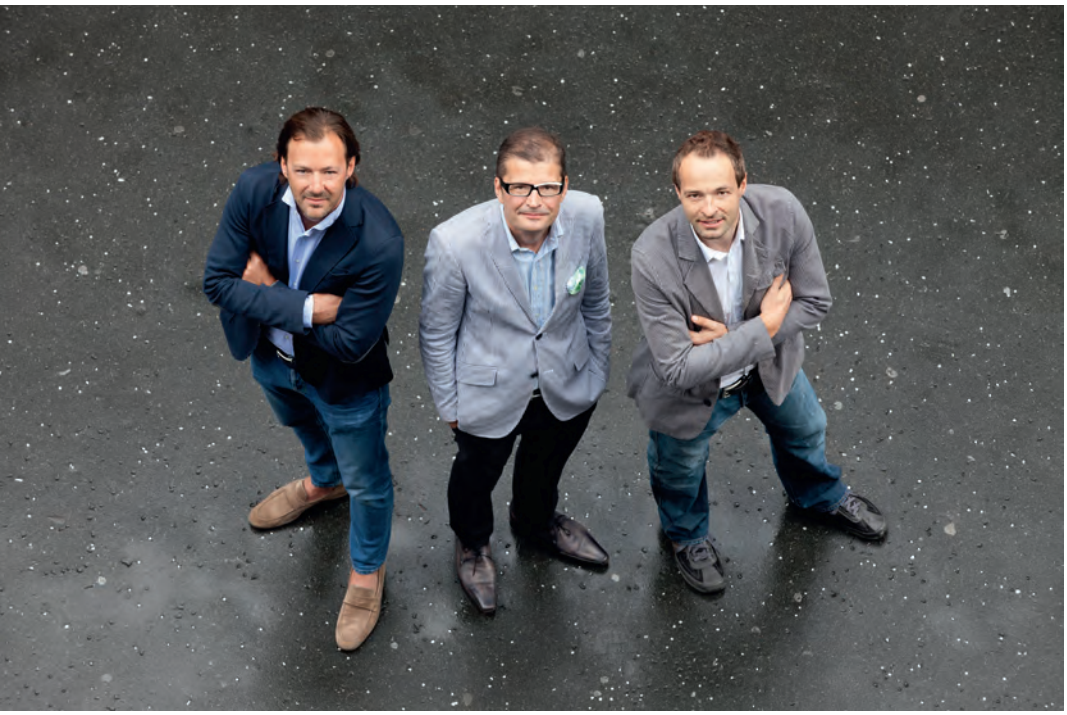
GeoVille Information Systems and Data Processing GmbH is a high-tech company providing innovative geoinformation solutions to a broad international client base in more than 130 countries worldwide. Its headquarters are situated in Innsbruck, Austria, a location known for its high quality-scaled ICT industry. GeoVille started with the goal to revolutionise the market and has since become an established name for delivering real-world geoinformation solutions that enable clients to get meaningful spatial insights into their businesses.

It all started in 1998 when Christian Hoffmann founded the company with the vision to remap the unknowns of human activities around the world. Years before Google Earth became part of our daily lives, he was already fascinated by watching the Earth and its changes from a bird's-eye perspective. Thus, the basis was laid for the company that is today one of the leaders in satellite-based land monitoring.

These days the company is internationally recognised for its leading role in the development of innovative Earth observation (EO) services. GeoVille is a true one-stop shop for targeted value-added geoinformation products providing evidence-based decision-making support for many key sectors. "We are definitely very proud to be an independent company that is recognised as one of the leaders in satellite-based land monitoring with a global footprint," says Christian Hoffmann, CEO of GeoVille. "In the last 20 years, we have established a broad international client base and successfully participated in more than 440 national and international projects. During that time the company has managed to grow in a sustainable way, by combining technical excellence with a profound service and market knowledge."

20 YEARS OF EXCELLENCE IN GEOINFORMATION SOLUTIONS

This year the company is celebrating its 20th anniversary with the main focus still being on the monitoring of environmental changes with satellites. From global predictions of crop growth and yield or coastline changes and deforestation in Africa to the evolution of land consumption in Europe, GeoVille constantly provides insights and monitoring solutions for real-world problems, thereby providing timely, comprehensive and



▲ *Andreas Walli, commercial director, Christian Hoffmann, CEO and Jürgen Weichselbaum, technical director (from left to right).*

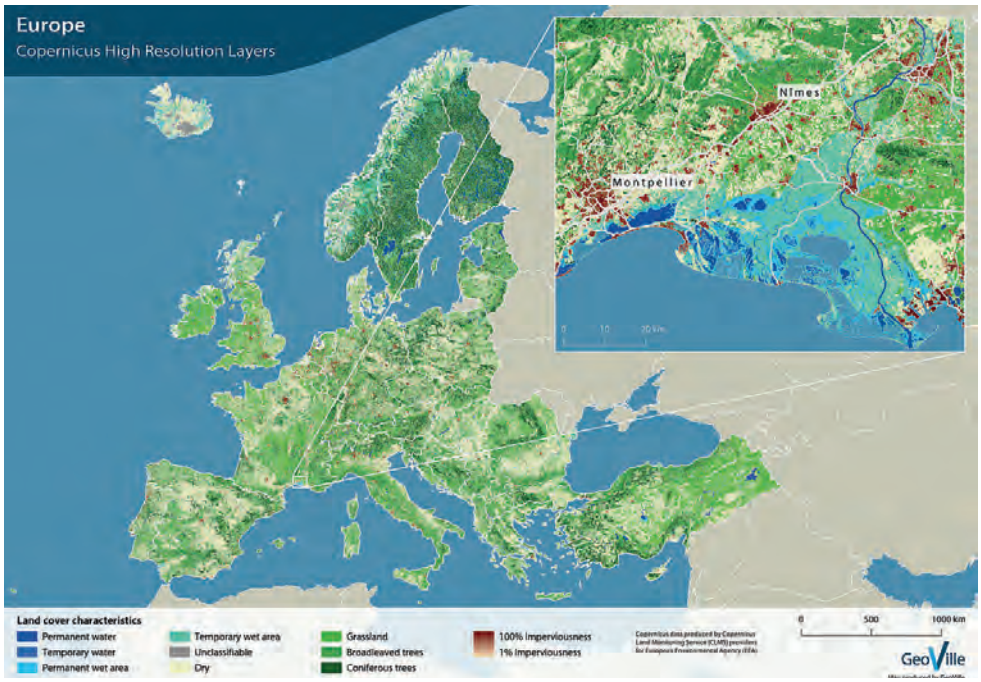
▲ *GeoVille provides meaningful spatial insights into clients' businesses.*

accurate information on the 'where' and 'how much' of land surface dynamics.
GeoVille's clients range from public authorities, international institutions and NGOs to corporate industry customers in need of reliable operational monitoring solutions with known performance for complex management issues. Especially for its public clients, GeoVille's data provides the ultimate baseline to evaluate governance options, take actions and control observance. At present, GeoVille is growing and employs more than 80 international experts and consultants from Europe and the USA, helping clients to perform their daily business efficiently and effectively.

INVESTING IN THE FUTURE

Ever since its foundation, GeoVille has allocated substantial resources to research, innovation and development in the context of national and international scientific activities to constantly provide answers to emerging challenges. This is a key asset of the company and provides the basis for forward-looking investments, such as the foundation of the Earth Observation Data Center (EODC) in 2014, a public-private partnership for the establishment of the first Sentinel-focused big data storage and processing facility. Through this investment, GeoVille has had a head start on how to employ machine learning techniques and combine EO with non-EO data streams from users to deliver continuous monitoring information solutions. To this end, GeoVille is currently in the process of opening up these technologies via www.landmonitoring.earth, a unique solution providing online access to its back-end production engine. The system is designed along Space 4.0 standards, which in recent years provided the entry point for the production teams to efficiently implement major client solutions such as the European Copernicus Land Monitoring Service products. Experts can specify desired land monitoring data for any place on the globe for any given time period and receive a quality-controlled output within days or even hours, depending on the required coverage and frequency.
GeoVille sees a shift in the demand from classic EO products towards numerical business intelligence services, which is why the company is currently focusing on vertical integration of its services into specialised industries. Just recently the company Geo4Agri B.V. was founded in The Netherlands with the aim of delivering highly specialised EO-based data streams to the agri-food industry to target the value chains surrounding the agricultural sector.

GeoVille will continue to develop groundbreaking solutions and products from Earth observation data to provide meaningful insights for its clients. In times where Earth observation is on the brink of a revolution, GeoVille believes that satellites will diversify the understanding of our planet. Interested to know more? GeoVille is continuously looking for partnerships to create new businesses. ◀



▲ *Copernicus High Resolution Layers providing consistent pan-European land cover characteristics derived from high to very-high-resolution satellite imagery, including ESA's Sentinel-1 and Sentinel-2 satellites.*

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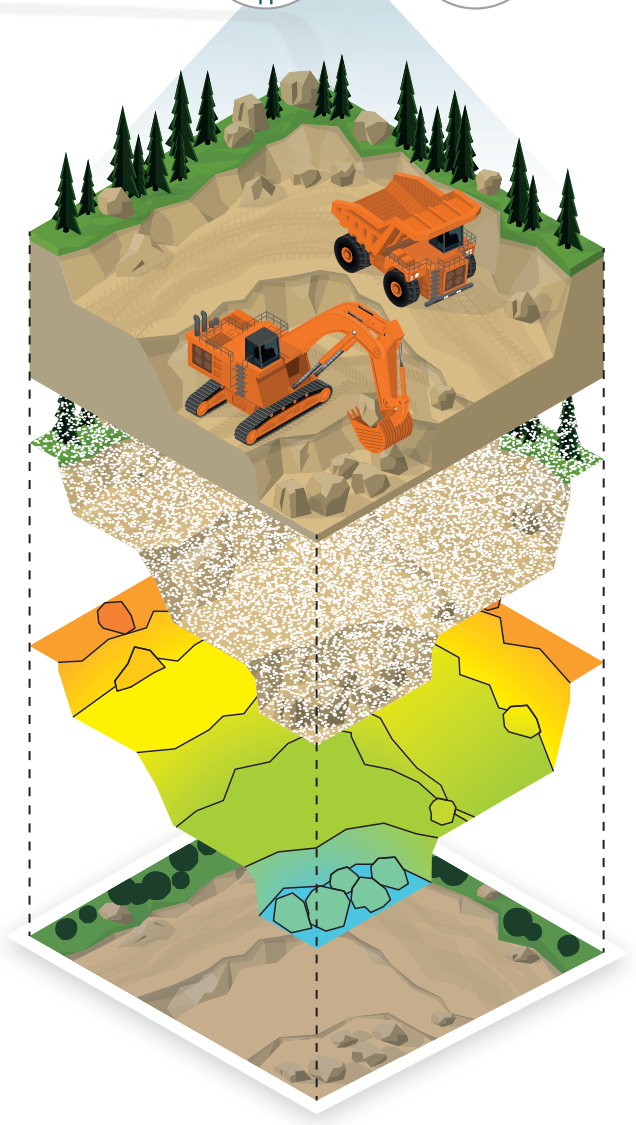

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ACCESS ALL AREAS: GEOMATICS SYSTEMS FOR THE FUTURE

Rapid Site Surveys Using SLAM Technology

The difficulties of undertaking geospatial surveys, particularly within unstable buildings or underground environments, are well documented. However, the pressure to collect accurate, real-time data within strict timelines has certainly intensified in recent years. With increasingly tight deadlines coupled with strict budgets, conducting surveys of hard-to-access sites can be a real challenge for engineering and construction firms. This article outlines how new innovations in building information modelling (BIM) are providing an answer with the aid of simultaneous localisation and mapping (SLAM) technology.

As engineering and construction firms grapple with issues such as skills shortages, robust safety regulations and fierce competition for contracts, traditional survey methods are increasingly coming under pressure to provide scan data which is accurate and turned around as quickly as possible. Added to this, many project managers cannot afford to solely rely on highly skilled operators to collect data if they would then need to spend multiple days processing it. Such lengthy process times often mean that operators run the risk of missing key information about the integrity of a structure.

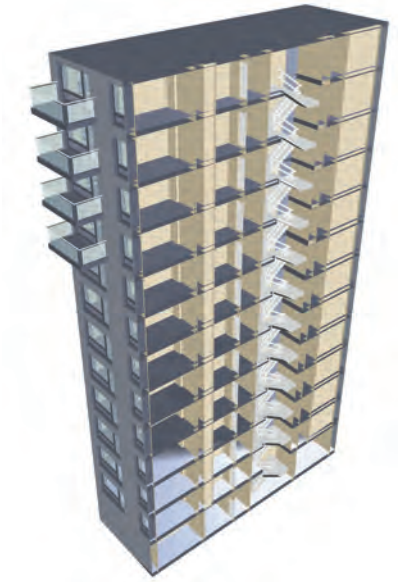
▲ *SLAM-based mobile mapping solutions have the capablility of rapidly scanning buildings.*

GROWING DEMAND FOR BIM

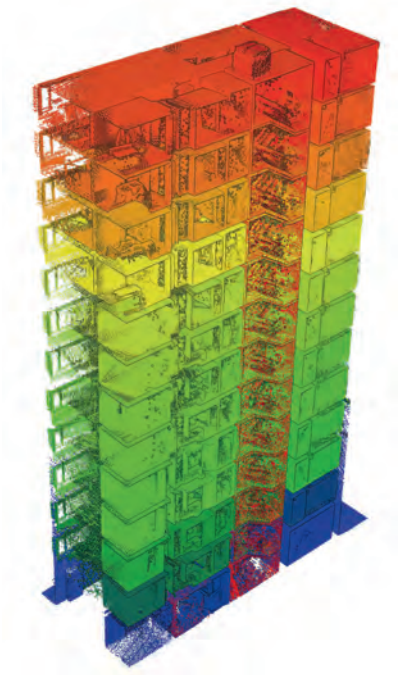
This need for greater operational efficiency is one of the reasons why demand for building information modelling (BIM) technology is growing so rapidly. Site teams can now test and optimise processes at every point of an asset's lifecycle via a dynamic 'digital twin', enabling them to identify potential issues such as unstable ground, existing utilities or, occasionally, historic remains that could unexpectedly halt work and push up the costs. Whatever the nature of the project, firms can ensure that any changes to building plans are digitally communicated to stakeholders wherever they are in the world, in real time. Fuelling some of the latest innovations in BIM are developments in high-definition 3D laser scanning technology, which enables operatives to produce digital representations of a building or asset while reducing the need for anyone to access hard-to-reach and/or dangerous parts of the site.

ADVANCES IN MOBILE SCANNING

Static scanning has certainly helped to improve the accuracy of site data, especially compared to manual tools like tape measures and total stations, yet it can be costly and time consuming compared to the recent technological innovations. Static surveys still require expert operators, and it takes hours – and often days – to process the data. Subsequently, without immediate access to information, decision-making is inevitably delayed and this could compromise the



▲ *BIM model of a 13-storey apartment block.*



▲ *BIM model created by importing the point cloud into third-party software.*

commercial viability of a project if deadlines are missed and costs escalate. To overcome this, project managers are increasingly deploying handheld mobile 3D laser scanning systems that empower anyone – not just surveyors – to scan a site in minutes and continually update a digital building model.

Mobile scanning is undoubtedly a great leap forward in terms of time savings and site accessibility. However, the fact that many devices rely on GPS can make them less suitable for use in tunnels, caves, mines or potentially dangerous buildings. One alternative is simultaneous localisation and mapping (SLAM) technology, which delivers the same accurate results without the need for GPS. When this is coupled with the ease of transferring to BIM, data can be captured and assessed quickly and efficiently.

HOW SCAN RESULTS ARE USED

One application for the implementation of SLAM-based mapping can be seen in a project undertaken by Danish survey specialist LIFA, which had been tasked with measuring the leasable floor area of a 13-storey apartment block that was under construction at the time. The site team needed a solution capable of rapidly scanning the building, and so turned their attention to SLAM-based mobile mapping solutions.

According to Danish law, all leased properties must undergo an official, interior, as-built survey for property tax reasons. Using traditional techniques, this process would have taken at least two days – but the entire survey was completed in just 30 minutes by walking with the GeoSLAM ZEB-REVO on site, plus another hour for data processing. After data for all 44 apartments and communal areas had been captured, the site team created a BIM model by importing the point cloud into third-party software. Having scanned almost 5,500 square metres, the measurements using a ZEB-REVO were accurate to within a few centimetres across the entire building. Moreover, the results were well within acceptable tolerances for the tax office. The BIM model was able to display the building and had enough detail and accuracy to meet the requirements of Danish law.

LIFA is now able to measure buildings up to ten times faster using mobile scanning devices. In just six months, a two-person team mapped over 16,000 rooms in approximately 400 municipal buildings. A task like this would once have taken years to finish, rendering it commercially unviable as the processed data would have been immediately outdated. However, LIFA can now obtain the results it needs in a relatively short period of time, and apply them accordingly. Furthermore, new advancements in real-time capability are allowing for simultaneous data collection and processing, paving the way for even shorter survey times.

BIM AND SLAM: WHAT DOES THE FUTURE HOLD?

All this seems light years ahead of the days when architects, surveyors and other

▶ *Walking with the GeoSLAM ZEB-REVO on site.*

stakeholders would manually update asset designs during the process. Instead, BIM technology enables project managers to carry out more work at the planning stage, identifying any potential issues before work begins on site. This is extremely important given that, according to industry research, a rework might amount to 12% of the total building cost. As well as speeding up construction projects, BIM also makes compliance more straightforward. For example, ISO certification can be easily shared with any stakeholder. Once the building work is complete, BIM continues to play an important role throughout the asset's lifecycle, even if it is eventually demolished.

Speed and ease of use make handheld mobile 3D laser scanning systems an attractive choice for firms looking to remain competitive. By embracing BIM firms have significantly reduced materials waste, enabling them to offer better value for money, increase investor confidence and secure new contracts for large-scale capital projects. The fact that surveys can be completed so rapidly also means that project managers can do them more frequently, so architects, designers and facilities managers have the most up-to-date information both during the construction phase and throughout the asset's lifecycle. As a result, scan-to-BIM, using SLAM technology, is increasingly being deployed both on large-scale projects in the construction and engineering, mining and forestry sectors and on comparatively small housing developments.

SPEED AND EASE OF USE MAKE HANDHELD MOBILE 3D LASER SCANNING SYSTEMS AN ATTRACTIVE CHOICE FOR FIRMS LOOKING TO REMAIN COMPETITIVE

Within tightly regulated industries such as engineering and construction, the need for more frequent surveys will only grow in the coming years, as contractors are expected to deliver detailed verification and progress monitoring reports. Rather than relying on professional surveyors only, it surely makes good business sense to equip others on the team with increasingly accessible geospatial devices so they can capture new data and update the BIM representations accordingly. ◀

ABOUT THE AUTHOR

Stuart Cadge is a marketeer specialising in the technology and geospatial sectors. After beginning his career in architecture, he moved into the GIS and mapping domain, obtaining his MSc in Cartography and GIS at the University of Glasgow in 2013. Following a spell as a mapmaker in Edinburgh, Stuart made the move to 3D laser mapping specialists GeoSLAM in 2015.

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Photogrammetry – Recent Developments and the Way Forward

Over the past few years, photogrammetry, remote sensing and spatial information science have witnessed great achievements, mainly due to societal, political, environmental and technological changes worldwide.
Human mobility has significantly increased due to population growth, climate change and globalisation. Photogrammetric innovations have also been strongly influenced by the developments in information and communication technology (ICT), computer vision and robotics. Moreover, with the usage of active remote sensing techniques such as Lidar and radar for obtaining point cloud data – even from reflective surfaces such as metal or glass and uniform textures like snow, white surfaces or ice – the opportunities for data collection, analysis and integration have increased tremendously.
All this geospatial data is acquired, processed, stored and disseminated in ever-more advanced ways using geospatial infrastructures, cloud computing and crowd sourcing. New sensors are continuously appearing nowadays, such as SAR (InSAR/IfSAR), flash lasers, mobile Lidar and various cameras such as 3D and multispectral to name but a few. Having the opportunity to acquire data with high spatial, spectral, radiometric and temporal resolution has directly resulted in developments in photogrammetric image processing for deriving high-quality 3D information. In particular, dense matching boosted photogrammetry leading to high-density 3D data.
Recent years have also seen significant progress in automatic image orientation, surface reconstruction, scene analysis, change detection, classification and information extraction with the help of data mining, spatial statistics and machine learning. As a result, the number of new applications using photogrammetric technologies has increased significantly.

Autonomous cars, which are equipped with cameras, laser scanners and radar sensors, are one recent example. To ensure safe driving, accurate real-time data processing is essential. Some other applications that are worth a mention are Earth system modelling, coastal monitoring, sustainable development, agriculture, cadastral and topographic mapping, cultural heritage, navigation, n-dimensional data modelling, object tracking, virtual and augmented reality and disaster management.
With the increasing variety of new and unconventional platforms, a new field in photogrammetry has emerged: UAV photogrammetry. Over the years, unmanned aerial vehicles (UAVs) have evolved from sole sensor-carrying platforms to automated flying robots with high-tech navigational and optical sensors on board. In the past, UAV flight missions that required a high level of geometric accuracy were necessarily accompanied by field measurements to include surveyed ground control points into the photogrammetric processing pipeline. Very often, this procedure took twice or three times as long as the time spent on the flight mission. This is especially true for large-scale mapping projects; the high costs of time-consuming ground truthing missions limited the exploitation of the full potential of UAVs. In recent years, however, the development of high-quality inertial measurement units (IMUs), global navigation satellite system (GNSS) technology and dedicated real-time kinematic (RTK) and post-processing kinematic (PPK) solutions promise accurate measurements which allow fast and easy image georeferencing. Tests carried out by related research projects (for example, www.its4land.com) have shown that the utilisation of such devices has the ability to increasingly minimise – or even eliminate – the need to measure ground control points. All these developments have the potential to contribute to the successful achievement of the UN's Sustainable Development Goals in which Earth observation (EO) provides indispensable data and insights. Photogrammetry in combination with other domains such as robotics, computer vision and mobile sensing for 3D simultaneous localisation can be considered as one of the disciplines which will contribute to the prosperity of our high-tech world.

▲ *Mila Koeva.*

ACKNOWLEDGEMENTS
The author would like to thank her PhD candidate Claudia Stöcker for her contribution to this column. ◀

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Mila Koeva is an assistant professor at the University of Twente, ITC, The Netherlands. Her main areas of expertise include 3D modelling, 3D cadastre, digital photogrammetry, image processing and producing large-scale topographic and cadastral maps. She is project coordinator of its4land, a multidisciplinary European Commission Horizon 2020 project - (www.its4land.com), and co-chair of 3D GeoInfo 2018 and ISPRS WG IV/10.

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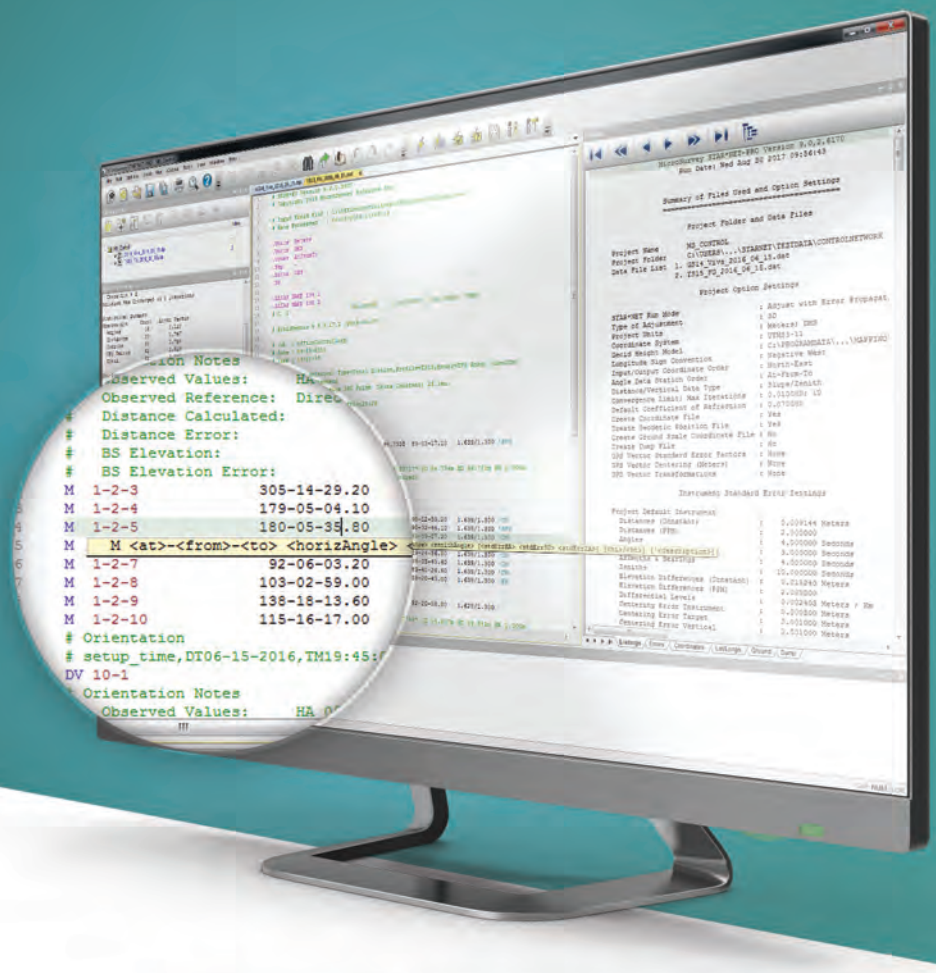

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ZOOMING IN ON THE LMAP INITIATIVE

Web GIS Improves **Lidar Collection** Response Time

The remarkable capabilities of airborne Lidar continue to improve, with scanners now able to emit more than a million pulses every second. Although it has never been easier to acquire high-quality laser data, storing and managing the huge volume of Lidar data collected can prove to be a challenge. Combined with associated metadata such as survey information, environmental conditions and flight lines, data management has now become a critical priority and focus. This article outlines a new initiative called LMAP that provides an automated workflow for uploading and storing Lidar and metadata into GIS.

Developed in a partnership between RIEGL of Austria, a manufacturer of ultra-high-performance Lidar scanners, and the USA's Esri, Inc., creators of the ArcGIS platform, the Lidar Management and Analytical Processing (LMAP) initiative provides a new, automated workflow to upload and store Lidar and metadata into GIS. Once organised and managed using standard GIS functionality, LMAP utilises web applications to visualise the information on a map and perform a range of analysis. As a user of both RIEGL and Esri technologies, the North American geospatial-only solutions provider Quantum Spatial Inc. (QSI) decided to employ an LMAP implementation to improve project data management and provide a venue for clients to quickly and easily provide feedback on Lidar collection quality and completeness.

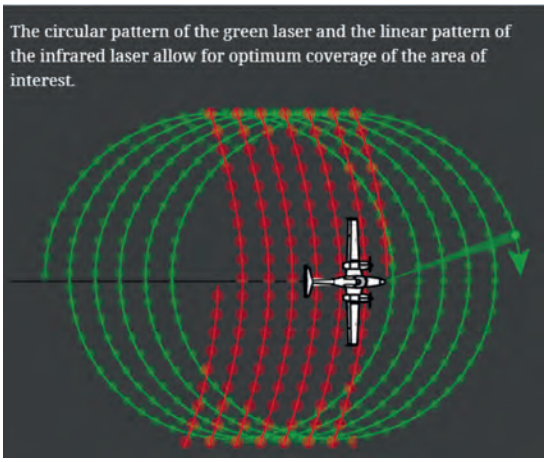
BATHYMETRIC LIDAR

Lidar is a survey measurement technique that uses light in the form of emitted laser pulses to measure ranges to the Earth, resulting in accurate three-dimensional (3D) models of Earth. These models have a wide variety of uses and applications, including in engineering, town planning, mining, archaeology, computer vision and environmental monitoring. Bathymetric Lidar is a Lidar scanning technology that penetrates the water column to measure seafloor depths. To map Chesapeake Bay in the USA for a client, QSI selected RIEGL's VQ-880-G, a fully integrated airborne scanning system for combined hydrographic and topographic surveying. Offered with an integrated GNSS/IMU system and camera, the VQ-880-G also houses both a green laser that penetrates shallow water for seafloor measurements and an infrared laser for improved capture of the water surface. The result is millions of Lidar points collected of the ground, vegetation, water surface and seafloor.

Results of a bathymetric Lidar survey are dramatically impacted by the environmental conditions at the time of acquisition, specifically water quality and turbidity. To record these conditions and to validate the Lidar, field personnel take measurements during the collection and monitor water-quality data transmitted from nearby buoys.

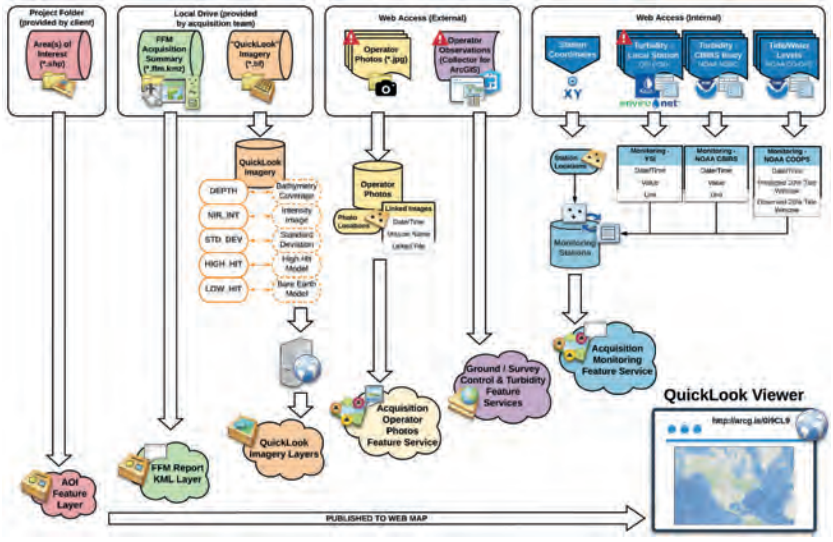
TIMELY CLIENT FEEDBACK

In February 2018, QSI collected topo-bathymetric Lidar and aerial photography over the extensive river delta regions of Chesapeake Bay within the states of Virginia and Maryland to generate improved shoreline and bathymetry data. This data provides highly accurate information of the bay's geographic features for official shoreline characterisation, nautical charting, geodesy and marine resource management assessments. Environmental factors such as water quality and weather were closely monitored to ensure data collection occurred during peak windows to guarantee the collection of the highest-quality data possible. Additional information was also collected, such as aircraft flight lines, survey ground control locations and photographs from the flight. All of this information was shared with project stakeholders in different locations using a variety of computing devices. Getting timely client feedback on the quality and acceptance of the Lidar data collected is a critical success factor in these types of projects. Long turnaround times can quickly lead to inefficient use of field teams and wasted money. Traditionally, QSI has relied on a myriad of technologies such as email, File Transfer Protocol (FTP), blogs, PDF reports, project status software and public websites in order to share data and receive client feedback. Each of these technologies have constraints and limitations including file size, data formats and bandwidth. Big data needs



▲ *Figure 1: Unique laser scanning pattern combining red and green.*

▲ *Figure 2: Data upload workflow.*



▲ *Figure 3: Workflow from source data to QuickLookViewer.*

present a growing challenge for mapping companies such as QSI and the clients it serves, especially as advances in technology generate more and more data. To address these challenges, QSI partnered with RIEGL and Esri using the Chesapeake Bay project data and workflows to discover new ways to efficiently manage large volumes of geospatial data.

WEB PORTAL PROTOTYPE

By leveraging the Esri platform and RIEGL's LMAP concept, QSI prototyped a mapping web application known as the QuickLookViewer to enable project stakeholders to make and share decisions about the quality of the collected Lidar data during the acquisition phase of projects.

This single web 'portal' provides access to preliminary Lidar data, derivatives such as the digital terrain model (DTM) and digital surface model (DSM) and all associated environmental data needed to support actionable decisions during acquisition. This has allowed QSI to replace numerous cumbersome workflows and methods.

QLV LMAP

Several products in the Esri platform were used to develop the QuickLookViewer (QLV). For example, ArcGIS PRO was used to create the Lidar-derived raster images as well as the scene layer packages, which were then organised as mosaic datasets. The project map was developed in ArcGIS Online (AGOL) and combined data layers from Collector for ArcGIS with geotagged oblique photos taken from the aircraft, project flight lines, environmental data from public websites and mosaic datasets. ArcGIS Server was used to host and publish the mosaic dataset. Finally, Web App Builder was configured to combine the AGOL project map with tools for viewing, analysing and inserting markups for feedback. Lidar point clouds were published as scene layer packages to ArcGIS Online and embedded as hyperlinks for 3D viewing in a web browser. The complete workflow from source data to QuickLookViewer is shown in Figure 3.

Esri's ArcGIS platform offers a variety of options to display and visualise 2D and 3D data including the key derivative terrain and surface models created from the bathymetric Lidar:

- 'Low Hit' or digital terrain model (DTM)
- 'High Hit' or digital surface model (DSM)
- Depth (created by subtracting the Low Hit from the High Hit) is used to represent bathymetry coverage and provide a visual representation enabling the identification of data gaps as well as a quantifiable representation of approximate depth extent.

Since these data layers are of significant importance to the client, they were made easily accessible in the QLV LMAP map interface. In addition to displaying each layer separately, a tool allowing the user to 'swipe' between any two layers created a simple way to do comparisons between layers. Since each data layer retains its intelligence (i.e. each pixel has a 'z' value), the user can click on any location and determine the depth or height above ground.

In addition to the swipe tool, several other tools were added to the web application to help the client provide feedback to QSI. These tools included:

- Draw (or mark up): The ability to mark up the map with text or symbols
- Measure: Perform both linear and area measurements, enabling easy quantification of areas of interest on the map
- Bookmarks: Enable the saving of an exact location and zoom level on the map, providing others with an easy way to revisit a view.

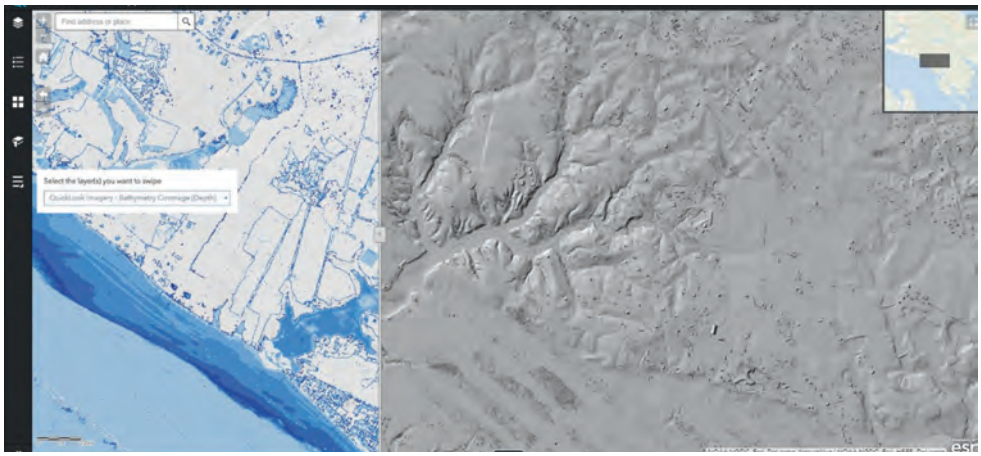
ABOUT THE AUTHORS

Cherie Jarvis is a practice lead for Quantum Spatial Inc. She provides leadership and direction to clients and technical teams on enterprise GIS solutions. She helps clients identify the best options for integrating and maintaining spatial information based on business needs, and coaches technical teams in applying agile project management methodologies throughout a project life cycle. Jarvis has been developing spatial solutions for clients for 18 years.
✉ cjarvis@quantumspatial.com

Ron Behrendt has been providing geospatial consulting services for organisations since 2005 with a focus on applying remote sensing technologies such as imagery and Lidar in combination with GIS. He provides clients with the expertise to identify useful applications, determine the appropriate manned or unmanned aircraft and sensor combinations, and develop and implement appropriate workflows ensuring maximum results. Past and present clients include Esri, RIEGL and NASA. Prior to founding Behron, he was one of the founding members and CEO of Positive Systems, an industry leader in the development and use of digital aerial photography systems.
✉ behron@centurytel.net

To enable the client to visualise the Lidar point cloud in 3D, QSI leveraged one of Esri's newest technologies: the scene layer package (SLPK). SLPK utilises the 'Indexed 3D Scene' layers (I3S) specification, an OGC community standard, and is designed to allow large 3D datasets for use in mobile, desktop and server-based workflows to be accessed over the web or as local files.

QuickLookViewer was developed by one senior GIS analyst with minimal experience in programming. The part-time development occurred over a ten-week period, with the majority of the time spent understanding the source data and required workflows to implement the final product. The development caused no disruptions to production as the majority of the input data was obtained from outputs of existing workflows.



▲ *Figure 4: Screenshot of swipe between Low Hit and Depth rasters.*

SUMMARY

The development of the Esri/RIEGL LMAP web application prototype demonstrates the viability of leveraging the ArcGIS platform to store, manage, analyse and visualise the many diverse datasets required for a bathymetric Lidar project, as demonstrated in this specific case study with QSI. Utilising a single map interface gives users the ability to easily compare and interrogate the derivatives of the Lidar data such as a depth map, review photos and water-quality information and provide collection-quality feedback to the vendor in a timely manner. The next step will be to work with the client to refine the QLV LMAP implementation and to begin deployment for day-to-day operations. ◀

MORE INFORMATION

https://bit.ly/2N7XTqt
Video: http://bit.ly/2QdGLBo

IS HIGH-DEFINITION MAPPING ENOUGH TO KEEP AUTONOMOUS VEHICLES ON TRACK?

Mapping for Autonomous Vehicles

As the fleets of self-driving cars increase, so too does the volume of high-definition mapping that is required for autonomous vehicles (AV). But what will happen when AV technology matures and the vehicles drive themselves away from these test routes? This article argues that, without increased collaboration and recognition of the evolution of traditional mapping technologies, it will take even longer until the use of autonomous vehicles extends beyond limited pre-defined routes and becomes pervasive.

The sight of an autonomous or self-driving car is becoming increasingly familiar. Both autonomous vehicles and mobile mapping vehicles alike use a collection of sensors that include cameras and laser scanners, together with sophisticated onboard computing systems, to create an instantaneous 3D picture of their surroundings. While an autonomous vehicle uses this 3D picture to navigate itself around obstacles in the road, a precursor to safe autonomous vehicle (AV) operations is that it is already loaded with high-definition (HD) map data to guide it. HD mapping companies are using mobile mapping vehicles to collect the data for these HD maps, but in many cases – due to the economics of these mapping procedures – HD mapping efforts are confined to certain cities.

HD maps are pushing the technical boundaries and scale of what has been produced before. An HD map differs significantly from both a road map as seen on a navigation device and a typical large-scale topographic map as produced by a national mapping agency. Unlike maps that incorporate various degrees of generalisation, the aim of the HD map creator is to produce a three-dimensional, digital representation of the relevant aspects of reality. In short, an HD map needs to provide the precision and comprehensiveness required for the robotic control of an AV. Not only should these maps locate the lanes on a road, but they should also make it possible to decipher how that road curves and how high the curves are. Using an HD map, the AV should know the exact position, direction and gradient of an exit ramp, for example. In addition to detailed information about the topographical structure of the roadway, HD maps also contain routing and traffic flow information. While one aim of these products is to provide data to an accuracy of up to 5cm, typical accuracy tolerances being achieved generally fall within the 7-10cm range.

CONVENTIONAL APPROACH

The conventional approach for collecting data for an HD map involves driving along streets using a mobile mapping vehicle fitted with a similar camera and similar laser scanning sensors as an AV has, along with sophisticated INS and GPS positioning systems. Keeping in mind the importance of accuracy and resolution, together with the requirement for the map to be understood by an autonomous system, an HD map's logical design takes priority over the cartographic design of the product. In theory, as the AV travels the route it also updates the HD map based on current conditions. However, not all places are currently mapped in HD. Originally as part of a research project to enable an AV to drive through the German countryside, Germany-based Here started deploying mobile mapping vehicles for HD map capture

in 2013. Firms such as Here, TomTom and, of course, Google have been driving mobile mapping vehicles along millions of kilometres of roads a year. But even at this rate, there are still many places where HD mapping data does not exist or is already outdated, and many of the areas that have been mapped are unlikely to have their mapping revised for some time. Not only does physically driving along a highway take time, but the data management and extraction procedures to produce an HD map from raw data require considerable effort too. All this means the entire HD map production process is very costly. Just a few kilometres' worth of driving by the mobile mapping vehicle will quickly amount to terabytes of raw data storage; a combination of human effort, judgement and increasingly sophisticated algorithmic processing operations are required to interpret and extract the relevant HD map features for the final product.

BUSINESS CASE RISKS

Different firms have a different focus. For example, General Motors 2017 Innovation Award-winner Ushr has mapped every 'limited-access highway' in the US and Canada. The company should be congratulated on such a mammoth undertaking, but how many public-access roads are left unmapped? Meanwhile, Google has focused on a select number of US cities for its HD mapping activities, perhaps taking the point of view that while autonomous vehicles are still in development, it is better to work with the very best HD map data – in terms of both quality and it being most up to date. With safety being the top priority, an AV needs to know not only where it is going, but also exactly where it is, continuously and under all driving conditions. It is fair to say that the first self-driving applications are more likely to be commercial fleet services such as taxi services (e.g. Uber) along pre-defined routes as opposed to consumer applications. One reason for this is the availability, quality and reliability of HD map information. Currently, the AV business case entails higher risks if the unpredictable consumer wishes to drive on a less travelled (and potentially unmapped) route.

ALTERNATIVE MAPPING METHODS

For several decades, various national mapping agencies (including some in densely populated European countries) have been

using a combination of ground survey and airborne photogrammetric methods to produce base topographic data at much higher accuracies and resolutions than regular highway maps. Deploying traditional large-format cameras entails high operating costs, but national base mapping data can be as detailed as 1:1,000 scale in urban areas and 1:2,500 scale in rural areas. The specific scale will be a consequence of the features the agency has chosen to include in its specifications. Nevertheless, while these scales exceed those of conventional highway road mapping data by a significant margin, they are still likely to fall short of what is preferred by HD map producers.

Just as autonomous vehicle technology continues to evolve, so too does aerial mapping technology. The expertise to process and interpret images to produce datasets that fulfil many HD mapping requirements already exists. Thanks to the latest medium-format cameras, high-resolution mapping projects can be completed using much smaller, more efficient single-engine aircraft or, where permitted, unmanned aerial vehicles (UAVs). These medium-format cameras can be flown at higher altitudes, maintaining the same or better ground resolution as before, and with similar ground footprints to traditional large-format mapping cameras. Using this breed of aerial cameras means that a greater range of mapping companies can now contribute to HD mapping efforts by deploying smaller, potentially cheaper aircraft platforms than were previously possible. For example, a Phase One Industrial camera can regularly collect data to a 4cm ground sampling distance (GSD) accuracy from conventional manned aerial platforms. Such cameras have already been deployed for rail network projects, collecting sub-5mm-accuracy mapping data using UAVs. With the smaller form factor of these cameras, multiple cameras can be flown at oblique orientations to the ground, and it is now possible to map 3D heights of structures and identify features such as signage. Some traditional geospatial firms have recently entered the market to provide data for HD maps using both aerial and mobile mapping methods. These pilot projects have produced excellent data for targeted areas but, since the AV development testing itself has been focused on specific locations, the pilot HD mapping projects are often not expanded.

CONCLUSION

It is understandable that there will be specific business relationships between HD mapping and AV vendors, but it seems that there is an opportunity for both mapping and AV vendor markets to grow thanks to a broadening in the types of technologies used to produce HD maps. For example, there are many smaller mapping vendors who have both the skills and the aircraft. Now, with advanced imaging equipment, they have the potential to help increase both the coverage and revision schedules of HD map data. While competition between existing HD map and autonomous vehicle partnerships is important, there should be room in the market for a wider brokerage of high-resolution base mapping data collected from both mobile and aerial sources that can then be styled and conflated in accordance with the requirements of specific vendors.

If HD mapping ventures are limited to specific pilot areas, or if only specific highways are driven with mobile mapping vehicles, then the proposition of widespread AV adoption outside of certain fleet-based applications is at risk. Without increased collaboration and recognition of the evolution of traditional mapping technologies, it will take even longer until the use of autonomous vehicles extends beyond specific areas and becomes pervasive. ◀

ABOUT THE AUTHORS

Will Tompkinson is lead consultant at Insightful Dimensions. A geographer by training, Will has spent more than 15 years working on state-of-the-art mapping projects, including in a position in R&D for Britain's National Mapping Agency. As an independent consultant, he currently advises global customers, ranging from asset owners to mapping service providers, on how to derive the greatest value from drone-based or mobile mapping systems.

Steve Cooper is VP Sales at Phase One Industrial, directing sales for the company's cameras and solutions. His extensive experience in the geomatics industry and technical understanding of advanced digital imaging help customers in wide-ranging markets – including utilities, transportation, communications and agriculture – to develop more effective ways to monitor and inspect their industrial assets.

Perhaps Nobody Knows it Yet, But Geomatics is Cool

The geospatial industry faces a major challenge: how to attract a new generation of mapping and surveying professionals. The sector is crying out for talented young individuals who are willing and able to enter the profession. But, as a quick glance at the labour market reveals, they are currently in short supply, so other measures are needed. A good starting point is to increase the industry's interaction with children in primary and secondary schools to help them see the relevance of geomatics.

If I look back on my own schooldays, geography and topography were among my favourite subjects, but as far as I can recall the teachers left us completely in the dark about the data aspect. I vaguely recollect a class in which the teacher mentioned Gerardus Mercator, but that was basically it. Very little attention was given to cartography and how map-making data is acquired – and that is a missed opportunity, in my view. I am sure that if we can make school pupils more aware of mapping the environment in all its aspects and on all its scales – let's call it increasing their 'geospatial awareness' – then we will see a steep rise in young people's interest in pursuing a career in this direction.

DYNAMIC EVOLUTION

In today's era of rapid digital advancements the new arrivals on the job market are all 'digital natives', so a lack of affinity with technology is no longer a barrier to entering the industry. Another box that can be ticked is the 'cool factor', which our sector indisputably has. Few other industries can match the dynamism seen in the evolution of geomatics over recent years. However, the geospatial industry as a whole is currently failing to convey the innovativeness and excitement of the profession and all its fields of application, meaning we are missing out on a big opportunity to energise and enthuse the younger generation. The time has come to show that land surveying no longer deserves its 'dull and boring' reputation!

TEAMING UP WITH SCHOOLS

Data that is acquired by satellites, aircraft, autonomous vehicles, drones; 3D scanning; the exciting area of Lidar and all its applications; 3D city models; the ability to overlay real-world imagery with database information; robotics, artificial intelligence and machine learning; virtual reality and the Internet of Things… this is a list of just a few of the 'cool' elements that can serve as input for 'cool' presentations and lessons. Geospatial professionals regularly hold guest lectures for university students. Couldn't (and shouldn't) that be done on a much bigger scale, and for children of a younger age? Wake up and connect with primary and secondary schools. Teaming up with schools and colleges will be worth the extra effort in the long run!

THE TIME HAS COME TO SHOW THAT LAND SURVEYING NO LONGER DESERVES ITS 'DULL AND BORING' REPUTATION!

HANDS-ON LEARNING IS FUN

One particularly innovative initiative is GeoFort, an educational geo-experience centre housed in a former defence fortress in the Netherlands. GeoFort aims to enthuse children of all ages for the geospatial world! The founders have developed educational programmes to fulfil three objectives: first and foremost a Sense of Fun, followed by a Sense of Experience and a Sense of Urgency. As Willemijn Simon van Leeuwen, one of the founders, said previously in a Q&A with *GIM International*: "We adhere to this very strictly. If the fun part is really good the children will explore very enthusiastically, which turns learning into an automatic process. A sense of urgency is very important because children are much more motivated if they see the relevance of what they are doing. At GeoFort they see a simulation of a flood and they have to make a good evacuation plan using digital maps. It's a serious business! And last but not least, learning is much easier when you experience it yourself."

▲ *Wim van Wegen.*

Couldn't this be rolled out worldwide? And shouldn't the geospatial industry take up the challenge to create more awareness of – and enthusiasm for – our beautiful profession? ◀

ABOUT THE AUTHOR

Wim van Wegen is content manager of *GIM International*. In his role, he is responsible for the print and online publications of one of the world's leading geomatics trade media brands. He is also a contributor of columns and feature articles, and often interviews renowned experts in the geospatial industry.

What's to See at Intergeo 2018?

Intergeo is commonly regarded as the main meeting place for the geospatial industry. Everyone who has attended the event before is familiar with the halls full of stands, with companies exhibiting from all over the world. It is a great opportunity to meet with decision-makers, developers and buyers, and is definitely the place to be to do new business deals and to maintain partnerships. Intergeo is also the perfect occasion to get up to speed on the latest technological developments in mapping and surveying methods and to discover new innovations for processing and using geospatial data. However, the world's largest event and communication platform for geodesy, geoinformation and land management has so much more to offer than the exhibition alone, thanks to a range of different side events that are organised in parallel with Intergeo.

One such event is **Interaerial Solutions**, the international trade show for unmanned aerial vehicles (UAVs or 'drones'). Drone manufacturers as well as drone surveying and drone inspection companies are gathering in Frankfurt to present their latest innovations and newest products. Visitors will be provided with a complete overview of the future directions of UAV technology and its applications. The increasing range of applications encompasses not only surveying, but also inspections in the agricultural, industrial and energy sectors, for example. If you keep your eyes peeled at Interaerial Solutions, you should certainly get plenty of ideas for how UAVs can help your organisation move forward.

Another side event worth mentioning is the **Smart City Solutions** forum, which is a platform encouraging dialogue between solution providers, cities and policymakers with the aim of developing cities that are a great place to live. Various keynotes will bring you up to date on the future direction of smart cities, which is no longer just a catchy buzzword but has now become a serious concept that will be adopted by thousands of cities and municipalities around the globe. Now that 5G internet is becoming the new standard, the concept is set to be rolled out in the coming years. In addition to approximately 50 presentations, another very important element of Smart City Solutions is the exhibition area, where over 70 exhibitors and partners are presenting their products and services. Participate in the forum to find answers to your strategic questions, solutions for mobility and smart grid, and products and services for the digitalisation of cities.

Intergeo clearly is more than just an exhibition; it also has a top-quality conference programme. The mix of theory and practice is what makes it the world's leading event for everyone who wants stay on top of the enormous opportunities that the geomatics profession offers society. During the **Intergeo conference**, at *GIM international* we are especially keen to highlight the conference session titled 'What's Next in Surveying and Mapping', which will be held on Thursday 18 October from 11.00 to 13.00 h at the Forum. Including speakers such as Mladen Stojic from Hexagon (discussing the smart digital reality), Gerd Hesina (talking about interacting with big geospatial data) and Pix4D's Christoph Strecha (who will share his thoughts on the impact on geospatial data of artificial intelligence and machine learning), we are sure you will not regret spending two hours of your time at Intergeo attending this session.

We wish you an enjoyable and inspiring Intergeo 2018!

INTERAERIAL SOLUTIONS
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CHC

At this year's Intergeo, CHC Navigation will be introducing a new series of innovative GNSS positioning and mapping solutions. Daily workshops will give visitors the opportunity to discuss their current projects and future requirements with CHC Navigation's application experts and local business managers.

▸ www.chcnav.com Hall 12.0, Stand B.040

ComNav

ComNav is showcasing the T30 GNSS receiver at Intergeo. As a high-performance GNSS RTK receiver, the T30 substantially minimises weight and size, combining a GNSS board, Bluetooth and adjustable TX&RX UHF, Wi-Fi and 4G modem into one rugged device for demanding surveying tasks. Its built-in tilt sensor supports maximum 30° pole tilt with 3cm compensation accuracy, and the electronic bubble can be checked on the controller for fast surveying in the field. With the advanced Quantum technology and global Beidou signal tracking capability, it remarkably improves position availability and reliability, meeting RTK survey demands even in harsh environments. Moreover, the T30 supports PPP and L-Band function, and its two 3400mAh hot-swap batteries help to extend working hours and ensure a fluent workflow in the field.

▸ www.comnavtech.com Hall: 12.1, Stand: E.001

Gexcel

Gexcel has been in the Lidar market since 2007 with the globally well-known JRC 3D Reconstructor software, compatible with and/or adopted by the main manufacturers (DotProduct, Faro, Geomax, Riegl, Stonex, SureStar, Teledyne-Optech, Topcon, Velodyne, Z+F). The latest product is HERON, the innovative professional geospatial system for mobile real-time change detection and hi-res coloured 3D mapping, with a unique automatic localisation feature. HERON successfully supports BIM 'quality-check' projects, facility management tasks, security planning, handling and logistics of bulky equipment, control of visual merchandising activities, etc. Always working in real time, HERON visualises the surveyed data on site, dramatically reducing costs and time. Another key product is Open Pit Mine Monitoring System (OPMMS), the solution for automatic and manual long-range profiling of the slopes and surfaces of open pits, currently operating with various long-range laser scanners. OPMMS continuously performs remote scanning and automatically compares the acquired scans to a reference one, detecting displacements and deformations.

▸ www.gexcel.it Hall 12.0, Stand B.055

FOIF

Founded in the beautiful Chinese city of Suzhou in 1958, FOIF has evolved over the past 60 years into a high-tech company with multiple solutions from the earlier optical field. During this time, FOIF has been constantly promoting technical reform and maintaining its competitive ability. In 2018 FOIF became one of the top 50 enterprises in China's geomatics industry. Advanced equipment is the guarantee of good products, and high-quality products ensure FOIF's strong reputation. Every production detail is the result of not only the professional technology and expertise of FOIF's employees, but also of the firm's focus on precise manufacturing, which promotes the company's continual development. FOIF supplies convenient and advanced surveying equipment as the foundation for ever-more precise and accurate surveying achievements. FOIF extends deep into the industry of precision measuring instruments and strives to pursue even more innovative and remarkable achievements, while building an internationally competitive advanced manufacturing base.

▸ www.foif.com Hall 12.0, Stand C.071

Hexagon

Hexagon is a global leader in digital solutions that create autonomous connected ecosystems (ACEs), a state where data is connected seamlessly through the convergence of the physical world with the digital, and intelligence is built in to all processes. Hexagon's industry-specific solutions leverage domain expertise in sensor technologies, software and data orchestration to create smart digital realities that improve productivity and quality across manufacturing, infrastructure, safety and mobility applications. Twitter: @HexagonAB

www.hexagon.com **Hall 12.1, Stand D.023**

Hi-Target

At Intergeo 2018, Hi-Target will present application cases at Interaerial Solutions and its full range of solutions in areas such as survey & mapping, GIS, Lidar and laser scanning, unmanned aerial vehicles and systems, hydrography and oceanology.

Live demo overview:
Tuesday, 16 October
1. SATLAB UAV mapping solutions
2. Supergeo Mobile GIS solution 1
3. Hi-Target UAV mapping solution
4. Archikart GIS solution introduction

Wednesday, 17 October
1. SATLAB mobile mapping solution
2. Hi-Target swift hydrographic survey solution
3. Supergeo Mobile GIS solution 2
4. SATLAB multi-purpose GNSS receiver

Details of live demos at Intergeo can be found via Hi-Target's Facebook and Twitter accounts.

http://en.hi-target.com.cn/ **Hall 12.1, Stand C.086**

MGGP Aero

MGGP Aero delivers state-of-the-art mapping, Lidar, geovisualisation and 3D mesh solutions for customers in Europe. It innovates in the growing geospatial industry, operating a fleet of aircraft armed with more than 30 sensors. MGGP Aero specialises in orthophotography, Lidar, oblique imagery, 3D mesh modelling and hyperspectral and visualisation web services for any kind of geospatial data. The company is constantly expanding its international reach and is looking to establish successful partnerships around Europe and beyond. Specialised corridor mapping and utility management services are provided by VIMAP, part of the MGGP Group of companies. Visual inspection, detailed oblique photography and collection of 3D Lidar point clouds are combined in a single helicopter flight to maximise efficiency. Actionable asset condition reports, engineering models and data analysis are then delivered in the company's dedicated, comprehensive software. MGGP Aero is able to provide critical insight for all linear assets including electricity, gas, roads and railways.

www.mggpaero.com **Hall 12.1, Stand H.084**

MicroSurvey

MicroSurvey will be holding a technology showcase at Intergeo demonstrating its next-generation FieldGenius for Android products, along with the latest innovations in its STAR*NET and MicroSurvey CAD products. MicroSurvey Software has been developing complete software solutions for surveying and forensic mapping since 1985. Specialising in the development of industry-specific solutions, MicroSurvey produces mobile software for use with total stations and GPS, as well as a full compliment of desktop solutions to increase efficiency and productivity in the office. From single-user applications to countrywide government implementations, MicroSurvey solutions are used around the globe for land surveying, engineering, mapping, law enforcement, forensic and accident reconstruction. MicroSurvey can be found at the Hexagon stand.

www.microsurvey.com **Hall 12.1, Stand D.023**

Myzox

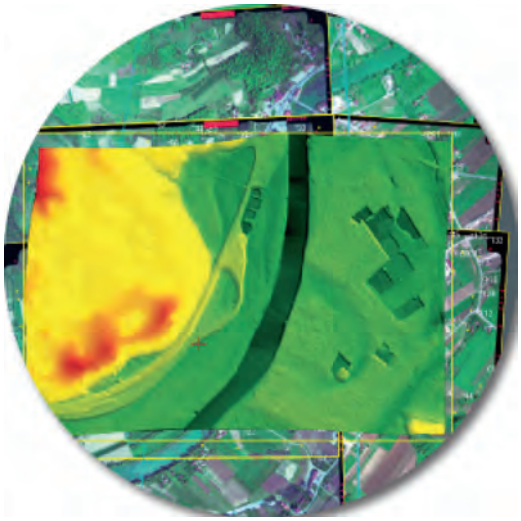
Myzox has been a professional manufacturer of surveying accessories for nearly 60 years. At Intergeo 2018, the company will be showing its latest product lineups, including 1) the Z-220P, a very compact wide-angle prism for robotic total stations, 2) the Myzox monitoring prism lineup that covers a wide variety of styles in displacement measuring, and 3) its brand-new customisable drones that will soon offer solutions to various industries such as agriculture, logistics and construction.

www.myzoxjapan.com **Hall 12.1, Stand A.065**

Racurs

It is almost hard to believe that Racurs has been doing the same work for 25 years: the development and use of photogrammetric technologies. Since its creation in 1993, the company has developed innovative digital mapping software for processing aerial, space and terrestrial imagery trading known as PHOTOMOD. Today, PHOTOMOD is the most popular digital photogrammetric software in Russia and is also used in 80 countries all over the world. Racurs is proud of its history, but still considers itself to be a developing and active company that is looking forward to the future and to new developments. Visitors to the Racurs stand can receive a special discount on a PHOTOMOD purchase and upgrade.

www.racurs.ru **Hall 12.1, Stand G.072**



RIEGL

RIEGL provides the latest Waveform-Lidar technology necessary to satisfy customer expectations. Celebrating 40 years in 2018, RIEGL will present the latest advancements in terrestrial, mobile, airborne, and unmanned laser scanning at Intergeo 2018. Visitors can see the latest additions to the company's portfolio of high-end sensors and systems, including the RIEGL miniVUX-1UAV with Integration Kit 600 for quick and smooth integration with a multi-rotor UAV, and find the perfect solution for them and their business. They can also meet with the international team of experts and network with the worldwide RIEGL community.

www.riegl.com **Hall 12.0, Stand C.080**

SBG Systems

SBG Systems designs, manufactures and markets real-time and post-processing motion and navigation solutions for mobile mapping as well as hydrography. At Intergeo, the company will present its new post-processing software with a live demonstration at 11:00h (every day) as well as at 15:00h (on Tuesday and Wednesday). SBG Systems has also released a new version of the Ellipse2-D, a compact inertial navigation system with integrated dual-antenna survey-grade RTK GNSS receiver for accurate heading and position. It provides roll, pitch, heading, velocity and position in real time and post-processing, making it ideal for mobile mapping whether air or land-based. The new Ellipse2-D benefits from major improvements such as lower power and full GNSS coverage (GPS, GLONASS, Beidou and Galileo are used simultaneously), offering a very good price/performance ratio.

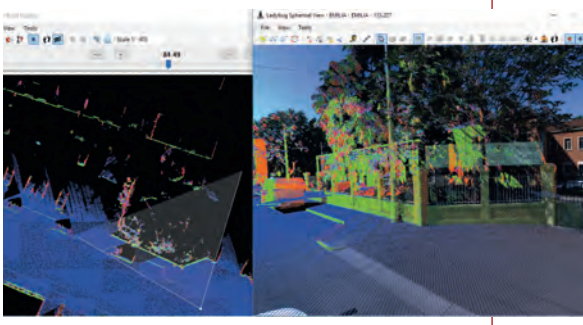
www.sbg-systems.com **Hall 12.1, Stand D.018**

senseFly

The eBee X is the fixed-wing drone for all mapping needs. It suits every job thanks to its range of groundbreaking cameras. These include the new senseFly S.O.D.A. 3D, for stunning 3D reconstructions of vertical environments such as urban centres, mines and coastlines, the best-in-class senseFly Aeria X RGB photogrammetry camera, and the senseFly Duet T for creating geoaccurate thermal maps. The eBee X can meet the exacting requirements of every project. Its unique Endurance Extension unlocks a flight time of up to 90 minutes – for vast coverage of up to 500ha (1,235 acres) at 122m (400ft) – while its high-precision on demand (RTK/PPK) helps to achieve absolute accuracy of down to 3cm (1.2in), without GCPs. The eBee X also allows professionals to work at virtually every site, no matter how demanding, thanks to its Steep Landing technology, ultra-robust design, live air-traffic data and more.

www.sensefly.com **Hall 12.0, Stand C.058**

SITECO



At Intergeo 2018, SITECO Informatica will present its mobile mapping system Road-Scanner Compact (RS-C), promoted with FARO, a world-leading 3D technology manufacturer. Applied for mapping/high-grade surveying, inventories and facility/infrastructure management, the RS-C is powerful, portable and self-calibrating, and suitable for any company that wants to increase productivity by 10-20 times. The equipment includes Faro laser scanners, high-accuracy INS and spherical camera. In an exclusive feature, the laser scanners are detachable and usable as stand-alone 3D scanners.

The RS-C is supplied with Road-SIT Survey software for feature extraction and imagery/point cloud management. The new release 7.0 provides strongly enhanced features to exploit data collected with Road-Scanner or any MMSs (e.g. RIEGL, Optech, Trimble or Leica) much more efficiently. The cutting-edge enhancements include calculation of normals and curvatures, a feature for providing the point cloud geometric information (edge detection and automatic processing of point clouds), semantic classification through a powerful deep-learning neural network, and object detection. Features have been also included for exporting data to other known applications like Topodot and Orbit.

www.sitecoinf.it **Hall 12.0, Stand B.073**

SOUTH

Ranking No. 1 among the top 100 enterprises in China's geoinformation industry, South Survey continues its efforts and explorations in delivering various affordable survey equipment and GIS solutions. Apart from the conventional instruments like GNSS RTK, total stations and so on, the dynamic team is committed to the new sectors of global geospatial society, such as UAV aerial photogrammetry, mobile 3D laser scanning, GIS handheld survey solutions, one-map web-GIS solutions, field-to-office data engineering services, etc. Based on its extraordinary manufacturing capabilities and years of experience in GIS development, the desire for business transformation and upgrade has motivated the Chinese giant to break through for the ever-evolving needs of mass data volume, dynamic dataflow, image presentation and multi-dimensionality. South's centimetre-level accuracy GNSS RTK with PPP methodology, new-type theodolite that can measure distance simultaneously, professional mapping drones with surveyor-oriented flight planning software, multi-platform Lidar solutions and all other new tools and kits will be on display at Intergeo this year.

www.southinstrument.com **Hall 12.0, Stand C.049 and D.058**

Teledyne Optech

Teledyne Optech has been pioneering the design and manufacture of advanced Lidar systems for over 40 years. Widely recognised for its technological depth, the company has decades of experience in Lidar, photogrammetry, GPS integration and waveform digitisation. The firm's impressive airborne solutions include the Galaxy PRIME, which boasts improved altitude performance and a 1MHz measurement rate, packing more power and accuracy than any other sensor. The autonomous Eclipse reduces overhead costs by eliminating the in-air operator, while the multispectral Titan offers simultaneous topo/bathy surveying and the CZMIL Nova collects bathymetric data at unparalleled depths. On the ground, the user-friendly Polaris TLS has an upgraded 2,000m maximum range, the Lynx mobile survey system collects dense and accurate data at highway speeds, and the ultra-light Maverick mobile mapping system can be used virtually anywhere. Visitors to the stand at Intergeo can learn how Teledyne Optech's Lidar solutions increase productivity for all their operations.

www.teledyneoptech.com **Hall 12.0, Stand C.048**

Tersus GNSS

The Tersus David is a cost-efficient, palm-sized GNSS receiver designed for surveying UAVs, AGVs and agricultural applications. Working with an external GNSS antenna, the free Tersus Survey App and post-processing software, the David GNSS receiver is a low-cost solution for all survey applications, including real-time RTK positioning and data collection for PPK. A 4GB in-built memory makes it easy to save data for post-processing. The compact size, IP67-rated enclosure and external Bluetooth module alleviate most of the inconveniences encountered in fieldwork.

www.tersus-gnss.com **Hall 12.0, Stand D.071**

Zoller + Fröhlich

The Z+F IMAGER 5016 is equipped with an integrated HDR camera, internal lighting as well as an indoor/outdoor positioning system for automatic, targetless registration – already proven from the Z+F IMAGER 5010X and Z+F IMAGER 5010C. It combines compact and lightweight design with state-of-the-art laser scanning technology – allowing the user to reach new levels. However, all components have been further developed and adjusted to the new design, resulting in even better scanning results and a more efficient workflow.

www.zf-laser.com **Hall 12.1, Stand A.001**

How Can We Attract Students to Geomatics?

Outside of our community, and arguably even within our wider community, the term 'geomatics' is unfamiliar and ill defined. More common in North America than in many parts of Europe, geomatics can be said to refer to the measurement and analysis of the properties of the Earth. Planetary scientists might argue that geomatics could equally refer to the measurement of other planetary surfaces. Some may argue in favour of a more comprehensive definition, while many in the community may reject the term entirely. If we as a community can't adopt a common terminology with common definitions and communicate that effectively, then how can we expect to engage with the public, decision-makers and future students? How can we attract new talent?

We can start by reminding ourselves that geomatics, or 'geographic information science' (GIS) if you prefer, exists within the Science, Technology, Engineering and Mathematics (STEM) framework. STEM is acknowledged to be fundamental to a knowledge economy. Everything from disruptive technologies (e.g. self-driving cars and e-payments) to sustainable living (e.g. fossil-free fuels and Blue Growth) requires a dynamic and STEM-educated workforce. The above-mentioned examples also require geomatics-related capabilities to greater or lesser degrees. Geomatics is a STEM subject, and students are increasingly aware that STEM-related jobs have a bright future with good prospects for career development and decent remuneration. We need to promote geomatics as STEM; we can then leverage the resources promoting STEM learning to encourage the uptake of geomatics education.

There is also much we can do ourselves, of course. We can encourage students at undergraduate level to develop skill sets that include numerical skills and technological skills. GIS is central to how we teach geography and related sciences in both the Science and Social Science faculties. Many students will have had a taste of GIS prior to university. We can emphasise that spatial analysis requires particular methods and tools. We can highlight the role geomatics plays in everything from planning fieldwork to producing maps, and modelling patterns in the landscape or populations. Big data and artificial intelligence (AI) have become popular buzzwords that border on clichés, but they are two technologies that will be deployed to address some of the pressing problems facing society and industry. Weather forecasting has used big data, quietly, for decades. Everything from agri-business/precision-farming and flood forecasting to global freight planning may reasonably be using big geodata in the near future, if not already. Generating data, analysis and services will require a mix of skill sets that includes geomatics expertise.

At our institution in Stockholm, we manage class sizes to maintain good staff-student ratios and to enable us to utilise well-equipped computer labs with professional software from leading vendors. We offer courses that deliver different levels of specialisation to enable students to meet their various needs, and we offer these across educational programmes rather than just to our specialists. Other programmes deploy their own geomatics teaching, tailored to meet their particular goals and reflecting how a mix of skills, including geomatics, can meet a broad range of user and employer needs. We emphasise that our students will develop a skill set that will allow them to perform well in the workplace after graduation, and we assign considerable time to working in the computer lab. We also give them ample opportunities to hone their capabilities for group work and individual project work.

▲ *Ian Brown.*

Today's students are unequivocally aware of the competitive labour market and they want skills that employers are demanding. Addressing this is key to successful recruitment and to providing employers with a workforce that meets their needs and tackles the challenges society faces. That in turn requires the development of geomatics skills at all levels of education and the provision of life-long learning opportunities. ◀

ABOUT THE AUTHOR

Ian Brown is a senior lecturer at Stockholm University in Sweden where he runs a master's programme in geomatics. He is an associate professor in Earth observation. Ian's research focuses on the use of geodata for environmental and climate monitoring. He is active in public outreach, including developing geomatics materials for use in schools.

Geospatial Information for a Smarter Life and Environmental Resilience

The FIG Working Week is an exciting week-long conference that brings the international community of surveying and spatial professionals together to discuss key challenges of our time within the wider surveying profession with fellow peers. FIG Working Week 2019 will be held in Hanoi, Vietnam, from 22-26 April 2019.

Few countries in the world have had such a rapid development as Vietnam over recent decades. Hanoi, the venue for the FIG Working Week, has grown extremely quickly during this time. This urban transition puts intense pressure on the city in terms of keeping pace with rising demands for transport, infrastructure, social services, housing, environmental controls, data management and public amenities. Further to this development, Vietnam is considered as one of the countries most affected by climate change. Hanoi is particularly at risk, as it is situated in a low-lying area near the mouth of a major and unpredictable river.

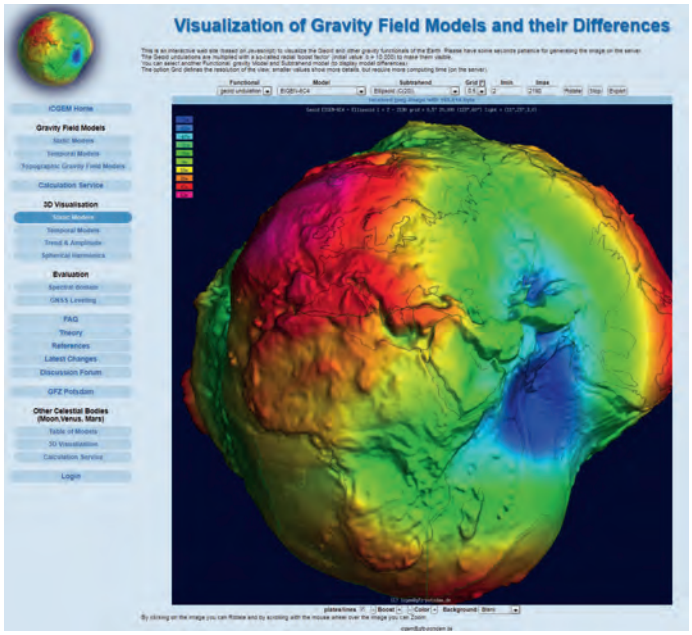
Addressing these challenges is crucial not only in Vietnam, but all over the world. Smart living is a major key in the fight against climate change. The FIG Working Week will focus on tackling climate change by working towards a smarter life, both through the development of smart cities and also in rural areas. Spatial information, big data, surveying, BIM, land administration and much more are essential factors in this development. The International Federation of Surveyors (FIG) and the local host, the Vietnam Association of Geodesy - Cartography - Remote Sensing (VGCR), have therefore decided that the theme for the Working Week 2019 will be 'Geospatial information for a smarter life and environmental resilience'.

FIG and VGCR invite high-quality contributions from researchers and practitioners within the above-mentioned topics.

Deadline for abstracts for regular and short presentations: 1 November 2018

More information
www.fig.net/fig2019

International Centre for Global Earth Models (ICGEM)



The geoid computed from the EIGEN-6C4 model using the ICGEM visualisation.

The determination of the Earth's gravity field is one of the main tasks of geodesy. With the accurate satellite measurements as products of today's advancing technology, it is now possible to represent Earth's global gravity field and its variations with better spatial and temporal resolutions. The computation of geoid and other functionals of the gravity field from the model representation is not only of interest for geodesy, but also for other geosciences.

The International Centre for Global Earth Models (ICGEM) provides essential services, such as maintaining access to the global models as well as calculation and visualisation services for the gravity field functionals and their variations. The ICGEM provides a web-based service that includes:

- collecting and long-term archiving of existing global gravity field models and

solutions from dedicated time periods (e.g. monthly GRACE models) and making them available in a standardised format

- providing Digital Object Identifiers (DOI) to the models, i.e. to the dataset of coefficients
- an interactive visualisation of the models (geoid undulations and gravity anomalies)
- a web interface for the calculation of gravity field functionals from the spherical harmonic models on user-selectable grids
- an ICGEM web-based discussion forum
- a comparison of the models in the spectral domain and with reference to GNSS/levelling-derived geoid values
- the visualisation of surface spherical harmonics as tutorials.

In order for users to benefit from the current ICGEM products and the upcoming GRACE-FO mission products, in May 2017 ICGEM launched a new website designed to improve the user experience with the service outcomes. A screenshot of the 3D visualisation of the well-known 'Potsdam potato' presented on the new website is shown on the previous page. The components of the new website are listed on the left-hand side of the screenshot.
ICGEM continues to offer free access to global gravity field models, derived products and tutorials. It is a platform for both experts and young scientists, and is widely used in the fields of geodesy, geophysics, oceanography and other geospatial disciplines. Franz Barthelmes, the long-time director of the ICGEM service, retired on 31 December 2017. Elmas Sinem Ince has since been appointed as the new director.

More information
www.iag-aig.org
http://icgem.gfz-potsdam.de/home

Spanning the Globe (Part 2)

The last ICA column in *GIM International* highlighted two separate conferences spanning the globe in September 2018 (in London and Wellington). Other ICA activities have a long history of actual global integration. The ICA Commission on GI and Sustainability encourages uniform actions (projects, conferences, engagement of experts) directed towards the sustainable development of territories, and highlights the vital role of cartography and GIS in such endeavours. One major activity has been delivery of an extraordinary series of international workshops and summer schools on GIS and cartography titled InterCarto/InterGIS, on an annual basis, organised primarily by Professor Vladimir Tikunov of Moscow State University. From the initial conference in Moscow in 1994, subsequent meetings have been held in various cities around the vast Russian nation until InterCarto 8 which was a two-site event, in Helsinki and St. Petersburg. Into the 21st century the multiple venues became more global, with a Russian site aligned to locations in Ukraine, China, Hungary, Canada, Belgium, Austria, Indonesia, France and Colombia. From 2014 there was an extension to a three-site conference (e.g. Belgorod, Kharkov and Kigali), with locations in Fiji, Australia, New Zealand and Alaska joining the roster recently. The 2018 InterCarto/InterGIS meeting took place in July in Petrozavodsk (Republic of Karelia, Russia) and Bonn (Germany). Preparations for the 2019 meeting are already being initiated in the city of Murmansk, which will be a bracing venue in February!
The organisation and delivery of these

Opening session of InterCarto-InterGIS-20 (Kigali, Uganda), 2014.

meetings has been a wonderful achievement by this ICA Commission, and a large number of eminent cartographers have assisted Prof Tikunov in delivering an insight into the role of cartography and GIS in development around the world. The working languages of these cosmopolitan conferences are the six official UN languages, so participation is an excellent opportunity to integrate with practitioners and researchers from around the world.

Associated with many of these conferences has been the organisation of schools of young scientists presenting educational and training workshops for students, and occasional interaction between the Commission and CODATA conferences organised by ICSU. These all further promote the important role of GIS and cartography in fostering global sustainable development.

More information
www.susgis.net
http://susgis.net/Infoletter_Intercarto_2018.pdf
http://www.intercarto24.net/

Invitation to Participate in the ISPRS Geospatial Week 2019

ISPRS warmly invites readers of *GIM International* to participate in the Geospatial Week 2019, which will take place at the campus of the University of Twente in Enschede, The Netherlands, from 10-14 June 2019.
Over 30 working groups have expressed their interest to jointly convene their workshops at the Geospatial Week 2019. As a result, the event is proud to be hosting the following 13 workshops:

- International Conference on Unmanned Aerial Vehicles in Geomatics (UAV-g)
- Laser scanning
- International Symposium on Spatial Data Quality (ISSDQ)
- Indoor 3D
- Advanced Geospatial Applications for Smart Cities and Regions (SmartGeoApps)
- Semantic Scene Analysis and 3D Reconstruction from Images and Image Sequences (Semantics3D)
- International Workshop on Advances in SAR: Constellations, Signal Processing and Applications (SarCon)
- Workshop on Collaborative Crowdsourced Cloud Mapping and Geospatial Big Data (C3M&GBD)
- Joint European Calibration and Orientation Workshop and Workshop on Multi-sensor Systems for 3D Mapping and Navigation (EuroCOW-M3DMaN)
- Hyperspectral Sensing meets Machine Learning and Pattern Analysis (HyperMLPA)
- International Workshop on Image and Data Fusion (IWIDF)
- Workshop on Planetary Remote Sensing and Mapping (PRSM)
- Workshop on Cryosphere and Hydrosphere for Global Change Studies (CHGCS)

Many of these workshops are the next edition in a well-established series of workshops convened in the past. The workshops will provide excellent opportunities to present and discuss the latest scientific developments in all ISPRS fields.
For further information on the dates and terms of references of the workshops, paper submission, registration, exhibition, travel and accommodation, please see the Geospatial Week 2019 website.

George Vosselman
Director of Geospatial Week

More information
http://www.gsw2019.org/

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Visit us at INTERGEO with our partners from Teledyne Optech, booth 12.0C.048.

For more geospatial solutions,
go to www.teledynecaris.com

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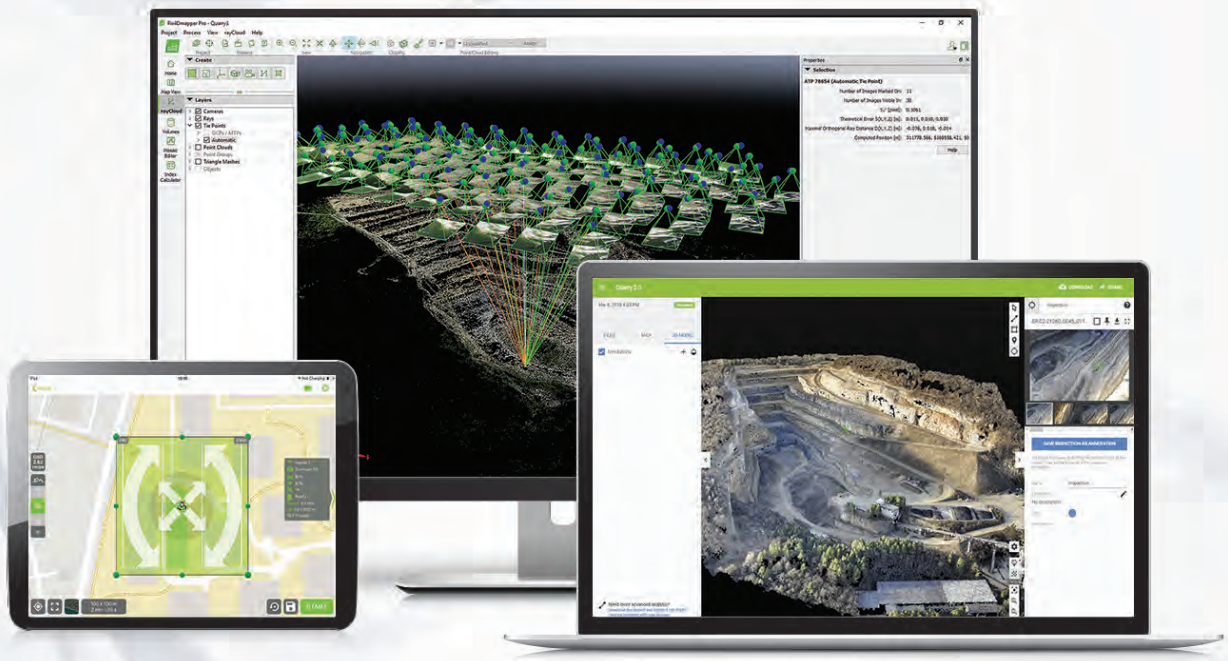

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