GIM INTERNATIONAL

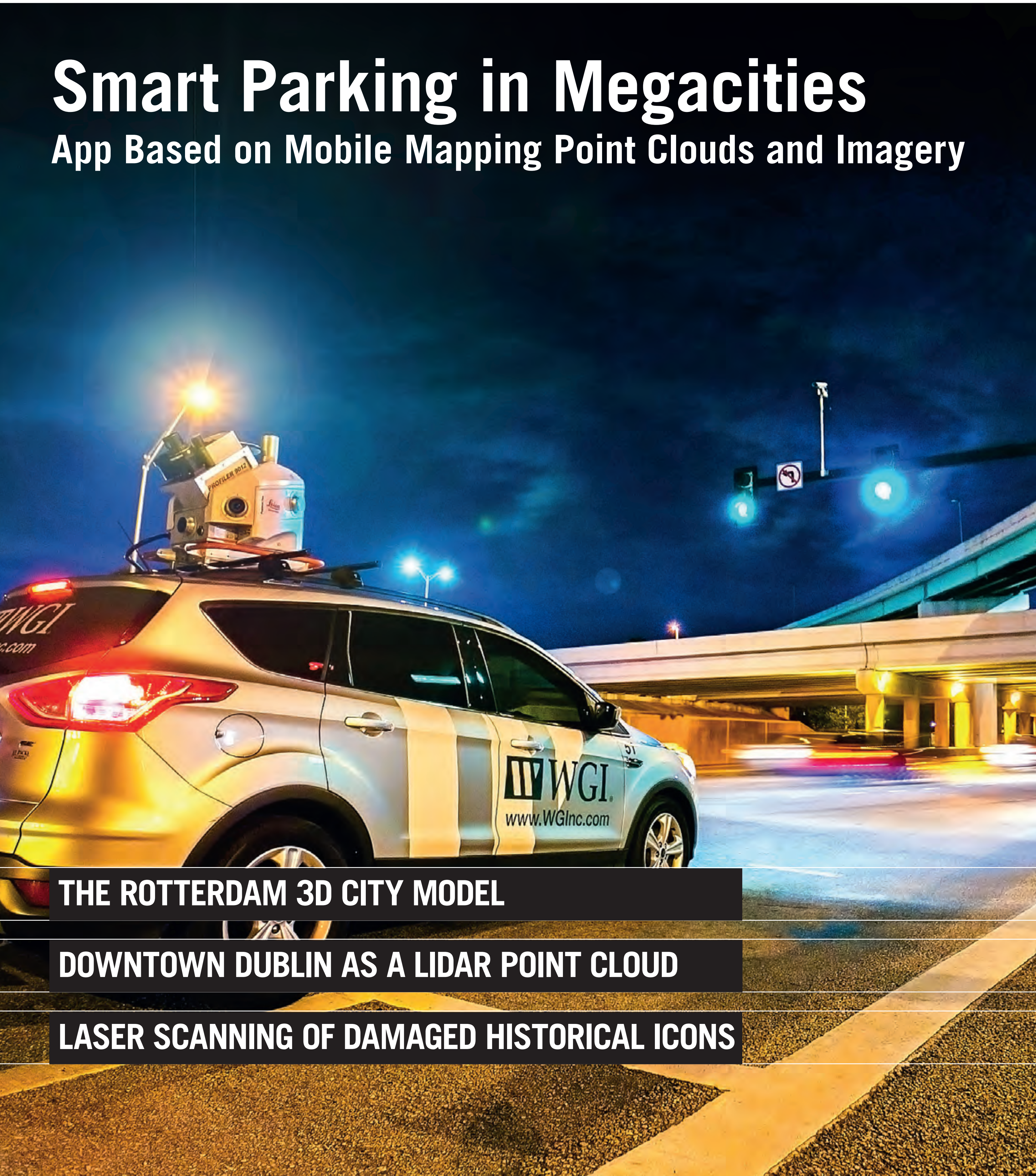
THE GLOBAL MAGAZINE FOR GEOMATICS
WWW.GIM-INTERNATIONAL.COM

geomares

ISSUE 6 • VOLUME 33 • NOVEMBER/DECEMBER 2019

Smart Parking in Megacities

App Based on Mobile Mapping Point Clouds and Imagery



THE ROTTERDAM 3D CITY MODEL

DOWNTOWN DUBLIN AS A LIDAR POINT CLOUD

LASER SCANNING OF DAMAGED HISTORICAL ICONS

TESTED AND APPROVED

Al Banks - Director/Senior Site Engineer at Banks Engineering And Management Ltd. United Kingdom
"As a FOCUS 35 user for some time I have been impressed on numerous occasions when it has out performed colleagues instruments, from other manufacturers, in terms of holding lock, speed of prism acquisition and resistance to inclement weather. The Survey Pro software is a great value as it isn't cluttered with unnecessary gimmicks for which I have no use (but otherwise have to pay for)!."

Florent Morellet - Surveyor at Urbis Foncier Bordeaux - France
"We have been using Spectra Geospatial Robotic Total stations for a few years now we particularly appreciate : the simplicity and efficiency of the prism searching and tracking system, the precision of angular aiming, securely maintained by the automatic locking of the axes, which protects your measurements from any unintentional movements and the possibility to switch over between reflector mode and reflectorless laser mode is very simple."

Armando Ortega - Municipal Surveyor at SAPASA S.A. de C.V. Atizapán de Zaragoza - Mexico
"The FOCUS 35 is bringing us more business. We are now asked to help other surrounding offices to complete their jobs. Much quicker, larger government agencies have asked us to step in and help with projects."

FOCUS 35, SIMPLY RELIABLE, EFFICIENT AND AFFORDABLE

SPECTRA® GEOSPATIAL

Learn more at spectrageospatial.com

GIM INTERNATIONAL

DIRECTOR STRATEGY & BUSINESS DEVELOPMENT
Durk Haarsma
FINANCIAL DIRECTOR Meine van der Bijl
SENIOR EDITOR Dr Ir. Mathias Lemmens
CONTRIBUTING EDITORS Dr Rohan Bennett, Huibert-Jan Lekkerkerk, Frédérique Coumans, Ian Dowman
CONTENT MANAGER Wim van Wegen
COPY-EDITORS Lynn Radford, Englishproof.nl
MARKETING ADVISOR Sybout Wijma
PRODUCTION MANAGER Myrthe van der Schuit
CIRCULATION MANAGER Adrian Holland
DESIGN ZeeDesign, Witmarsum, www.zeedesign.nl

GIM INTERNATIONAL
GIM International, the global magazine for geomatics, is published bimonthly by Geomares. The magazine and related e-newsletter provide topical overviews and accurately presents the latest news in geomatics, all around the world. *GIM International* is orientated towards a professional and managerial readership, those leading decision making, and has a worldwide circulation.

SUBSCRIPTIONS
GIM International is available bimonthly on a subscription basis. Geospatial professionals can subscribe at any time via https://www.gim-international.com/subscribe/print. Subscriptions will be automatically renewed upon expiry, unless Geomares receives written notification of cancellation at least 60 days before expiry date.

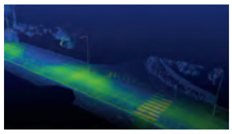
ADVERTISEMENTS
Information about advertising and deadlines are available in the Media Planner. For more information please contact our marketing advisor: sybout.wijma@geomares.nl.

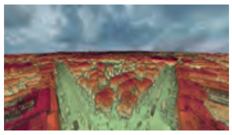
EDITORIAL CONTRIBUTIONS
All material submitted to Geomares and relating to *GIM International* will be treated as unconditionally assigned for publication under copyright subject to the editor's unrestricted right to edit and offer editorial comment. Geomares assumes no responsibility for unsolicited material or for the accuracy of information thus received. Geomares assumes, in addition, no obligation to return material if not explicitly requested. Contributions must be sent for the attention of the content manager: wim.van.wegen@geomares.nl.

geomares

Geomares
P.O. Box 112, 8530 AC Lemmer,
The Netherlands
T: +31 (0) 514-56 18 54
F: +31 (0) 514-56 38 98
gim-international@geomares.nl
www.gim-international.com

 ISSN 1566-9076





COVER STORY
Mobile mapping systems are employed to acquire high-definition mapping data of the environment. The demand for 3D maps of cities and road networks is steadily increasing and mobile mapping systems are often the preferred acquisition method for capturing scenes. [Image courtesy: WGI (West Palm Beach, FL, USA) – www.wginc.com]

To subscribe to **GIM International** *go to*
www.gim-international.com/subscribe

SOUTH Surveying & Mapping

E-mail: mail@southsurvey.com
www.southinstrument.com www.southsurvey.com

3D manager

"A land surveyor is a professional who determines positions on or near the Earth's surface," states Wikipedia. According to this definition, the surveyor's work is quite constrained, but we all know that the tasks and responsibilities of the surveyor now extend to so many more fields than merely 'determining positions on or near the surface of the Earth'. To express the core tasks of a surveyor more accurately, it would be a good idea to change the job title from 'surveyor' to '3D manager'. The surveyor of yesteryear is now managing the 3D model of reality – which is indeed linked to the Earth's coordinates – for many purposes. Needless to say, one of the most common application areas of surveying these days is construction. People not only want to know where a building is located, but also how it fits into its environment – both aesthetically and economically. After all, much of the value ultimately depends on the combination of the building itself and the location. Mining, cultural heritage and even precision agriculture are other areas where the 3D model plays an equally big or sometimes even bigger role than positioning. In fact, the term '3D' might well occur more often than the word 'surveyor' in this issue of *GIM International*.

I haven't counted it, and I don't expect you to either, but there's no denying that the function of the surveyor's role is changing rapidly – and therefore the definition should too.

Durk Haarsma,
director strategy & business development

durk.haarsma@geomares.nl

Geospatial surveying in the 2020s

By the time this issue of *GIM International* lands on your desk – or, if you are a digital reader, on your screen – we will almost have reached the end of 2019. That means 2020 – a new decade! – is about to start. It's hard to believe that it has been 20 years since the millennium bug crisis. If you're a millennial you might not even have heard of the millennium bug. To cut a long story short, it turned out to be a lot of fuss about almost nothing. The digital age was still in its infancy. Now, with the first 20 years of the 21st century behind us, we are facing challenges of a different nature. The ruthless way humans are treating Planet Earth is not without consequences. The ominous prophecies have almost become so omnipresent that there is a danger they will fall on deaf ears. But an overwhelming majority of the scientists confirm that we ignore the warnings at our own risk. We only have to open our eyes to already see signs of global warming and climate change. Over the next few decades, the rising sea level is predicted to threaten areas where hundreds of millions of people live. Megacities are at serious risk of flooding unless costly flood defence systems are constructed. Meanwhile, out of all the ways climate change can cause damage, drought should perhaps be people's biggest concern. Yet there is still reason for hope and optimism; besides adapting our way of life, we can use technology to help us in this race against the clock to (literally) turn the tide. And geospatial technology can play a role too – in terms of accomplishing the climate goals, mitigating climate change and dealing with the effects caused by global warming. In 2020, we will continue to bring you the latest need-to-know and sometimes also nice-to-know information relating to the surveying profession. The majority of our articles are inevitably linked to the challenges of our time. Photogrammetry, UAVs, point clouds, mobile mapping, 3D modelling, Lidar, land administration, urban planning, Earth observation… all these topics will be extensively covered throughout the coming year, and often in the context of the 17 Sustainable Development Goals. As we enter the new decade, we hope *GIM International* will remain a valued and inspiring guide for geospatial professionals. We are always open for new ideas from your side, and that won't change in the new decade, so feel free to send me a message anytime (including when you notice a bug!).

Wim van Wegen,
content manager

wim.van.wegen@geomares.nl

Semantic enrichment

This issue focuses on laser scanning. Terrestrial laser scanning (TLS) has come a long way since its emergence in the late 1980s. Point density, the speed of capturing and accuracy have all greatly increased, while purchasing and maintenance costs, size and weight have gradually decreased. TLS is increasingly the preferred method for the 3D documentation of historical buildings. Mobile mapping systems (MMSs) – which combine laser scanning and photogrammetry in one device – became operational for 3D mapping of road scenes around 2003. Today, they produce thousands of points per cubic metre. However, continuous and reliable high-accuracy MMS surveying in cities is challenged by GNSS signal blockages and multipath, which can only be resolved by high-performance inertial measurement units (IMUs) and sufficient ground control points. 3D mapping from MMS data is also labour intensive, so the demand for automated methods is high. Based on the achievements of artificial intelligence, researchers are investigating machine learning methods for automated 3D mapping. The most popular method is deep learning using convolutional neural networks. Although successes are claimed, there are issues with the complexity of outdoor scenes. One of the major challenges is occlusion; cars and other irrelevant objects in the line of sight block the view of relevant objects. Many algorithms have been developed to eliminate occlusion. They are implicitly based on assuming that the occluded areas show similar characteristics to their visible vicinity. Tobler's law – "Everything is related to everything else, but near things are more related than distant things" – is valid in many cases. However, one may not rely on its ubiquitous validity. The use of algorithms to invent data which is then presented as original data is 'cheating' and a surveyor sin of the first kind. The thought that automated classification of point clouds – today we could perhaps better say 'semantic enrichment' – could be at all difficult does not get through to those who have never tried it. It turns out to be an elusive problem.

Mathias Lemmens, senior editor
m.j.p.m.lemmens@tudelft.nl

New Platform Connects Construction and Surveying Professionals

Publishing company Geomares, the name behind the leading international magazines *GIM International* and *Hydro International* for geospatial and hydrographic surveying professionals, is now expanding its activities with the launch of '*Geo4Construction*'. This new online platform brings together construction engineers and geospatial professionals in order to disseminate surveying knowledge in the Architecture, Engineering & Construction (AEC) industry and pave the way for the digital future. "The use of geospatial technologies such as photogrammetry and Lidar as well as mapping methods such as aerial and terrestrial laser scanning is growing all the time in the AEC sector," explains Wim van Wegen, content manager of *Geo4Construction*. "This is leading to a rising demand for relevant knowledge in that industry. As a reliable source of surveying and geospatial information and inspiration, *Geo4Construction* helps AEC professionals develop the skills they need to deliver maximum value in the 3D environment," he adds.

▸ **https://bit.ly/2OxcGzi**

Vexcel Imaging Launches European Aerial Image Library

▲ ***Vexcel aerial imagery of Munich, Germany.***

Vexcel Imaging, a leading provider of aerial camera systems, mobile mapping platforms and fully integrated photogrammetry software, is launching one of Europe's highest-quality and most up-to-date aerial image libraries. Starting in Germany, the cloud-based image library enables companies, public safety organizations and government agencies to save a significant amount of time and money. They will now find it quicker and easier to acquire up-to-date, concise and high-definition imagery and to leverage it organization-wide into critical location intelligence. "Acquiring current, accurate and useful imagery is a time-consuming and expensive challenge for organizations of all shapes and sizes across the globe," said Alexander Wiechert, CEO of Vexcel Imaging. "Our goal is to solve this issue by making efficient acquisition of current imagery possible at anytime, anywhere. We've already seen strong success in pilot programmes leveraging the imagery for state and local governments in the United States and Australia, and are excited to see how this library will further impact outcomes for other industries moving forward."

▸ **https://bit.ly/314Yxw5**

DJI and Delair Announce Visual Data Collection Partnership

▲ ***Mapping with a DJI drone.***

DJI, a global leader in civilian drones and aerial imaging technology, and Delair, a leading provider of visual data management solutions for enterprise, are partnering up to collaborate on enhanced and integrated solutions for visual data collection and analysis for businesses. The partnership will include an agreement for Delair to sell DJI products through its worldwide sales channel, along with launching a relationship to build compatibility across platforms. The partnership builds on the two companies' success in the enterprise market, and firmly establishes Delair as a leading provider of complete, end-to-end visual intelligence solutions. DJI unmanned aerial vehicles (UAVs or 'drones') are the most deployed drone hardware for enterprises today, and this partnership facilitates the accessibility to incorporate both DJI drone products and Delair's data management platform, providing a hassle-free option for enterprise drone programmes.

▸ **https://bit.ly/2ovu64C**

Machine Learning: Crucial Leap Forward for Ordnance Survey

▲ ***Ordnance Survey hopes to unlock the potential of AI by creating quality assurance and standards for the industry.***

Ordnance Survey (OS), Great Britain's national mapping agency, is on the verge of a quantum leap in its data capture after being granted access to a supercomputer to develop machine learning techniques that will extract extra information and features from aerial imagery and mapping. The Science and Technology Facilities Council (STFC) Hartree Centre's supercomputer being used is, appropriately for OS, named 'Scafell Pike'. It is expected that, if successful, this will lead to new business opportunities for OS at home and internationally. It is also projected that it could bring annual efficiencies of more than £2 million for OS, which by 2024 will rise to £8 million per year. This news builds on OS's already successful work with artificial intelligence (AI) and machine learning to date. It was used to capture and accurately map 373,919km of England's farmland hedges to create a new digital dataset for the Rural Payments Agency, and was deployed in a joint project with Microsoft that saw a machine learn and identify different roof types – it went from zero to 87% accuracy in just five days.

▸ **https://bit.ly/31OFJxC**

Atmos UAV Integrates Thermal, Multispectral and High-resolution Imagery

▲ *The Atmos UAV Marlyn package.*

Atmos UAV, a drone manufacturer for mapping and surveying from Delft, the Netherlands, continues to expand its payload options. The most recent addition is the new MicaSense sensor, Altum, which integrates a radiometric thermal camera with five high-resolution narrow bands. This produces advanced thermal, multispectral and high-resolution imagery in one flight for advanced analytics purposes. Marlyn, the fixed-wing VTOL surveying platform developed by Atmos UAV, is now one of the few unmanned aerial vehicles (UAVs or 'drones') in its class capable of carrying this new high-end sensor. With this integration, the Atmos team wanted to offer professionals a tool that maximizes their surveying capacity in numerous applications. The new Altum is among the most advanced sensors for capturing calibrated data that can be used in phenotyping, crop health mapping, water stress analysis, leak scouting, fertilizer management, zone mapping, disease identification and more.

▶ **https://bit.ly/2Ms29TI**

The Economic Benefits of Geodata in Urban Planning in Sweden

▲ *A countryside landscape in Sweden. (Photo: Max Pixel)*

Spatineo and its partner GIS-kvalitet i Norden recently supported Lantmäteriet, the National Land Survey of Sweden, in answering an essential and important question: 'What is the economic benefit of national harmonization and standardization of geodata and the national platform for access to geodata?'. The companies conducted a project for Lantmäteriet in which they assessed the potential economic benefit of the use of geodata in the digital urban planning and building process in Sweden. The estimated annual economic value is between SEK22.6 and 42.2 billion. The urban planning and building sector is the biggest sector that affects the built environment in Sweden. Therefore, Lantmäteriet has been commissioned by the government to work for a streamlined digital urban planning process. The goal is to achieve more effective interaction between authorities, citizens and businesses. This is promoted by providing all actors with the most important national basic datasets – which are mainly produced by cities and municipalities – as a geospatial service from the national platform.

▶ **https://bit.ly/2MpS89b**

Bluesky Launches MetroVista City Mapping Service

▲ *Bluesky's MetroVista city mapping service.*

Aerial mapping company Bluesky has recently introduced its MetroVista city mapping service for Europe based on data from the Leica CityMapper. At this year's Intergeo in Stuttgart, Bluesky showed the MetroVista imagery created from the hybrid airborne sensor that can simultaneously capture vertical and oblique aerial photography as well as Lidar. Bluesky's MetroVista range includes impressive high-resolution imagery together with high-accuracy, wide-scale 3D models. The first in Europe, and still only one of a handful in operation around the globe, Bluesky's CityMapper has already been used to capture MetroVista data for cities across the UK including London, Manchester, Newcastle and Bristol. Bluesky is also able to offer the MetroVista service, using the CityMapper sensor, around the world using its network of international operating and flying bases.

▸ **https://bit.ly/2OzjM6k**

ESA Leads Drive into 5G Positioning Future

▲ *These two testbed vehicles were field-tested in Germany to simulate the likely future use of 5G positioning services. (Courtesy: DLR/GMV)*

A pair of testbed vehicles went out on the road in Germany to simulate the way we are all likely to be using 5G positioning services in the future. The field test focused on assessing the performance of highly precise 'hybrid' satellite/terrestrial positioning for autonomous vehicles, drones, smart cities and the Internet of Things. The two vehicles were driven for a week around Munich and the surrounding area in a variety of environments, from the open-sky terrain surrounding the German Aerospace Center DLR's site in Oberpfaffenhofen to the deep urban canyons of the city's dense Maxverstadt district. As they drove they combined a broad range of on-board systems – including multi-constellation satellite navigation (combining Europe's Galileo, the USA's GPS, Russian Glonass and Chinese BeiDou), incorporating localized high-accuracy correction, and long-term evolution 4G and ultra-wide-band terrestrial wireless broadband communication – to measure their positions. They then shared their positioning information with one another, performing ongoing vehicle-to-vehicle ranging to simulate future 5G operating standards.

▸ **https://bit.ly/2Mpjzjz**

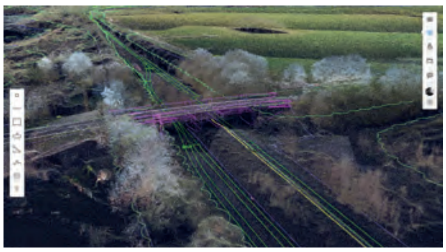
Juniper Systems Announces New Geode GNS2 Sub-metre GPS Receiver

▲ *The Juniper Systems Geode GNS2.*

Juniper Systems has launched the Geode GNS2 sub-metre GPS receiver. This new release of the Geode now features connectivity with a range of iPhone and iPad devices providing users with a more versatile and powerful tool. This is made possible by the Geode's new 'Made For iPhone/iPad' (MFi) certification. The Geode GNS2 retains all the features and connectivity of the original Geode while adding this support for iPhone and iPad. The Geode is an all-in-one sub-metre receiver that provides users with real-time, precision GNSS data at an affordable price. Designed with versatility in mind, the Geode features one-button simplicity and can be used with any of Juniper Systems' rugged handhelds, as well as a wide range of Windows, Windows Mobile, Android and now iPhone and iPad devices – a useful feature, particularly for bring-your-own-device workplaces.

▸ **https://bit.ly/2VqloAO**

SenSat Raises US$10 Million for Simulated Reality Technology



▲ *Screenshot from SenSat's Mapp platform.*

SenSat – a UK-based geospatial startup company using artificial intelligence to unlock value in the infrastructure industry based on digital representations of real-world locations – has announced a US$10 million Series A funding round, led by Tencent, with participation from Sistema Venture Capital. The new capital will be used to support growth, enabling SenSat to expand its London team of 30 experts by more than threefold over the next year. It will focus on data scientists, mathematicians, software developers and creative problem solvers, as well as driving continued international expansion. SenSat creates digital representations of real-world locations – otherwise known as digital twins – infusing real-time datasets from a variety of sources. The result is an accurate, digital and up-to-date copy of the real world in a machine-readable format. This enables offline industries, such as infrastructure, to make more informed decisions and perform accurate analysis, driving vast improvements in safety, cost-efficiency, waste generation, project collaboration and carbon reduction.

▸ **https://bit.ly/2Mutxjt**

Woolpert and iXblue Partner up to Deliver Aerial Mapping Services in Oceania

Woolpert and iXblue Sea Operations division, part of iXblue Group based in France, have formed a strategic partnership to provide aerial mapping services to clients in Australia, New Zealand and across the South Pacific. The pairing combines the reputation and regional business development expertise of iXblue, a global marine survey and technology firm, with Woolpert's internationally known aerial topographic Lidar, bathymetric Lidar and geospatial capabilities. Under this partnership, Woolpert and iXblue will collect, process and deliver airborne digital imagery, topographic Lidar and bathymetric Lidar operations from helicopter and fixed-wing platforms to provide custom solutions to commercial and government clients in Oceania.

▸ **https://bit.ly/2Ow838I**

▲ *Imagery collected to support the Pacific Regional Navigation Initiative (Courtesy: iXblue, Woolpert)*

It is NOW.
Forget your measuring tape as a must tool to get the instrument height.
The UltraPlumb
measures the instrument height automatically with an accuracy up to 3.0mm.
Available on the upcoming New RCS soon.
RUIDE

Add Performance to your Mobile Mapping Solution
Navigation
Heave
Georeferencing
High Accuracy
& Cost-effective
Inertial Navigation
Systems
+
NEW
Qinertia
INS/GNSS
Post-processing
Software
www.sbg-systems.com
SBG SYSTEMS

APP BASED ON MOBILE MAPPING POINT CLOUDS AND IMAGERY

Smart Parking

Motorists who regularly drive around busy megacities such as London can waste a week or more per year hunting for a parking space. The quest for somewhere to park burns fuel unnecessarily, pollutes the air with particulate matter and increases greenhouse gas emissions. The smart parking app – based on mobile mapping technology – offers welcome relief for seekers of parking spaces while also helping to preserve the environment. One such app by London-based company AppyWay, named AppyParking, is available for free download for iPhone and Android devices.

The AppyParking app allows users to see all on-street and off-street parking areas, restrictions and operating hours. Before arrival motorists can make informed decisions about where to look for a parking place and can find the nearest and cheapest options. At the very core of such a smart parking app lies an accurate, detailed and up-to-date map. Ideally, the map should not only cover the locations and outlines of the parking zones, but also provide additional information on their characteristics or features. The signs placed at or near to the parking spaces are a major source of such features.

In the case of AppyParking, the data used to create the map consisted of street-level laser point clouds and imagery. The survey was conducted by Getmapping PLC – a company headquartered in Fleet, Hampshire, UK, that is specialized in aerial photogrammetry, mobile mapping, Lidar, digital mapping and web-based services across Europe and Africa.

MOBILE MAPPING SYSTEM

Getmapping PLC operates multiple Pegasus:Two Ultimate mobile mapping systems (MMSs). This survey was conducted using a Pegasus:Two Ultimate MMS (Figure 1) and a Pegasus:Two upgraded to the Ultimate version. The cameras of the Ultimate have a high dynamic range thanks to a large sensor-to-pixel ratio and a dual-light sensor. The camera's high dynamic range enables crisp images to be captured in a variety of lighting conditions and at various vehicle speeds. The image quality is further improved by the camera sensor resolution of 12MP. The onboard JPEG compression allows massive amounts of images to be stored on the removable drive on the spot without compromising on image quality. Data can be

▲ *Figure 1: All sensors of the Pegasus:Two Ultimate are rigidly integrated in the same casing; the rack can be mounted on a variety of vehicles including cars (left).*

▲ *Figure 2: Mobile laser scan of Admiralty Arch on The Mall in London, coloured from simultaneously captured 360-degree panoramic images.*

saved directly and connected seamlessly to any PC or server with a USB 3.0 interface. Compression is a prerequisite for prolonged surveys without interruptions since the camera produces imagery with a three times higher resolution compared to standard systems. The side cameras capture eight frames per second (FPS) at a field of view of 61 x 47 degrees. The maximum ground sample distance (GSD) at a distance of 10m from the camera is 3mm. The fish-eye camera system, which consists of two cameras mounted back to back, provides seamless 24MP imagery with a 360-degree field of view. The dual fish-eye camera system is aligned with the laser scanner, enabling colourization of the laser points (Figures 2 and 3).

SURVEY

The MMS capture of London's boroughs was conducted in two steps. In the first step, six boroughs were surveyed in autumn 2017. Three surveyors drove approximately 50km per day to capture 25km of road trajectories, usually in back-and-forth pass. The survey continued throughout the winter, even when light conditions were poor. No surveyors or traffic management crews were needed on the street – all data was captured from the vehicle. The captured images and laser point clouds were subsequently converted into maps during the first six months of 2018. Two office-based operators processed the data and stored it on hard disks using Leica Pegasus:Manager, which leverages the latest system calibration methodologies to precisely overlay imagery and point cloud data.

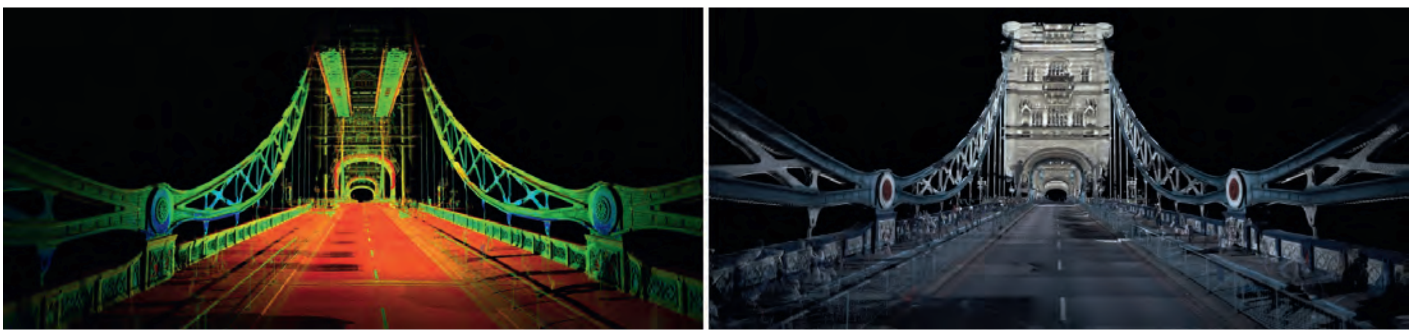
The second stage, in which a further 13 boroughs were surveyed, was completed by mid-2018. Many roads needed second passes to eliminate or reduce occlusions. The capture rates varied significantly depending on the borough being captured and the time of day. Each day's data was processed within four days of being captured. The total time span between survey planning and delivery of the end products was three weeks. To give an impression of the amount of data captured: an MMS survey of 120km of roads resulted in around 0.5TB of raw data.

MAPPING

The points, symbols, polygons and point features making up the parking zones were extracted manually and in a (semi-) automated manner from the point clouds and 360-degree fish-eye imagery lines using Leica's MapFactory which is embedded into ESRI ArcMap. The extracted data can be easily imported into Esri solutions or other GIS platforms for further processing and usage. The information on parking signs was extracted from the imagery and attributed to the relevant parking zone. The outlines of each parking zone were represented by polygons. Wherever outlines were occluded (i.e. visibility was obstructed by cars or other objects in the line of sight), the polygons were interactively collected and refined. For example, the visible lines were extended and intersected with each other to obtain the coordinates of invisible corner points of parking zones.

RESULTS AND CHALLENGES

The relative accuracy of outlines belonging to the same parking zone is better than two

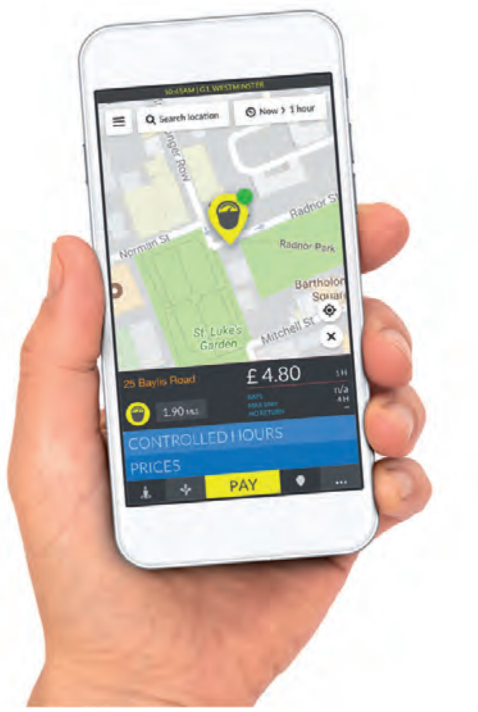


▲ *Figure 3: Laser point cloud of Tower Bridge in London, intensity coloured (left) and the point cloud resulting from colourizing from simultaneously captured 360-degree panoramic images.*

centimetres, and the absolute accuracy lies between three and ten centimetres depending on the area. Achieving that high absolute accuracy over the entire territory entailed measuring as a reference 250 ground control points (GCPs) distributed throughout the urban canyons of the city of London. During the MMS surveying step, which took 100 days in total, 19 London boroughs and five cities were captured (Getmapping also surveyed Brighton, Cambridge, Oxford, Portsmouth and Coventry to support smart parking). The total length of the MMS trajectory was more than 6,500km including multiple passes. The one million laser points captured per second together with the imagery resulted in 24TB of raw data, which expanded to 50TB after processing and mapping. For each parking zone, 27 features were extracted from the point clouds and imagery. The combination of 360-degree panoramic imagery supplemented by four 12MP side cameras ensured that all parking signs were clearly identifiable. All data requested by the client was delivered ahead of time. In terms of challenges, continuous and reliable high-accuracy GNSS positioning in urban environments is made difficult by multipath interferencel and frequent GNSS outrage. A high-grade inertial measurement unit (IMU) and sufficient GCPs are crucial to resolve these issues. A further challenge is that weather conditions and difficult light conditions may hinder the extraction of all the information on parking signs from the images.

CONCLUDING REMARKS

The imagery and point clouds can also be used for asset management, drainage projects, road safety improvements, highway maintenance, 5G telecoms and environmental analysis. Based on all the collected data and extracted features, AppyWay is able to deliver highly accurate and detailed traffic management data to its smart parking systems. ◀



▲ *Figure 4: The app shows on-street and off-street parking areas, restrictions and operating hours.*

SinoGNSS®
By ComNav Technology Ltd.

To make your work easier is our original motivation

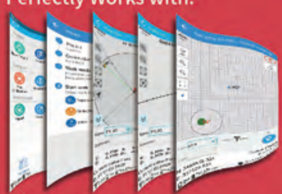
T30 GNSS
Receiver

T30 GNSS Receiver featuring full-constellation tracking capability, tilt compensation, 4G/WiFi/Bluetooth® connection, and easy survey workflow with Android-based Survey Master Software, Dustproof&Waterproof design makes T30 GNSS Receiver perfectly and effectively work even in harsh environments. Collect more accurate data easier and faster no matter for beginners or professional surveyors.

Features

- L-BAND Support L-Band and PPP
- Two 3400mAh Hot Swap Batteries
- Rugged Al-mg alloy Housing
- All Constellations
- Tilt Compensation
- 4G Tx & Rx Built-in 4G/ TX & RX
- 67 IP67

Perfectly Works with:



Survey Master

Google play
Download for free

SinoGNSS®
By ComNav Technology Ltd.

Sales@comnavtech.com
www.comnavtech.com

INTRODUCING A LUMINANCE-CALIBRATED MOBILE MAPPING SYSTEM

Night-time Mobile Mapping of Road Surface Luminance

The installation of lighting improves safety in a road environment. Road lighting standards set requirements for the average luminance and luminance uniformity on a road surface. The authors of this article are working to develop a novel approach for evaluating night-time road lighting conditions based on luminance-calibrated 3D point cloud data. This new measurement system integrates imaging photometry, which is commonly used to measure road lighting, with mobile laser scanning techniques, which are mainly used to measure the 3D geometry of the road environment. Here, the authors explain how the measurement system is utilized to produce a georeferenced luminance point cloud and discuss the potential applications of their measurement system.

In road traffic, the role of illumination is to improve the visibility of the road and the surrounding environment. Illumination is also one of the most effective ways of increasing road safety; it has been shown to reduce the number of accidents in road traffic by 30%. Road and street lighting also promotes the implementation of an unimpeded environment. However, the hazardous effects of light include external light shining into an illuminated area which causes discomfort and interferes with the visibility of essential information.

LED-based illumination technology has become widespread over the past few years because of its energy efficiency, even light quality, excellent colour reproduction and long life. The energy consumption from road illumination can be reduced significantly by switching to LED luminaires. Another trend in lighting solutions for road and street environments is the intelligent lighting system. Intelligent road lighting will automatically

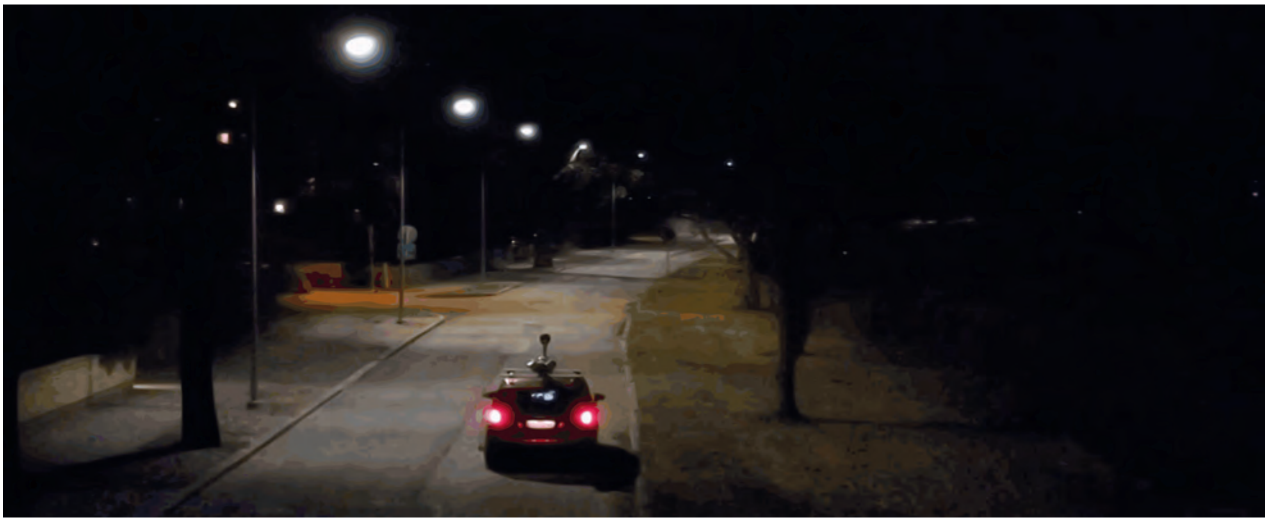
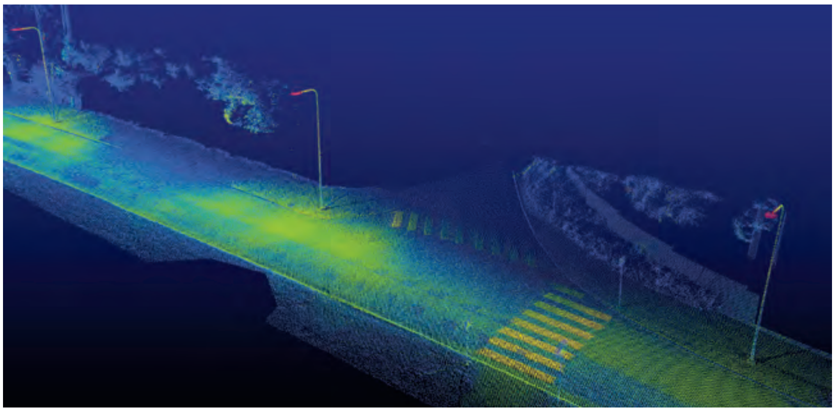


Figure 1: Street lighting measurements with a mobile mapping system in Munkkiniemenranta, Helsinki, Finland. (Courtesy: Rantanen)

optimize the illumination conditions, taking into account the prevailing road and traffic situation, the properties of the road surface and the luminous flux of the lamps. A new, feasible method for road-illumination data gathering and presentation could possibly accelerate and proliferate the advantages of novel road lighting technology.

Illumination conditions in street and road environments are defined using a luminance value (cd/m²). Commonly used parameters are the maintained average luminance over the whole driving lane, the uniformity ratio on the driving lane and the longitudinal uniformity ratio. The traditional measurement approaches for illumination conditions in road and street environments are point measurements of luminance as well as imaging luminance measurements taken on site. Planning instructions for road illumination do not actually stipulate the measurement approach, but just the number of measurement points and their locations as well as the location of the observer. Of these measurement approaches, point luminance measurement is only suitable for small-scale use as it is too slow to measure extensive road environments. Most road environment luminance measurements are made using an imaging luminance meter. In practice, an imaging luminance meter is a digital camera that has been calibrated so that the RGB values it records can be interpreted as luminance values.

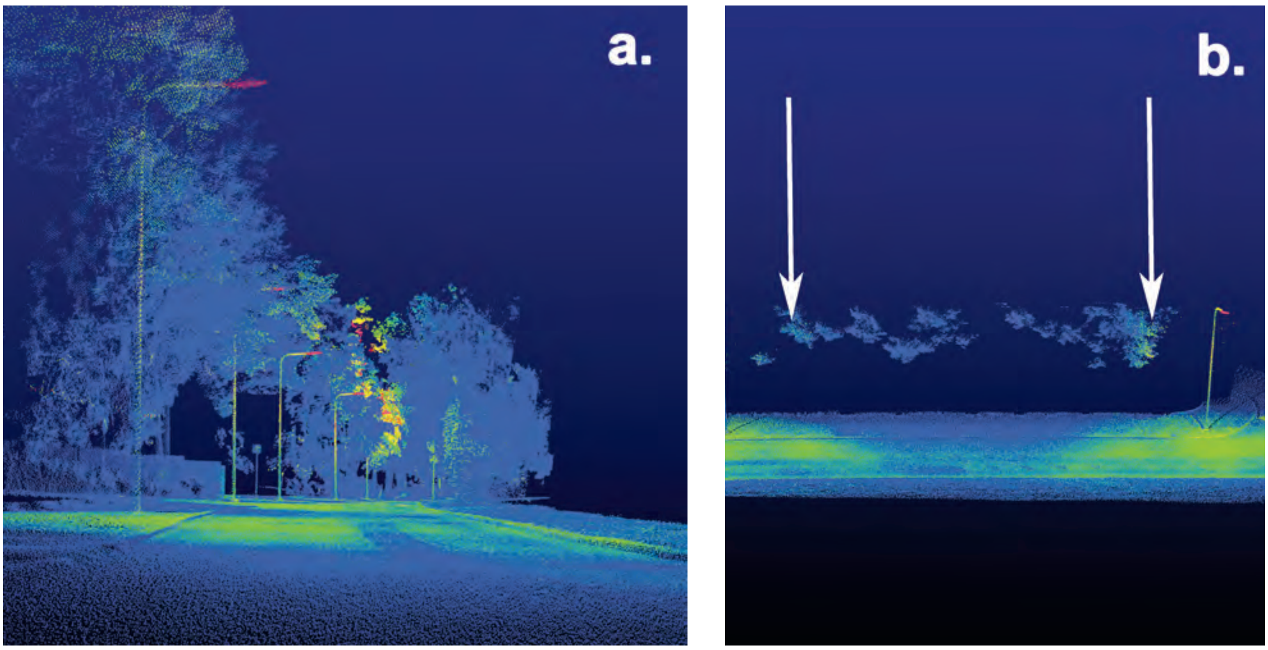


▲ *Figure 2: 3D luminance point cloud from Munkkiniemenranta.*

This article outlines methods for 3D measurement and modelling of road surface luminance using mobile laser scanning and luminance imaging (Figure 1). In addition, an example is presented in which the mobile measurement of 3D luminance is used for assessing the light-obstructing effect of roadside vegetation, and this is compared to the conventional 2D method.

LUMINANCE CALIBRATION

Digital cameras have been used for luminance measurements for around two decades. The use of digital photography for taking illumination measurements in a road environment requires that the pixel values of the raw pictures are calibrated against a known luminance source. Colouring a 3D point cloud in luminance pictures further requires the calibration of the camera's internal geometry, and corrections need to be made to the pictures' lens distortions. In luminance calibration it is essential that the same settings are used in the calibration as in the imaging in the field. In practice, calibrations are done in a dark room with a known standard luminance source which is regulated to correspond to the luminance levels of an illuminated road surface. In this way, the picture's RGB values in relation to the luminance values can be resolved. For



▲ *Figure 3: a) View of the 3D luminance point cloud similar to conventional luminance Imaging. b) Possible view of the 3D luminance point cloud showing the light-obstructing effect of roadside vegetation.*

the mobile imaging in this study, a Ladybug 3 panorama camera of the Trimble MX2 MMS was calibrated.

COMBINING LUMINANCE IMAGES WITH MOBILE LASER SCANS

Combining luminance images with mobile laser scans was tested at Munkkiniemenranta in Helsinki, Finland, where the experiments were carried out in night-time illumination on a two-lane stretch of road which was one kilometre in length (Figure 2). The material was measured using a Trimble MX2 mobile mapping system. The equipment consisted of a panorama camera (Ladybug 3), two laser scanners (SLM 250) and a positioning system (Trimble AP20 GNSS-inertial system). The stretch of road was mapped in both directions and the data was collected over a period of about 10 minutes. The equipment preparation and initialization of the positioning system, taking into account the measurement site, took about 30 minutes. The laser scanning material of the site consisted of about 40 million point observations. The panorama camera was set up to take images at two-second intervals.

In the post-processing of the material, the mapping system's location data and the measurement route were calculated using the Applanix POSPac MMS software to create a VRS base station network around the measurement area. The measurements produced by the laser scanning were combined with the location data in the Trimble Trident software, where the measurement observations were also combined with the RGB values from the images taken with the panorama camera. The luminance calibration of the panorama camera enabled a final luminance value to be calculated for each measurement point.

The whole measured road environment was segmented into areas of analysis which were similar to the measurement areas in the road lighting design recommendations. One area of analysis encompassed a one-lane-wide area between two adjacent road luminaires longitudinally. In order to calculate the longitudinal uniformity, a 20cm-wide longitudinal strip of the point cloud was considered as the centre line of the lane. In digital image processing, it is common to reduce noise using a median averaging filter. Hence, median filtering was used to reduce noise from the luminance values of the point cloud. The filtering was executed on the XY plane on the road surface for each point with a radius of 50cm.

One possible application for 3D mobile luminance measurement is assessing the light-obscuring effect of roadside vegetation. Figure 3 shows the road environment luminance with a view similar to conventional 2D imaging and a possible view using a 3D luminance point cloud. The difference is obvious. In 2D, the decrease in the road surface luminance can be observed, but the presentation is very limited. In 3D, even a branch that needs to be pruned can be identified, and the road surface can be viewed in a more comprehensive manner.

CONCLUSIONS

In this study, imaging luminance photometry was integrated in a mobile laser scanning system, which made it possible to produce 3D luminance point clouds of street and road environments in night-time illumination. The camera settings were adjusted to take images at low illumination levels so the material could be used especially for defining road surface luminance values. In terms of luminance dynamics and measurement accuracy, the measurement results are slightly limited compared to conventional stationary luminance imaging. Evident benefits of the developed system include registering the luminance information into dimensionally accurate and georeferenced 3D models, and a mobile method of measurement which enables the measurement of large traffic areas rapidly.

The 3D measurement and modelling of street and road illumination will improve opportunities to assess the reflection of road lighting from the road surface, distinguish disturbing light coming into the environment, identify places which are in shadow, assess visibility conditions and compare the capabilities of different lighting systems to illuminate a road environment. In addition, laser scanning methods enable detailed modelling of the road environment so the material can be used to automatically identify road markings, curbs, posts, traffic signs and signals. Furthermore, nimble assessment and monitoring of the light-obstructing effect caused by roadside vegetation is possible utilizing combined luminance imaging and mobile 3D measurements. The authors consider this method potentially suitable for other lighting measurement purposes such as in tunnels, park areas and recreational sports-field complexes. ◂

FURTHER READING

- Video of a luminance point cloud: www.youtube.com/watch?v=bV0L8mfY_Ns

- Vaaja MT, Kurkela M, Maksimainen M, Virtanen JP, Kukko A, Lehtola VV, Hyyppä J, Hyyppä H. Mobile mapping of night-time road environment lighting conditions. *The Photogrammetric Journal of Finland*. 20 Dec 2018;26:1-7. https://doi.org/10.17690/018261.1

- Kurkela M, Maksimainen M, Vaaja MT, Virtanen JP, Kukko A, Hyyppä J, Hyyppä H. Camera preparation and performance for 3D luminance mapping of road environments. *The Photogrammetric Journal of Finland*. 7 Dec 2017;25(2). https://doi.org/10.17690/017252.1

- Vaaja M, Kurkela M, Virtanen JP, Maksimainen M, Hyyppä H, Hyyppä J, Tetri E. Luminance-corrected 3D point clouds for road and street environments. *Remote Sensing*. Sep 2015;7(9):11389-402. https://doi.org/10.3390/rs70911389

ABOUT THE AUTHORS

Matti Vaaja is a professor of digital photogrammetry at Aalto University's School of Engineering in Finland. His research topics include development of close-range photogrammetry, laser scanning and mobile mapping methods and applications.
✉ matti.t.vaaja@aalto.fi

Mikko Maksimainen is a doctor of science in illumination engineering. He currently works as a postdoctoral researcher at Aalto University in the Research Institute of Modelling and Measuring for the Built Environment (MeMo). His research includes lighting measurement applications, 3D luminance data and mesopic luminance measurements.
✉ mikko.maksimainen@aalto.fi

Matti Kurkela holds a Licentiate of Science (Technology) in photogrammetry and an MA in industrial design. He works as a 3D studio manager at Aalto University in Finland, specialized in close-range photogrammetry and laser scanning.
✉ matti.kurkela@aalto.fi

SURVEYING TECHNOLOGY IS HEADING FOR MATURITY

Laser Scanning of Damaged Historical Icons

Terrestrial laser scanning is becoming an increasingly preferred surveying technique for the 3D documentation of historical buildings. 3D point clouds provide a wealth of information which advanced 3D mapping software can exploit in a relatively simple way, at least when compared to the tedious surveying techniques of the past. However, effective cooperation between architects and the survey team of experts is necessary in order to get the best out of this geodata acquisition technology. In this article, the authors first provide an overview of equipment based on the size of the site and the surveying aim, and subsequently give four examples of how terrestrial laser scanning can benefit the restoration of damaged historical buildings.

Throughout the ages, the preservation of iconic buildings has been a labour-intensive and expensive endeavour requiring the most advanced measuring techniques available at that time. Only buildings that were highly appreciated by rulers and citizens alike have survived the ravages of time, and such buildings usually fulfilled an important religious role in society: churches, cathedrals and temples, for example. In recent times, another type of building has been added to this list: industrial heritage. Today, terrestrial laser scanning (TLS) is one of the most advanced measurement techniques for the 3D documentation of such sites. The value of TLS for capturing damaged or decayed historic buildings is that scans can be used to accurately measure and virtually reposition partially or fully destroyed statues, ornaments and other elements. This provides insight into the damaged objects and into which elements can be restored and which will have to be completely remade.

CHOICE OF EQUIPMENT

The choice of specific surveying equipment depends on the size of the site and the aim of the survey. Scanning small or medium-sized sites requires one or more 3D laser scanners, with the setup dependent on size, budget and criticality. The instrumentation could include a laser scanner and/or scanning total station, tripods, batteries and data storage (USB key or SD card). For projects in which visual detail is important, an external high-end camera and panoramic head are recommended. Some laser scanners have a built-in camera with simple controls, and the image texture can be easily projected on the point cloud without cumbersome geometric transformations. However, an external high-end camera may be preferred for higher-quality imaging, although this requires more expert control. A necessity in the case of larger sites – and optional for

Figure 1: The 13-storey Liuhe Pagoda at Hangzhou, China.

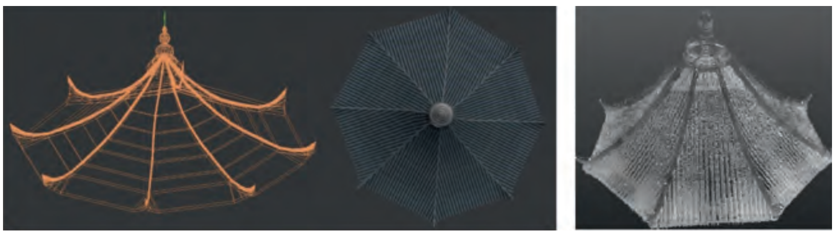


Figure 2: Two views of the 3D models of the roof of the Liuhe Pagoda (left) derived from a laser scanning point cloud.

smaller ones – are black and white markers, spheres and/or survey prisms in the overlap of scans for registration and georeferencing purposes. In addition, larger sites require the establishment of a network of ground control points (GCPs) using a total station or GNSS receiver. Continuous monitoring of building parts for deformation or subsidence requires prisms to be mounted on the relevant parts and multiple high-accuracy total stations to be permanently mounted on stable pillars. Combining the total station measurements in real time requires one or more controllers.

SCANNING THE LIUHE PAGODA

The Liuhe Pagoda (Six Harmonies Pagoda), located at the mouth of the Qiantang river in Hangzhou, Zhejiang province, China, has been demolished and rebuilt several times since originally being constructed in AD 970. Today it is a major tourist attraction (Figure 1). In addition to suffering human devastation, forces of nature have caused the monument to decay. Combined with the size of the pagoda, which is 13 storeys tall, this makes it a challenging restoration project. In 2013, its fourth major repair and renovation project began. The interior and exterior were scanned over a period of six months to support restoration. After scanning, which took three minutes per scan position, the building was modelled to find the missing parts, which required two to three hours per scan (Figure 2). Next the missing parts were designed, crafted by hand and assembled. For quality assurance and control inspections and detailed 3D documentation, the building was scanned using a compact 3D laser scanner resulting in 23 billion 3D points.

MINING HERITAGE IN ALASKA

Kennecott Mines, Alaska, is a complex of abandoned copper mines and has been a US National Historic Landmark since 1987. The site's iconic 14-storey building received raw ore delivered by aerial trams and delivered processed copper to railcars (Figure 3). To preserve the site after nearly 80 years of neglect, the site was placed under protection and mapped. In 2018, to improve detail and accuracy, the site was scanned during a three-day period using a Trimble SX10 scanning total station. The same instrument also measured individual points of key features of the building, such as roof and wall-corner points. The blue lines visible in Figure 4 show the traverses of the SX10 and the individual points. Ground control points were measured using Trimble R8 and R10 GNSS receivers; the base lines are shown in green. The traverse and GNSS measurements were combined with Trimble Business Center (TBC) software and registration and georeferencing was done with Trimble RealWorks.

▲ *Figure 3: Copper ore was milled and melted in furnaces in this building at Kennecott Mines, Alaska.*

NOTRE-DAME IN PARIS

The construction of Notre-Dame Cathedral in Paris, France, started in 1160. Although it is today regarded as a world-famous example of Gothic architecture, by around 1830 Notre-Dame was in such a state of decline that demolition became a serious option. Notre-Dame Cathedral survived the demolition plans, thanks in part to various citizen initiatives to save the cathedral – including Victor Hugo's novel *Notre-Dame de Paris* which was published in 1831 and later translated into English as *The Hunchback of Notre-Dame*. However, on 15 April 2019 a fire destroyed the spire, lead roof and oak frame of Notre-Dame. From the beginning it was clear that TLS would support restoration immensely. Although new TLS surveys allow accurate assessment of the damage, stability of the structure and required restoration works, they cannot provide information

▲ *Figure 4: A georeferenced photo mosaic of the Kennecott mill viewed from the valley floor, created using Trimble VISION.*

▲ *Figure 5: In this aerial view of Notre-Dame Cathedral in Paris, orange circles represent the scan positions during the 2010 TLS survey.*

about the cathedral's pre-fire stage. Fortunately, however, Prof Andrew Tallon – an architectural historian from Vassar College in the USA – had captured the entire cathedral using a Leica Geosystems TLS in 2010 (Figure 5). That accurate and detailed point cloud will be of tremendous help in obtaining a faithful reconstruction of Notre-Dame in its original state.

This illustrates the urgent need for accurate and detailed 3D models of cultural heritage sites, before disaster strikes or the natural elements erode their splendour. Detailed 3D reconstruction from dense TLS point clouds may also uncover construction details. For example, TLS revealed that the apparent skewness of the balcony of the south facade of Notre-Dame Cathedral in Amiens is not an optical illusion but is actually due to a 23cm height difference between the left and right sides which was caused by them being constructed independently (Figure 6).

CHURCH OF SAINT SIMEON STYLITES IN SYRIA

Another – albeit more remote – example of a demolished building that had luckily been scanned prior to hazard striking is the Church of Saint Simeon Stylites, Syria. The church dates back to the fifth century and was partly destroyed by a Russian rocket attack in 2016. Since 2003, the site had been regularly surveyed by crews from France, including by using laser scanning (Kurdy et al., 2011). One of the surveys was conducted with TLS equipment from the Ecole Nationale des Sciences Géographiques (ENSG) in 2004. The cruciform church (Figure 7) was captured from 36 positions using a Trimble TLS device with a horizontal field of view of 360º and a vertical field of view of 60º. In the overlaps of the scans, spheres were mounted for registration purposes. After manual removal of unnecessary points, the 250 million remaining points were processed to create 3D representations of relevant parts of the building. The resulting 3D documentation forms a historical record of the building and is very valuable in preparing and conducting the restoration work.

CONCLUDING REMARKS

TLS has come a long way since the late 1980s. Performance and productivity have greatly increased, while the cost of ownership, size and weight have decreased. TLS is not yet fully mature, however. Manufacturers still recommend a yearly calibration to maintain the specifications. Standard warranty periods are just one year, whereas two years is the norm for all other optical instruments. Once matured, TLS will be used much more broadly. Each innovation simplifies and speeds up the capture of 3D scanning data and eases the burden of expertise on geospatial professionals, thus opening up new business opportunities.

Figure 6: Misalignment of the balcony of the south facade of Notre-Dame Cathedral in Amiens.

Figure 7: South facade of the Church of Saint Simeon Stylites before the 2016 attack.

FURTHER READING

Kurdy, M., Biscop, J-L., De Luca, L., Florenzano, M. (2011), 3D Virtual analysis and reconstruction of several buildings in the site of Saint-Simeon, Syria. *Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XXXVIII-5/W16, pp. 45 - 52.

ABOUT THE AUTHORS

Gregory Lepère is marketing director of Optical & Imaging for Trimble Geospatial. He has been fascinated by cathedrals since he was a young boy growing up in France. He has participated in the 3D laser scanning of many historic structures during his geospatial career, including Notre-Dame in his hometown of Amiens.
gregory_lepere@trimble.com

Mathias Lemmens is an independent geomatics consultant and the author of the book *Geo-information – Technologies, Applications and the Environment*. He lectures on geodata acquisition technologies and data quality at Delft University of Technology, the Netherlands, where he is director of the MSc Geomatics for the Built Environment. His book on point clouds will be published in mid-2020.
m.j.p.m.lemmens@tudelft.nl

3D DIGITAL TWIN: URBAN IT CROSSOVER OF INTERCONNECTIONS

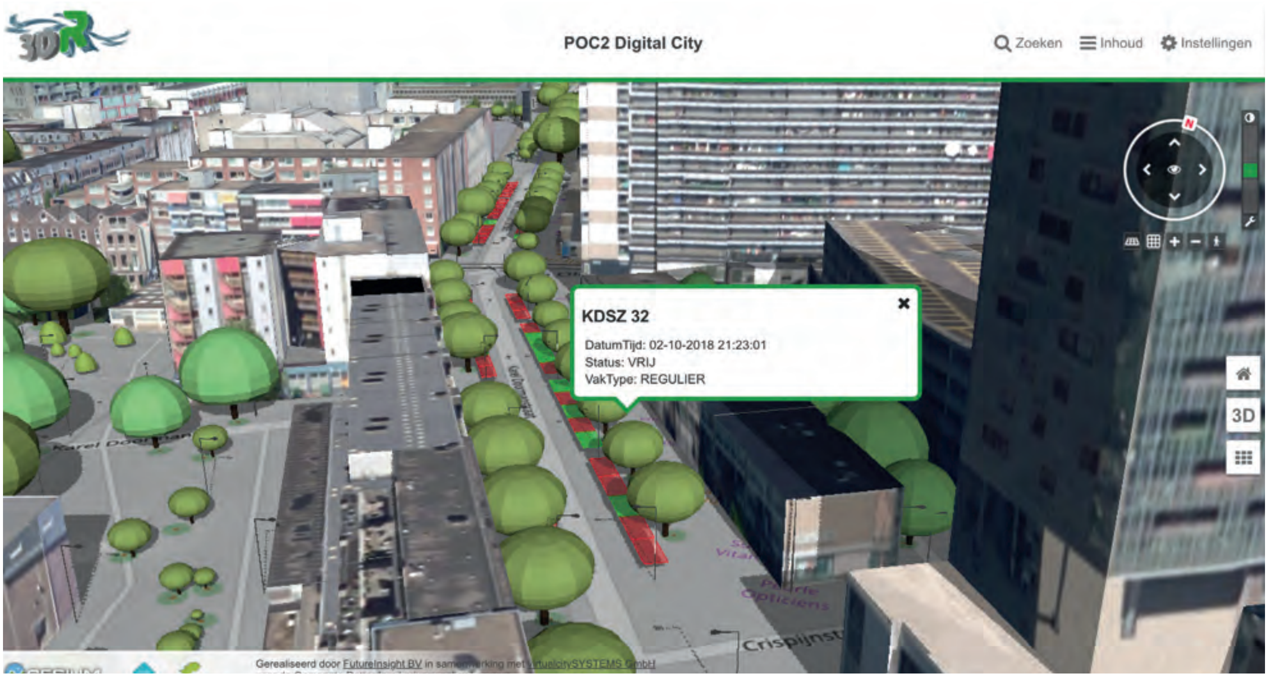
'Digital City Rotterdam' Anticipates Human Life 2.0

If 3D is becoming the new normal in spatial data infrastructures, how can it be used in an urban environment? The Dutch city of Rotterdam, known as home to the largest port in Europe, is preparing for that next step by developing a digital twin of the physical city. The primary aim of 'Digital City Rotterdam' is to improve the efficiency of urban planning and management. But at the same time the city council is on the lookout for applications that will help people integrate the digital world into their real one – or will it be the other way around in the not-so-distant future?

What will the inhabitants of Rotterdam expect of their city in a couple of decades' time? According to the figures, 60% of the 650,000 inhabitants are active on the labour market, more than half are single or a single parent, and 30% are under 25 years old. Unfortunately, these statistics tell us nothing about how people interact with the physical infrastructure and with each other. But the dynamics are clearly changing, says Roland van der Heijden, programme manager of 'Digital City Rotterdam': "The city has long thrived on the interaction between people and the physical environment. But now this reality is under pressure from several major changes – just think about how we shop, work, find our way around, use our free time, communicate and so on. We want to facilitate the citizens of Rotterdam by building a digital urban platform. Two years ago we were working on 350 so-called 'smart city projects'. But even if we do a thousand such projects, that still doesn't make Rotterdam a smart city if they are not interconnected – and they weren't, so that is where it all started."

OPEN DATA STANDARDS

The platform is intended to interconnect as many Rotterdam-related applications as possible making use of open data standards. It should present a continuous image of the current, measurable physical reality. How many cars are driving through a particular



▲ *The 3D digital city platform will have customers who sell information services, such as real-time parking management, but also based on artificial intelligence to analyse trends.*

street? Is a specific parking space occupied? How many people are in a certain area? Are streetlights not working? Are communal rubbish bins full? What is the current air quality?

Since most applications have a location component, a 3D object-oriented data model of the physical reality is the most efficient approach for this 'digital twin'. The topographic 3D basic registration is under construction. The buildings are ready (although individual accommodation units in apartment blocks still need to be discerned) and are available for everybody to connect their data to. It is designed as a smart query environment ("contrary to Google Earth"). More and more objects such as lamp posts, street furniture and communal rubbish bins are also available in 3D. But conversion remains a serious challenge in connecting data that used to be in separate compartments. Van der Heijden: "Commercial parties had no interest in writing their applications in a language everybody could understand. It took us some time to win the battles to change that. Now, every new contract specifies our data standard and the companies have to comply. Most companies are willing to supply their data as a service, but we still have to convert it to enable other parties to use it via the digital twin platform to build information services. We work with the likes of City GML, BIM-IFC, WFS and Sensorthings API, depending on the data concerned. The platform will have software which can connect BIM to sensor data, for example, in such a way that it remains open. Moreover, GIS data need extra work, even if the supplier plays a major role in the international open-data arena. Most software can handle all kinds of data formats as inputs, but extracting it is a different story and you often need to pay for help. So with GIS we're falling back on the WFS standard."

▲ *Roland van der Heijden: "The city of the future is beyond a new layer. Most people will largely live in the digital reality, which will be interwoven with everything you can imagine." (Image courtesy: Jeroen van Berkel, VBB)*

'EVEN IF WE DO A THOUSAND SMART CITY PROJECTS, THAT STILL DOESN'T MAKE ROTTERDAM A SMART CITY IF THEY ARE NOT INTERCONNECTED'

NO GRAND DESIGN

The strategy for winning this war on compartmentalization is focused on avoiding a top-down 'grand design'. "Such designs are like works of art – with their arrows, trapeziums and webs, they are almost fit to hang on your wall at home, but they are too complex to be implemented. And by the time everyone has finally reached agreement, you can start again because the technical design is already outdated. As technicians we can also make things extremely 'advanced', leading to systems in which you get lost in the countless possibilities. On the other hand, listening only to your potential customers doesn't work either. They tend to focus on making minor changes to what they currently use, which misses the big picture and results in just a little tweaking based on today's problems. In Rotterdam we are always on the lookout for a 'coalition of the willing' to ensure sufficient energy to play this iterative game between the demand side and the supply side," the programme manager continues. "We respect the autonomy of the various city departments and therefore do not want to change their processes, dashboards or data silos, but they have to make doors in those silos to automate the extraction of their data into an open data standard, and also in real time if it concerns real-time data."

His team of ten can devote half their time to the digital platform. For now, they are focusing on ten functionalities: conversion, API strategy, safety & privacy, viewing (3D digital twin), connection to other initiatives in the country, data market function to balance data demand and supply, rules around ownership and platform governance, (meta)data & applications, data storage, and geofunctionality. But is geofunctionality still a separate item for an urban data platform in this day and age? "All other Dutch urban open data platforms I know of function as a data hub without geofunctionality. In Rotterdam we're explicitly making sure a location component is possible in every dataset," he answers.

BUSINESS CASE

Data storage is another interesting issue. Over the coming years, every local civil servant, business and citizen will be stimulated to use the platform. Cloud storage is inevitable in order to handle the exchange of such massive amounts of data. What role should a governmental organization want to play in the infrastructure? Are the Chinese or American governments a good example? Or can this digital twin of everything that takes place in the city be entrusted to the private sector? "Several European and world-leading companies have visited us at our city hall with fantastic presentations. They want to install all the necessary network infrastructure, manage all the data – everything you can think of, and for free. A 'platform as a service' sounds very attractive to our managers, who are always in search of ways to save costs. But in Rotterdam we realized that such a setup, in which a commercial firm gets to be the middleman of all data flows, makes the city a powerless customer of its own data. There would be more safety, privacy and financial concerns than when the local authorities would retain governance of the digital city," says Van der Heijden, summarizing the deliberations. That does not mean the platform's business case is simple; it is not merely regarded as an investment for the city overall, but is also expected to make some profit. In a few years' time, he expects that the platform will probably have some customers who sell information services. Those services could be in real time, but could also be based on the use of artificial intelligence to analyse trends.

APPLICATIONS

The generic platform will be released in 2022. The first two proofs of concept have been successful and just one more has to be completed before the system can be built. The first applications will relate to building permits. Another early application will use augmented reality. People will be able to scan QR codes on information panels at building sites and see the BIM model of the new building materializing on their screen as they point their smartphone at the construction area. A third application concerns time and place-independent participation by citizens in urban development projects based on gamification. People have to take into account the consequences of their choices and will be able to virtually move through the 3D environment they co-created. So far, functionalities like these have been stand-alone applications. "But in the near future the digital city will be an IT ecosystem in which we can do such things from behind our desks. It is a crossover of interconnections, all based on the same view of reality," he comments.

'LISTENING TO ONLY YOUR CUSTOMERS MISSES THE BIG PICTURE AND RESULTS IN JUST A LITTLE TWEAKING BASED ON TODAY'S PROBLEMS'

To illustrate the situation, Rotterdam – which is located five metres below sea level – has an effective 3D e-water model showing how the city would flood if a particular dike were to be breached, and it also has a successful traffic model. But to see which roads should be used during evacuation in the case of flooding, an extra application is needed that combines those two data models. Another benefit of an easy crossover is that

The Rotterdam skyline by night.

it can open up new and often surprising possibilities. Sensors have been installed in communal rubbish bins that indicate how full they are, for example. When the managers of Rotterdam's home-care organizations discovered that such data existed, they instantly realized they could put it to good use. Home-care professionals work to a very tight schedule. When taking the trash out to the communal bin for their customers, it can save them valuable time and energy if they know beforehand that the closest option is full and where the best alternative is located.

'WORLD-LEADING COMPANIES HAVE VISITED US AT OUR CITY HALL, WANTING TO INSTALL AND MANAGE EVERYTHING YOU CAN THINK OF – AND FOR FREE'

NEXT GENERATION

Roland van der Heijden illustrates the necessity of more fluid boundaries between the social, physical and digital environments with an example relating to Rotterdam's young people. Community workers signal a fast-growing percentage – in some areas more than half – of the city's youngsters withdrawing from physical and social life in their own neighbourhood. While they might attend school locally, due to social media and online gaming they form part of a digital community and their friends are not next door but around the world. "If a growing section of the population is spending more and more time in a 'virtual' world, what will that mean for Rotterdam in 25 years' time? And what does that mean for the functionalities they will look for on a digital city platform?" he asks. "A platform programmed according to our reality will not relate to how people live in 2045. We can't even ask ourselves the right questions. We look at the city and see it as we have always known it, plus some extra digital options. But that's not the city of the future; it is beyond a new layer. In the future, most people will largely live in the digital reality, which will be interwoven with everything you can imagine. And that's what we have to try to anticipate."

ABOUT THE AUTHOR

Frédérique Coumans is a contributing editor for *GIM International*. For more than 25 years, she has been covering all aspects of spatial data infrastructures as editor-in-chief of various magazines on GIS, data mining and the use of GIS in business. She lives near Brussels, Belgium.

fcoumans@vbkcontent.com

A HIGHLY ACCURATE, DIVERSE AND DENSE ANNOTATED LASER SCANNING DATASET OF A CITY CENTRE

Downtown Dublin as a Lidar Point Cloud

The advance of Lidar data acquisition technologies is substantially increasing the amount of spatial data obtained and it is becoming cost-prohibitive to process it manually. Artificial intelligence (AI) has now started to offer cost-effective solutions to analyse and utilize those big datasets. AI can be employed for scene understanding, accurately detecting objects and classifying 3D assets. These are the significant fundamentals of several applications including autonomous navigation, intelligent robotics, urban planning, emergency management and even forest monitoring. The most popular types of 3D spatial information for such applications are Lidar and imagery data. This article describes the dense annotated ground-truth Lidar dataset that was generated in 2019. The labelled dataset was produced from Lidar data of Dublin that was captured alongside aerial images of Dublin in 2015. Both datasets are publicly available and their URLs are included in this article.

With two thirds of the world's population already living in urban areas, and a further increase of two billion predicted by 2050, the number of megacities (i.e. with populations of more than ten million) is predicted to increase to 41 in the next decade (UN 2014). Most of these cities had less than two to three million inhabitants in 1950, which means that their infrastructure is totally unable to support such huge growth. To plan sustainable growth of such urban areas, geometrically accurate three-dimensional (3D) models are essential for city planning. Accurate spatial modelling and interventions related to city planning are especially challenging as most parts of cities

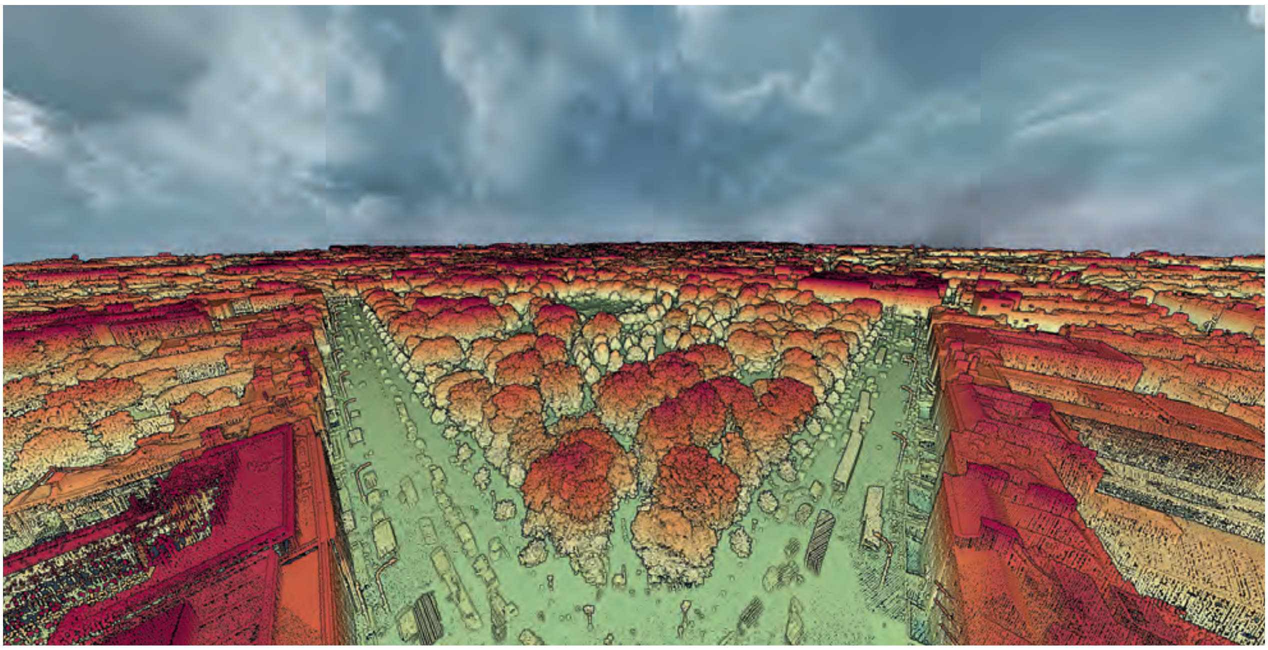


Figure 1: Laser scanning point cloud of Dublin, Ireland's capital city.

Figure 2: A sample labelled tree that shows its trunk, branches and leaves.

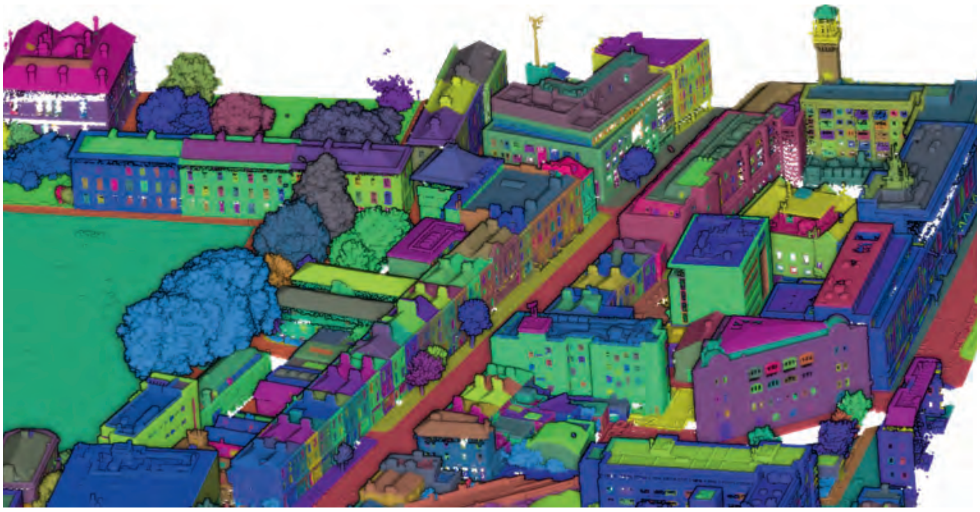


Figure 3: A sample portion of the annotated dataset.

are largely undocumented, and the cost of collecting the relevant data through traditional mapping methods is typically very high. In such cases, remote-sensing technologies offer cost-effective alternatives.

Lidar laser scanning and photogrammetry are outstanding solutions amongst the current technologies. The latest Lidar scanners are able to capture around one million georeferenced points a second in the form of a point cloud. This point cloud can be acquired via three major sources: a) Terrestrial laser scanning (TLS), which is able to collect most of the vertical facade data but little of any roofs, balconies and other horizontal planes, usually from the street point of view; b) Mobile laser scanning (MLS), which is performed by scanners mounted on moving cars or other vehicles (e.g. autonomous patrolling or even boats) to survey relatively short distances up to 300m with the same characteristics of TLS (but usually with less density); and c) Airborne laser scanning (ALS), which can contain full-waveform data with a good bird's-eye view but usually limited facade data. ALS is generally used for obtaining data for a large area (e.g. an entire urban region).

THE DUBLIN DATASETS

In 2007 and later in 2015, the Urban Modelling Group at University College Dublin captured a massive urban dataset of the Republic of Ireland's capital city, Dublin, under supervision of Prof Debra Laefer. The datasets include laser scanning point cloud (i.e. Lidar) – as shown in Figure 1 – as well as aerial imagery (i.e. vertical, oblique images and video data). As the footage in the overview of the dataset shows, the density of the dataset was hugely improved in 2015 compared to the initial capturing in 2007. The 2015 dataset is one of the densest urban aerial Lidar point clouds that has ever been collected (over 1.4 billion points) with an average point density of 250 to 348 points/m^2. In this project, the initial dataset consisted of 5.6km^2 of Dublin's city centre which was scanned with an ALS device carried out by a helicopter at an average flying altitude of 300m. The data was collected in March 2015, as there is usually minimum vegetation and hence shadows on the buildings at that time in Dublin.

While the primary output of the dataset was to generate a Lidar point cloud, the mounted cameras also captured imagery data during the flight. The imagery dataset consists of 4,471 images as georeferenced RGB images with a resolution of 9,000x6,732 pixels with a ground sampling distance of 3.4cm in TIFF format. The geographic information is given as GPS information in the EXIF metadata and the camera used for the capture was Leica RCD30. The dataset also includes 4,033 oblique JPEG images with a resolution of 7,360x4,912 pixels that were captured by two NIKON D800E cameras. The total size of the imagery dataset is around 830GB. All Lidar and imagery data can be accessed at the NYU data repository.

In addition to that dataset, in 2017 Dr Jonathan Byrne et. al. also captured aerial images of Trinity College Dublin (TCD) campus at an average altitude of around 30m by drone and generated an image-based point cloud. The dataset would be interesting for comparison of the campus from 2015 to 2017.

THE REASONS FOR ANNOTATION

The laser scanning data has no inherent classification information in the point cloud or any predefined relationships between its points. Consequently, in order to use these points in various applications, the data must be classified and the desired localized features must be extracted. Despite advances in the technology for accurately and rapidly capturing Lidar data on a large scale, automated analysis and understanding of the huge datasets obtained is still being developed.

The traditional methods of dataset processing usually use geometric fitting (e.g. RANSAC) or Region growing. These methods are for coarse segmentation as an initial step of classification of the dataset (e.g. buildings, streets, etc.). Coarse segmentation is typically followed by explicit feature extraction based on algorithms developed to extract smaller objects (e.g. windows, doors or chimneys) for specific applications. Despite the above-mentioned available techniques, machine learning (ML) and AI appear to be more efficient and cost-effective approaches. For example, neural networks (NN) can be trained to intelligently detect and classify 3D assets in the dataset with minimum manual intervention. However, the key point for training NN models is having an accurate, diverse and well-annotated ground-truth dataset. Therefore, it is significantly important to access a full-3D, dense and non-synthetic labelled point cloud at city scale that includes a variety of urban elements (various types of roofs, building facades, windows, trees and pavements). However, the generation of such detailed labelled datasets is difficult and expensive. While there have been several attempts to generate such a labelled dataset, including by using semi-automated photogrammetric or morphological methods, a review of the commonly available datasets shows that none of them can completely satisfy all requirements.

A NOVEL ANNOTATED MASSIVE POINT CLOUD

Iman Zolanvari et. al. provided a novel labelled dataset (Figure 3) from the above-mentioned Lidar data of Dublin at Trinity College Dublin. In this project, over 260 million laser scanning points were manually labelled into 100,000 objects within 13 classes. Those classes included a hierarchical level of detail, from coarse (i.e. buildings, vegetation and ground) to a refined level (e.g. windows, doors and trees).

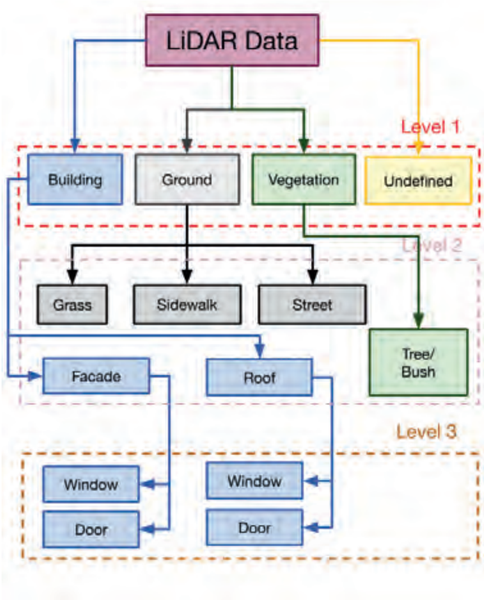
The first level produced a coarse labelling that includes four classes: Building, Ground, Vegetation and Undefined. 'Building' refers to all shapes of habitable urban structures (e.g. homes, offices, schools and libraries). 'Ground' mostly contains points that are at the ground level. The 'Vegetation' class consists of all types of separable plants. Lastly, 'Undefined' points are those of least interest to include, such as urban elements (e.g. bins, decorative sculptures, cars, benches, poles, post boxes and non-static objects).

Approximately 10% of the total points were labelled as undefined and they were mostly rivers, railways and construction sites. In the second level, the first three categories from Level one were divided into a series of refined classes. Buildings are divided into roofs and facades. Vegetation is classified into separable plants (i.e. trees and bushes). Ground points are divided into street, pavement and grass. The third level includes any types of doors and windows placed in the roofs (dormers and skylights) and facades. Each class could be extracted separately or in a combination of other classes for various applications. Figure 4 shows the labelling order of the dataset.

LABEL GENERATION

To generate labels, the initial Lidar dataset was divided into 13 sub-tiles of around 19 million points for annotating. The process started with importing data into the CloudCompare 2.10.1 software. Points were then coarsely manually segmented using segmentation and slicing tools into three categories (i.e. building, vegetation and ground) and labelled accordingly. Next, the process continued to the third level of the finest details (i.e. windows and doors). Hence, this pipeline produced a unique label for each point. The process took over 2,500 hours with appropriate supervision and was carefully cross-checked multiple times to minimize the degree of error.

The annotated dataset includes diverse types of historic and modern urban elements in the city centre of Dublin. Types of buildings include offices, shops, libraries and residential houses. The buildings range from detached and semi-detached to terraced houses and date from different eras (from the 17th-century Rubrics building to the 21st-century George's Quay complex). This detailed labelled dataset is the first of its kind regarding the accuracy,



▲ *Figure 4: Order of labels and the hierarchy.*

▲ *Figure 5: The white points show the differences between the 2017 and 2015 data of the TCD campus.*

FURTHER READING

- United Nations (UN) report, 2014. http://esa.un.org/unpd/wup/highlights/WUP2014-Highlights.pdf

- Debra F Laefer, Saleh Abuwarda, Anh-Vu Vo, Linh Truong-Hong, and Hamid Gharibi. 2015 Aerial laser and photogrammetry survey of Dublin city collection record. https://geo.nyu.edu/catalog/nyu-2451-38684

- Video showing an overview of the dataset of Dublin: https://www.youtube.com/watch?v=qEi2Wo7Bcuk

- Video on the National Geography channel: https://youtu.be/iSRK1NIT-vA

- NYU data repository: https://archive.nyu.edu/handle/2451/38684

- Byrne, J., Connelly, J., Su, J., Krylov, V., Bourke, M., Moloney, D. and Dahyot, R., 2017. Trinity College Dublin drone survey dataset: http://www.tara.tcd.ie/handle/2262/81836

- Zolanvari, S.M., Ruano, S., Rana, A., Cummins, A., da Silva, R.E., Rahbar, M. and Smolic, A., 2019. DublinCity: Annotated Lidar Point Cloud and its Applications. arXiv e-Print arXiv:1909.03613.

density and diversity of classes, particularly regarding its city-scale coverage area. The hierarchical labels offer excellent potential for various classification and semantic segmentation applications in urban science.

APPLICATIONS AND FURTHER INFORMATION

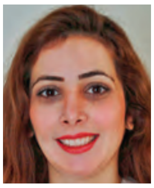
The main goal of the labelled dataset is to train convolutional neural networks (CNNs) for classification of urban elements in massive point cloud data. For example, the labelled dataset can be employed to train and use PointNet, PointNet++ and So-Net. These networks are able to classify urban elements for several important applications (e.g. robotic or autonomous navigation) based on semantic segmentation of the ground level which consists of streets, pavements and vegetation. These are essential elements for an autonomous navigation industry. Also, the vegetation class is highly beneficial for the detection of trees and it can be used to monitor the health of plants in an urban or even forest area. For example, a change detection technique applied to the drone and helicopter data from 2015 to 2017 clearly shows the location, size and number of removed trees. The white points (e.g. trees and the building) indicate what was removed after the 2015 scanning project (Figure 5).

More information about the dataset (i.e. further description with video, link to the academic paper and a download link) can be found at **bit.ly/GIM_magazine**.

ABOUT THE AUTHORS

Dr S. M. Iman Zolanvari has a BSc in Civil Engineering and an MSc in Structural Engineering. He received his PhD on automated feature extraction of 3D models from Lidar data from the School of Civil Engineering at University College Dublin. He spent almost three years working as a postdoctoral research fellow at the School of Computer Science at Trinity College Dublin. He has experience on a broad range of projects, from medical engineering to VR/AR. He is currently working as a data scientist with a speciality in spatial data and image processing at Ambisense Ltd. in Dublin.

iman@zolanvari.com



Dr Atteyeh S. Natanzi has various qualifications relating to surveying, structural and material engineering (i.e. diploma and two MScs). She received her PhD from the Urban Modelling Group of the School of Civil Engineering at University College Dublin. She is a postdoctoral researcher at the School of Civil Engineering. Her main research interests are Lidar, 3D modelling and 3D concrete printers.

atteyeh.natanzi@ucd.ie

The Age of Mobile Mapping

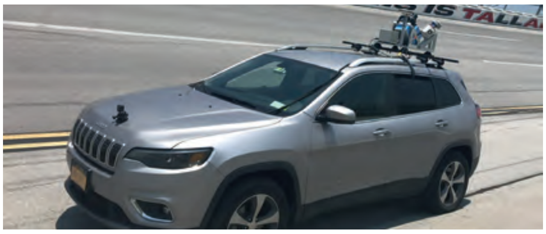
Geomatics students in the mid-1980s were exposed to GPS test satellites, the first GPS receivers and the enormous potential that GPS offered the geomatics community (who had already perfected what could be done with the Transit satellite system). With unprecedented absolute accuracy and an impeccable timing mechanism, GPS clearly offered a quantum leap in geomatics capabilities. Two decades later, Lidar – and in particular mobile terrestrial Lidar – seemed to represent the next quantum leap in geomatics technology since the advent of GPS.

The integration of GPS/inertial measurement unit (IMU) systems with other sensors either enhanced or replaced many of the traditional instruments and methods used in the survey and navigation world. A paradigm shift was underway. Using kinematic differential GPS positioning coupled with orientation data provided by IMUs, calculating the precise geoposition and attitude of a moving camera at the precise moment of exposure established the exterior orientation of a photogrammetric camera. The process of aerial triangulation was made more simple and more accurate. These advancements made GPS-based photogrammetry possible. Electronic distance meters coupled with electronic theodolites, popularly known as 'total stations', constituted another great breakthrough in instrumentation that revolutionized mobile surveying. These new instruments could collect five or six discrete points per minute at centimeter-level accuracy. 2D laser profilers were added to the mix and, like total stations, were used in static mode. Positioned over known survey points, these scanners could rotate 360 degrees, capturing a point cloud that accurately represented the surrounding environment. Encouraged by the results generated using kinematic platforms, laser scanners coupled with GPS/IMU systems were installed on aircraft and helicopters. The first system integrations, while bulky and heavy, provided groundbreaking results. It was possible to fly and directly reference tens of thousands of points per second with remarkable accuracy and resolution. But acquiring test and calibration data using aircraft is expensive. A side-looking scanner system was developed in order to facilitate cost-effective testing and calibration; 6T3 Inc. rolled the laser through 90 degrees, pointed the system through the side opening of a van, and collected the data while driving down the road. In the process, the world's first mobile terrestrial Lidar mapping system (called SideSwipe) was accidentally born. Nowadays, the geomatics business has standardized on the term mobile mapping system (MMS). Acquiring and maintaining a solid GPS solution while operating on the ground presented another set of challenges. In an environment where there are many sources of potential satellite obscurations (overhanging trees, buildings, etc.) so substantial efforts were focused on developing a blended GPS/inertial positioning solution.

In 2004 6T3 was asked to survey a heavily damaged road connecting Kabul, Kandahar and Herat in Afghanistan using its helicopter-based system. Flying in Afghanistan at the time was considered prohibitively dangerous and so the first real application for the MMS was proposed. (In 2014, 6T3 built a sub-centimetre, engineering-grade MMS to respond to clients who needed highly accurate and dense 3D point clouds. Four different versions of the system were developed in response to client requirements, and in 2015 the company developed the first backpack-mounted MMS, thus opening the door to a wide range of possible applications – including even by bicycle.

It is remarkable to see how far the MMS industry has progressed. As for crystal-ball gazing, it is difficult to make predictions on where we are going to be 20 years from now, but I will offer the following for consideration. I believe that high-accuracy point clouds covering urban areas all around the world should and will take the place of traditional geodetic control points. Once these high-end point clouds are recognized as verified control points, they will be used as the reference framework for future surveys and the base upon which all kinds of sensor data will be compiled. Mobile mapping data will be essential in the development of autonomous driving and automated vehicle systems. High-accuracy reference point-cloud data will be required and the market for regular periodic updates will be significant. Change detection, fast and prompt accident and disaster monitoring, city planning, emergency response, traffic control and simulation, agriculture and forestry are all current applications that will expand in the future.

Sensors continue to get smaller, lighter and more affordable. Drone platforms are emerging. New sensors like SLAM, smartphones, dash-cams, personal cameras, security and traffic detectors and sensors installed and operating inside autonomous vehicles will be increasingly integrated in the global point cloud for further refinement. How will the current technologies be eclipsed by new solutions? How much detail and accuracy do we really need? How will the next paradigm shift in the geospatial world look? Opinions differ. However, looking back over the past 30 years, it's hard to believe just how far we've come in such a relatively short space of time.



FURTHER READING

- http://www.cajunbot.com/wiki/images/6/68/Gps_world_july_2005.pdf

- https://www.spar3d.com/news/lidar/riegls-vux-1ha-lidar-backpack-mapping-system

ABOUT THE AUTHOR

Kresimir Kusevic is technical director at 6T3, a company that develops mobile mapping Lidar systems which measure up to two million points per second. 6T3 is specialized in surveying Formula 1 racetracks, mapping military test ranges and conducting road surveys. Kusevic received his Master's in Geodesy Engineering from the University of Zagreb, Croatia, in 1990.
kresimir.kusevic@6t3.ca

USING PPP CORRECTIONS IN PRECISE REAL-TIME APPLICATIONS

Minding the Gaps

Satellite-delivered GNSS correction services can be used in many real-time applications where real-time kinematic (RTK) and virtual reference stations (VRS) are not available. In areas without regular communication systems, satellite-broadcast precise point positioning (PPP) corrections can deliver centimetre-level positioning worldwide in real time.

While geospatial professionals who use RTK and VRS enjoy reliable, cost-effective performance in a broad array of tasks, there are many instances where conditions conspire to make working in real time difficult or even impossible. For example, hilly terrain may block radio signals from an RTK base station, while inconsistent cellular coverage can disrupt or cut off communications with the VRS network. In many locations, VRS service is not available at all and accurate geodetic control marks needed for RTK are unavailable. To fill these gaps, users can turn to PPP technologies.

Modern approaches to PPP enable users to obtain real-time GNSS positions with centimetre-level accuracy horizontally and sub-decimetre-level accuracy vertically. With PPP integrated into existing geospatial workflows, users can choose RTK, VRS or PPP to optimize their productivity while obtaining the required accuracy in situations where real-time positioning has up until now been impractical or overly expensive.

TRIMBLE CENTERPOINT RTX

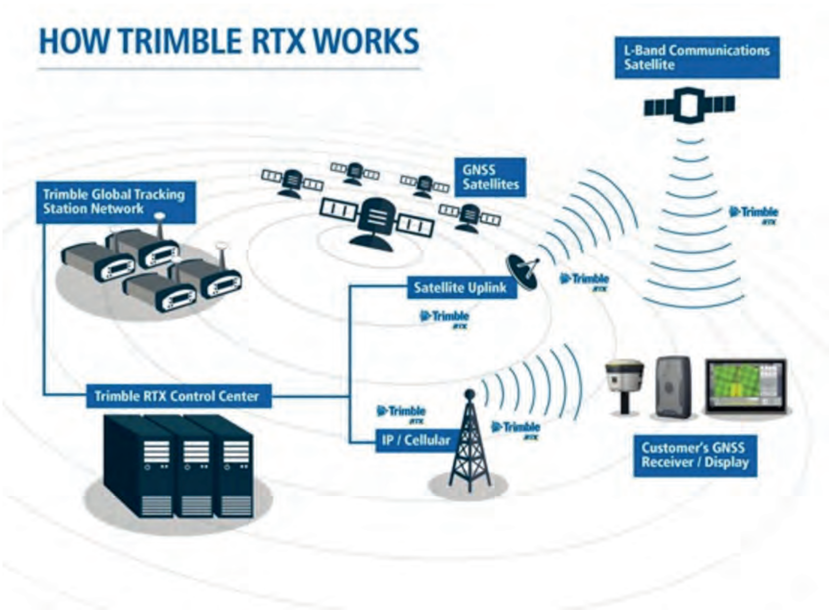
Trimble's approach to PPP is called RTX and consists of three parts. First, Trimble operates multiple control centres to provide redundant, highly secure data management, processing and distribution. Second, a network of more than a hundred GNSS tracking stations around the world streams multi-frequency, multi-constellation data (GPS, GLONASS, Galileo, BeiDou, QZSS) to the control centres. Advanced data processing algorithms analyse the three main error sources – satellite orbits, clock offsets and atmospheric effects – and develop models and correction data. For example, the satellite orbits are modelled with an accuracy of one to two centimetres in real time, which is a significant advantage over the broadcast orbit data that is accurate to roughly one metre. The GNSS tracking stations are constantly checked for performance and stability to ensure accuracy of modelling and correction data. Third, the data is delivered to GNSS rovers via L-band satellite communications using geostationary satellites or, where available, wireless internet. The rover combines the correction data with its own satellite observations to produce accurate positions.

The ability to produce high-accuracy positioning also relies on the increasing capability of hardware in the field. New-generation rovers such as the Trimble R10 have the ability to track all available GNSS signals and L-band communications, and also have the computing horsepower to handle the data and complex computations. The highest-accuracy RTX service, CenterPoint RTX, can produce horizontal accuracy of 2cm root mean square (RMS).

With more data from more stations fed into improving algorithms, the time needed to obtain high-accuracy positions is improving as well. Users can typically obtain an accurate PPP solution anywhere in the world in less

▲ *A South African surveyor using RTX to capture accurate positions in real time.*

than 15 minutes. In many areas, including much of Western Europe and North America, the higher density of tracking stations in the RTX network supports more accurate regional atmospheric models that allow initialization in less than one minute. Once the initialization is complete, GNSS users can work in the same manner and with the same accuracy as with RTK or VRS.



PPP VS RTK/VRS

PPP systems such as RTX are not a replacement for RTK or VRS. Rather, they are complementary or supplemental to those methods. The satellite-delivered PPP corrections help users to maintain productivity when they would otherwise be forced to use approaches that are slower or less accurate. This is the result of satellite corrections having a different transmission profile from RTK or VRS as considered in the examples below:

- VRS users require a connection to the internet, typically via cellular networks. A lost connection can result from technical issues with their cellular provider or from simply moving behind a hill or outside of the cellular coverage and losing cellular connection. Because RTX uses satellite delivery for its correction data, users can continue to operate provided they have a clear view of the sky in the direction of the geostationary communications satellite(s). When cellular connection is regained, they can resume operation in the VRS.

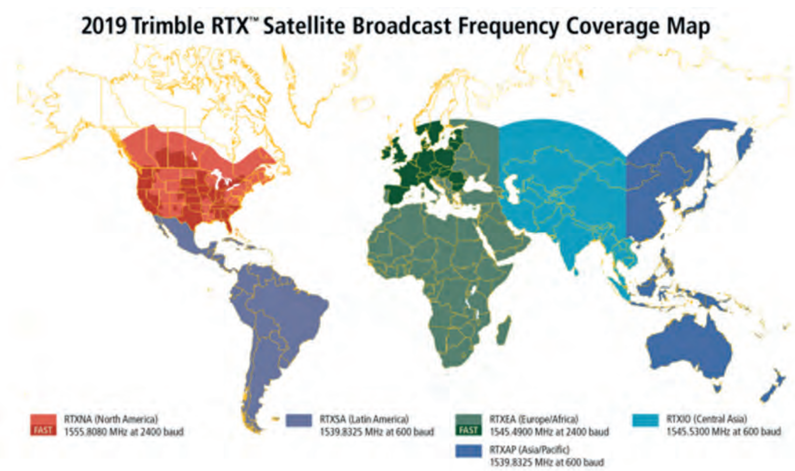
- For accurate positioning outside of VRS coverage, both PPP and RTK can be solutions. However, PPP eliminates the need to set up, move and manage local base stations. Additionally, many RTK operators use cellular communications to transmit corrections from their base stations; they are vulnerable to the same communications limitations as VRS.

PPP APPLICATIONS

PPP solutions such as Trimble RTX have been used for years in agricultural settings, where farm operators need 24/7 positioning for precise agriculture applications. The system is also used in an even more critical application: autonomous vehicles. The Cadillac Super Cruise hands-free driving assistance system relies on CenterPoint RTX to provide the consistent, accurate positioning needed for safe operation of the cars.

Satellite-distributed PPP corrections are also useful in the land survey industry, such as for cadastral surveys in the back country far from suitable control, for example, or for establishing control in aerial imagery for large-scale projects in areas not covered by VRS and with poor cellular coverage.

Looking ahead, PPP points to more flexibility for GNSS users across the board. It is reasonable to expect growth in location-based applications that can benefit from high-accuracy real-time positioning. Besides that, industry trends indicate further expansion of fast initialization availability together with increased use of PPP in the traditional geospatial markets. By acting as a complement to RTK and VRS, PPP is a proven and cost-efficient tool to enable geospatial professionals to provide improved service and value to their clients. ◂



ABOUT THE AUTHOR

Mark Richter is strategic marketing director for the real-time networks and services (RTNS) business area within Trimble's Advanced Positioning division. He is responsible for global business strategy and product marketing for RTNS for positioning services (Trimble RTX and Trimble VRSNow). He holds a master's degree in geodesy from the Munich University of Applied Sciences, Germany.


PENTAX
Focusing on true performance
NEW
Upgraded Advanced Total Station
G6Ti and G6Ni
GNSS Receivers
Powerful GNSS engine in compact and robust housing which provides stable precision measurement outcome in harsh outdoor environment.
R-2500NS Series
Total Station
A full-featured reflectorless total station with enhanced functionality. Providing exceptional performance and cost effective solutions to modern professional surveying works.
PENTAX
TI Asahi
TI Asahi Co., Ltd.
International Sales Department
4-3-4 Ueno Iwatsuki-Ku, Saitama-Shi
Saitama, 339-0073 Japan
www.pentaxsurveying.com/en/
Tel.: +81-48-793-0118
Fax: +81-48-793-0128
E-mail: International@tiasahi.com

REFLECTIONS ON INTERGEO 2019

Towards Smaller and Smarter Solutions

Intergeo is a leading annual industry showcase where geospatial professionals gain an excellent impression of the latest innovations. On the brink of a new decade, Intergeo 2019 gave us a glimpse of the future. In general, we can conclude that solutions are getting smaller and smarter, and there are some new kids on the block. But with all the buzz around machine learning and artificial intelligence, how can we cut through the hype to get the most out of the rapidly advancing technology?

One thing was crystal clear at this year's Intergeo: the unmanned aerial vehicle (UAV or 'drone') has well and truly moved beyond the hype. The unmanned aerial system (UAS) has now become a standard survey method which has proven its practical value for a multitude of applications. The annual geospatial gathering in Stuttgart revealed an increase in the number of hybrid UASs. Examples included the Marlyn autonomous vertical-takeoff-and-landing (VTOL) drone – developed by Atmos UAV – that combines the flexibility of a multirotor with the efficiency and speed of a fixed-wing, and a similar solution from Switzerland-based Wingtra, a spin-off company from the Autonomous Systems Lab at ETH Zurich.

DRONES WITH LASER SCANNERS

The miniaturization of scanners combined with the increased payload capability of drones is leading to a rapid increase in drone-based laser scanners for point cloud capture, such as the new UAV scanner from RIEGL and the small Velodyne HDL-32E scanner. Determining the position and attitude of the scanner during the flight requires the inclusion of high-quality GNSS and IMU equipment. One such solution on display at Intergeo 2019 was from French company YellowScan, which showcased its turnkey 3D UAV-Lidar systems. Overall, drone-based Lidar is clearly making a serious impact for specialists across many professions.

SMALLER MOBILE MAPPING SYSTEMS

Around a decade ago, mobile mapping systems (MMSs) were the newest innovation in Intergeo's vast exhibition halls, with lots of big systems comprising laser scanners, cameras and navigation equipment mounted on top of big vehicles. Today, the number of suppliers has declined to just a few companies. The mobile mapping systems are much harder to spot too, because they have become much smaller over the years. New, miniaturized sensor technology enables the sensors to be mounted on various types of moving platforms and opens up new possibilities for more versatile and less expensive MMSs. Most systems can now be lifted easily, allowing for hassle-free mounting and dismounting, and many are even portable.

INVASION OF AUTOMOTIVE SENSORS

Alongside traditional suppliers of land survey equipment, there was a notably higher number of suppliers with origins in automotive sensors. Thanks to the economies of scale resulting from their existing production activities, these suppliers are capable of delivering lower-cost sensors. Although they are not especially built for surveying, those sensors are suitable for use in situations where quality is not essential, such as visualization. Integration with centimetre-level GNSS and MEMS IMUs can turn laser scanners from the automotive industry into a mapping payload for UAVs.

▲ *Delegates arriving at Messe Stuttgart, this year's Intergeo venue.*

INDOOR MAPPING EXPANDS

Staying on the topic of sensors, there were also many new sensors for indoor mapping applications. The solutions, which included backpacks and a new handheld scanner from Leica Geosystems, typically work on the simultaneous localization and mapping (SLAM) principle. The development of SLAM algorithms has enabled the advancement of mobile laser scanning (MLS) to provide 3D data from GNSS-denied environments, such as indoor locations and industrial sites. Recent further improvements in SLAM technology and software tools mean that surveyors can use mobile devices for an ever-expanding range of applications. Moreover, the data can be automatically processed and visualized as intuitive HD maps or realistic, interactive digital twins, thus making it accessible for a broader customer base.

PHOTOGRAMMETRY REVIVAL

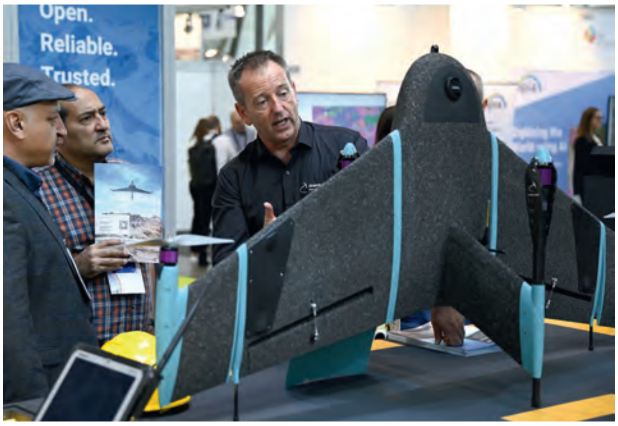
The continued rise, advancement and applications of Lidar as a prevalent geodata acquisition technology were visible at this year's event, but visitors could still find plenty of photogrammetry on the exhibition floor. Thanks to significant improvements in both hardware and algorithms, dense image matching (DIM) – a computer vision-driven technology that allows for the generation of detailed and reliable point clouds from images – has led to a real revival of this field. At *GIM International*, we spotted the key role of DIM in many geoinformation-related innovations almost a decade ago, and the technology is now clearly allowing photogrammetry to step out of Lidar's shadow.

ARTIFICIAL INTELLIGENCE – HYPE OR HOPE?

On the topic of algorithms, artificial intelligence was hard to ignore at this year's Intergeo. But are artificial intelligence (AI) and machine learning (ML) worth the hype, and should you be taking action now? Or is it better to wait and see how things pan out? In our view at *GIM International*, you should consider what AI and ML can actually add in your situation at the moment. Solutions that incorporate machine learning are not automatically better than those that do not. Having said that, machine learning already plays a role in many aspects of our daily lives. AI is already being applied in Lidar or photogrammetry imagery, for example, but it requires high-quality and accurate data… and the accuracy of algorithms can be a challenge. But ML and AI-based methods certainly hold considerable promise in terms of improving automatic object detection in point clouds in the future, for instance. One good example of how AI and machine learning can add value to mapping and surveying solutions is Harris Geospatial's ENVI geospatial analytics software. Its deep learning module delivers image-driven insights and also helps to make deep learning more widely available to the industry.

A GLIMPSE OF THE FUTURE

This year, *GIM International* organized a full-day track as part of the Intergeo conference on the final day of the event. The morning session, titled 'Geomatics in the Next Decade', gave a realistic yet enthralling glimpse of the geospatial future. As Esri celebrates its 50th anniversary in 2019, Lawrie Jordan, the company's director of imagery and remote sensing, took the audience on a journey into the future of GIS,



▲ *Intergeo 2019 revealed an increase in the number of hybrid unmanned aerial systems.*

▲ *In line with tradition, this year's Intergeo press conference once again took place at noon on Wednesday.*

▲ *A view of one of the exhibition halls.*

▲ *Esri's Lawrie Jordan delivering his keynote.*

saying that a new view and a new vision is now emerging of GIS as the "Intelligent Nervous System" for our planet. During his keynote, Jordan provided insights into some of the latest software technology trends intersecting with this nervous system, including practical examples employing AI, ML, deep learning, real-time and predictive analytics, multi-temporal image cubes, etc. The future-oriented and often mind-boggling technology offers the potential for a wide range of concrete applications.

The afternoon session, titled 'The Many Faces of Mobile Mapping', covered advancements in mobile and aerial mapping. Gottfried Mandlburger (Vienna University of Technology) delivered an excellent update on recent developments in airborne Lidar, putting emphasis on hybrid multipurpose 3D data acquisition. Pere Molina (GeoNumerics,) pointed out how GNSS technology – as a central ingredient in the positioning mix – struggles to fuse the numerous available frequencies and constellations and still deliver error-free trajectories. In his presentation, Molina elaborated on the problem and potential approaches to its mitigation. GeoNumerics' mapKITE solution works with an analogy to the conventional ground control points (GCPs) by simply taking advantage of its operation; as the UAS follows the terrestrial vehicle, the target is observed in all the images providing ready-to-use kinematic ground control points (KGCPs) for every image. This results in a high-accuracy, high-resolution surveying method.

THE SOLUTIONS OF THE GEOSPATIAL INDUSTRY BECOME EVER-MORE MAINSTREAM

CONCLUSION

Following three busy days of Intergeo, we can conclude that sensors are getting smaller and more sophisticated. Hybrid mapping methods are becoming increasingly mature and, as a consequence, mainstream. Although Lidar technology is omnipresent, the market seems to have rediscovered the benefits of photogrammetry thanks to the many possibilities of DIM. A significant number of the exhibitors in Stuttgart were new entrants to the geospatial industry from other sectors. Many companies that were eye-catching start-ups and innovators (or 'disruptors') five years ago have since been acquired by major players such as Trimble and Bentley. Last but not least, having started as a niche around two decades ago, the geospatial industry now has a bright future ahead as it increasingly interacts with other industries and its solutions become ever-more mainstream.

ACKNOWLEDGEMENTS

The author would like to thank Mathias Lemmens, senior editor of *GIM International*, and Martin Kodde, consultant and director at Geodelta, for sharing their experiences after attending Intergeo 2019.

ZOOMING IN ON A GROUNDBREAKING REVOLUTION

Use of InSAR to Create Ground Stability Maps

Satellite radar interferometry (InSAR) is a technique that can measure millimetre-scale movement of the ground from space. It does this by comparing the return echoes, and thus the signal-path length, from two or more radar images taken over the same place, over time. Modern InSAR is now used by a range of industries concerned with ground or structural stability, from building development and control, to oil and gas production, to mining, to road and rail management. This article explains some key aspects of InSAR technology, including its innovative use to produce ground stability maps.

InSAR is based upon 'repeat-pass' (multi-temporal) data collected by radar satellites orbiting the Earth at several hundreds of kilometres altitude. These satellites actively emit microwave radiation and record the echo on a pixel-by-pixel basis. The echo comprises a sine wave caught by the receiving antenna at a specific point in its 360° phase cycle. All things being equal, the echo response in any subsequent image for this pixel will be caught at the same point. However, in real life, all things are not equal, and an amount of phase shifting between images can occur for various reasons, including; system noise, instrument vs target geometry, influence of topography, decorrelation due to ground-cell disturbance (e.g. vegetation movement), atmospheric refraction, and then the signal in which we are most interested; any difference in the signal path length due to movement of the ground away from or towards the satellite (see Figure 1).

The first three of these phase-shifters can be corrected. The effects of most vegetation, or other ground-cell decorrelation, cannot be overcome, but can be helpfully indexed as a quality measure of coherence. Signal refraction, however, cannot usually be corrected, and becomes a main limiting factor in the 'displacement resolution' of the InSAR process applied.

InSAR processing in its simplest form for movement detection uses two radar images of near identical specification, bracketing in time the event of interest, say, an earthquake. The phase data of the first radar scene is compared with that of the second one to produce an interferogram that shows the different range values between the two image dates - the displacement resolution of such a product is typically one or two centimetres at best and is limited mainly by the round trip of each radar signal through the atmosphere. Indeed, rainclouds and other atmospheric phenomena can severely refract signals and completely disrupt useful measurement.

Although conventional interferometry has its limitations, in some commercial scenarios such as open-cast mining where potential movements can be relatively large and rapid, these products can have real value in augmenting ground-based instruments to provide regular and fast safety assessments. However, for smaller, more subtle movements, the vagaries of our atmosphere were always going to prevent 2-scene differential interferometry from developing into a tool of more clinical precision.

PERSISTENCE PAYS

Around the turn of the millennium, a team led by Professor Fabio Rocca at Milan Polytechnic came up with an elegant solution to the effects of the atmosphere that exploited the large archives of satellite radar data that were being systematically collected by ESA's ERS missions (Ferretti, Prati, & Rocca, 2001). The technique they invented looks at all the images archived over a certain location to identify arrays of ground features that naturally and persistently reflect back to the satellite in every image - 'persistent scatterers' (PS – sometimes referred to as 'permanent scatterers'). The phase for

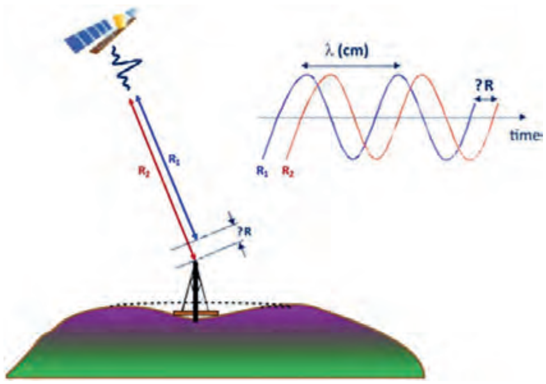


Figure 1: The principle of InSAR for measuring ground movement.

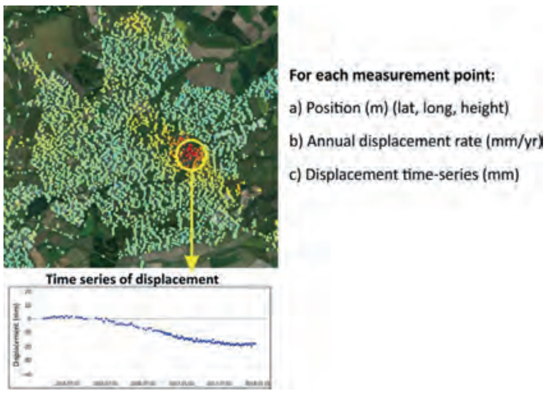


Figure 2: Example of persistent scatterer products.

each scatterer is cross-compared across all the scenes of the archive to calculate any movement. By analysing a minimum number (a few tens) of images, the major effects of the atmosphere can be modelled out, and displacement resolution improved by an order of magnitude over conventional InSAR. Quite remarkably, using this technique, movements of the ground as small as a millimetre per year can be measured from 700km away in space. Persistent scatterers are typically buildings, infrastructure, or even bare rocks, and in urban environments can number from a few hundred, to many thousands of points per square kilometre, depending on satellite resolution. In Figure 2 we can see an array of InSAR measurement points (permanent scatterers) related to a small town within an agricultural context. The points are colour-coded by average velocity; green points are stable, yellow-red points are moving away from the satellite, in this case, subsiding. Each point holds a time-series that can reveal trends in deformation.

Since 2010, further refinements to the 'PS'-InSAR process have ensued to squeeze as much out of the data as possible. Persistent scatterers are related to the radar impulse responses of individual ground-cells, and their point spread functions result in single points (even though the satellite spatial resolution might be, say, 20m x 5m (Sentinel-1), a correctly oriented, 1m trihedral corner reflector in an uncluttered field would still be clearly discernible). Through further advanced research, the arrays of PS measurement points have now been joined by arrays of 'distributed scatters' (DS), where clusters of ground cells with adequate coherence but low amplitude are aggregated to create a secondary form of measurement point, thus significantly increasing overall coverage (Ferretti, Novali, Rocca, & Rucci, 2011) (see Figure 3).

PRODUCTS

So, what are the actual products from the PS+DS InSAR process? The main output is the array of measurement points as a spreadsheet. For each point, its location, elevation, average velocity, time-series, and quality parameters are given. This data enabled a 2D vector plot to be visualized in a GIS where each point is colour-coded depending on velocity in the line of sight of the satellite. Depending on software, clicking on a point will reveal its time series where the evolution of its motion can be examined. The overall period measured is user-specified and archive-dependent, but data for some applications go back to 1992, so ground motion trends over the last 26 years can be assessed. This data can be superimposed by other geospatial layers to determine any coincidence of ground motion to help assess risk.

It is not suggested at all that InSAR is a panacea for monitoring ground motion, nor does it replace conventional survey techniques. It does, however, have its unique perspective and 'non-invasive' attributes, and can help prioritize ground surveys, or reduce their required frequency and density; moreover, it can provide displacement data over very wide areas (thousands of square kilometres), where the cost of a conventional survey would be prohibitive and not always possible.

LIMITATIONS

Although a remarkable technology, InSAR has some limitations:

- Radar data availability: Data acquisition by the various InSAR-compliant satellites has not always been of consistent quality or adequate coverage, or of high enough frequency. Before any job, the archives have to be checked for suitable time sequences and for quality.
- Rural coverage: Ground-cell similarity between images decorrelates with time, and so the interval between data acquisition is critical to getting good measurements. Currently, and especially at temperate latitudes, InSAR is unreliable over most types of vegetated landcover, limiting its application to the built (or rocky) environment. Soil moisture also directly effects penetration of the radar signal, and so variation in the former may result in phase changes mistaken for displacement. However, rural areas often contain linear or sporadic infrastructure from which good measurements can be taken, and movement of these can be indicative of a bigger picture.
- Where's the PS? The precise location of persistent scatterers cannot be predicted before processing (unless radar corner reflectors are specifically sited). What constitutes a PS depends on many factors such as materials, geometric shape, orientation and aridity. Plus, some echoes may in fact be the result of bounces between multiple ground-based objects before the signal is returned to the satellite. This presents a marketing dilemma, particularly for more medium-resolution products where the density of scatterers, even in towns, can be insufficient; the client wants to know if a certain area or feature is moving, but we don't know if there will be any measurement points in the right places until after we've invested in processing. Pre-processing and experience help overcome this problem.
- Costs: InSAR processing is complex, from accessing the right radar data to understanding what the outputs mean. InSAR service provision means advanced and complex software, high-performance computing power, and highly qualified and expert staff. For higher-resolution InSAR, there is also the high cost of the raw radar data needed. InSAR can be expensive and is not cost-effective in some scenarios.
- Market inertia: There can be resistance to disruptive technology, especially if significant investment has already been made in alternative survey technology. It's also not always clear to see exactly how InSAR might fit into an organization's existing workflow. The only answer here is education, in both

▲ *Figure 3: Example PS vs SqueeSAR.*

▲ *Figure 4: UK InSAR map of ground stability. Colours indicate average ground velocity in mm per year. Greens are stable, yellow-red points are moving away from the satellite with blue points moving towards the satellite.*

directions. The pros and cons of using InSAR need to be balanced against using current methods. InSAR is now gaining traction and becoming accepted by a growing number of sectors.

THE ERA OF COPERNICUS

Copernicus is the world's largest single Earth observation programme, directed by the European Commission in partnership with ESA. The programme went live in 2014 with the launch of the first of the Copernicus Sentinel satellites, Sentinel-1a, a high-quality radar specifically configured for operational InSAR service provision. This was joined a year later by Sentinel-1b, an identical sister satellite placed in orbit 180° apart, to double temporal resolution of the overall mission to an InSAR-compliant repeat every six days. Sentinel-1 has since been joined in orbit by the (non-InSAR) Sentinel-2, 3 and 5 missions that are focusing on other issues such as agriculture, pollution and climate change. The data from all Sentinel missions are free and openly available via the Copernicus Open Access Hub, although of course they need processing.

SENTINEL-1

Sentinel-1 has disrupted the InSAR market – in a good way. Finally (at this 'medium' resolution), after 20 years of scrabbling around trying to develop commercial markets with unreliable or non-existent radar data, we now have reliable global coverage that repeats every six days from two different look-angles. That equates to 120 regular acquisitions a year over all areas. As less change is occurring in between image acquisitions, overall coherence is higher (although vegetated landcover still remains problematic). Given the right processing in the right circumstances, Sentinel-1 data provides clean, precise InSAR measurements. Furthermore, robustness and continuity are assured, with follow-on satellites already in the pipeline. This fosters confidence and enables the public and private sectors to build satellite services into their workflows and benefit from the many advantages of operational satellite remote sensing.

It must be emphasized that Sentinel-1 provides what we term 'medium-resolution' data, meaning that derived InSAR products are mostly suitable for wider-area, synoptic analysis of ground and structural motions, equivalent to around 1:50,000 scale mapping. Other higher-resolution satellites are available for more detailed inspection of individual buildings or infrastructure. Sentinel-1 data can be considered useful for identifying ground motion hotspots over a wider area that might then demand a closer analysis with a higher-resolution radar mission, such as the Airbus TerraSAR-X that will give results in urban scenarios to around 1:10,000 scale.

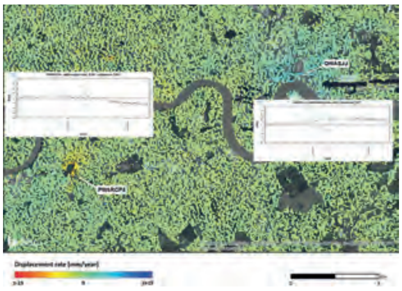
BRAVE NEW WORLD

Extraordinary volumes of data are downloaded from Sentinel-1, currently around 3.5TB per day (>1PB per year). As of February 2019, 3.5 million Sentinel-1 products were available for download, their raw versions representing ~7PB total. Each raw radar image is around 8GB. The sheer amounts of data now available challenge computing power and traditional methods of image processing. Fortunately, through Moore's Law, computing power has kept up, and rather than analysing individual images, big-data principles mean that complete multi-temporal archives are being intelligently mined to extract new types of change-data. PS-InSAR was perhaps the 'remote sensing pioneer' in big data processing, pushing technological boundaries by processing complete archives, albeit over relatively small areas. Now, with advanced InSAR algorithms that exploit multi-node cloud computing combined with the systematic radar data generation and supply that Senintel-1 affords, large-scale processing – and, significantly, pre-processing – of very wide areas is not only practically possible, but already a commercial reality.

UK MAP OF GROUND STABILITY

Based on the processing of 7,500 Sentinel-1 radar scenes covering 2016 and 2017, TRE ALTAMIRA has produced the first ever double geometry PS-InSAR map of the UK, mapping the nation's ground stability to an unprecedented accuracy (see Figure 4). By integrating different satellite acquisition modes, motion vectors have been deconvolved to produce two geospatial layers: one of purely vertical motion, the other of just east-west (the satellite is not sensitive to ground motion parallel to its orbital path, which is nearly north-south around the Earth). Measurement points are provided on a regular grid to ease integration with other data.

The map was updated mid-2018 with some improvements, with 2019 being updated quarterly. This is in fact the sixth very wide area product processed by TRE ALTAMIRA and made possible by Sentinel-1, the others being all of France, Denmark, Japan and Italy, plus a large part of California, USA.



▲ *Figure 5: Ground motion in London.*

As mentioned, this data is not suitable for the monitoring of individual structures, but appropriate for wider-area identification of hotspots that might then require closer inspection (see Figure 5).

CONCLUSION

This article has given a brief overview of the development of terrestrial InSAR since its pioneering beginnings in the mid-90s to the automatically computed national products that are based on data from truly operational and service-driven satellites. InSAR is not yet a commodity, and potential users still need to be careful who they choose to do their processing, and of course there will always be the demand for more customized InSAR processing, and with higher-resolution satellites. Nonetheless, the Copernicus programme has broken new ground by providing some fantastic satellites by which it can be measured. ◀

This article was originally published in Geomatics World *March/April 2019. All images in this article are courtesy of TRE ALTAMIRA.*

MORE INFORMATION

- Copernicus Open Access Hub
https://scihub.copernicus.eu
- Sentinel missions
https://sentinel.esa.int/web/sentinel/missions

ABOUT THE AUTHOR

Dr Renalt Capes has 26 years' experience in satellite remote sensing, 24 of which have been devoted to the development of InSAR. He currently contracts to TRE ALTAMIRA in support of the development of the UK market.
✉ ren.capes@tre-altamira.com


GNSS Solutions
Visit leica-geosystems.com/gnss to find out more and request a demonstration.
Leica GS18 T
World's fastest GNSS RTK rover
Meet the world's fastest and easiest-to-use GNSS RTK rover, the Leica GS18 T. Now you can measure any point faster and easier without the need to hold the pole vertical. This latest innovation combines GNSS and inertial measurement unit (IMU) being the first true tilt compensation solution that is immune to magnetic disturbances and is calibration-free. Save up to 20 per cent over conventional surveying practices, measure where others can't, faster than ever before and forget the bubble.

LADM2019 Held in Kuala Lumpur

The 8th Land Administration Domain Model (LADM) Workshop was held in Kuala Lumpur, Malaysia, from 1-3 October 2019. The focus of the LADM2019 workshop was on preparing input for the second edition to follow on from the first edition (published in 2012). ISO Technical Committee 211 on Geographic Information is developing this new multipart edition of the LADM (titles may still change):

Part 1 - Land Administration Fundamentals
Part 2 - Land Tenure
Part 3 - Marine Space
Part 4 - Land Valuation
Part 5 - Spatial Planning
Part 6 - Implementations

Possible extensions were addressed in Kuala Lumpur: a fiscal/valuation extension module; a spatial planning module; further modelling of LADM's rights, restrictions and responsibilities; marine cadastre; relations with building information modelling (BIM), further modelling of LADM's survey and spatial representation and 3D/4D cadastre. Attention will be paid to the Operational Standards in Land Administration. FIG is a liaison member of TC 211 and is strongly involved in the development of the standard. All proposed extensions are covered by the knowledge domains of FIG's Commissions.

FIG COMMISSION 3 ANNUAL MEETING AND WORKSHOP AND ROMANIAN SURVEYING WEEK HELD IN ROMANIA

Specialists in surveying, land administration, spatial planning & development and land valuation gathered for a whole week in Cluj-Napocal, Romania, from 23-28 September for the first edition of the Romanian Surveying Week. The Romanian Surveyors Union event was organized jointly with the FIG Commission 3 Annual Meeting and Workshop on 'Advances in Geodata Analytics for Smart Cities and Regions' and the University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca International Conference on 'Life Sciences for Sustainable Development'. Hartmut Müller, chair of FIG Commission 3 Spatial Information Management, reports: "Our Romanian hosts had generously offered this opportunity to organize the Annual Meeting and Workshop of FIG Commission 3 during the Romanian Surveying Week. We, the members of the commission, are very grateful to our colleagues in Romania for making this event possible. With their excellent organization they laid the foundation for a very fruitful and enjoyable event, both professionally and personally. Notable progress has been made on one of the commission's key objectives of involving young surveyors more closely in the work of FIG as a whole. By organizing a special Young Surveyors session, the joint Commission 3 and 8 Working Group 'Geospatial next' chaired by Cemal Ozgur Kivilcim has proved very helpful in connecting young surveyors with long-term FIG activists."

The FIG Commission 3 Annual Meeting and Workshop brought together a remarkable number of active professionals, fostered understanding of the challenges of the host country, and opened the door to future activities and opportunities.

More information
www.fig.net

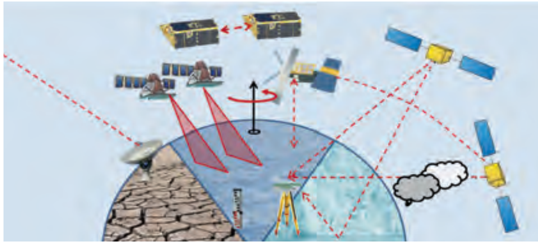
▲ *Chair of FIG Commission 3, Hartmut Müller, at the opening of the meeting which brought together 130 participants. A record number of 35 young surveyors and professionals registered.*

New IAG Inter-Commission Committee on Geodesy for Climate Research

During the IUGG General Assembly in Montreal, the IAG established a new Inter-Commission Committee on Geodesy for Climate Research (ICCC) to enhance the use of geodetic observations for climate studies. Geodetic observations relevant for climate research include tropospheric water vapour, thermospheric neutral density, terrestrial water storage, ice sheet and mountain glacier mass, steric and barystatic sea level, sea surface winds, ocean waves, subsurface and surface currents, or sea ice extent and thickness. Many of these are listed as Essential Climate Variables (ECVs) according to the definition by the Global Climate Observing System (GCOS).
Specific goals of the ICCC are:

- to deepen the understanding of the potential (and limitations) of geodetic measurements for the observation, analysis and identification of climate signals
- to advance the development of geodetic observing systems, analysis techniques and data products regarding their sensitivity to and impact on ECV
- to advance the improvement of numerical climate models, climate monitoring systems and climate reanalysis efforts through incorporating geodetic observations
- to stimulate scientific exchange and collaboration between the geodetic and the climate science communities
- to make geodetic variables more user-friendly by sharing them publicly and explaining their usefulness.

The activities of the ICCC will primarily be carried out through its thematic working and study groups to be set up in the coming months. Furthermore, plans of the ICCC comprise the organization of a series of workshops to intensify the exchange between different geodetic communities and the climate monitoring and modeling communities, the organization of related sessions at international conferences, and the establishment of links to other climate science-related bodies within IUGG and beyond.



More information
- ICCC on Twitter (@iag_climate)
- ICCC website: https://iccc.iag-aig.org/

International Cartographic Conference 2021

The 30th International Cartographic Conference (ICC) will take place in Florence, Italy, in 2021, and is provisionally scheduled for 19-23 July (although these dates are still subject to change). The ICC 2021 will be organized in line with the tradition of ICA Conferences and – in the city of marvelous works of art, the Ponte Vecchio bridge and the Boboli Gardens – it will certainly be an event for cartographic and geospatial professionals to look forward to.

PROGRAMME AND CONFERENCE PRESENTATIONS

ICC 2021 in Florence will represent the opportunity to reflect on the state of the art in cartography and related disciplines, considering the international context as well as the trends in Italy through oral and poster presentations of papers. As for the other ICA conferences, the ICA Executive Committee and chairs of commissions and workshops will be involved in realizing the final programme and reviewing the papers submitted. These will be also reviewed by referees chosen from researchers and scholars who are experts in the field of cartography and related disciplines. Posters, abstracts and full papers will provide insights into cartography-related research and experience.

SCIENTIFIC PROGRAMME AND THEMES

The organizing committee has selected a set of main themes to characterize ICC 2021 Florence under the umbrella theme of 'Cartography: planning our future from lessons from the past' which highlights the aspects for which Italy is renowned in the field:
- Cartography in and over the Web 2.0
- Cartography as decision support tools and to foster sustainability
- The quality of spatial data
- Cartography and geographic information systems
- Cartography and remote sensing
- Unconventional cartography: networks, news, media, art and participation
- Historical cartography and history of cartography
- Cartography and cultural heritage

The conference certainly will not be limited to these themes, and a more detailed list of themes to be tackled in ICA's commissions and workshops will follow later. Furthermore, ICC 2021 will be the perfect occasion to shed light on new cartographic techniques – offering new ways of seeing and interpreting the Earth and its phenomena and playing a fundamental role in promoting and governing the territory.

More information
- https://icaci.org/calendar/
- http://cartography.web.auth.gr/ICA-Heritage/Thessaloniki2019/programme.html
- www.e-perimetron.org

How ISPRS Cooperates Internationally

The International Society of Photogrammetry and Remote Sensing is an international organization with 92 Ordinary Members representing 92 countries. The society cooperates with other organizations whose main focus is on the Earth – i.e. on geosciences.

• Among other organizations, ISPRS is a member of the International Science Council (ISC). The ISC was created in 2018 as the result of a merger between the International Council for Science (ICSU) and the International Social Science Council (ISSC). ISC is the only international non-governmental organization bringing together the natural and social sciences, and is the largest global science organization of its type.

• Together with other geo-societies, ISPRS created a group called GeoUnions within ICSU. Members of GeoUnions meet at least once per year to discuss items in common: scientific developments such as the new era of data collection, archiving and processing, etc. Such meetings bring new ideas for scientific development, as well as support for young scientists.

• ISPRS is also a member of the United Nations Committee of Experts on Global Geospatial information Management (UN-GGIM). UN-GGIM members that are involved in geosciences – as ISPRS is – created UN-GGIM Geospatial Societies, which was previously known as JBGIS. This organization is involved mainly with topics focused on geoinformatics.

• Another is the United Nations Office for Outer Space Affairs (UNOOSA). UNOOSA works to promote international cooperation in the peaceful use and exploration of space, and in the utilization of space science and technology for sustainable economic and social development.

• Cooperation with other non-governmental organizations and sister societies brings together scientists and stakeholders from various spheres, enabling them to follow new developments in the various branches and to span the gaps between individual societies.

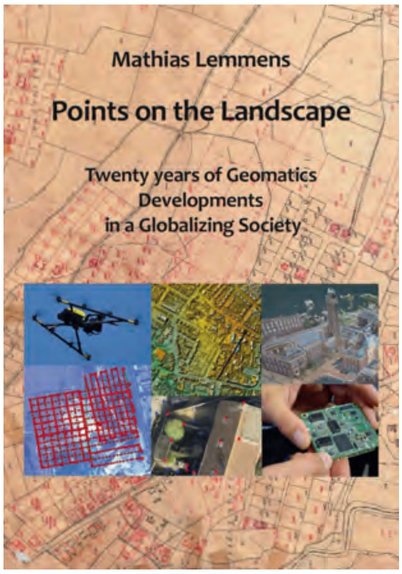
Membership in three of these organizations – JBGIS, ISPRS and UNOOSA – allowed ISPRS to combine the activities of all organizations to publish two books: *Geoinformation for Disaster and Risk Management: Examples and Best Practices*, and *The value of Geoinformation for Disaster and Risk Management (VALID): Benefit Analysis and Stakeholder Assessment*. These books contain the collected information on disaster management and offer methods on how to use remote sensing and geoinformation technologies to assist during disasters in the world.

All societies and organizations are invited to attend the 2020 ISPRS Congress in Nice, France, and discuss hot topics with colleagues during special sessions which they themselves are able to organize. For more information, please contact Congress Director Nicolas Paparoditis: contact@isprs2020-nice.science.

More information
- https://council.science/about-us
- http://www.icsu-geounions.org
- http://ggim.un.org
- http://www.unoosa.org/oosa/en/aboutus/index.html
- https://www.isprs.org/society/interorganization.aspx
- http://www.isprs2020-nice.com

Book Review: *Points on the Landscape*

TWENTY YEARS OF GEOMATICS DEVELOPMENTS IN A GLOBALIZING SOCIETY



The book starts as follows: “Any landscape around our globe is given shape by three imprints. Endogenous forces – volcanism, earthquakes, continental drift – sculpt the rough outlines; exogenous forces – erosion, weathering, denudation – engrave the thinner structures, whilst mankind continuously polishes the landscape’s skin.” On page 51, we can read: “Never before in history has mankind lived with so many people, so close together, on such small pieces of land.” This is typical of the author’s vision and messages: to the point yet sculpting and compelling.

The author joined the editorial board of *GIM International* in the autumn of 1997, first as technical editor, then as editor-in-chief before becoming senior editor in 2009. In January 2000 – precisely at the turn of the millennium – he began contributing a monthly column in which he commented on technological and societal trends. In his first column he wrote: “The geomatics discipline is facing a fascinating, bright and vivid future. I am strengthened in this opinion by the developments going on in society. The growing world population increasingly needs accurate and highly detailed information, in its full spatial and temporal dimensions, concerning virtually every square metre of both the land and the sea area of the Earth”. These words are still valid and have lost none of their meaning even now, two decades later.

The author initially baptized his monthly columns ‘Pinpoint’, but this had been altered to ‘Endpoint’ by January 2009. This new book contains a selection of those columns plus two recent articles. They cover a time span of 20 years, from his start as a columnist until May 2019. They have been carefully edited and grouped by topic into two parts and 15 chapters. The first part, entitled ‘Wealth and the Art of Map Maintenance’, contains six chapters focusing on societal trends in the context of globalization. The second part, entitled ‘From Light to Maps’, contains nine chapters and largely covers geomatics technology. The book does not contain illustrations. “The text originates from columns in which the words have to do the work, not the images,” the author explains. “The anthology should reflect this.”

His strong commitment to the liveability and sustainability of our planet and the creatures that populate it is tangible on every page. His writing not only presents an inspiring take on world literature, history and economics, but also displays a high level of professional geomatics knowledge. “He is one of the best on surveying,” noted one reader of *GIM International*. With this book, the author has published a collection of powerful prose that goes straight to the surveyor’s heart.

Points on the Landscape – Twenty Years of Geomatics Developments in a Globalizing Society, by Mathias Lemmens. November 2019. Published by GeoTexs, Delft, The Netherlands, info@geotexs.nl; ISBN: 9789490533090; price: €35.90; 204 pages. ◂

And the most powerful software to bring it all together.

Trimble

geospatial.trimble.com