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Integrating the ‘Constructioneering’ Workflow Together

The How and Why of the Topcon and Bentley Partnership

COMPARING LIDAR AND PHOTOGRAMMETRIC POINT CLOUDS

SURVEYING THE PAST USING A DRONE

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DIRECTOR STRATEGY & BUSINESS DEVELOPMENT Durk Haarsma
FINANCIAL DIRECTOR Meine van der Bijl
SENIOR EDITOR Dr Ir. Mathias Lemmens
CONTRIBUTING EDITORS Dr Ir. Christiaan Lemmen, Dr Rohan Bennett, Huibert-Jan Lekkerkerk, Frédérique Coumans, Ir. Sabine de Milliano
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CIRCULATION MANAGER Adrian Holland
DESIGN ZeeDesign, Witmarsum, www.zeedesign.nl

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Geomares Publishing
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

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COVER STORY

In the spotlight this issue is the collaboration between Topcon and Bentley. Learn all about how both companies envisage the geospatial industry by reading the extensive in-depth interview from page 12 onwards.

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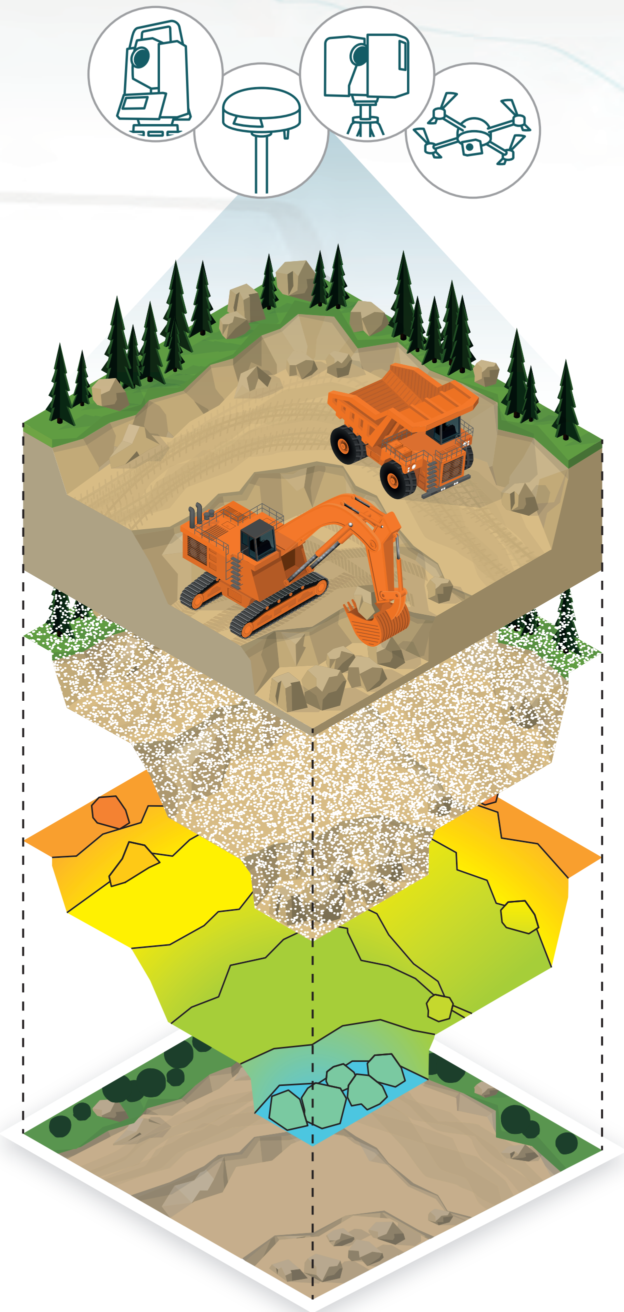

Mining

- Maximize revenue by making better stacking and reclaiming decisions
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- Create reports of your progress
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ANALYSE, MANAGE & MONITOR

Teamwork

A new year always brings new challenges, new changes, and – for many people - new year's resolutions (but let's not dwell on those; I've forgotten mine already!). One new change for me is that, having had page three of *GIM International* all to myself for the past 14 years, from now on I will be sharing this space with the other editors who have also worked on this issue of the magazine. My fellow editors will give you, the reader, insight into their experiences while writing an article or conducting an interview, or will share their general thoughts about the geospatial sector. As well as providing you with food for thought about this dynamic industry we're all active in, we also want to show you that every issue of *GIM International* is the product of successful and effective teamwork! Another big change for us this year is the fact that we will be publishing six issues as printed versions instead of the 12 you have been used to. I'm sure you'll understand this decision in view of the large amount of valuable content that can be found online these days. However, we still feel that print adds value, and we believe that this move is the best way to strike a balance between the advantages of both channels. The biggest challenge that the *GIM International* team will be rising to in 2018 is to continuously bring you – through our magazine, newsletter and website – valuable content, updating you on the state of the art in geo so that you can benefit from the latest knowledge and insights in your professional life. And that's the true purpose of our teamwork!

Durk Haarsma, director strategy & business development

Point clouds

Point clouds are soaring as the dominant source of geodata for creating 3D maps of cities, roads or other sites. Since the demand for detailed and up-to-date 3D maps is growing exponentially, point clouds are increasingly acquired using a variety of sensors. The major methods used are photogrammetry, exploiting dense image matching techniques, and various laser scanning platforms. Creating 3D maps from point clouds manually is time-consuming and costly. Hence, there is a strong desire to automate 3D mapping. However, progress is slow. Automated 3D mapping is challenging, because of the complexity of outdoor scenes and the sheer volume of points. But there is also another issue. While many people may regard point clouds as a generic data source, irrespective of from which sensor the point cloud emerged, there is actually a close connection between the type of sensor, the type of scene and the types of object one can extract. The objects that can be extracted from a mobile laser scanner point cloud significantly differ from those in a point cloud acquired from images recorded by a camera on board a UAS, for example. The type of point cloud, type of scene and use case dictate the classification method.

Mathias Lemmens, senior editor

Fewer issues, more content!

With fewer issues – as Durk mentions elsewhere on this page – but more content; that's how we at *GIM International* will be providing you with need-to-know and sometimes also nice-to-know information this year. In-depth articles, thought-provoking columns, product comparisons, Q&As with influential people in the geo industry… we will bring you the finest selection in the printed edition of our magazine, but please note that there's much more to be found on our website. And if you are interested in contributing an item yourself, feel free to contact me: wim.van.wegen@geomares.nl! I'm also keen to hear your feedback and any suggestions. Happy reading!

Wim van Wegen, content manager

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#GeoToo

At the beginning of my career, in the early nineties, the book '*How to Lie with Maps*' was a must-read for young GIS specialists. I was working in the GIS department of Wageningen University & Research Centre back then and, at the water cooler, colleagues often tried to outdo each other giving extreme examples of map representations that totally messed up correct decision-making and interpretation of facts. At that time we didn't call them 'alternative facts', but it was clear that GIS was an excellent tool to mislead the world.

In the subsequent years I worked in Bolivia on a project constructing a national database of the country's natural resources. There I learned another lesson about the usability of GIS and maps; geospatial information can be used in two ways: a good way and a bad way. We made maps of vulnerable species in forests that helped nature conservationists to identify potential areas for protection. At the same time, this database was extremely interesting to wood loggers, helping them to find the species of trees and wood that would fetch a good price on the black market. Same database, different interests.

And now, almost three decades later, a new challenge is emerging. Instead of GIS and maps, the same problems are arising around the huge quantities of geospatial data we are producing every day. Big data is not just a data collection and management issue; the quality and usability of the data will once again be an important issue too.

During the 5th High Level Forum on UN-GGIM in Mexico last November, an excellent state of play of global geospatial information management was presented to the participants in just a few days. It was confirmed once more to me that geo-related technologies and data flows are continuing to expand exponentially and the true challenge will lie in the management and use of all this data. The best examples came from remote sensing companies and distributors. They talk about petabytes nowadays, instead of terabytes. While most people are still figuring out how to collect and manage this huge amount of data, I am increasingly wondering what it will mean for the quality, reliability, relevance and usability of the information we provide to society. In the geospatial domain it seems that 'more is better', but I am not convinced this is true if usability and quality are not known and available as metadata. Do we have the criteria, domain models and standards in place to make evaluation of our information possible? Or, perhaps even more importantly, is there a kind of international code of ethics for how to value representations and usability of geospatial information for decision-making? Can we supply data and information to society without considering the way it is used, good or bad?

I have great confidence that this has the full attention of the international organisations like FIG, OGC and UN-GGIM. But are we aware enough? And can we be responsible in for non-geo-experts using geospatial information on the conclusions they draw from our datasets?

If we do not consider this in time, I foresee a #GeoToo discussion regarding our sector and the misuse of the power of geospatial information leading to the wrong choices and decisions in spatial planning, environmental sciences, land administration and so on. We should realise that data is power. And the misuse of power is not acceptable – neither in Hollywood nor in geomatics.

Kees de Zeeuw.

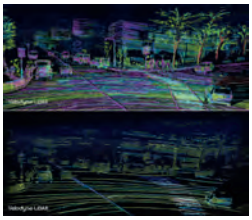
Matterport Enhances Immersive 3D Media Platform

Matterport Pro2 3D device.

Matterport, a 3D media technology company, has announced open betas for publishing to Google Street View and new camera firmware enabling faster space capture. These two significant initiatives are expected to create more business opportunities for Matterport's thousands of customers across numerous industries, including restaurants, retail, travel and hospitality, real estate, and architecture, construction and engineering. With Matterport's rollout of Google Street View publishing capabilities, Matterport users will be able to quickly create and publish a Google Street View experience from any Matterport 3D Space with the click of a button. Matterport 3D Spaces can now be exported to show up on Google Maps, Google Earth and the mobile Street View application as fully linked panoramic photo tours, driving additional traffic to businesses' websites. Clients get the best of both worlds, leveraging the highly immersive Matterport 3D experience of a company's space on their website and publishing a 360 tour on Street View.

▸ http://bit.ly/2EKOOeK

Velodyne Announces New Breakthrough in Lidar Technology



Comparison of a street image created by Velodyne's new VLS-128 Lidar sensor, top, with the resolution of an image from its previous top-end unit, below.

Velodyne LiDAR, a world leader in 3D vision systems for autonomous vehicles, has announced its new VLS-128 Lidar sensor for the rapidly expanding autonomous vehicle market. Featuring an industry-leading 128 laser channels, the VLS-128 is a major step forward in Lidar vision systems thanks to the trifecta of the highest resolution, longest range and widest surround field-of-view of any Lidar system available today. The VLS-128 technology provides three major advances for autonomous driving: a reduction in vision system compute complexity, highway driving, and robotic assembly of the sensor itself. The VLS-128's high-resolution data can also be used directly for object detection without additional sensor fusion, which improves the safety and redundancy of the autonomous vehicle's compute function and reduces overall compute complexity. With its long range and high-resolution data, the VLS-128 allows autonomous vehicles to function equally well in highway scenarios and low-speed urban environments. It is designed as a solution for all corner cases needed for full autonomy in highway scenarios, allowing for expanded functionality and increased testing in new environments.

▸ http://bit.ly/2mF9mTR

New Solution for Precise Autonomous Vehicle Localisation and Navigation

The Civil Maps Fingerprint Base Map.

Civil Maps, a leading developer of cognition software for autonomous vehicles, has announced the availability of Fingerprint Base Map, a scalable solution for precise autonomous vehicle localisation and navigation. Architected from the ground up to meet the demands of production-scale vehicle autonomy, Fingerprint Base Map allows self-driving cars to precisely determine their location in six degrees of freedom (6DoF), while evaluating the safest route to travel. This technology serves as the localisation layer in the company's HD Semantic Map. For self-driving car makers and mobility companies, Fingerprint Base Map leverages Civil Maps' proprietary fingerprinting process to tackle some of the most significant obstacles related to operating autonomous driving programmes at scale. Using the company's novel algorithms, raw point cloud data collected from self-driving cars is transformed into lightweight voxel-based fingerprints, which vehicles use to find their location within a map. Unlike conventional solutions that are dependent on costly processing hardware, large storage arrays and third-party data centres, Civil Maps' Fingerprint Base Map is created and utilised entirely on-the-edge and in-vehicle.

▸ http://bit.ly/2FEB2j0

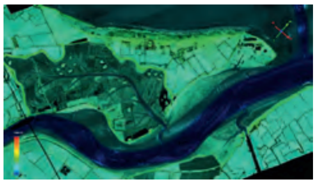
TerraDrone and LG U+ Launch First UTM System in South Korea

TerraDrone.

Terra Drone, a leading Japanese unmanned aerial vehicle (UAV) service company, has launched the first unmanned traffic management (UTM) system in South Korea in collaboration with LG U+, a South Korean cellular carrier owned by LG Corporation. Thanks to the UTM system, it is now possible to confirm the position of a drone beyond visual line of sight (BVLOS). Users can connect to the UTM system via various portable devices such as PCs, tablets and smartphones. In a world first, high-quality full-HD images captured by the drone can be viewed in real time through IPTV. In the demonstration of the UTM system, an autonomous drone took off from a remote location, performed its duties at the destination and returned to the control centre on its own. The task was to locate a six-year-old boy wearing a red jacket, representing a lost child, at Kamiwa Koro Park in Seoul, Korea. The autonomous vehicle successfully located the child after three minutes of remote flying. The drone sent real-time information about the location of the missing child to the nearby safety personnel before returning safely to the planned route.

▸ http://bit.ly/2r3i9ny

Environment Agency Uncovers England's Landscape with Lidar



The English maps are created by airborne Lidar.

The British Environment Agency has announced plans to map England's entire landscape by 2020, using the data to assess flood risk and inform conservation work. Using aircraft equipped with laser scanners, the Environment Agency will map all 130,000 square kilometres of the country, including rivers, fields and national parks – equivalent to 32 million football pitches. As well as being used to understand flood risk, the data will also be made available for free to the public and industry to be used by archaeologists, environmental and urban planners, and even gamers to make accurate 3D models of the landscape. Currently about 75% of the country is mapped but with only sporadic coverage of upland areas. The new project, beginning over winter, will cover all of England's national parks, areas of outstanding natural beauty (AONBs) and sites of special scientific interest (SSSIs) such as the Peak District and the Yorkshire Dales.

▸ http://bit.ly/2FG4Ex1

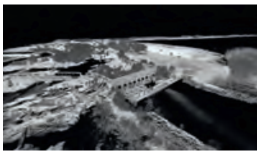
New United Nations' Global Data Hub Powered by Esri

The SDGs at a glance.

Esri and the United Nations Statistics Division (UNSD) are working with a number of member states to utilise a data hub that will allow countries to measure, monitor and report on the Sustainable Development Goals (SDGs) in a geographic context. This new hub, called the Federated System for the SDGs, is based on Esri's ArcGIS platform and will use location intelligence to make it easier for countries to collect, analyse and share the data required to monitor progress toward the SDGs. The SDGs are a set of global goals that include such objectives as poverty eradication, access to safe water, clean oceans, eliminating hunger, gender equality, climate action, peace and justice, education, and other important areas on the UN agenda. The Federated System explores new pathways for facilitating dataflows and action through data hubs. It then supports and informs data-driven decision-making by making the data open, usable, interoperable and visual. Based on the early success, UNSD and Esri are working to advance the initial research exercise to support broader adoption by other member states and organisations in 2018.

▸ http://bit.ly/2mEXUHX

3D Laser Mapping Gives Free Access to Lidar Data



ALS point cloud data captured by the ROBIN +WINGS unit.

A leading geospatial technology specialist is launching a campaign to give free access to Lidar data in order to showcase the capabilities of a new generation of mobile mapping systems. 3D Laser Mapping will be offering open access to point cloud data which can be viewed and manipulated using GIS software. This information can be extracted for use by businesses, academic research and for in-house training opportunities. The company will be releasing data collected using its flexible ROBIN mobile mapping system, which can be used on foot, in a vehicle and mounted to aircraft or UAV. Data from Sherwood Forest, Nottinghamshire, UK, collected using the ROBIN WALK system, will showcase the applications of mobile mapping when used on foot, collecting in-depth forestry data. The ROBIN DRIVE system, designed for use in vehicles, collected point cloud data from the Silver Jubilee Bridge over the River Mersey, demonstrating its capabilities of mapping the built environment for civil engineering projects. 3D Laser Mapping will also release data gathered using its new ROBIN +WINGS unit, which is designed for airborne use.

▸ **http://bit.ly/2D57daz**

3D Scanning Technology Helps Solve Dutch Shipwreck Mysteries

3D scanning of a model ship.

Maritime archaeologists from Flinders University in South Australia are using 3D photogrammetry, laser and CT scanning to capture the highest possible level of detail of the last remaining 17th and 18th-century scale model ships in The Netherlands to help shed light on the demise of the full-size versions off the coast of Australia 300 years ago. The 'Ship Shapes' project has the potential to reveal what happened to the most famous Dutch shipwrecks including the Batavia, the Vergulde Draak, the Zuiddorp, the Zeewijk and at least three others believed lost in Australian waters. The scans will be used to create reconstructions and animations as well as 3D prints and even virtual reality simulations.

▸ **http://bit.ly/2EIuxuU**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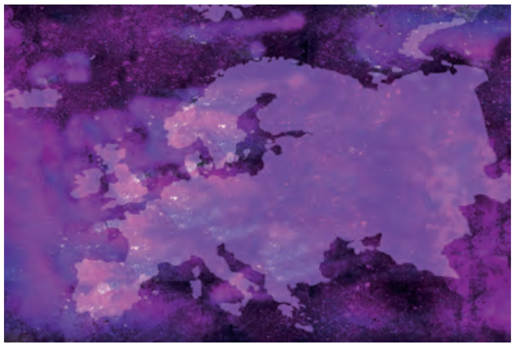
UK Government Invests in Geospatial Data


The United Kingdom seen from space.

The British government has announced a new Geospatial Commission to maximise the value of all UK government data linked to location, and to create jobs and growth in a modern economy. Its first task will be to work with government authorities and Ordnance Survey by May 2018 to establish how to open up freely the OS MasterMap data to UK-based companies, particularly small businesses. The announcement is a further boost to the UK's status as a world leader in digital innovation and an example of how advances in technology can be used to foster economic growth, deliver outstanding public services and generate savings for citizens. Location-aware technologies are revolutionising the economy. From navigating public transport to tracking supply chains and planning efficient delivery routes, the digital services built on GPS and the current mapping data have quietly become parts of daily life and everyday commerce.

▸ **http://bit.ly/2Dzsdaa**

Research Reveals Scope of Open Geospatial Data across Europe


Open data is available from the majority of European NMCAs.

Open data is available from the majority of European National Mapping, Cadastral and Land Registry Authorities (NMCAs), a new survey has found. Research by the Open European Location Services (ELS) project reveals that 98% of respondents provide at least some of their data free of charge. Of these, 37% make all their data available under an open licence. Whilst open data models vary, more than 85% provide view and search services, 72% enable downloads and 67% allow its re-use in products. Users include public authorities, public services, research and education as well as commercial companies. This survey provides a snapshot of the scope of open data from official national sources across geographical Europe according to EuroGeographics, the international not-for-profit organisation which is coordinating the Open ELS project.

▸ **http://bit.ly/2FGZktC**

Crossing Drones with Satellites: High-altitude Aerial Platforms

The European Space Agency (ESA) is considering extending its activities to a new region of the sky via a novel type of aerial vehicle, a 'missing link' between drones and satellites. High Altitude Pseudo-Satellites, or HAPS, are platforms that float or fly at high altitude like conventional aircraft but operate more like satellites – except that rather than working from space they can remain in position inside the atmosphere for weeks or even months, offering continuous coverage of the territory below. The best working altitude is about 20km, above the clouds and jet streams and 10km above commercial airliners, where wind speeds are low enough for them to hold position for long periods. From such a height they can survey the ground to the horizon 500km away, variously enabling precise monitoring and surveillance, high-bandwidth communications or backup to existing satellite navigation services.


Thales Alenia Space's Stratobus airship.

▸ **http://bit.ly/2EJY2wx**

THE HOW AND WHY OF THE TOPCON AND BENTLEY PARTNERSHIP

Integrating the **'Constructioneering'** Workflow Together

Digitalisation and new technologies with the ability to revolutionise the geospatial industry are creating a new playing field for mapping and surveying professionals. This evolving landscape is also reshaping the industry, with new entrants gaining ground and established players seeking to collaborate and combine their specialist areas of expertise in order to offer a total solution. *GIM International's* Wim van Wegen met with Ted Lamboo, senior vice president of strategic partners at Bentley Systems, and Ewout Korpershoek, executive vice president at Topcon Positioning Systems, at Bentley's 2017 Year in Infrastructure Conference in Singapore. They discussed the partnership between the companies, their views on where the industry is heading and much more.

Topcon and Bentley joined forces around a year ago, in November 2016, to serve the construction industry, or 'constructioneering' as you call it. What is the difference between constructioneering and building information modelling (BIM)?

Ted: "There are many definitions of BIM, as there are probably with GIS. In our case, we regard the word 'building' as a verb, not a noun. Unfortunately a lot of other people translate 'building' to mean a physical building, rather than the process of building something. We've always said that the 'information modelling' part of BIM should actually be seen as two different axes – there is information management and there's information mobility, so that means that BIM is on both the horizontal and the vertical axis. You see that reflected in constructioneering as well: the necessity to manage the information smartly and pass it on through the workflow, and the necessity to let information travel from one spot to another. In the bigger definition of BIM, it covers the entire life cycle – you've got BIM level 1, 2, 3, 4 and 5, although most organisations are not that far – whereas constructioneering actually defines a shorter period from engineering to construction, with the data handover at the end. One true difference from BIM is that constructioneering is not trying to resolve subjects that get into the operational phase. I also believe that constructioneering is more of an applied science, because it results in a physical construction at the end of the process, whereas BIM is still a bit too much a 'something that happens at the office' experience – although that's not our intention; we want the data to be mobile. But maybe BIM is a more global definition, and constructioneering is a narrower definition for particular heavy civil industry."

▲ *Ewout Korpershoek.*

Ewout: "I agree. BIM is more of a holistic approach to a process that, via constructioneering, starts connecting all the practical activities that need to happen. The whole BIM process involves a lot of work – from planning, conception to scheduling, detailed building and life-cycle management – but the actual building is a fairly limited part in this total timeline. When I hear other people talking about BIM, they often mean the whole process that spans all those activities, whereas we really look at what is happening in the field. Other people often downplay or forget the actual work in the field – they see it as a necessary evil – but given our expertise we believe that is really where significant progress can be made. Together with Bentley we came up with the term 'constructioneering' to describe what is a very practical sub-activity inside any BIM process. In addition to that, BIM's origins lie more in the design profession. Often when our customers say 'I need to do BIM' they mean 'I need to work in 3D'. So suddenly instead of a paper-based plan they get a coordinate file, but that's not maximising the true capabilities of BIM. So that's why we came up with the term 'constructioneering', which goes beyond just making the move from 2D paper plans to 3D coordinate files."

In 2017 Topcon celebrated its 85th anniversary. How did you evolve to become a global player in the surveying market, and where do you stand now?

Ewout: "Traditionally, an important part of our focus has been on the high-tech survey business where, through time, we have added new technologies such as GNSS, laser scanning, imaging and machine control to serve our customers' growing needs. We acquired or developed directly related technologies like telematics, inertials and specific software additions, and we entered the agricultural field through several acquisitions. Our main drive has always been to be at the forefront of technology and provide cutting-edge solutions for mobile workforces to solve their positioning and data needs. Today we're adding cloud communications, Internet of Things (IoT) and we are partnering with companies like Bentley as important components of our mission to offer a truly real-time platform for automation of all position-related fieldwork. This places us right at the heart of what we call the 'intersection of infrastructure and technology'. We are committed to serve our customers through leading-edge technologies, solutions and partnerships in order to increase the quality and performance of their daily work."

Bentley Systems was founded in 1984, originally as a CAD and GIS software development company. Do you agree that the revolution in sensor technologies enabling massive collection and real-time processing of various geodata, including point clouds, marked a key turning point for your company?

Ted: "Well, I would prefer to define Bentley a little differently because we have been promoting asset management for a very long time now. Big data is created at two moments; the first type is the data you collect to define the geometry that you're working with in the field – point clouds, scanning, photos, there are many sources of big data in the survey process. The second type of big data is created at the very end of the asset management life cycle when sensors measure vibrations, traffic, CO^2 pollution and so on. That's a different type of sensor data and obviously involves different types of sensors. I would say it has always been in Bentley's roots as we have always supported raster, we have always supported aerial photography behind CAD, we have always supported point clouds and have been very good at unlimited file sizes – that's important because we have always been involved in big infrastructural projects, and big projects come with big data. Nowadays, big data has become much bigger and point clouds are much bigger – the terabytes are flying around – but it's now up to the user to choose which data and how much of it they want to use, during either the engineering, the construction and/or the operational asset management phase."

Bentley has a strong global presence, and Topcon has a global network of subsidiaries and affiliates and a network of distributors. Is your partnership a push for further global expansion in tandem?

Ewout: "The main driver for the Bentley-Topcon business partnership is the opportunity that we see in automating a market that we jointly consider as being core, which is related to construction, infrastructure and management. The reality is that Topcon customers traditionally work out in the field and Bentley customers work in the office. That has been the status quo, with data basically carried back and forth. In today's connected environment and with the current technologies, there is absolutely no reason why data created and collected by Topcon systems in the field could not immediately be used, analysed, packaged and reviewed in the office. That's what makes our cooperation even more important; technology has been driving us closer. It's a very logical step in my opinion."

Ted: "Bentley is a mixture of direct business that we do globally and also global partnerships. In terms of size, our two companies are pretty similar – Bentley employs 3,000-plus people, Topcon around 6,000. Topcon makes physical products and has more obligations in terms of manufacturing and inventory shipment, which we in the software world don't have. In the field we represent different areas of the market – Bentley benefits the engineer in the office, and Topcon reaches the surveyor in the field – so we visit different users, and that's where the synergy comes from. As the workflow becomes more integrated, there is a growing opportunity for both of our companies and for our partners to pick up a bigger part of the workflow and sell it as a complete solution."

THE SURVEYOR IS TRANSFORMING FROM SOMEBODY WHO PHYSICALLY STANDS IN THE MUD AND PUTS STAKES IN THE GROUND, INTO A DATA AND QUALITY MANAGER

▲ *Ted Lamboo.*

Topcon started out as a manufacturer of surveying devices. These gradually evolved into total stations which are advanced systems packed with electronics and software nowadays. How can your two companies reinforce each other, given today's rapid technological and societal changes?

Ewout: "The opportunity to reinforce each other is one of the main drivers for our relationship. It's not our intention to heavily invest in developing products similar to Bentley's, and likewise it's not Bentley's ambition to start developing hardware. Developing hardware is our core DNA, and whereas hardware and software used to be fairly separate we're now seeing them increasingly merging. Customers no longer get excited about a mobile phone with a touch screen, what matters are the apps and functionalities. That's the opportunity in our relationship."

Ted: "A phone is not smart without the apps, and the apps are useless without proper

▲ *Ewout Korpershoek chatting with Bentley's CEO Greg Bentley at the Year in Infrastructure Conference.*

hardware that can understand them. So the integration necessities between hardware and software are bringing both worlds closer and closer together in many ways."

Which developments can surveyors expect over the next five years?

Ewout: "I'm a surveyor myself, and I don't expect the core surveying profession to disappear. A lot of new markets offer opportunities for growth and the expansion of the activities. In the future, the surveyor is transforming from somebody who physically stands in the mud and puts stakes in the ground, into a data and quality manager. It's a process that we've already been seeing over the past couple of years, especially in the construction industry. This will continue and it opens up a number of new opportunities for the traditional surveying or geodesy professional to expand into all sorts of applications and markets where data management and data quality are critical."

Ted: "As a former surveyor as well, I would like to add that the surveying profession is becoming broader. Both Topcon and Bentley encourage the whole concept of continuous representation of reality – before, during and after construction. In the past we didn't have the tools and the capability of processing the data so quickly that the interim results would be beneficial to the process, but that has really become much more pervasive now and, as a result, the need for surveying has increased. That's good for Topcon, but it's also good for us because it provides more information during the process. So we both encourage more frequent surveying and a broader collection of data than the narrow geometry that we used to ask for in the past."

Ewout: "To put it very simply, you could say that the specialism of the traditional surveyor was to model reality in a very simplified form, creating 2D maps. That was generally a post-processing process; you captured data and you took it back to the office, so the simplified model that was created was never truly current and up-to-date. Today we have technology that allows us to capture nearly continuously – and it will soon be continuously – all the information that we can visually see in all its dimensions. That means that the surveyor's product is changing and the application opportunities are growing tremendously. And I believe that's the changing role of the surveyor."

GNSS technology is a major area within the positioning business, alongside total stations. Which key developments do you foresee in GNSS technology, what are their implications for the surveying profession, and how will the developments affect your consumer base?

Ewout: "GNSS has become a major positioning technology for both survey and construction execution operations. When Topcon introduced the first dual-constellation receivers in 2000, we could already see the benefits of more satellites, providing higher uptime, better accuracy and faster initialisation. Since then, GNSS technology has rapidly evolved to the current high-performance levels, providing the basis for increased adoption as the standard for many new and existing applications. The next step in this journey is the deeper integration with other sensors and positioning solutions. There are good examples in the use of GNSS in our construction machine control applications; when coupled with advanced inertial technology, the user is able to operate his machine at much higher speed and performance levels. By combining different sensor technologies we offer more robust, accurate and reliable positioning solutions that open up both new markets and new opportunities in existing markets."

Today's airborne, terrestrial and mobile laser scanners are able to capture billions of 3D points in the blink of an eye. However, the processing of the massive volumes still requires a lot of human intervention. How can cooperation between Topcon and Bentley help to solve this?

Ted: "Let me first deal with the volume, which is also a great example of our cooperation. There are a number of new technologies and I use the ContextCapture and the photogrammetry side as a fantastic example of that. As mentioned, both of us studied geodesy and in our day you had to study for years in order to understand photogrammetry and use the technology in practice. It was a lot of work; you could only overlay two photos with each other at any one time. Once you had done the overlap part you could move on to the next couple of photos. Now we just throw tens of thousands of photos into a black box, that black box does the photogrammetry for us. In other words, the process has been simplified a lot – you don't have to be a photogrammetrist in order to do photogrammetry using ContextCapture, so there's been a tremendous simplification. Of course, you still need to understand a couple of first principles about control points and suchlike, but the software helps you a lot. It guides you in what you need to capture and it warns you if there's not enough overlap. But there's still a lot of data and the processing still takes a lot of horsepower, so what both Bentley and Topcon are doing is moving applications into the cloud, where we have an unlimited amount of processing power. We have one particular user who is using a thousand CPUs in the cloud at the same time, just to speed up the processing. Scalability with the cloud is literally endless, and we're clearly scaling up to take advantage of that. There's a lot of commitment between Bentley and Microsoft with their Azure cloud processing solution, and I'm sure this is just the start."

Ewout: "The level of human intervention has definitely not increased, in fact it's becoming less and less. If I consider how much manual labour was involved back when I was using a theodolite and a distance metre to calculate coordinates, there was more manual labour than computer time – although computers in those days were so slow that they also took two days to calculate a couple of hundred coordinates! But technology continues to evolve, and it's human nature that we will always push the envelope: computers get better, storage gets bigger, CPUs get faster and at the same time sensors are being developed that capture millions of points rather than thousands. We're always going to be at the edge, and in a sense customers expect that from us; if we want to develop cutting-edge technologies, they expect us to be at the forefront of technology. One big focus for both our companies is definitely that, with increased computing power and intelligence at your fingertips, the human interactions can be minimised and dumbed down so far that a lot of the previous specialism is eliminated. We will certainly see this more and more going forward when machine learning starts to play a more important role. Knowledgeable human interaction will still be necessary, if only for determining mistakes and errors and judging quality. That brings us back to the point we discussed earlier; the role of the surveyor is changing from a data processor to a quality manager."

Ted: "The functions and processes have been simplified, but they are being replaced by the need to interpret, assess and know what do with the outcome. So I actually think the human brain is being used at a higher level than merely learning formulas off by heart or learning which steps to take in a particular sequence."

Ewout: "In everything we produce, there's a lot of focus on making things as intuitive as possible, to optimise the use of the instrument and to minimise the manual labour requirements."

Topcon entered the unmanned airborne systems market through a partnership with Ascending Technologies, which has been fully owned by Intel since January 2016. What are your expectations of the UAS market worldwide and where do you see the synergy with your other positioning solutions?
Ewout: "First of all, UASs and mobile mapping solutions in general – whether they fly, drive, however they move – are an exciting new data capture addition to our entire portfolio. The interesting thing about the drone or mobile mapping system is that it offers data capture possibilities for applications that are not traditionally in the survey field, so for all sorts of inspection purposes. The market for mobile visualisation or data capture solutions has expanded enormously, although it is still early days for the market itself. Legislation is an issue in every country and, although we're slowly moving towards national and then international standards, that process will take a while. That's also why there are so many drone manufacturers; it's still a very local business because you need to understand the local needs and requirements. Big companies such as DJI and Intel have stepped in over recent years, and that is the next phase. We have chosen not to invest in developing drones ourselves. Instead, we are partnering with what we believe to be the leading drone manufacturers, Ascending Technologies and MAVinci – both of whom have been acquired by Intel, by the way, which means that Intel is currently a valued and appreciated partner of Topcon."

And how does Bentley view the UAS market?
Ted: "I too prefer the term mobile mapping because that's broader than drones only. It covers the mobility of an aircraft, but also the mobility of a vehicle-mounted scanner or the mobility of scanning and inspecting on the water. I see two 'waves' in that marketplace: the high-precision drones that Intel/Topcon is specialised in, which require geometric accuracy, a long time in the air, a lot of data storage, for professional and high-end geodetic use. There's also the more consumer-type drones, which are very small and low-cost. These type of drones have their own advantages, such as they use swarm technology to monitor on another's position in the sky. For inspection purposes you often only need images, without precise accuracy, which makes low-cost solutions very suitable. Hence the drones that are used for general inspection and image collection will remain a separate market from the very specific high-end drones for high-accuracy mapping and surveying. These will be pursued by specialists who need the best equipment and will command a very different price tag. At Bentley we love both, as we want the inspection data as well as the accuracy data.

THE WORD 'SURVEYING' GOES WELL BEYOND JUST CAPTURING TECHNOLOGY – NEW TECHNOLOGIES ALLOW SURVEYING TO HAPPEN CONTINUOUSLY

Ewout: "Drones are the first and very logical step towards fully automated robotic data acquisition. It's still early days, so we're trying to choose our partnerships carefully, but it's definitely receiving our full attention. Mobile mapping in general is a core focus for us as a data acquisition company…"

Ted: "And for us as a data processing company!"

The 3D mapping of buildings is increasingly moving from mapping facades, roofs and other building exteriors and the surroundings to the indoor environment. How are you anticipating the needs linked to this trend?
Ted: "The surveying of indoor space is indeed a growing market opportunity and we

▲ *Ted Lamboo during the Intergeo 2017 press conference.*

encourage the capture of indoor geometry and textures just as much as outdoor. The circumstances are somewhat different, though; indoor surveying has its challenges because of lack of natural light and the confinement of space, which means that each room or space has to be captured separately and the data then needs to be put in the context of the entire building. But the technology already exists and is improving all the time. From a data processing perspective, today our ContextCapture is capable of creating texturised 3D (mesh) models of both photos and point clouds, so from a processing perspective we are ready to handle this growing market. We anticipate further growth in use cases of how the mesh model data will be 'consumed' or combined with other data sources, such as facilities management, sensor data, etc."

TED LAMBOO

Ted Lamboo currently serves as senior vice president of strategic partnerships at Bentley Systems, Inc. From mid-1994 to December 1997, Mr Lamboo served as senior vice president of sales at Bentley Europe, Middle East and Africa, and from January 1998 to January 2000 he served as president of Bentley Asia/Pacific, based in Australia. From January 2000 onwards, he served as senior vice president of international operations at Bentley Systems, Inc. Prior to Bentley, he served for 13 years at Intergraph Europe, the European headquarters of Intergraph Corporation. Mr Lamboo holds a geodetic engineering degree from the University of Utrecht in The Netherlands and several post-graduate diplomas in computer engineering and development. From 1979 to 1982, Mr Lamboo worked for Topographic Services, the governmental topographic mapping organisation of The Netherlands.

EWOUT KORPERSHOEK

Ewout Korpershoek is executive vice president of mergers and acquisitions at Topcon Positioning Group. He serves on the board of directors of Topcon Europe Positioning BV. He joined Topcon in 1991. Prior to his current position, he served as chief marketing officer (CMO) and senior vice president with global marketing and product management responsibilities for Topcon Positioning Group. Prior to his role as CMO, he held responsibility for all the European positioning business as managing director of Topcon Europe Positioning. He holds a MSc in geodesy from Delft Technical University. He has prior experience with the Dutch National Department of Roads and Waterways and has also worked in the software mapping business.

Ewout: "The ability to map and survey our environment is highly technology driven. As technology in general advances — think of cloud, connectivity, super computing power in the palm of your hand and highly advanced 3D data capture, registration and visualisation tools — it is becoming possible to map our environment in all its visible dimensions in almost real time. GNSS has been a major driver leading to real-time positioning but, due to its limitation to outdoor use, the indoor mapping business still has a lot of development to go through. As new mass data technologies and new sensors are continuing to evolve, and get bundled into solutions via smart and powerful software, new possibilities like indoor mapping are opening up. Topcon and Bentley are at the forefront and are leading technology industry directions. So we're actually not anticipating, but rather opening doors for many new applications."

Manufacturing surveying equipment is highly procyclical from an economic point of view. How has Topcon managed to survive all the economic booms and busts for nearly a century?

Ewout: "The traditional survey equipment business is indeed generally procyclical. But as we have been driving market development through technology, we have been able to stay ahead in most downturns with exciting new solutions, offering improved ROI to help battle economic concerns. Especially in the construction market, our advanced positioning solutions are the basis for complete process automation, which allows our customers to significantly reduce costs and increase their efficiency and productivity."

In 2015 Bentley acquired Acute3D providing Bentley with an application – ContextCapture – which automatically turns digital images into photorealistic 3D models. How does this acquisition fit within your portfolio?

Ted: "Since the acquisition, one of the major items that we have added is that we can also generate 3D models from point clouds as well as from digital images, and we are making this available as a web service too rather than only as an application. We have subsequently integrated the mesh model support into our MicroStation-based applications as well as in our information management solutions, and various ways of viewing and publishing the data via the web. So the solution and the data usage is now a fully integrated part of our portfolio, and a cornerstone addition of how we view the design, construction and management of infrastructure to be enhanced via continuous surveying, dependent on the users' workflows."

Both of you have a background as a professional surveyor. How do you envision the future of mapping and surveying?

Ewout: "Surveying is a technology-driven profession: for hundreds of years the technology enabled us to model and map our environment in pretty rudimentary 2D shapes and maps. As technological growth has become exponential, the opportunity for the survey profession has grown and developed exponentially as well. We can capture and model our environment in all its geometrical dimensions, in real time, and it's allowing us to add attributes, planning and budgeting components. With technology re-inventing and obsoleting itself at such a rapid pace, the same concept applies to the survey profession and is opening up a whole new and previously unseen range of accurate modelling, management and planning opportunities. From that perspective, surveying is probably one of the most dynamic and exciting professions that one can think of!"

Ted: "Absolutely! I'd just like to add that the word 'surveying' goes well beyond just capturing geometry. New technologies allow surveying to happen continuously through new sensors and new data capture techniques like drones. The outcome allows a 3D texturised reality survey that can be combined with other data sources like IoT big data for comparison of what was constructed or what is designed with what is the reality as surveyed at any particular time. As a result, inspection can happen at any point in time and is now much easier to do repetitively. The rise in studying changes, construction progression or deterioration of infrastructure has increased the demand for rapid surveying. Hence I believe that the need for surveying, and the ongoing innovation of survey processes, is going to continue for many years to come." ◂

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MONITORING CROP GROWTH AND ESTIMATING YIELD PRODUCTION IN PRECISION FARMING

UAS-based Measurement of Crop Height and Biomass

Monitoring crop growth provides timely and reliable spatial information to farmers and decision-makers employed in precision agriculture. The authors of this article tested the usability of UAS RGB images for estimating crop heights and biomass. The assessment was done at eight growth stages to provide timely and reliable spatial information.

Studying growth of crops throughout the growing season is a prerequisite for informed farming, decision-making and estimating yield production. Measuring the evolution of crop height and biomass during the growing season provides the essential indicators for growth and health and thus provides a means for dedicated irrigation, fertilisation and estimation of yield. Field-based data acquisition is able to give accurate results but is costly and time-consuming which can lead to under-sampling and thus compromise accuracy. Added to this, data acquisition in the field causes damage to the vegetation due to trampling. Therefore, non-destructive methods of measuring changes in crop height over time at high spatial and temporal resolution are essential.

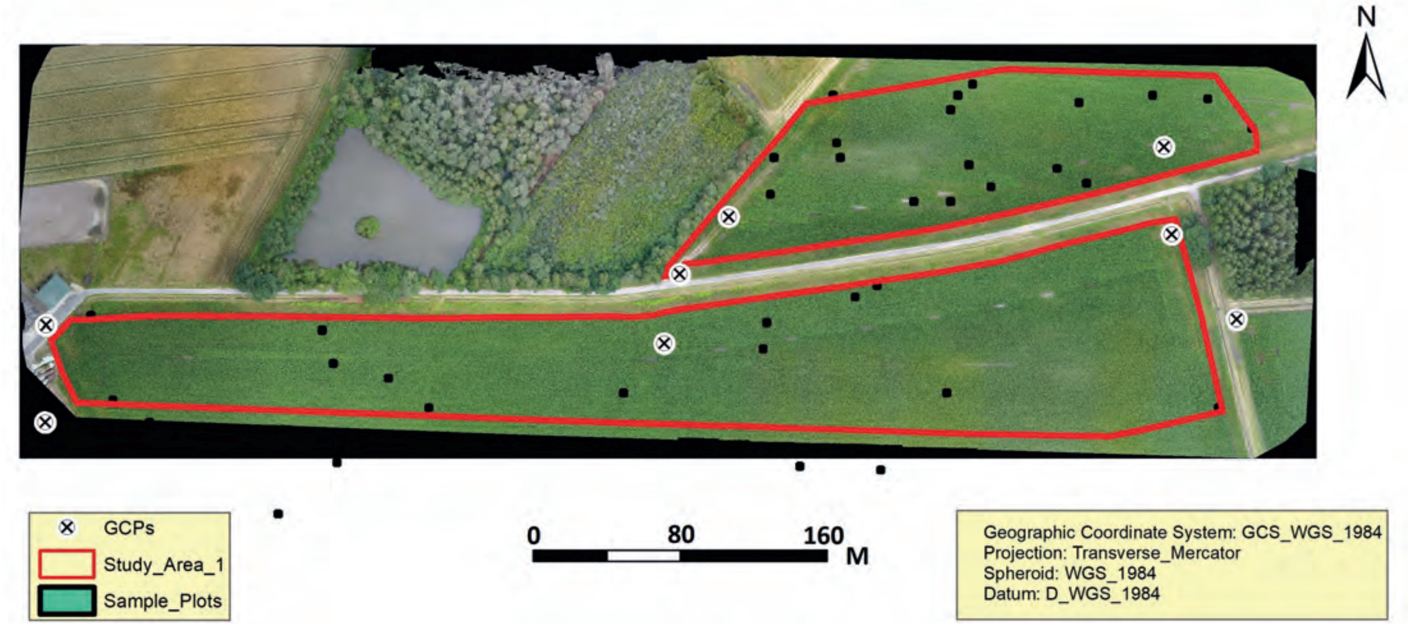
UAS

Changes in crop height can be determined from time series of digital surface models (DSMs) generated from overlapping images. Changes in biomass can be computed from vegetation indices which are also a good indicator for crop health. Multispectral satellite images are well-suited for this purpose, but they are expensive – as are aerial images captured from manned aircraft. Images captured using unmanned aerial systems (UASs) equipped with a camera have emerged as an alternative to expensive satellite or airborne data. Flying at a low altitude, camera-equipped UASs can acquire high temporal and spatial-resolution aerial images of small or medium-sized agricultural fields for a reasonable price and without causing damage to the crops.

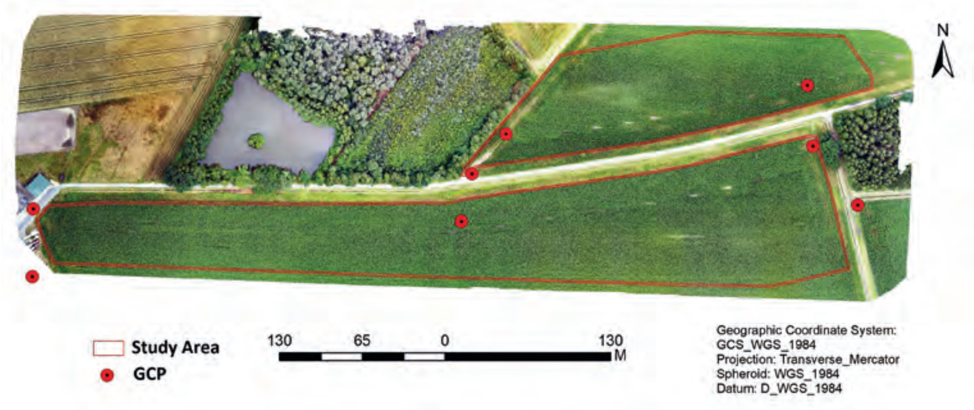
DATA ACQUISITION AND PROCESSING

To test the feasibility of using UASs for crop monitoring, a study has been conducted on a maize field of 14ha in Gronau, western Germany. A UAS-based workflow suited for crop monitoring includes flight planning, selection and measurement of ground control points (GCPs), conducting flights, generating a digital surface model (DSM) and an orthomosaic, and exploring the spectral image information. The UAS used is a Phantom-4, an inexpensive quadcopter equipped with a stabilised CanonEOS600D camera (Figure 1). The focal length of the camera is 3.722mm. The 4,000 x 3,000 pixels produce images in the RGB part of the electromagnetic spectrum, i.e. red, green and blue. To enable georeferencing of the images, eight ground control points (GCPs) were measured using a Leica CS10 field controller with a positional accuracy of 2cm. The majority of the GCPs were unevenly distributed along the border of the field, while a few GCPs were located inside the field, which unfortunately made them increasingly less visible as the growing season progressed (Figure 2). Eight flights were conducted

▲ *Figure 1: Phantom-4 quadcopter used in the pilot study.*



▲ *Figure 2: Distribution of GCPs and sample spots over the study area.*



▲ *Figure 3: Orthomosaic.*

during the whole growing season from May to September 2016 in the morning hours. The time interval between two flights was 10 to 15 days; the variability in time interval was mainly due to weather conditions. The images were taken with 80% forward and 60% side overlap and processed with Pix4D to generate a DSM and an orthomosaic (Figure 3). The collection of ground truth data was done by a field survey at 40 spots well distributed over the maize field. The crop heights were measured with measuring tape during the eight growth stages. Crop samples were collected at the same 40 spots at harvest time as ground truth for determining the biomass using the weighing balance method. The DSMs formed the basis for the generation of the crop surface models (CSMs) for crop height estimation.

IT IS WORTHWHILE STUDYING DIRECT GEOREFERENCING BY MOUNTING A HIGH-ACCURACY GNSS RECEIVER ON BOARD THE UAS

CROP SURFACE MODELS

The eight DSMs were used as CSMs representing the surface of the crops. At each time interval, the crop height was determined by calculating the difference between the CSM and a digital elevation model (DEM) representing the ground surface. This DEM was generated from the first flight when the maize seeds were sprouting and thus the bare ground was actually captured. The average crop height obtained from the CSMs and the field-measured crop height at each sample spot during the eight growing stages were used to determine the accuracy of crop heights. The comparison revealed an accuracy of between 68% and 85% and a root mean square error (RMSE) of 30cm to 24cm respectively. Higher accuracy of crop heights can be obtained by using more GCPs than the eight used in the present pilot. These GCPs should also be well distributed along the field border and highly visible. Small systematic errors occurred due to the decreasing visibility of GCPs inside the field and also because of repetitive patterns caused by maize being sown in rows which sometimes impeded image matching.

BIOMASS

Biomass is an important parameter for efficient crop management during the growing season and for yield estimation.

FURTHER READING

Tumlisan, G.Y., Bronsveld, M.C., Koeva, M.N. (2017) Monitoring growth development and yield estimation of maize using very high-resolution UAV images in Gronau, Germany. (ITC)

Vegetation indices provide an indication of the biomass as well as the health status of the crops at different growth stages. From the RGB images, vegetation indices were calculated exploring various ratio, summation and band difference computations (see Figure 4), using ENVI (band math tool) and QGIS (Semi-automatic Classification Plugin, SCP) software. These vegetation indices were selected based on the available spectral bands and their suitability for crops like maize. Combining biomass estimates with crop height at the various growth stages enables estimation of fresh and dry biomass at harvest time. The best estimation of biomass at harvest time is obtained from crop height and biomass estimates halfway through crop growth, i.e. the period between stem elongation and inflorescence emergence.

FUTURE OUTLOOK

The CSMs generated could be the main error source for accurate crop height measurement. Improvement can be achieved by placing sufficiently well-distributed GCPs over the entire field which remain visible during the entire growing season. It is worthwhile studying the abilities of direct georeferencing without using GCPs by mounting a high-accuracy GNSS receiver on board the UAS. To improve the estimation of the biomass it is recommend to mount a near-infrared (NIR) camera alongside the RGB camera. NIR can provide a clear picture of crop health and moisture variations and also enables visual interpretation and digital analysis. ◀

S.No	Item	Computation algorithm
1	Excess Green VI (**ExG**)	2G – R – B
2	Color index of vegetation (**CIVE**)	0.441*R - 0.881G + 0.385B +18.78745
3	Vegetetiven (**VEG**)	G/R^aB^{1-a} with a=0.667
4	Excess green minus excess red (**ExGR**)	ExG – 1.4R – G
5	Normalized green-red difference index (**NGRDI**)	(G – R) / (G + R)
6	Combination (**COM**)	0.25ExG + 0.3ExGR + 0.33CIVE + 0.12VEG

▲ *Figure 4: Formulas to compute various vegetation indices from the visible spectral bands (RGB).*

ABOUT THE AUTHORS

All authors are or were affiliated with ITC Faculty, University of Twente, The Netherlands.

Ghebregziabher Yemane Tumlisan gained an MSc degree from ITC and is specialised in natural resource management.

✉ gymoa2011@gmail.com

Kees Bronsveld is a retired lecturer at ITC specialised in the use of remote sensing and GIS for natural resource management.

✉ mcbronsveld@gmail.com

Mila Koeva is an assistant professor at ITC specialised in 3D geoinformation. She is chair of 3D GeoInfo 2018, co-chair of ISPRS WG IV/10 and project coordinator of its4land (www.its4land.com).

✉ m.n.koeva@utwente.nl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BY **FRÉDÉRIQUE COUMANS**, CONTRIBUTING EDITOR, GIM INTERNATIONAL

ENHANCED SDI-BASED HUMAN-MACHINE INTERACTION

Smart Factories Need Space and Time Anchors

Spatiotemporal referencing can be used to enhance contextualisation of Industrial IoT (IIoT) data and information flows within 'smart' factories, according to Studio iSPACE in Austria. Its five-step approach models an adaptive workflow to organise large-scale 3D data of a production facility. The goal is to support the extended personnel-machine interaction for indoor positioning, production asset monitoring and location-based management.

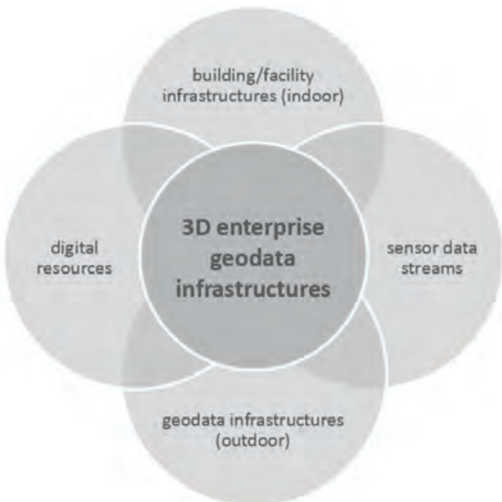
In the event of problems with a production line, every minute counts for the factory's managers. Service staff must be able to respond as efficiently as possible. All necessary information should be directly available and location-based. Studio iSPACE, part of Research Studios Austria Forschungsgesellschaft mbH, recently transformed its experiences with spatial data infrastructures (SDIs) into an approach called OLS3D (Organising Large-Scale 3D Data). It tackles the use of building information modelling (BIM) for production environments and smart factories in the context of Industry 4.0. With the help of tablets or smart glasses and a central software system in the background, the knowledge is brought exactly on time to where it's needed – to the service technician on site. Studies of these tasks for production environments are new; as far as iSPACE knows, the prototype it developed is still unique. Some parts overlap with facility management, where the integration of CAD, BIM and GIS systems is an important topic. A major issue proved to be the lack of indoor inventory definitions in geoinformation models. In factories, the indoor inventory is the dynamic layer where tasks are performed, data is created and which has a high optimisation potential.

IN FACTORIES, THE INDOOR INVENTORY IS THE DYNAMIC LAYER WHERE TASKS ARE PERFORMED, DATA IS CREATED AND WHICH HAS A HIGH OPTIMISATION POTENTIAL

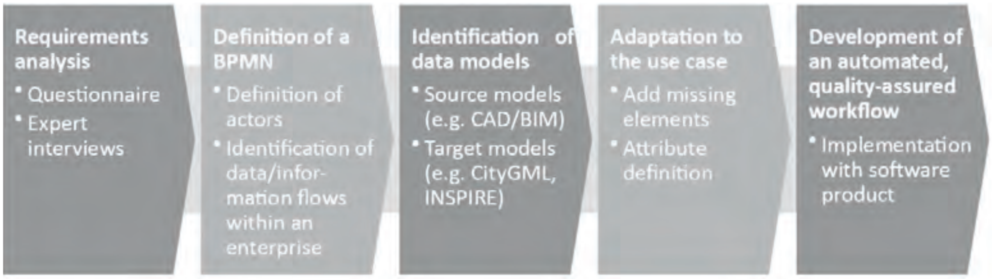
CYBER-PHYSICAL PRODUCTION SYSTEM

Industry 4.0 relates to facilities and production environments where humans and machines can directly interact to solve problems together. This is also known as the Industrial Internet of Things (IIoT). Industry 4.0 is aimed at achieving full integration of processes, machines and products to optimise availability, costs and resource consumption in smart factories. Objects only can become smart if they can be linked with data and other digital resources. "By using space and time as anchor points, digital resources such as documents for maintenance as well as real-time sensor data for automation and facilitation of work processes can be linked to the real world. A spatiotemporal 'anchor' acts as a uniquely identifying referencing element," is how Laura Knoth, researcher at Studio iSPACE, outlines the heart of the approach she developed together with her colleagues Bernhard Vockner and Manfred Mittlboeck. She gives an example: "In a cyber-physical production system, when a machine needs to be serviced, the authorised worker gets a signal on his mobile terminal about its priority or planning, a report on the machine's status, where it is, and all related manuals."

An Enterprise SDI should contain geodata on the outdoor and indoor building/facility infrastructures. A production environment has specific elements that need to be modelled and integrated to obtain the big picture of all processes. These elements include the machines and corresponding sensors as well as associated data in the shape of digital resources such as maintenance reports. This is mostly data in three dimensions – not only because buildings consist of several floors, but also because machines with complex structures and overlapping parts can only



▲ *Figure 1: Components of a 3D enterprise SDI.*



▲ *Figure 2: Workflow for the development of the OLS3D approach.*

CONTEXTUAL INFORMATION IS PROVIDED ON EITHER TABLETS OR, IF BOTH HANDS NEED TO REMAIN FREE, SMART GLASSES

be meaningfully displayed using 3D. The time component is addressed as being able to look at the past with versioning and archiving of data, as well as being able to use this data to 'look into the future' through extrapolations and prognoses. The linking of data follows the Linked Open Data approach. In terms of sensor data, the information can be linked directly; other less structured data is harder to integrate. This is especially the case for maintenance documents, such as documentation prepared by a maintenance employee who worked on the machine earlier. To link such data, machine names can be used as attributes in the spatial data model and PDFs can also be used for linking documents to objects.

FIVE STEPS

The OLS3D approach consists of five steps. Firstly, a requirements analysis has to be performed to identify the structure of the organisation and its needs. The second step is to ensure that the quality of the data stays well organised. Modelling of the business process should take into account the whole process from data acquisition to use and updating, resulting in workflow models that automatically push changes – in infrastructure, inventory, all moving assets – through the entire pipeline. "In order to leverage the information in an interoperable manner we need mapping schemes between BIM, CAD and GIS. Per specific production chain there are also probably additional semantically harmonised 'dictionaries' for assets and machinery needed," states Ms Knoth, speaking from experience. For an industrial facility building model, the source data models are mostly from BIM and CAD systems. When additional infrastructure information is needed, scanning in 3D is the solution – which becomes cheaper and easier with photo capture techniques. The target models are from the GIS world, since the end use takes place in GI systems. Open Geospatial Consortium's CityGML/ IndoorGML model and the INSPIRE Building model are the main standards that need to be considered. In CityGML, each object has at least three attributes. For 'Building furniture', the list contains 19 possible class attribute values. An additional code list contains descriptions and numbers for the 'function' and the 'usage'. While CityGML is an ubiquitous standard, issues have been raised about the inconsistency of the levels of detail (LoDs) as well as the size of the files. The INSPIRE Building model (coming from the INSPIRE Directive: Infrastructure for Spatial Information in the European Union) also has a data specification on buildings. It includes a mapping scheme to exchange data with CityGML. While CityGML provides the possibility of adding movable furniture elements, such elements do not exist in the INSPIRE Building model.

The existing models will probably need to be adapted to fit the use case; that is the third step in the Austrian approach. It might include the definition of a CityGML ADE or a new intermediate model as transitioning step for the harmonisation tasks. Afterwards (step four), the transition process can be automated by using a spatial ETL tool such as Safe FME or OpenSource HALE. This opens up the possibility to integrate quality assurance mechanisms during processing.

PILOT

The implementation of a prototype of the new framework is the last phase in the Organising Large Scale 3D Data approach. To guarantee smooth development and the inclusion of all important aspects, it is necessary to consider not only the technological viewpoint, but also the organisational one. Referring to successes in the field of SDIs, Laura Knoth says: "The main differences between a 3D model and a 3D SDI are made by 'organisation' and 'people'. Every stakeholder must want to share in all phases."

Studio iSPACE implemented a prototype of a web-based 3D building representation that includes data streams of real-time indoor positioning in alignment with the presented standards. It has been implemented with the Esri JavaScript API 4.0. This representation can be highly customised in order to provide the best possible view depending on the user's context: not distracting, no information overload, depending on the role, etc.

The building model was acquired using CAD plans that were transformed with Safe FME Desktop into a geodatabase, which was then extracted and uploaded as an Esri web service. The indoor positions were generated by a smartphone app developed by iSPACE. Knoth explains: "In order to be independent of specific companies for indoor mapping, we propose VGI as a way to capture building information: geographic data provided voluntarily by people working in a certain building. With tools from OpenStreetMap, for instance, the amateurs can model what they need in a simple manner which makes it possible for them to contribute their expert knowledge."

The goal of all this is to support human-machine interaction in smart production environments for indoor positioning, production asset monitoring, orientation, location-based management, operational safety as well as situational perception of personnel and machines. According to the users' positions, contextual information is provided on either tablets or, if both hands need to remain free, smart glasses. When an authorised maintenance employee approaches a machine, the employee's smart device displays a website showing information and the status of the machine as well as links to maintenance documents. This approach can also be used for remote maintenance; a worker on site

▲ *Figure 3: The prototype with the building as a fully interactive model in a web app. The user's position in 3D can be shown as a point in the building.*

can be supported by a second employee at a different location based on live information. Additionally, using virtual data ('digital twin'), maintenance personnel are able to get an overview of a machine and its environment before they even enter the location. Any photos, videos, text or voice memos created are provided as support for similar cases in the future. Needless to say, the big picture provided by the map and the current status of the production line supports management decision-making. Managers obtain location-based status information about the current maintenance visits and are supported in their planning and inspection tasks, e.g. monitoring, diagnostics and prognostics. ◂

ABOUT ISPACE GI RESEARCH

Research Studios Austria Forschungsgesellschaft mbH manages the transfer of innovation and knowledge between the market and the universities of Vienna, Linz, Salzburg and Innsbruck. It currently has six research studios with different specialisations in IT-related research. Studio iSPACE is dedicated to geoinformatics and GIScience. The prototype in this article has been developed within the context of 'Assist 4.0', a research project that leading Austrian industrial, commercial and research companies have been working on since 2014 (budget of €3 million, with €1.8 million donated by the Austrian Research Promotion Agency). Production staff are supported during troubleshooting, servicing and remote maintenance with context-sensitive information. The industry dissertation project OLS3D became a spin-off concerning the use of building information models for production environments. Testing of Assist 4.0 has been done, for example, in the semiconductor production clean room at Infineon Technologies Austria and in the automotive industry. The application is controlled multimodally in line with the individual requirements of each case through touch, voice commands and, in the future, gestures.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POINT CLOUDS FOR INSPECTING FLOOD CONTROL STRUCTURES

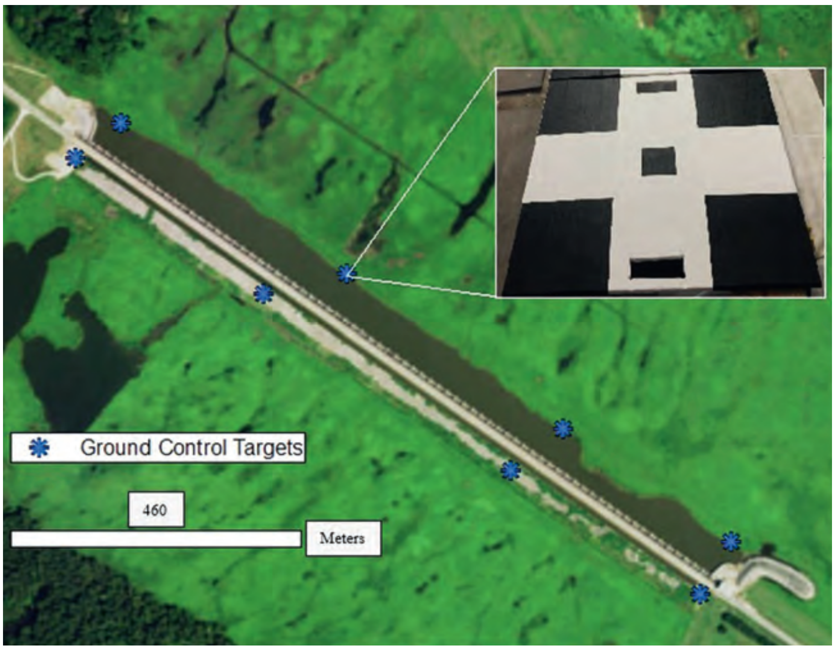
Comparing Lidar and Photogrammetric **Point Clouds**

Airborne Lidar and photogrammetry are both viable methods for capturing point clouds for 3D modelling of man-made hard structures. Although both methods produce point clouds, the manner of capturing data differs in many ways, resulting in point clouds with differing characteristics. In this article, the author evaluates Lidar and photogrammetric point clouds captured from unmanned airborne systems for inspecting a flood control structure.

The New Orleans District of the U.S. Army Corps of Engineers (USACE) has been using small unmanned airborne systems (UASs) for land surveying, environmental monitoring, structural inspections and other applications. However, the characteristics of one UAS platform may greatly differ from those of another, and the same is true for the large variety of sensors. To identify key differences between the point clouds produced by UAS Lidar and UAS photogrammetry, a comparison has been conducted using a flood control structure as test site.

TEST SITE AND SENSORS

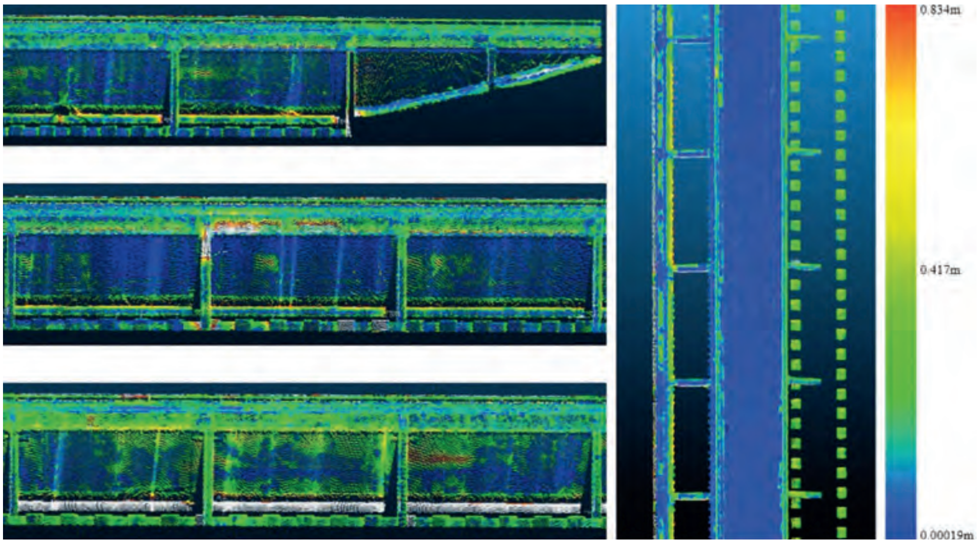
The flood control structure is located in central Louisiana and aims at regulating the flow of water leaving the Mississippi into the Atchafalaya River. The structure undergoes routine inspections on deformations and other damages. This study involved two types of sensors: a RIEGL VUX-1UAV lightweight airborne laser scanner and an RGB camera. The laser scanner used is compact (227 x 180 x 125mm), lightweight (3.5kg) and captures up to half a million measurements per second with an accuracy of 10mm. Mounted on a RIEGL RiCOPTER, an octocopter weighing approximately 25kg with a maximum flight endurance of 30 minutes, the field of view is 230 degrees.



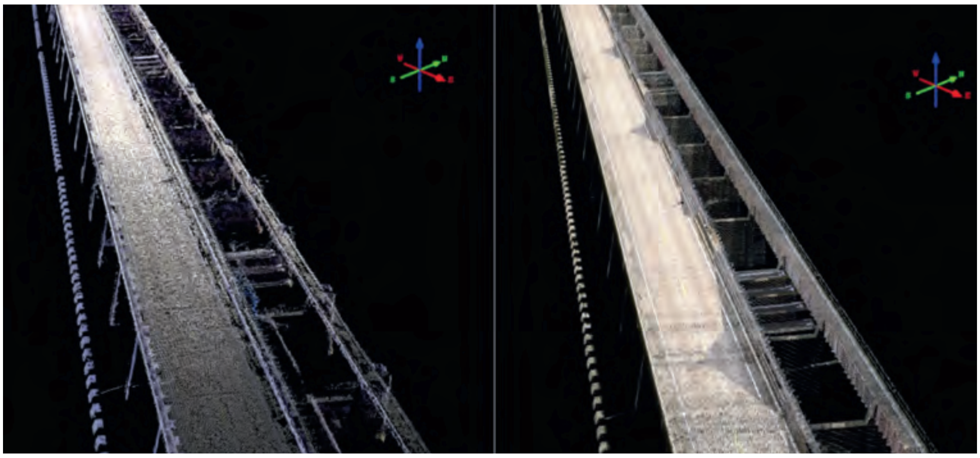
▲ *Figure 1: Location of the eight ground control points.*

SURVEY

To capture images of the top of the structure, a 20Mpx G9X RGB camera was mounted on an eBee, a fixed-wing UAS with a wingspan of 96cm and a weight of 0.7kg including camera and battery. The eBee can stay in the air for up to 40 minutes. To capture images of the sides of the structure, the 38Mpx RGB built-in camera of the Albris was used. The Albris is a V-shaped quadcopter that weighs 1.77kg including the battery, payload and shrouding, and can stay in the air for up to 22 minutes. Its TripleView camera head makes it possible to switch between HD and thermal video. Both the eBee and Albris are platforms from senseFly. For georeferencing of the point clouds, eight ground control points (GCPs) were placed: four on either side of the ▶



▲ *Figure 2: Profile view on the nearest neighbour distance from the two point clouds; colours indicate distances.*



▲ *Figure 3: Photogrammetric point cloud after cleaning (left) and Lidar point cloud; point clouds coloured by RGB value.*

structure (Figure 1). The GCP targets were placed prior to flight and surveyed with a Trimble R10 real-time kinematic (RTK) GNSS receiver at 180 epoch observations per GCP.

PROCESSING

The determination of a point cloud from overlapping images requires the use of image matching algorithms. The photogrammetric processing software used was Pix4D. The ground sampling distance (GSD) was set at 3.5cm for the images acquired with the eBee and just slightly less for the Albris. This small GSD resulted in a dense point cloud. The images of the top of the structure acquired by the eBee and the images of the sides of the structure captured with the Albris were processed together in the same Pix4D project, each using the same GCPs. The resulting photogrammetric point cloud captures the entire flood control structure.

COMPARISON

The point clouds have been compared with respect to density, point spacing, number of points and positional precision as well as standard deviation, minimum, maximum and average of the X, Y and Z coordinates. The latter makes it possible to check whether the Lidar point cloud and the photogrammetric point cloud cover the same space. The photogrammetric point cloud has a density of 178 points/m^2 while this value is 135 for Lidar. The spacing of the photogrammetric points is 3.6cm, and 4.6cm for Lidar. The photogrammetric point cloud consists of slightly over 13 million points, and for the Lidar point cloud this number is nearly ten million. The horizontal extent is very similar for both point clouds (Tables 1 and 2), showing that the two point clouds cover approximately the same horizontal plane. The Z coordinate shows how well the two point clouds align vertically (Table 3). The difference of the minimum Z values is 1.18m. Because of the water that runs along the length of the structure, the photogrammetric point cloud contains many spurious points along the bottom of the structure. While both point clouds successfully capture the bottom edge of the structure, points along the bottom have been removed from the photogrammetric point cloud during data cleaning, explaining the difference in the minimum Z values. The difference of the maximum Z values (0.28m) is caused by the fact that the photogrammetric point cloud does not cover the entirety of the guard rail that runs along the structure, whereas the Lidar point cloud does.

VISUAL INSPECTION

To determine how well the two point clouds align spatially, the Cloud-to-Cloud Distance tool from CloudCompare was used. The tool takes a compared point cloud and a reference point cloud and determines the

	Min X (m)	Max X (m)	Mean X (m)	StdDev X (m)
Photogrammetric	973,427.568	974,311.698	973,877.075	250.23
Lidar	973,427.281	974,311.299	973,863.200	253.05

▲ *Table 1: Minimum, maximum, mean and standard deviation of the X coordinate.*

	Min Y (m)	Max Y (m)	Mean X (m)	StdDev X (m)
Photogrammetric	285,965.618	286,592.583	286,268.455	174.16
Lidar	285,964.996	286,592.579	286,281.644	177.28

▲ *Table 2: Minimum, maximum, mean and standard deviation of the Y coordinate.*

	Min Z (m)	Max Z (m)	Mean Z (m)	StdDev Z (m)
Photogrammetric	12.60	23.13	20.04	2.59
Lidar	13.78	23.41	21.26	2.07

▲ *Table 3: Minimum, maximum, mean and standard deviation of the Z coordinate.*

nearest neighbour distance between the two. These distances are visualised by a colourised point cloud. The shortest distance (Figure 2) is 0.2mm while the greatest is 6.5m. Nearly 95% of the distances are between 0.2mm and 0.8m while 0.0106% of the distances are in the range between 5.7m and 6.5m. The deck of the structure shows the tightest spatial agreement between both point clouds with most distances smaller than 15cm. Visual inspection shows that the Lidar point cloud has less noise and clutter, displaying cleaner surfaces along the deck and piers, with sharper edges. These are characteristics which make it easier to take precise measurements, create a 3D mesh or interpolate a digital surface model. The raw photogrammetric point cloud requires extensive cleaning. The cleaning of the point cloud was done manually by clipping spurious points, and automatically by classifying misplaced points by their RGB value and removing them. The cleaning resulted in a clean model with very few spurious points (Figure 3).

CONCLUDING REMARKS

Both methods succeeded in accurately capturing the structure. The Lidar output took far less time to capture and process and provided a clean and sharp point cloud that was easy to work with. A Lidar scanner is an active sensor, and thus insensitive to the surrounding water and able to measure surfaces within the structure. The photogrammetric data collection and processing took slightly longer and the point cloud required extensive cleaning. Photogrammetric processing relies on identifiable features to be matched across sequences of images. Because the surface of water is void of identifiable features, photogrammetric processing will fail in these areas, resulting in gaps and sometimes spurious points that extend well above and below the water body's extent. Removing these misplaced points can be time-consuming and difficult. The misplaced water body point's RGB values could be discriminated and removed from the point cloud using CloudCompare software. ◂

THE LIDAR OUTPUT PROVIDED A CLEAN AND SHARP POINT CLOUD THAT WAS EASY TO WORK WITH

ABOUT THE AUTHOR

Michael Schwind is the lead small UAS coordinator for the New Orleans District U.S. Army Corps of Engineers and is a co-founder of Osprey Geospatial Solutions LLC.
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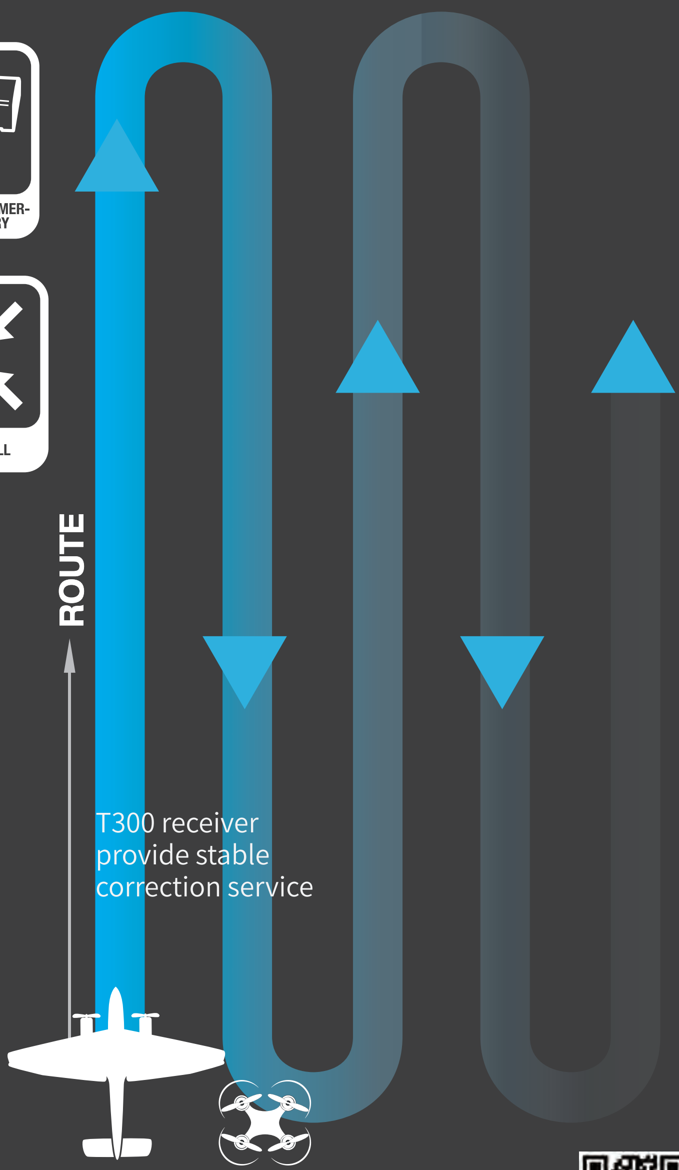

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BY **FRÉDÉRIQUE COUMANS**, CONTRIBUTING EDITOR, GIM INTERNATIONAL

COMBINING BIM AND GIS FOR A SUSTAINABLE SOCIETY

Community-scale Assessment of Energy Performance

Nikken Sekkei Research Institute in Tokyo, Japan, has developed a vision for cities to help them choose an energy optimisation strategy for neighbourhoods comprising a variety of building types. The optimisation of energy consumption is approached from an area-wide standpoint. The added value of the method for city renewal programmes has been demonstrated based on a central district in the Japanese capital.

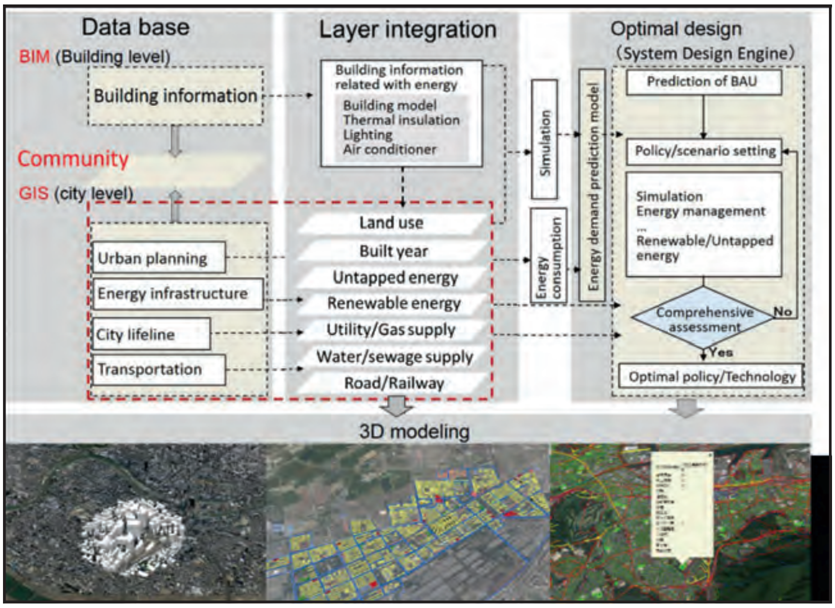
Japan has low energy resources and a high population density. That provides extra stimulation to develop ecofriendly urban planning. City and environmental designs use low carbon footprint solutions as their starting point, and planners, urban designers, architects, engineers and landscape specialists work together to provide integrated solutions. Urban energy supply and demand is an important item in this context of smart city management. It is a far more complex system than a single building since there are synergies between various elements like transport and the city infrastructure. Especially in Japan's largest cities, that infrastructure is becoming more and more compact.

TRANSIT-ORIENTED DEVELOPMENT

According to the latest forecasts, more than a quarter of Japan's citizens will be aged over 65 in 2055. By then, the population will also have shrunk from the current 127 million to 90 million. In Tokyo (13 million people), one in four elderly citizens live alone with no family to take care of them. The predicted population growth in the 65-and-over group is one of the reasons that, for the past two decades, city planning has been based on compact, multifunctional neighbourhoods concentrated around the public transport system. Japan has no choice but to invest in developing such infrastructure rather than controlling road traffic.

Tokyo Metropolitan City is huge, but the scale has remained human in its neighbourhoods since Tokyo opted for the transit-oriented development (TOD) concept. Most people live no more than 1,000 metres from a train station. In these communities, everything is within walking distance: shops, offices, public ▶

▲ *Figure 1: Tokyo opted for the transit-oriented development concept. Most people live no more than 1,000 metres from a train station. Every circle is a fully functional community in which everything is within walking distance: shops, offices, public facilities, parks and green spaces, and of course transport.*



▲ *Figure 2: Structure of the energy assessment tool.*

facilities, parks and green spaces, and of course transport. "It helps people of all ages to live independently in their own homes and communities. It also saves emissions by vehicles and contributes to mitigating the production of greenhouse gases," elucidates Mr Shinji Yamamura, executive officer at the Nikken Sekkei Research Institute. Reducing CO^2 is very important for Tokyo. The city is a typical example of an urban heat island; the annual mean temperature has increased by about 3°C (5.4°F) over the past century. The municipality wants to reduce greenhouse gas emissions by 25% by 2020 compared with the level in 2000. Therefore, the city has not only created a thousand hectares of new green space over the last decade, but there is also a pressing need to reduce energy consumption, both in transport and in buildings.

LOW-ENERGY BUILDINGS

Tokyo's urban infrastructure evolved during the city's period of rapid economic growth, and now requires renewal. Of course, energy saving is part of the plan. Mr Yamamura explains: "New buildings will be recommended, but net zero-energy buildings (ZEB) are not always possible. That is especially so in renovation. Much larger investments are needed than when one aims at the more common level of low-energy buildings. And even for that level, owners of very large commercially exploited buildings can perhaps generate enough budget, but it is still very difficult for the owners of small to medium-sized buildings." Nevertheless, it is necessary. In 2014, the average annual energy consumption in Japan's commercial buildings was around 2,140 to 2,450MJ/m^2, in office buildings it was 1,457MJ/m^2,

AFTER INPUTTING THE LOCATION OF A TARGET AREA, THE PLANNER ALSO OBTAINS THE ENERGY TECHNOLOGY PACKAGE THAT IS LIKELY TO BE MOST EFFECTIVE

in hospitals it was 2,952MJ/m^2 and in residential buildings it was 778MJ/m^2.

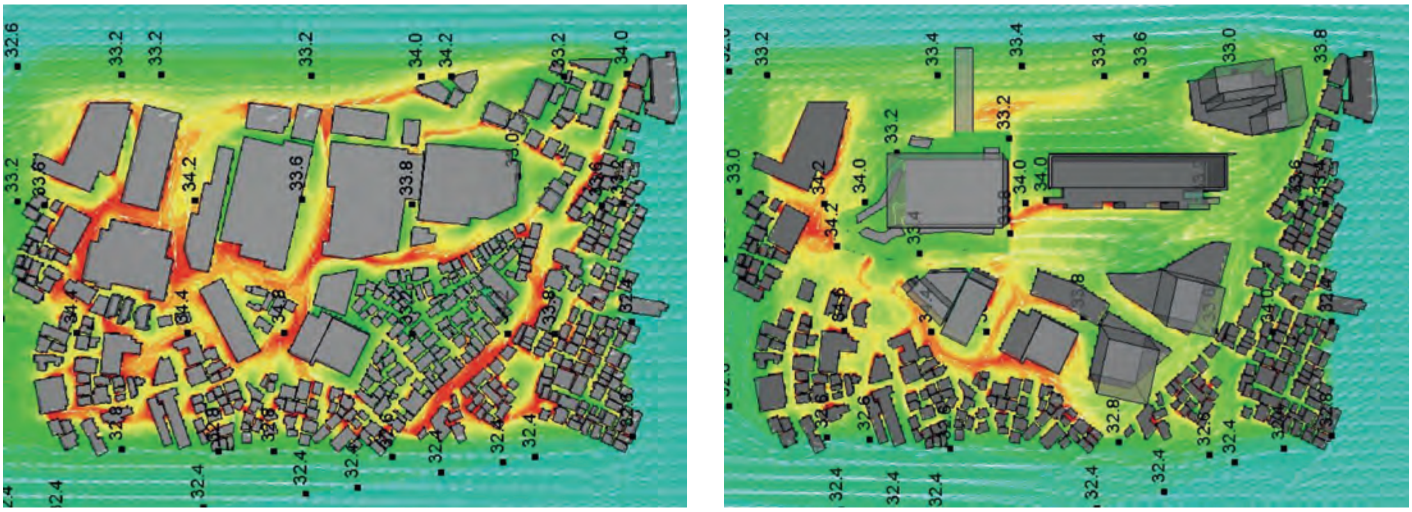
These elements – community infrastructure, renovation needs, energy reduction policies – inspired the researchers to develop a flexible strategy to renovate all the buildings in a neighbourhood as energy-efficiently and as pragmatically as possible, instead of each building on its own. It is the overall result for Tokyo that counts. Minimising the range of the infrastructure to be renewed would also reduce the initial costs.

The researchers developed three variations of pragmatic renovation policies and studied the effects of them in different areas of Tokyo. "In this process, BIM-GIS integration is essential to combine data in an efficient and holistic, user-friendly way," states Shinji Yamamura. Building information modelling (BIM) is essential for the energy consultants and urban planners to prepare the building-related data, which can be combined with simulation software to predict the effect of every measure within or amongst buildings. The urban infrastructure data for this energy simulation comes from the local geographic information system (GIS) databases. The result is returned to the 3D city model on the GIS platform to check its effect at city or community level. The platform developed by Yamamura and his colleagues enables energy management operators or local government staff to visualise the energy consumption of the city, district or building. After inputting the location of a target area for city renewal, the planner obtains not only the urban plan information and the community features, but also the energy technology package that is likely to be most effective and needs further simulation and analysis.

THREE PACKAGE VARIATIONS

Along one train line (East Japan Railway Company) in Tokyo, the researchers picked 12 communities which each have a train station at their centre. The GIS analysis combined with BIM databases from the urban planning department showed that there are a total of 150,000 buildings in those communities, 72% of which are small to medium-sized buildings. Only one community is made up of approximately 50% large buildings (over 50,000m^2). In three of the 12 communities, buildings are in use for commercial or business purposes; the other nine are more residential areas.

The first option is to check whether the community has buildings with more than 50,000m^2 of floor space. The owners of these large buildings would be in a better position to raise the budget for low-energy renovation work than the owners of small and medium-sized buildings. Rigorously renovating the large buildings only in such a way that they consume over 60% less energy and leaving the small and medium-sized buildings as they are would produce



▲ *Figure 3: Osaki Station West Exit Area, Tokyo – microclimate plans with thermal environment simulation support the municipality in creating breeze corridors.*

around 18% energy savings across the whole community, concluded Nikken Sekkei Research Institute. "By using advanced technologies such as ZEB-ready methodologies, the large buildings can achieve that 60% reduction," claims Yamamura. But it is expensive.

As the second alternative, the government should still stimulate renovation of all the large buildings, but more simply. The aim is for them to use 20% less energy. That is feasible with today's more common technologies to reduce energy consumption in the field of isolation, lighting, cooling and heating. Simultaneously, all the small and medium-sized buildings should implement rather small and easy measures to reduce their energy consumption by only 10%: change to LED lighting, use slightly more efficient air-conditioning systems, etc. In this case, the community achieves 20% energy savings overall.

The third option is that half of the large buildings implement measures to save 20% and all the small and medium-sized buildings likewise save 20%. In that case, energy consumption is reduced by more than 27% for the whole area. To reach that goal, the same reduction steps as in the second renovation policy have to be taken and an area energy management system also has to be implemented. Using the cluster of computer-aided tools, the electricity grid operator optimises the performance of the energy generation and transmission systems.

Looking to the near future, Shinji Yamamura reveals: "The software platform we developed suggests the best-performing strategy, depending on the input from the BIM and GIS databases. Artificial intelligence (AI) can automatically design the optimised energy consumption communities; I am now developing such an AI-oriented tool."

HEAT ISLAND

BIM-GIS integration is useful in all kind of 3D simulations; Yamamura also uses it a lot for 3D-environment thermal simulations. Although only the energy-oriented issues are highlighted for the purpose of this article, this energy management technology can be part of a comprehensive system that includes the transportation system and urban design measures for heat island mitigation. Yamamura explains his vision: "It is part of a smart city concept with the aim to develop solutions simultaneously and widely at different levels. I believe that prevention of global warming and pursuit of comfortable living conditions are both realisable at the same time."

When a government decides to invest in BIM-GIS integration, it has a multipurpose functionality in environmentally friendly design. Yamamura, who is also an expert on urban thermal environment planning, has advised on many 'cool city' design projects that mitigate heat island phenomena in Japan and elsewhere in Asia. Microclimate plans with thermal environment simulations support municipalities in creating breeze corridors in city centres to alleviate the heat problem. The starting point is the same as with area energy management: neighbourhoods or districts must be seen as part of the whole system to achieve success at city level. ◀

WHEN A GOVERNMENT DECIDES TO INVEST IN BIM-GIS INTEGRATION, IT HAS A MULTIPURPOSE FUNCTIONALITY IN ENVIRONMENTALLY FRIENDLY DESIGN

ABOUT SHINJI YAMAMURA AND NIKKEN

Shinji Yamamura is executive officer and principal consultant with Nikken Sekkei Research Institute in Tokyo. He has a PhD in engineering and is a registered building mechanical and electrical engineer. Nikken Sekkei Research Institute was founded in 2006 and is one of the companies in the Nikken Sekkei Group (1950), providing a large variety of city planning, design and redevelopment services (2,600 employees). Its award-winning urban services can be seen throughout Japan, Russia, Asia and the Middle East.

FIELD TEST OF THE PHASE ONE IXU-RS1000 CAMERA

Medium-format Cameras for **High-accuracy Mapping**

Small and medium-format cameras are increasingly gaining popularity for mapping small and medium-size areas, corridors, construction sites and cities. They are also used as companions of Lidar systems, mounted on unmanned aerial systems (UASs), and for monitoring and inspecting infrastructure. The author of this article investigated the suitability of the Phase One iXU-RS1000 camera for high-accuracy mapping and found this medium-format camera to be a metric camera with stable and clearly definable interior orientation parameters, producing images of high geometric and radiometric quality.

In photogrammetry it is important that cameras produce images of which the geometric distortions are as small as possible or in compliance with known distortion models, while the focal length of the lenses and the principal point remain stable over time.

▲ *Figure 1: PhaseOne iXU-RS1000 camera.*

Flight altitude (above ground)	2,500 feet / 760m
GSD	4cm
Distance between flight lines	230m
Side overlap	49%
Forward overlap	80%
Frame size	450m x 340m
Orthophoto angle	17°
Building lean	15%
Ground speed	100 knots
Strips	SN – 9; WE – 2

▲ *Table 1: Aerial survey parameters.*

The photogrammetric accuracy assessment of the Phase One iXU-RS1000, a medium-format camera, was carried out to test its suitability for high-accuracy mapping and was done by a field test. The test included a flight over a test field, image matching and aerial triangulation (AT), camera calibration based on AT, and analysis of the accuracy of stereoscopic measurements.

MEDIUM FORMAT

The iXU-RS1000 series consists of 100Mpx cameras with a pixel size of 4.6µm, an image capture rate of 0.6 seconds per frame and an exposure time of up to 1/2,500 seconds. The cameras can be equipped with lenses with five different focal lengths: 50mm, 70mm, 90mm, 110mm and 150mm. The camera size (10x10x20cm including lenses) and its weight of less than 2kg (see Figure 1) allow easy installation in small and lightweight aircraft, gyrocopters or medium-size UASs. The small dimensions and lightweight characteristics significantly reduce the operational costs of mapping projects.

TEST FLIGHT

The test site, situated in the vicinity of the village of Kfar-Vitkin in Israel, covered 1.2km from north to south and 2km from east to west (Figure 2). Manmade features and manholes were chosen as signalised ground control points (GCPs). All 53 GCPs were located on the ground and were measured according to the static GNSS survey procedure with one reference station. The coordinates of this base station were measured during two independent one-hour sessions. Each GCP was measured by two independent half-hour sessions resulting in an absolute planar accuracy (X,Y) of 0.8cm root mean square (RMS) and an RMS of 1.3cm in height (Z). The camera used in the test had a focal length of 90mm and was installed at the rear of a Cessna 172 aircraft (Figure 3). The aerial survey parameters are listed in Table 1.

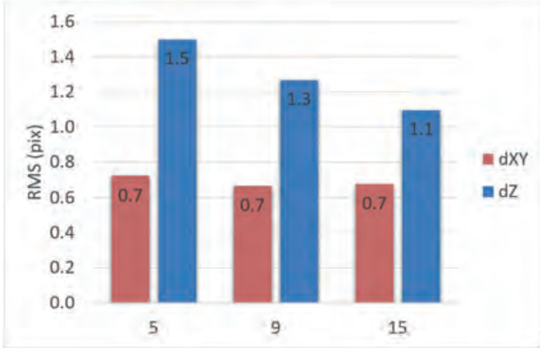
The testing procedure included flight planning and execution, image matching for determination of tie points and aerial triangulation (AT), camera calibration based on AT, analysis of AT accuracy using different GCP and checkpoint (CP) configurations, and stereoscopic measurements of GCPs and CPs. Agisoft Photoscan Professional was used for image matching and for GCP and CP measurements. Bingo was used for bundle block adjustment, camera calibration and accuracy assessment. AtlasKLT was used for stereoscopic measurements of GCPs and CPs.

CAMERA CALIBRATION

Self-calibration is aimed at the accurate calculation of focal length and principal point of the camera. These interior orientation parameters are calculated from a simultaneous bundle adjustment of all images of the block using tie points and GCPs. The

▲ *Figure 2: Test site with control points and flight lines.*

▲ *Figure 3: Cessna 172 used for the test flight.*



▲ *Figure 5: Residuals on check points (in pixels).*

accuracy depends on the number and size of image overlaps, number of tie points and GCPs and their accuracy, and other factors. A total of 202 images were used with an average of 222 tie points per image. All 53 GCPs were used. The adjustment resulted in a high photogrammetric overall accuracy of 1.84µm (0.4 pixel). The RMS error of tie points was 1.7µm in the image plane (0.3 pixel). The RMS of tie points on the ground was 0.8cm in planar position (0.2 pixel on the ground) and 3.8cm in height (0.8 pixel on the ground).

During the self-calibration the lens distortion was also calculated. Figure 4 clearly shows symmetrical radial distortion with a maximum of 24µm before the image was fixed. After fixing with additional parameters describing a simple symmetrical radial distortion, the maximum distortion decreased to 0.91µm, which is just 0.2 pixel. The distortion model of the iXU-RS1000 with a focal length of 90mm fully corresponds to a standard Brown-Conrady distortion model. By applying radial corrections, the maximum distortion is reduced to less than 1µm.

ACCURACY

The accuracy of the block was determined using three GCP and CP configurations: 5 GCPs and 48 CPs, 9 GCPs and 44 CPs, 15 GCPs and 38 CPs (Figure 5). The planimetric accuracy always lies at around 0.7 pixel, regardless of configuration. Height accuracy ranges from 6cm (1.5 pixel) with 5 GCPs to 4.4cm (1.1 pixel) with 15 GCPs. This high accuracy can be made even better by improving the accuracy of GNSS data.

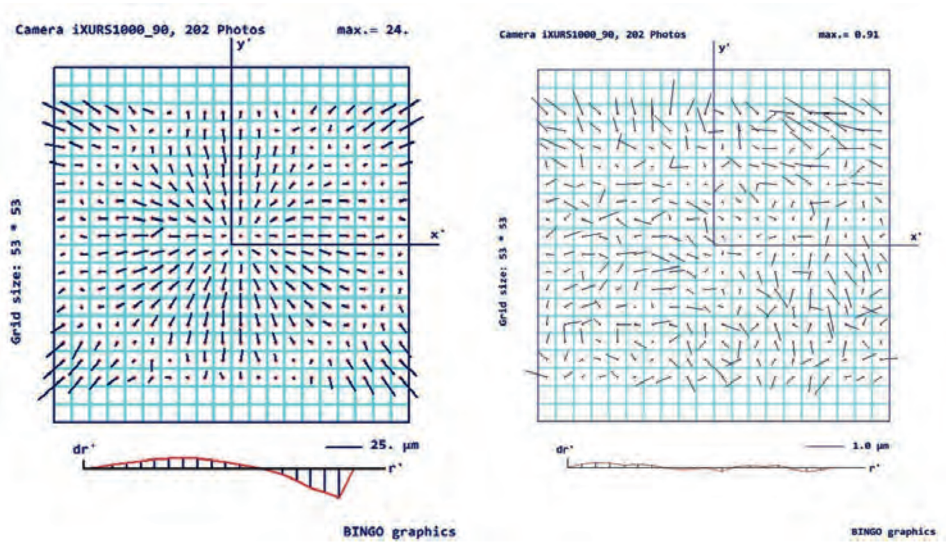
To determine the accuracy of the stereoscopic measurements and the presence of vertical parallax residuals after relative orientation, 53 GCPs were measured on 91 stereo pairs with 60% forward overlap. On each stereo pair the points were measured twice. To eliminate effects of possible block deformations on stereoscopic measurements, exterior orientation parameters were calculated from bundle block adjustment with the use of all 53 GCPs.

It can be calculated that the theoretical planimetric accuracy will be 0.5 pixel (2cm) and the theoretical height accuracy will be 2.8 pixels (11.2cm) for a camera with a focal length of 90mm and forward overlap of 60%. The test obtained a planar accuracy in terms of RMS of 0.8 pixel (3.14cm) and a height accuracy of 1.72 pixel (6.87cm). The planimetric and height accuracy obtained in the test were affected by the accuracy of the GCPs, of which the planar RMSE was 0.8cm and the height RMSE was 1.3cm. When these effects are taken into account, the planimetric accuracy of stereoscopic measurements corresponds to the theoretical accuracy, and the height accuracy obtained in the test is even better than the theoretical value. ◀

ABOUT THE AUTHOR

Dr Yuri Raizman is CEO of GeoCloud and chief scientist of Phase One Industrial. From 2008 until 2017 he served as VP EMEA and chief scientist at VisionMap.

✉ yra@phaseone.com



▲ *Figure 4: Original distorted image (left) and undistorted image.*

MODELLING THE CAESAR’S CAMP OPPIDUM UNDER DENSE COVER

Surveying the Past Using a Drone

Archaeology has long been reliant on ground-level geophysical disciplines and aerial photographs shot from an aircraft or ultralight. Airborne observations not only enable remains that are invisible on the ground to be detected and studied in a non-destructive way, but also to pinpoint where reconnaissance probes or excavations should be performed. If a site is covered by dense vegetation, Lidar is the only tool practicable for aerial observation. Lidar was applied in a unmanned aerial system (UAS or ‘drone’) survey of the site known as ‘Caesar’s Camp’, situated in the French municipality of Changé/Saint-Piat, located 2km south of Maintenon.

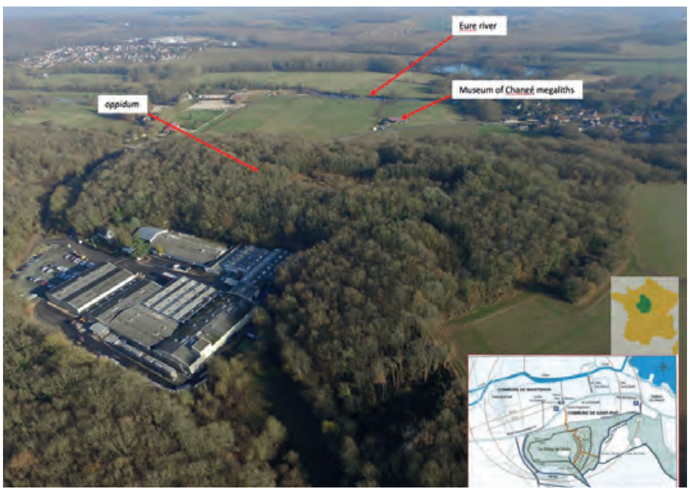
The Caesar’s Camp site is an ‘oppidum’ (Figure 1), which is an archaeological term for a fortified habitat (elevated or in the plain) found in Europe around 100 B.C. Julius Caesar mentions the murus gallicus in the Gallic wars, constructed from earth, wood and stones and possibly reinforced by a huge, massive rampart, preceded by a moat, as at Châteaumeillant in the Cher.

Geographically, the site is a plateau forming a natural promontory of 5.5 hectares, rising on a relatively steep slope of some 40 metres above the Eure valley to the east, and a small dry river to the west and the north. The strategically advantageous position was strengthened by the construction of a 7m-high and 250m-long rampart to the south, erected using the materials excavated on the spot, leaving a 6m-deep trench outside the system. The oppidum overlooks Neolithic to Merovingian burial places which were the subject of research and excavations from 1924 to 1927 and from 1983 to 2000. Partial topographic surveys and observations were carried out by excavation teams in 1980 but the site was abandoned due to lack of funding. Since the 1980s, bibliographic research, land acquisition and management of the site have been done by Comité Archéologique d’Eure-et-Loir (CAEL) whose motto is ‘Publicise to better protect’.

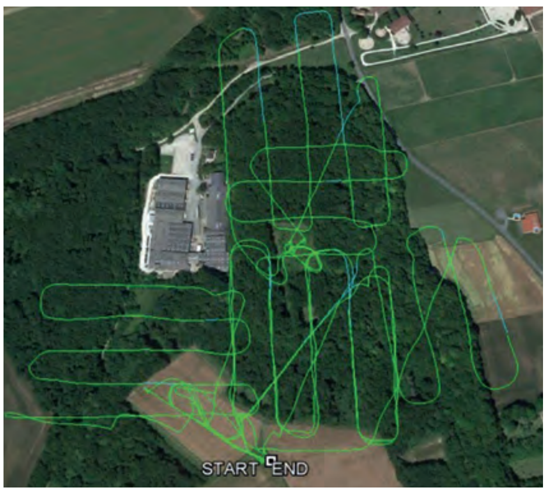
One of the key issues is the age-dating of the oppidum. A few Roman objects have been found, which are probably why the site got the name ‘Caesar’s Camp’. The site was possibly in use in Celtic times, or by the people who installed the Neolithic burial zone. The oppidum at Changé could date back to anywhere from the middle Neolithic period up to the Iron Age and its origins could make it much older than other oppida. It also may have been modified over subsequent centuries.

SURVEY SYSTEM

A thorough topographical survey of the site had never been carried out due to the dense tree cover. Only airborne Lidar could be used, and up until recently such surveys were very costly due to the use of a plane or helicopter. CAEL asked AIRd’ECO-drone to carry out a drone-based Lidar survey to



▲ *Figure 1: Overview and location of ‘Caesar’s Camp’ oppidum site.*



▲ *Figure 2: UAS flight lines.*

obtain a topographic map. A DPS4-Urban, four-engine drone was used, equipped with a Yellowscan (YS) Mapper. This powerful, 2kg, class-1, 905nm laser scanner can survey from a maximum altitude of 100m, with a range resolution of 4cm, a precision of 10cm and a scanner field of view of 100° performing 18,500 measurements per second. The sensor operates independently from the drone and uses an inertial navigation system (INS) based on the SBG Ellipse E and a Septentrio AsterX-m RTK GNSS with its own base station. The total weight of the drone including all equipment is 5.2kg. Since the batteries are the limiting factor, a compromise was sought between weight and power to allow 15 minutes of flight.

DATA COLLECTION AND PROCESSING

Five flights were performed covering 10 hectares on 14 and 15 December 2016 when there was minimal vegetation cover. The survey was performed in two half days as the number of daylight hours were limited and the temperatures were too low to fly safely in the morning. The RTK base station was placed in a clearing on the plateau. The flights were conducted at an altitude of 50m, a speed of 4m/s and an overlap of 50% (Figure 2), corresponding to a 50m spacing between the tracks. The mean density was 140 points/m^2 spread out according to the density of the vegetation.

Immediately after the flight, data was retrieved from the drone and visualised in the field using the YS plug-in in QGIS. Newer versions make it possible to instantly view the point cloud while the drone is flying. The visualisation not only allows both verification and adjustment of the next flight, but is also a powerful tool for teaching the uninitiated.

Once the flight levels had been adjusted using Terrascan, the post-processing chain was 'classical' classification of the point cloud, processing of the digital terrain model (DTM) in QGIS and creating contour lines, modelling and orthophoto realisation in 3D Reshaper. The 3D model was digitally represented as a shaded relief map in Google Earth. The mean density of the points conserved after classification was 25 points/m^2. The measurements were considered to have a precision of between 5 and 15cm and an averaged DTM was computed with an estimated precision of 20cm (1√ point/m^2). When compared to a profile taken in a topographical field survey carried out in

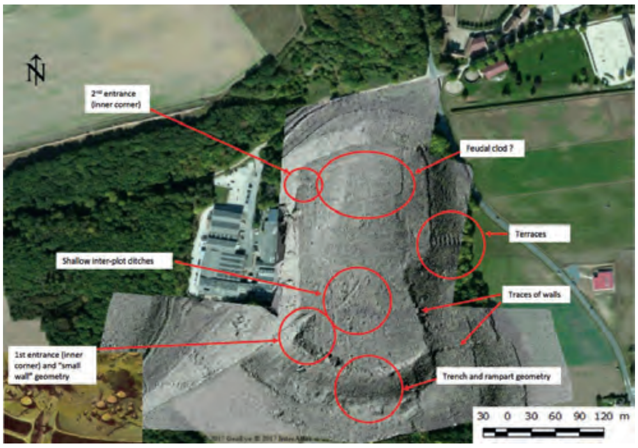


Figure 3: Shaded DTM used for interpretation.

1980, the results were found to coincide well. The final processing consisted of creating a 'real' model in resin.

ARCHAEOLOGICAL RESULTS

Based on the processing products, a number of features were of interest to the archaeologists (Figure 3). The curvature of the ramp, and that of the trench that borders it, had been believed to be more linear. In particular, two inner corners could be observed at the western extremities. This positive relief towards the interior suggests that they were the entrances to the oppidum. The southern entrance was probably framed by two inner corners, of which the second one on the western side is masked by an excavation with sharp edges, oriented along a small NE-SW dried-up valley which certainly dates to the period of the construction of the Maintenon aqueduct (17th century). The archaeologists discovered remains of this second inner corner on the western side of the present-day access pathway. The geometry of the trench was established using profiles along the full length of the rampart extracted from the DTM.

In the southern portion of the eastern slope, traces of a low wall run perpendicularly down the slope towards the Eure valley. The DTM also clearly reveals 'steps' or terraces stretching some 15 metres, with a regularity that is not visible in the field. It is supposed that these terraces are related to the cultivation of grapes, also shown on an old postcard. On the northern edge of the plateau a slightly elevated rectangle is observable which is also shown on a chart from 1859; archaeologists propose this is a feudal clod. In the plateau's centre, intersecting 'lines' are visible which coincide with the modern-day plot map and may correspond to shallow inter-plot ditches.

One of the requests was to obtain, insofar as possible, the micro-topography of a seemingly unfinished low wall on the western part of the rampart. This zone is overgrown with very thick *Buxus* bushes, allowing little if any daylight to penetrate. However, the Mapper was powerful enough to record a sufficient number of points to reconstruct this low wall (Figure 4). The altitude atop this small wall was the same as that of the top of the rampart in its mid-section, and the current hypothesis is that the low wall might

FURTHER READING

- Museum of the Changé megaliths discoveries: www.megalithesdechange.fr
- Fatima De Castro and Dominique Jagu, 2014: Le Camp de César de Changé, commune de Saint-Piat.1989-2014, 25 ans d'activités. CAEL.
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- Isabelle Heitz and Dominique Jagu, 2017: Modélisation d'un oppidum sous couvert végétal dense, en Eure-et-Loir, par un LiDAR aéroporté par drone. *Revue XYZ* No. 153, pp.45-50

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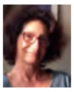
have been used as a construction guide for the rampart.

CONCLUSION

This project proves UAS-based Lidar's effectiveness for a mapping and archaeology application in the case of dense vegetation cover. Over and above the topographical map, it was possible to obtain precise data of the foreseen morphological elements such as the rampart and ditch as well as the discovery of virtually invisible morphological elements such as the entrances and terraces. These visualisations enable the team of archaeologists to be actively involved in the survey. They also allow, in a second phase, communication to the public. A video is currently being finalised integrating pictures from the ground and the drone as well as a visual with a camera travelling in the 3D model as if flying on-board the drone. Based on this success, other Lidar surveys of wholly or partially covered archaeological sites are scheduled for autumn and winter using even higher-performance Lidar systems (e.g. the YS Surveyor) on a more powerful hexacopter (DPS6-BL) authorised to fly in populated zones. ◀

▲ *Figure 4: Detail of the small wall in the resin-based 3D model.*

ABOUT THE AUTHORS



Isabelle Heitz is a geologist and geophysicist from University of Paris-Sud (DEA, 1984). She has worked in the field on dam studies in Algeria and the USA. She subsequently worked in the field of water management in France and archaeology in Egypt, and later in France on waste management and landfill site qualification. Also a glider pilot, she founded the AIRd'ECO-drone society to provide technical drone solutions. She applies her Lidar expertise in the field of archaeology and is also a member of CAEL, of Fédération Française du Drone Civil (FDDC) and of DRONEPERF.

✉ contact@airdeco-drone.com

Dominique Jagu was a dental surgeon in Maintenon, Eure-et-Loir, France, for 40 years. He officially entered the field of archaeology in 1994 (DEA prehistory at the Sorbonne) and is now an archaeologist at Comité Archéologique d'Eure-et-Loir (CAEL). Having directed excavations since 1972 and specialising in megalithic monuments, he led excavation projects on two barrows in Eure-et-Loir – Changé and Yermenonville – between 1984 and 2010. He has authored some 40 publications devoted to megalithic monuments and to odontology studies of the contents of graves.

✉ dominique.jagu@orange.fr

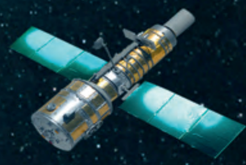


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FIG Commissions 7 and 9 Annual Meeting 2017 and Conference, Cartagena, Colombia, December 2017

The FIG Commission 7 on Cadastre and Land Management and Commission 9 on Valuation and the Management of Real Estate Annual organised a joint annual meeting from 4 to 8 December 2017 in Cartagena, Colombia. This event hosted the Annual Meeting and Conference on Cadastre for Emergencies and Disasters 'Challenges and opportunities for islands and coastlines'.
The cadastral system and land registry in Colombia is under renewal. A proper land administration is relevant in the context of the peace treaty between the Colombian government and FARC. Many issues in that context are land related and were a subject of discussion during the conference.
The main keynote was presented by Mr Jorge Muñoz, practice manager of the World Bank's Global Land and Geospatial Unit. Mr Muñoz brought experiences and lessons learnt in land administration. First of all, fit-for-purpose approaches in land administration require support. Turnkey land information systems are not available. It is ideal to merge cadastre with registry under one entity. If this is not possible, there should be at least full integration of information systems. Goal of the Land 2030 Initiative is to enhance commitment of governments and partners to achieve ambitious global and regional targets to secure land rights by 2030, especially on women's rights, fragility and forced migration. This includes an expansion of World Bank's land portfolio, by US $760 million to US $1,432 million over the next 18 months. The World Bank welcomes increased collaboration with FIG members in multiple countries.

More information
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Upcoming GSDI Marine/Coastal SDI Workshops

The Global Spatial Data Infrastructure (GSDI) Association is engaged in a project investigating coastal/marine SDI best practices. The project conducts research into effectiveness of marine information geoportals and other aspects of delivering successful marine/coastal SDIs, including policy and governance challenges and successes. It is supported by funding from European Spatial Data Research (EuroSDR) and focuses closely on land-sea interactions, especially in regard to implementation of the EU Maritime Spatial Planning Directive and national and regional work on marine cadastres.

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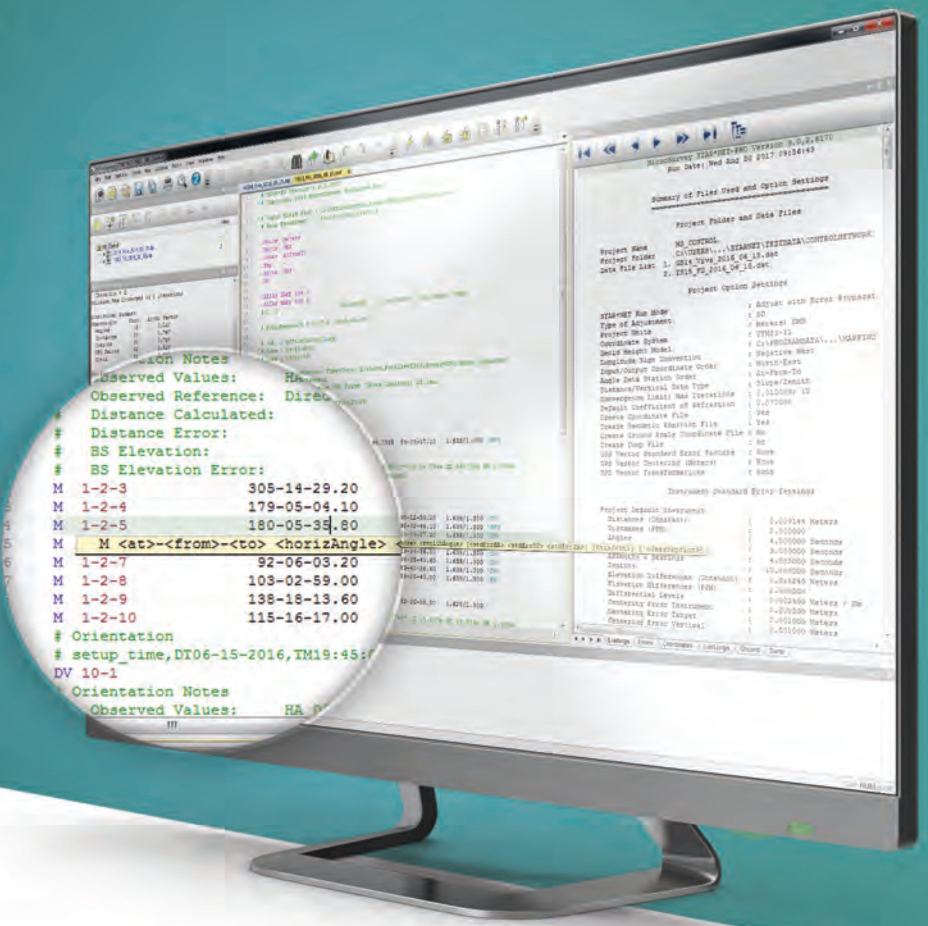

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wrecks, offshore installations, pipelines, cables), administrative and legal boundaries, areas of conservation and marine habitats and oceanography. Rapid changes in coastal and marine areas demand implementation of processes and tools to enhance knowledge and management of these territories. To contribute to these goals, coastal/marine SDIs facilitate sharing and use of spatial data across a broad range of stakeholders by promoting data and metadata harmonisation and service interoperability.

Several coastal/marine SDI workshops are part of the activities of the project.

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http://gsdiassociation.org/index.php/publications.html

IAG Workshop SGCS2017

The IAG Sub-commission 2.6 ‘Gravity and Mass Transport in the Earth System’ and the joint Working Groups 2.6.1 ‘Geodetic Observations for Climate Model Evaluation’ and 4.3.8 ‘GNSS Tropospheric Products for Climate’ held, for the first time, a joint workshop on ‘Satellite Geodesy for Climate Studies’ (SGCS) from 19-21 September 2017 at the University of Bonn, Germany. In total, 68 scientists participated in four sessions addressing such topics as: 1) Requirements for validating climate models using geodetic data, 2) Long and consistent geodetic time series, 3) Climate modelling and observable variables, and 4) Prospects of future missions and constellations.
Geodesists and climate scientists met in breakout sessions to draft a roadmap for closer collaboration between these communities. While it is generally recognised that geodetic data such as GNSS troposphere and radio-occultation observables, satellite-gravimetric surface mass change, and altimetric sea level measurement provide invaluable information for studying the Earth’s changing climate, programmatic obstacles and open scientific questions have been identified that hamper a wider acceptance of geodesy as a tool for climate research. To address this challenge, a number of suggestions were put forward.

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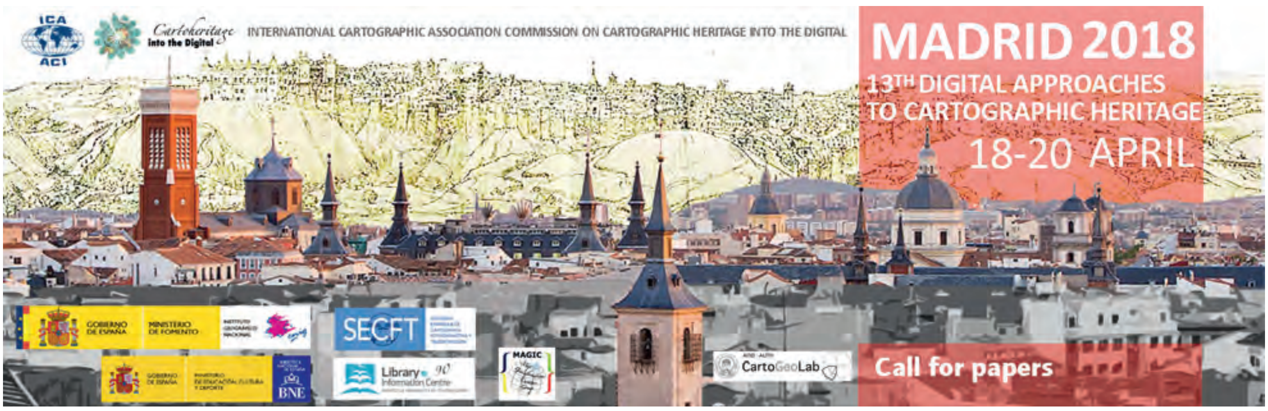
Heritage into the Digital

It is over three and a half years since readers of this column have been updated about the activities of the lively ICA Commission which addresses the role of contemporary digital technologies in the study and application of historical mapping and cartographic heritage. This commission was titled ‘ICA Commission on Digital Technologies in Cartographic Heritage’ from its confirmation in Moscow in 2007; its status was re-affirmed in 2011, and in 2015 it was approved by the ICA General Assembly in Rio de Janeiro under a new title, ‘ICA Commission on Cartographic Heritage into the Digital’. This commission has been a model for other ICA commissions to follow,



from its initiation as an ICA working group in 2005 to its current activities.
Thus, an active website is available for this commission at http://cartography.web.auth.gr/ICA-Heritage/. This richly illustrated resource is regularly updated with news items and is a portal to the wide range of further activities. A definition of cartographic heritage and a description of the environment within which is studied are presented. The extensive Terms of Reference present the aims and objectives of the commission, whilst the section titled 'Targets and Tools' informs the visitor of its purpose and the means by which it pursues its work. The working tools include a yearly conference, focused workshops, thematic tutorials, an electronic journal publication and partnerships with other groups and institutions. Regular annual conferences (each titled 'Digital Approaches to Cartographic Heritage') have been held in striking locations including Thessaloniki, Barcelona, Venice, Rome and Riga. The 2018 Conference, the 13th in the series, will take place in Madrid from 18-20 April 2018.

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More information
www.icaci.org
www.un.org/sustainabledevelopment/sustainable-development-goals/

Strengthening the Role of Geodesy

The inaugural meeting of the Subcommittee on Geodesy was convened on 26 and 27 November 2017 in Mexico City, on the margins of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) High Level Forum. 19 member states and organisations participated in the meeting.
"This is certainly a good day for geodesy," says Gary Johnston, one of the two co-hairs of the subcommittee. "The new subcommittee is now established and this is an important step for improving global geodesy. We must work for the benefit of all member states," says Alexey Trifonov, who is the newly elected co-chair from the Russian Federation.
Australia's Gary Johnston is continuing as co-chair for the next year, while Norway's Laila Løvhøiden is stepping down. "It is important that the co-chairing of the subcommittee is shared between the member states as this will increase the involvement and spread the workload," comments Løvhøiden. "Norway has co-chaired the geodesy working group under UN-GGIM since 2013, and I am convinced that it will be very good for our work that the Russian Federation now has acceded this position."

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