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

GIM INTERNATIONAL

BUSINESS GUIDE 2020

UAVS: WHERE TO FOCUS ON NEXT?

GEOSPATIAL AND CONSTRUCTION

SURVEYING AND LAND ADMINISTRATION

ANNUAL INDUSTRY SURVEY

3D CITY MODELLING

ASK THE SPECIALIST!

Mobile Mapping in Color

Z+F MapCam® S and Z+F MapCam® C

Zoller+Fröhlich

Our Mobile Mapping System combines:

- Easy and fast way to colorize 3D - point cloud almost parallax free
- Several possibilities to combine different types of Z+F MapCam® with the Z+F PROFILER®
- High mapping accuracy due to camera-calibration-tool in Z+F LaserControl®

Zoller + Fröhlich GmbH | Wangen i. A. | Germany |
Phone: +49 7522 9308-0 | info@zf-laser.com | www.zf-laser.com

CONTENTS

GIM INTERNATIONAL

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

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

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

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

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

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

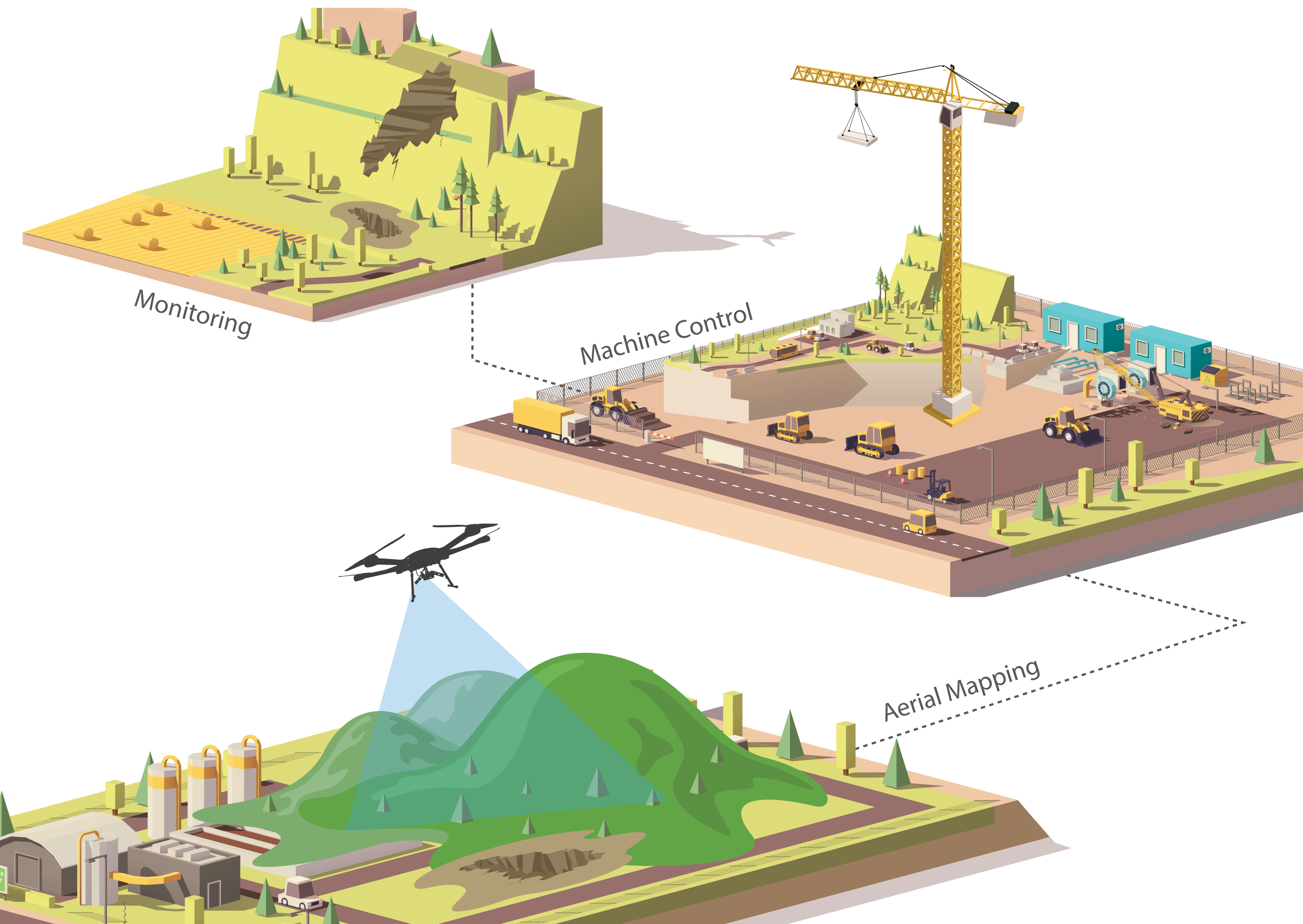
ISSN 1566-9076

ADVERTISERS

Unlock

Your Industrial Mobility

Satlab Geosolutions delivers comprehensive solutions using Swedish Engineering and Technology to seamlessly cover your work flow from the office to the field.



UNLOCK YOUR MOBILITY

Made By Sweden
info@satlab.com.se
Learn more at www.satlab.com.se

Investment

The best way to find out what's really going on in the business is to ask. So that's exactly what we did! Once again, we sent a survey to all our readers to ask them about the state of the industry, how they think it will develop and which trends they foresee for 2020. As in previous years, the response was good; we received more than 400 completed questionnaires, representing a fair cross-section of our readers. Moreover, just like the industry and all the professionals in it, there was a broad geographical spread. You can read full details of the findings on page 7 of this *GIM International* Business Guide, but I'd like to highlight a few interesting insights here. For instance, there is considerable optimism about the future of our business in 2020: more than 40% of the respondents are expecting this year to be better than last, and a further 20% even expect it to be much better than 2019! The question regarding where these improvements will come from generated many different answers, but UAVs/drones were definitely mentioned the most. More than 65% of the respondents are planning to invest in hardware or software this year – ranging from laser scanners and GNSS receivers to Lidar systems and aerial cameras, and GIS and photogrammetry software. This figure is an important indicator of business growth; it is not just about buying a drone to improve surveying efficiency, but it also signals a readiness to invest across the board. Another outcome that made me glow with pride was the fact that a staggering 95% of the respondents regard *GIM International* as a very important source that helps them to keep their knowledge up to date. It's always good to hear that our readers recognize and appreciate our efforts to put together consistently well-balanced editions full of high-quality, exclusive content. I sincerely hope that our readers' predictions for 2020 will come true. In that case, it will end up being a very successful year for the geoindustry as a whole and for the countless individual survey companies, manufacturers and software providers alike!

Durk Haarsma,
director strategy & business development

durk.haarsma@geomares.nl

Let's get digital

As a child, I could happily spend entire afternoons perusing maps and atlases. I remain an avid map lover and recently bought two large atlases. One of them depicts the history of the Netherlands in a hundred old maps – it's absolutely stunning. The other takes you on a journey back in time to the Dutch Zuiderzee, a former inlet of the North Sea: wonderful hand-drawn maps dating from the 16th century onwards. Not surprisingly – we're talking about the Netherlands, after all – a large part of the former Zuiderzee was reclaimed as land and turned into 'polders'... and I was born, raised and still live on one of them. But when it comes to cartography, much has changed since my younger days. Almost everything in our daily lives has become digitized, and maps are no exception. Besides having my nose stuck in old atlases, I also spend much of time with my eyes glued to a screen nowadays, as there is a lot about digital maps that fuels my curiosity and captures my imagination. The introduction and rise of digital maps has opened up a whole host of new possibilities – many more than we could ever have dreamed of before the digital era. Think of geoanalysis in all its forms, for example. We use map-based apps every day, and as for the good-old cartographers with their breathtaking craftsmanship, they can now benefit from innovative technology such as processed data from satellite images or 'big geodata'. The digital transformation has radically changed surveying methods and tools, and it goes without saying that this is set to continue. This edition of the *GIM International* Business Guide zooms in on the opportunities that digitalization encompasses, especially in connection with various application fields such as construction and infrastructure.

Wim van Wegen, content manager

wim.van.wegen@geomares.nl

Artificial intelligence

Never before in history have humans generated such gigantic volumes of geodata as we do today. The production of images and point clouds using a wide variety of geodata acquisition technologies is just one side of the coin; on the flip side is the extraction of meaningful information which is useful for a specific geo-related purpose. Information extraction is a skilled, labour-intensive and tedious task which is mainly executed by specialists. To diminish manual involvement, many researchers are working on developing automated mapping methods. The drive for automation has resulted in the revival of a research area which was first presented some 50 years ago as the Holy Grail for automatic object recognition from images, but eventually died a silent death along its winding road. It was called 'artificial intelligence' (AI). Just two of the catchy AI-related terms that have found their way into today's vocabulary are 'machine learning' and 'deep learning'. The sheer number of papers written in recent years on the application of AI in geomatics tasks shows that many believe deep learning based on convolution neural networks (CNNs) is the definitive solution for automating mapping. Other popular methods are random forest and support vector machines. A CNN is not a magic box of tricks, but rather software built on a sequence of 2D differential filters, such as the Laplace operator, and 2D integrating filters to construct a hierarchy of image pyramids by aggregating small neighbourhoods, e.g. windows of 3x3 or 5x5 pixels, in a process called pooling. This makes the approach sensitive to noise and texture. Many claim that this approach gives promising results, although the researchers also admit that there are several challenges to overcome due to the complexity of Earth-related scenes, such as the presence of shadows and occlusions. In other words, there are still mountainous problems to be resolved. A generally accepted research method is to collect a huge amount of prototypes, of which 80% are used as training samples and 20% for validation. Indeed, deep learning requires a huge amount of prototypes. But hopefully the optimistic promises will become reality and artificial intelligence will not die another silent death.

Mathias Lemmens,
senior editor

m.j.p.m.lemmens@tudelft.nl

HOW DIGITALIZATION AND THE IMMENSE NEED FOR 3D DATA DRIVE THE BUSINESS FORWARD

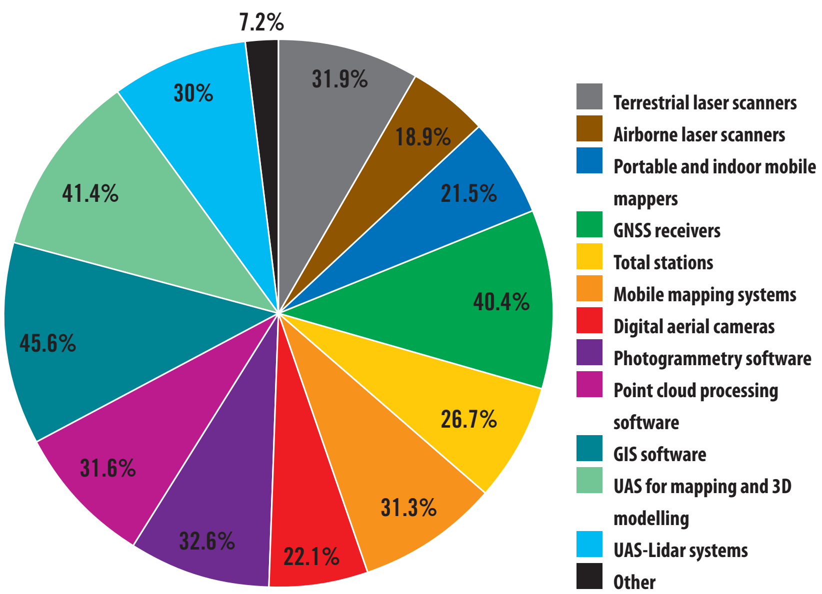
The Geospatial Industry is Alive and Kicking

The advancement of new technology in the geospatial industry is opening up new horizons for surveyors. The profession has rapidly become high-tech, which has brought many benefits and also an ever-greater need to invest in advanced data acquisition, processing, analysis and visualization solutions. According to the findings from the annual *GIM International* survey among geospatial professionals, the demand for such solutions is set to reach new heights in 2020 and beyond. It is a case of 'full steam ahead' for the surveying and mapping business – which is great news in particular for hardware and software companies.

The mood among this year's survey respondents can safely be described as optimistic. There are several reasons for this, and they will be explored in more detail below. One respondent hit the nail right on the head, commenting: "We're experiencing a growing need for the modelling of the geographical space, which requires mapping the environment – which means more work for us, resulting in our need to invest in equipment to capture and manage all this data."

ECONOMIC SITUATION AND PROSPECTS

To put the current market situation into perspective, it helps to first zoom out and consider the macro developments. According to the most recent World Economic Outlook Update (January 2020), global growth is projected to rise from an estimated 2.9% in 2019 to 3.3% in 2020 and 3.4% for 2021. In line with the economic growth rate, Frost & Sullivan predict global spending in the architecture, engineering and construction (AEC) industry to rise to US$17.5 trillion by 2030. Additionally, Deloitte reports that the construction industry will be capitalizing on trends that help improve operations and deliver a competitive advantage, and overcome the challenges of cost pressures, labour shortages and trends toward fixed-bid projects. The adoption of digital technologies in the construction sector finally seems to be gaining ground. This is creating terrific chances for companies that are able to support the digital transition – and many of them are in our industry, since geospatial data is a vital pillar of this shift.



▲ *In which new systems does your organization plan to invest in 2020?*

BLURRING BOUNDARIES BETWEEN GEOMATICS AND CONSTRUCTION

One survey participant from Canada noted that technical surveying levels in construction are low in Canada and the potential of GIS in this sector is still underutilized due to a lack of awareness. Meanwhile, a consultant from the USA stated that the construction sector still is too "old fashioned" and reluctant to try geospatial technology. Nevertheless, the digital transformation is creating a growing need for both geospatial data and geospatial knowledge in construction, and the blurring of the boundaries between the AEC sector and the geospatial industry is opening up a multitude of new opportunities for geospatial professionals. Surveying skills are essential in order to capture a whole range of crucial measurements with the necessary precision –

not only during the planning and construction phase, but also throughout the entire life cycle of buildings. However, the rapid rise of building information modelling (BIM) is increasingly changing the way that surveyors work. BIM is helping to boost the popularity of laser scanning to provide the data that project teams need. In a nutshell, this is where manufacturers of Lidar solutions come into play and why their business prospects look very promising. Competition is fierce, however, as new kids on the block are snapping at the heels of the traditional laser scanning companies in their enthusiastic attempts to disrupt the market with new and usually cheaper solutions.

GROWTH IN AEC, INFRASTRUCTURE AND URBAN PLANNING

In the *GIM International* study, a relatively high number of surveying companies mentioned the AEC and infrastructure markets as areas where they foresee the biggest possibilities for business growth. The rising demand for the acquisition and management of high-quality geospatial data to support the development of infrastructure – railways, roads, telecom, etc. – is creating an abundance of chances. There is also an increasing number of national mapping projects around the world. In a very extensive project in Japan, for example, Mitsubishi Electric backed a consortium engaged in developing high-definition 3D map data of all the country's highways, while also providing much of the key technology. Meanwhile, Malta is using unmanned aerial vehicles (UAVs or 'drones') to conduct a nationwide survey aimed at developing a new orthophoto map database. The data will be used to evaluate the state of the country's roads as part of a seven-year, €700 million government investment project to upgrade the quality and safety of the Maltese road transport infrastructure.

Now that 3D spatial data infrastructures are becoming the standard, the demand for 3D city models is set to bring lots of work opportunities for survey and mapping companies. Recent developments in what is called 'hybrid aerial mapping' – in which three sensor types are combined in a single geodata acquisition system – are taking the creation of such 3D models to a new level. This approach is opening up new possibilities for large-scale projects, as illustrated by recent aerial surveys conducted in major cities across the UK and Ireland, for example.

The shift to hybrid mapping is being driven by the need for the fast capture and delivery of high-accuracy aerial imagery and Lidar data as the basis for 3D modelling. Airborne Lidar and photogrammetry are both viable methods for capturing point clouds for 3D modelling. Manufacturers and suppliers of airborne hybrid systems will undoubtedly be delighted to hear that our survey revealed a surprisingly high level of awareness of the benefits of hybrid aerial mapping and considerable interest among our readers.

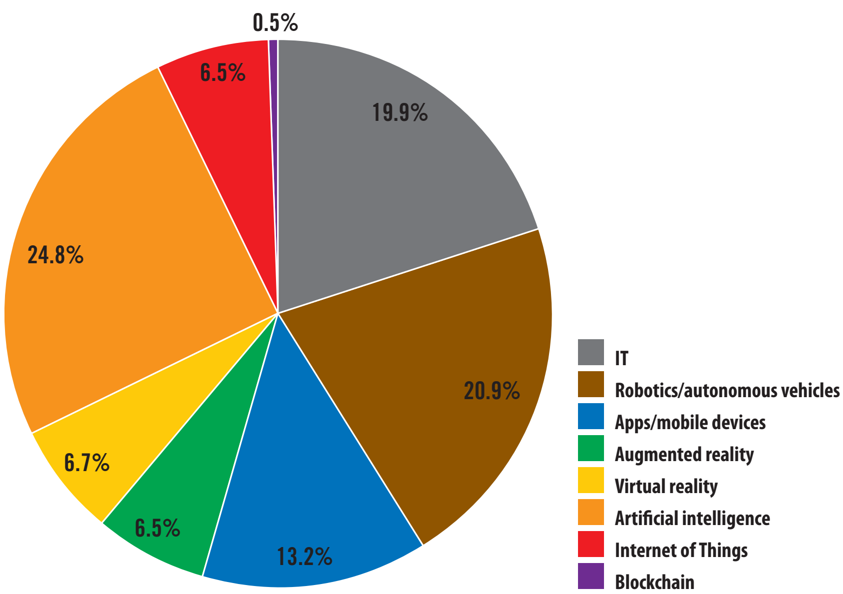
GROWTH IN LAND ADMINISTRATION

Another application that is regarded as holding great potential is cadastral mapping. According to analysis by the International Federation of Surveyors (FIG) and the World Bank, only around one quarter of people's land rights across the world are formally recognized by cadastral or other land recording systems – so there is clearly lots of work still to be done! Fortunately, a growing number of national governments – often supported by experienced national mapping agencies from countries with a sophisticated cadastral system such as The Netherlands and Sweden – are launching initiatives to recognize and register land rights for all. As a result, modern land administration methods based on GNSS receivers for consistent and accurate spatial data collection are being embraced by surveyors, the private sector, policymakers, governments and communities alike.

All the leading manufacturers of measuring, surveying and mapping equipment such as Hi-Target, Leica Geosystems, Pentax, SOUTH, Topcon and Trimble offer a broad portfolio of tools and customizable solutions that enable surveyors to map cadastral boundaries. However, there is also a growing demand for low-cost and scalable mapping alternatives aligned with fit-for-purpose land administration. This need is driven by the enormous scale of the task on the one hand, and the fact that sophisticated survey methods may be too expensive for many governments on the other. The UAV-based mapping of land tenure inspired by state-of-the-art approaches from remote sensing, geoinformatics and computer vision is a good example of one such solution. According to the latest research, about 90 countries lack land registration systems while a further 50 countries are in the process of establishing such systems. Therefore, it is no surprise that a significant number of geoprofessionals who participated in our industry survey see a lot of potential in land administration-based mapping projects.

UAVS: A PROVEN GAME-CHANGER

Both the AEC and land administration sectors have significantly benefited from the emergence of the drone as a mainstream surveying tool over the past decade. The advantages of UAVs over traditional survey methods include faster data collection over much larger areas and high-precision positioning, to name but a few. But even though the UAV market may have matured, there is still plenty of room for further growth. Now that many companies have discovered



▲ *Which technology do you believe is currently having the greatest impact on the surveying profession?*

A notably high number of geoprofessionals who participated in this year's survey plan to invest in UAV technology.

and embraced the benefits of unmanned mapping, they are investing more not only in drones, but also in the various collection techniques that they can be used for. One of the survey respondents commented: "As a surveying tool, drones are fast becoming the most efficient way of mapping larger areas. With UTM (*unmanned traffic management, Ed.*) and BVLOS (*beyond visual line of sight, Ed.*) operations on the horizon, we are going to see some great technology in the next few years."

A notably high number of geoprofessionals who participated in this year's survey plan to invest in UAV technology, with both high-end and lower-end solutions attracting a great deal of interest. Regarding the latter, the owner of a surveying company from Ivory Coast stated: "We have planned to introduce cheap drones for surveying into the African market. We expect to deploy our strategy in mid-2020." Frequently mentioned applications of UAV mapping included topographical surveys, mining, cadastral mapping, agriculture and construction. According to Strabag, a leading Austria-based construction company, UAVs are an essential addition to the surveyor's toolbox and will play a major role in the digital transformation of the construction industry.

MANY GEOPROFESSIONALS PLAN TO INVEST IN UAV TECHNOLOGY, WITH BOTH HIGH-END AND LOWER-END SOLUTIONS ATTRACTING A GREAT DEAL OF INTEREST

INTEREST IN UAS-LIDAR

The increasing use of Lidar and unmanned aerial systems (UASs) is expected to converge in what can conceivably be labelled as 'the next big thing' in the aerial mapping sector: UAS-Lidar. Laser scanners have tended to be substantially heavier than cameras, so it has taken a few years to successfully equip drones with survey-grade time-of-flight Lidar sensors. But nowadays it is possible to buy UAS platforms with integrated laser scanners and an IMU featuring full-waveform recording, scan rates of up to 1MHz and centimetre-level precision – and some of them weigh less than 3kg. UAS-Lidar is already attracting interest. "We are looking at new survey-grade UAV and Lidar processing software," and "We plan to invest in lightweight, compact and integrated UAS-Lidar for our 3D modelling and mapping projects," are just two examples that summarize customers' readiness to invest in this high-tech way of mapping the world.

VOLUMES OF GEODATA

As a direct result of the advancements in data capture techniques, the volume of geodata we produce is reaching new heights every day – and will continue to do so for the foreseeable future. Thanks to the availability of the massive computational power needed to process it, this abundance of geospatial data is increasingly being combined with artificial intelligence (AI) – resulting in 'geospatial AI' which has the potential to transform the future in countless exciting and as yet often unimaginable ways. AI techniques can be used in a variety of geospatial applications, such as remote sensing for Earth observation and spatial data analysis. Image recognition and analysis from satellite-derived geospatial information is one example of how AI has been widely used to exploit the value of geodata over recent years. For instance, the European Space Agency (ESA) derives key geoinformation products from Earth observation (EO) data in support of urban planning tasks. Other new AI approaches for EO could include the automatic learning of satellite data formats, increasing satellite autonomy for 3D real-time analysis and monitoring, and using AI to infer geolocation data from disparate data sources. There are

also real-life examples of machine learning – a subset of AI – being used to handle geospatial data, e.g. in the classification of Lidar point clouds by means of deep learning.
Perhaps unsurprisingly, 34% of the respondents in our survey indicated they would like to see more coverage of artificial intelligence in our magazine, and 38% asked for more insights into big data. “Projects will be automated using data capture with point clouds and processed with artificial intelligence,” one respondent suggested. Another made the following prediction for AI: “Geomatics and GIS won’t be separate topics or professions anymore. AI will completely take over imagery analytics, among other things.” With datasets becoming ever larger and more complex, however, it is safe to say that AI will present more opportunities than threats from the geoprofessional’s perspective.

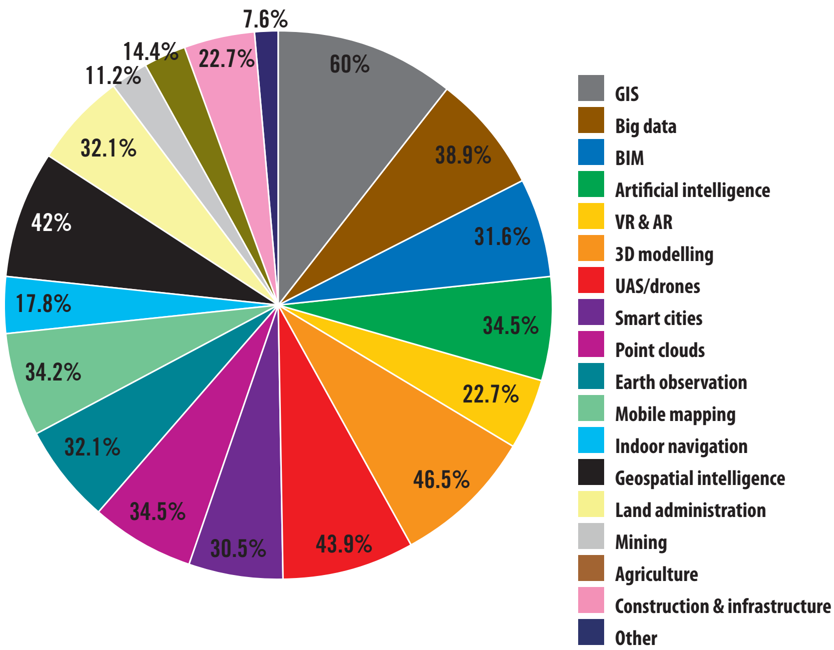
IN THE MOOD TO INVEST

When asked whether their organization plans to invest in new systems in 2020, two thirds of the survey respondents answered affirmatively. The top three investment areas are GIS software (45%), UAS for mapping and 3D modelling (41%), and GNSS receivers (40%), followed by terrestrial laser scanners, point cloud processing software and – climbing the charts – UAS-Lidar systems. Manufacturers of total stations also do not need to worry; more than a quarter of respondents intend to purchase new total stations.
Compared to last year’s survey, substantially more respondents indicated that they plan to replace or upgrade existing survey equipment this year, which will surely be encouraging news for many readers of this article. The need to replace outdated equipment is the primary motivator, but another reason given for spending money on new technology is the awareness of the possibilities offered by new hardware and software solutions. The bottom line is: based on their investment plans, geospatial professionals are optimistic about the future.

GLIMPSE OF THE FUTURE

That optimism does not always extend to the future role of surveyors themselves. “I foresee the profession will continue degrading, with fewer professionals and more unqualified people in the business,” commented one of the respondents. On a more positive note, a fellow surveyor envisions the profession of surveyor will be rebranded as a kind of ‘digital reality specialist’. Some geoprofessionals see 5G as a new game-changer and believe it has the capability to change the future of surveying. It will enable vast amounts of Lidar data generated by state-of-the-art laser scanners to be processed in the field, with the point cloud data being uploaded to cloud services for processing in real time. It will be interesting to see how people’s views of 5G have changed by the time of next year’s survey on the state of the geospatial surveying industry!

Once again, our survey reminded us that the huge impact of geospatial data on everyday life cannot be underestimated, and many more exciting opportunities lie ahead. However, most members of the general public are still unaware of the importance of our profession in society. Therefore, it remains crucial that we are all ambassadors of the beautiful surveying profession! There is a strong need for us to engage with the public, businesses, policymakers and youngsters in order to attract much-needed new talent to our sector, now and in the future. ◂



▲ *Which topics should receive more frequent coverage by* GIM International*? (Multiple answers possible.)*

GEO4CONSTRUCTION

Geo4Construction is a leading online platform that connects the AEC and infrastructure sectors with the geospatial industry. As the importance of geospatial data continues to grow in today’s era of digital transformation, the worlds of construction and geomatics are becoming increasingly intertwined. There is no doubt that digitalization is creating new opportunities for significant efficiency improvements and hence cost savings in the AEC industry. To take full advantage of these opportunities, it is extremely important for construction engineers to understand the specific needs associated with the digital transformation in their industry – and *Geo4Construction* provides them with all the necessary insights.
www.geo4contruction.com

FURTHER READING

- World Economic Outlook, January 2020
- Deloitte, 2020 Engineering and Construction Industry Outlook
- Traxler C., Hesina, G. Interacting with Big Geospatial Data, *GIM International* (www.gim-international.com/content/article/interacting-with-big-geospatial-data)
- Paul Hahn, Three Trends Driving the Geospatial AI Revolution, *European Business Review* www.europeanbusinessreview.com/three-trends-driving-the-geospatial-ai-revolution/

ABOUT THE AUTHOR

Wim van Wegen is content manager of *GIM International*. In his role, he is responsible for the print and online publications of one of the world’s leading geomatics trade media brands. He is also a contributor of columns and feature articles, and often interviews renowned experts in the geospatial industry. Van Wegen has a bachelor degree in European studies from the NHL University of Applied Sciences in Leeuwarden, The Netherlands.
✉ wim.van.wegen@geomares.nl

NEW TECHNOLOGIES REQUIRE NEW KNOWLEDGE AND REGULATIONS

UAVs: Where to Focus on Next?

In June 2018, *Photogrammetric Record* (a publication produced by the UK's Remote Sensing and Photogrammetry Society or 'RSPSoc') devoted 11 pages to determining which term they would use for drones. They ultimately decided on 'unmanned aircraft system' or 'UAS'. However, the mere fact that this required 11 pages goes some way towards highlighting the complexity and cross-discipline potential that drones bring, not only to the remote sensing industry but also for multiple other uses.

TRIED AND TESTED

Over the past decade we have seen a number of drone uses come through the tried-and-tested period, resulting in unmanned aerial vehicles (UAVs) becoming a proven technology for a range of industries and professions, e.g. aerial photography for construction and surveying, search and rescue (SAR) and agriculture. At one stage, around 2015, significant hype was building in relation to drones, and conferences were popping up everywhere to discuss them. In fact, I remember at one conference hearing of a new drone that could see through concrete walls (perhaps a case of Chinese whispers)! At this time drones were also viewed by some as a hindrance to the aviation industry as they tried to find their place in the skies.

THE NUMBERS

In mid-2014 there were just 359 people in the UK permitted to operate drones of up to 20kg. By September 2015 this figure had almost tripled, and by 2019 there were around 5,000 permitted operators in UK airspace. A recent PwC study predicts that there could be 76,000 drones operating in that airspace by 2030. It also predicts there will be 628,000 jobs in the drone economy, and the drone industry will contribute to a £42 billion increase in the UK's gross domestic product. So clearly, finding their place – and muscling in on airspace previously restricted for manned aircraft – was only a matter of time.

SURVEYORS AND DISRUPTING TECHNOLOGIES

Geomatics surveyors are used to new technologies disrupting their profession. When selective availability was turned off by the US

Using drones for baseline environmental studies for a proposed hydro dam project in Georgia.

military in 2000, it opened up accurate GPS data for the masses that led to many changes in technology and society. These were particularly interesting for geomatic surveyors, as suddenly knowledge of trigonometry was no longer needed for topographical surveying; you could now survey any point (located outside!) by just pressing a button – on your own, with no need for an assistant to hold a staff. Anyone could do this, no need for a qualification! I joke, of course – specialized knowledge was required of level datums, geoid models, coordinate systems, check points and achievable accuracies. In other words, surveyors were still needed! The barrier to entry was far greater back then with a differential GPS costing upwards of £20,000. This barrier to entry doesn't exist for the new drone survey tool, with commercial off-the-shelf (COTS) drones available for a couple of hundred euros and affordable cloud processing options available for photogrammetric software. So now it's cheap and simple enough for anyone to fly a drone – or should I say get a drone to fly itself – after watching a 5-minute YouTube video and to produce a high-resolution 3D point cloud of anything, and even to comply with the relevant regulations in their country. Industry bodies have been quick to update members on the advantages of this new technology and to fund research to assess related pitfalls and recommend preferred data collection methodologies. This has all aided the uptake of drones by surveyors. But what about the integrity and accuracy of the data? That's crucial for those in the geospatial industry and those relying on geospatial data.

THE DRONE IS JUST A DEVICE

For me, as a mineral and geomatics surveyor and environmental consultant, it was never about the drone, but about the high-resolution and high-accuracy 3D photogrammetric model. In the 2000s I surveyed many a quarry and construction site on foot using GPS systems or a total station – carrying survey equipment close to high quarry faces and large plant and machinery never really felt safe. Then along came the eBee fixed-wing drone, with Pix4D's structure from motion (SfM) photogrammetry software. More recently, drones with Lidar have become available, increasing the number of sites that can now be flown, e.g. forestry and vegetated areas. I haven't surveyed a site on foot in over five years! And I am now using far richer and more useful survey data that has been collected with me out of harm's way – with the added bonus of saving time as well. That's not to say that flying a drone has been entirely safe. I've had my share of incidents and have hit at least one tree, one fence post and also managed to 'land' a drone in a tree in a remote mountainous area outside a cave in a country known for its bears, wolves and wildcat population!

EXPERTISE REQUIRED

As with all new technologies there is a skills shortage, and some survey data is being produced by drone pilots without a survey qualification. And it's not just point clouds that drone pilots can produce – they have their pick of new careers, with the ability to fly a drone opening up a range of options for pilots. These are linked to the payload that the drone can carry – be it a camera

▲ *UAVs equipped with next-generation technology for autonomous inspection of wind-turbine rotor blades. (Courtesy: Sulzer & Schmid Laboratories AG).*

for topographical survey data, multispectral sensor for assessing vegetation health (useful for farmers) or thermal sensors for asset inspection and search & rescue (SAR). But all these technologies require expertise knowledge, and in some cases ground truthing and standardized methodologies for data collection.

DRONE MONOPOLY

In the past decade, Chinese company DJI has succeeded in building a drone monopoly with its high innovation, fast pace and low-cost manufacturing, flooding the world markets with affordable, reliable and technically advanced drone products. Drone manufacturing companies in more developed countries could not compete with DJI and most have either ceased trading or retrenched. A change to their fortunes may have recently commenced with the US military recently issuing a direction that DJI products can no longer be used due to cybersecurity concerns. This once again opens the door for domestic drone manufacturers in the USA. The current drone technology is really impressive and it is hard to see how it can be greatly improved, except for increased flying time and more affordable high-accuracy GNSS options. Having said that, keeping a drone in the air for over an hour requires diligence and concentration, so the current battery power and flight time limits might be just right!

REGULATIONS AND STANDARDS

Due to the pace of technological advancements, regulators and standards bodies in the drone industry have had to take the 'follow, not lead' approach. The key question for regulators and standards bodies is what to focus on next. There is plenty of low-hanging fruit – some ripe for picking and some a couple of decades away from fruition!

EXAMPLES

1. Using a drone and SfM photogrammetric software to produce a digital twin of a working wind turbine that can then be used by an engineer to inspect the structure for damage. The wind turbine market is growing and the production of a digital twin is a proven survey method. However, my methodology in producing the photogrammetric model and the model parameters – e.g. resolution, accuracy, etc. – will be different to the next person's, so we need a standard to define the data collection and data processing methods.

2. Urban air mobility: this is the term of the moment, as a number of big companies (Airbus, Boeing) are developing passenger-carrying drones. These are electric vehicles with vertical takeoff and landing capabilities (eVTOLs) – similar to helicopters, but not as loud and not as expensive to run. 2023 has been suggested as the year we can expect to see autonomous passenger-carrying drones in some cities. Testing and certifying these systems may take a bit longer, however. In fact, realistically, they will need to be manned as it will be hard to achieve public acceptance for autonomous aircraft over and within cities. Especially considering the recent negative experiences of testing driverless cars (with a human behind the virtual wheel), that could be a difficult challenge! There are lots of stakeholders – from fast-moving entrepreneurs to the more cautious regulators – all of which will need careful management. Not to mention the work required to align current city zoning and address privacy concerns along with the infrastructure, policy and regulatory deficits. And there will be a requirement for accurate up-to-date 3D models of cities – so work here for us surveyors.

3. Orthoimagery and image-based point cloud data. Similar to when producing a digital twin, drone pilots (or surveyors with drones) will determine their own methodology for data capture based on a number of considerations, e.g. survey requirements, weather on the day of the flight, type of platform, etc. The flight parameters, and associated survey methods, with the type of equipment being used and the processing software being employed will influence the accuracy of the data produced. The expertise of the data collector will also have a part to play. Guidance for practitioners is required to ensure reliable and usable survey data is produced.

WHAT NEXT?

So now that the hype is settling down and we've realized that drones can't see through walls, what will happen next? There are enough proven advantages of using drones for ongoing required tasks that will ensure they are here to stay, and enough potential uses for people to continue investing in research. For example, the recent bush fires in Australia have started a new conversation about drone usage for firefighting. Flying a drone can be nerve-racking and also fun, but it's never been about the drone – to survive in today's world requires finding ways to do business more efficiently, more safely and with a higher-quality end result. Drones have helped the survey, construction and agricultural industries tick all these boxes,
and drones can help lots of other professions and industries. Collaboration and innovation are required to ensure drones continue to reach their potential in improving lives and society. ◀

▲ *3D point cloud resulting from a UAV photogrammetry cell tower inspection project. (Courtesy: Pix4D)*

ABOUT THE AUTHOR

Peter Kinghan is an environmental engineer with over 20 years' professional experience. He is a Chartered Geomatics Surveyor and Chartered Minerals Surveyor and past chair of the Society of Chartered Surveyors Minerals professional group. He has gained a broad range of experience within the waste, construction and extractive industry sectors, working on projects throughout Europe, Georgia, Australia, Botswana and Namibia. He currently leads SLR's drone team and is the RICS representative on the British Standards Institute's 'drone' committee.

✉ pkinghan@slrconsulting.com

SIX CHALLENGES FACING 3D DATA AS A PLATFORM

State of the Art in 3D City Modelling

Semantically enriched 3D city models have the potential to be powerful hubs of integrated information for computer-based urban spatial analysis. This article presents the state of the art in 3D city modelling in the context of broader developments such as smart cities and digital twins, and outlines six challenges that must be overcome before 3D data as a platform becomes a reality.

3D city models, as digital representations of urban areas, can be used to facilitate many applications, such as urban wind and dispersion simulations, energy studies, noise studies and various types of analysis that require a planned architectural design to be placed in its context (e.g. line of sight and shadow analysis, clash detection with cables and pipelines in the underground, impact of wind circulation, see Figure 1). These 3D models, which also contain semantics, are different from 3D meshes (as found in computer graphics and the gaming world) and from raw point clouds. These can be used for visualization and visual analysis, but they are not suitable for most other spatial analysis purposes.

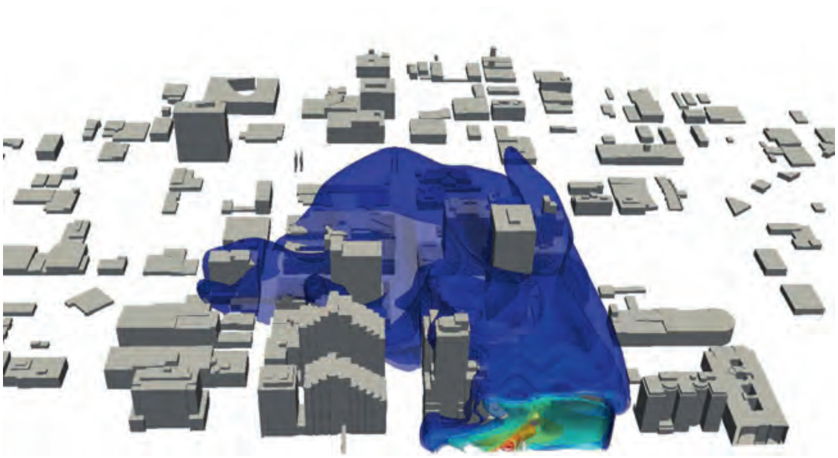


Figure 1: Determining the impact of wind circulation with 3D city models, taken from García-Sánchez (2017).

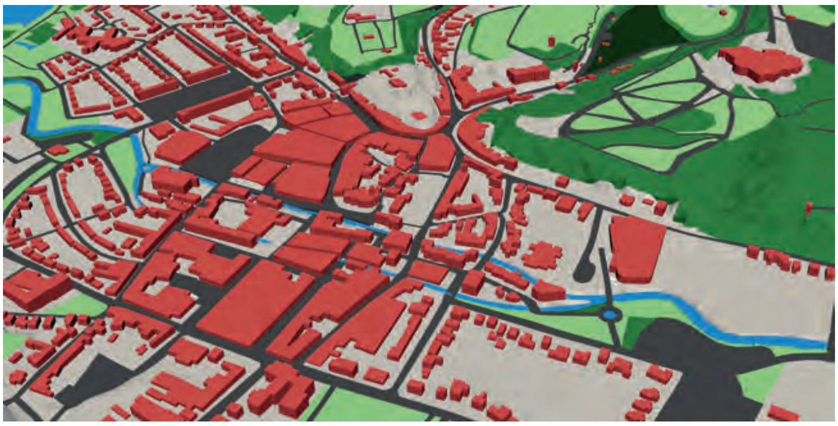


Figure 2: Part of the 3D city model of Valkenburg, the Netherlands. Elements that can be represented in a 3D city model include: buildings, vegetation, water bodies, built-up areas, green areas, roads, etc. (Courtesy: Dutch Kadaster)

In order to allow for the development of advanced applications, a 3D city model should describe the geometry and attributes of all the individual elements that are typically present in a city, e.g. the terrain, roads, water bodies and buildings (Figure 2). In addition, relevant semantic information can be included with the geometries, such as the year a building was constructed, the number of people living in it and the construction materials it is made of – all important information to optimize circular economy flows or energy consumption. Such semantically enriched 3D city models potentially represent powerful hubs of integrated information to be used for computer-based urban analysis purposes, including in the context of broader developments such as smart cities and digital twins.

Advances in technologies for the collection of 3D elevation information through Lidar and photogrammetry have made it relatively easy for practitioners in different fields to automatically reconstruct 3D city models (see Figure 3 for a couple of examples). These models typically contain mainly buildings, but other object types are increasingly being

▲ *Figure 3a: Example of a 3D city model from Swisstopo. (Courtesy: https://map.geo.admin.ch)*

▲ *Figure 3b: 3D city model of Helsinki. (Courtesy: https://kartta.hel.fi/3d/#/)*

included too, such as roads, bridges, trees (see Figure 4) and water. The availability and applications of 3D models are still increasing in the fields of city planning and environmental simulations, as listed above. Furthermore, since elevation data can be acquired at relatively low cost, this data can be frequently updated. It is also possible to reconstruct 3D city models covering the same region at different periods in time.

3D city models have the potential to play a crucial role in shaping the future. This holy grail of 3D city models that goes beyond 3D visualization requires an integrated approach to 3D city modelling based on the implementation of 3D data as a platform. In this approach, the same up-to-date, 3D virtual representation of reality serves different urban applications and at the same time offers an environment for integrating the findings of different applications. However, before 3D data as a platform becomes a reality, several challenges must be overcome.

CHALLENGE 1: CONSISTENCY BETWEEN MODELS

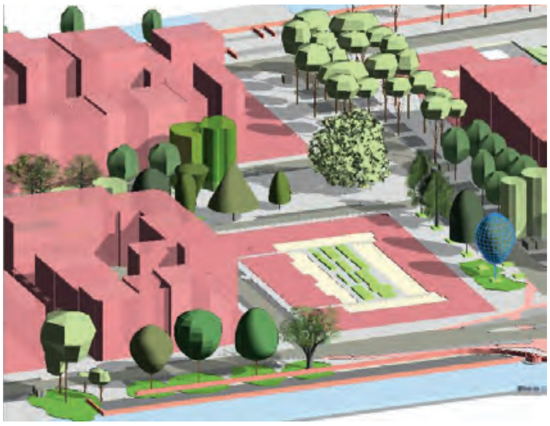
The first challenge is the lack of consistency between 3D city models covering the same area. Currently, 3D city models are generated independently, often using different base (sensor) data, reconstruction methods and software. Therefore, the resulting models often significantly differ in their geometry (e.g. a collection of surfaces versus a volumetric representation), appearance and semantics. Moreover, as these models are stored using different formats (XML, graphics or binary formats), their underlying data models often also differ. Substantial differences can even occur when models that were originally identical are processed independently, either through mismatched updates or through conversions between different formats (e.g. in an attempt to deal with software incompatibilities). All these differences have profound consequences in practice, such as affecting the applications for which a 3D model can be used, the processing that is necessary to use it and the likely errors that will be present in the end result. It is thus important to be aware of the way 3D city models are modelled and to provide this information explicitly in the metadata of the model.

CHALLENGE 2: STANDARDIZATION

To ensure consistency, both for geometry and semantics, standardization is essential. The OGC standard CityGML is the main standard for storing and exchanging 3D semantic city models. Its aim is to define the basic classes that can be used to describe the most common types of objects present in a 3D city model, their components, their attributes and the relationships between different objects. Although most CityGML examples and datasets focus on buildings, CityGML also represents other feature classes, such as land use, relief, roads and railways, vegetation, bridges and city furniture. While CityGML prescribes a standard data model for a 'generic' city, it is possible to extend it for specific domains by defining application domain extensions (ADEs), such as for the energy demand of buildings or for a country-specific data model. The main issue with ADEs is that software packages and libraries often cannot automatically read and process the application-specific information from them because extensions do not need to follow many prescribed rules.

CityGML is used both as an information model (in the form of UML models of its classes) and an encoding model, which is an XML-based representation using geometric definitions from the Geography Markup Language (GML). One challenge when working with CityGML-encoded data is that software support for CityGML is still limited. This is partly due to the huge number of possible ways in which objects can be defined in CityGML, which makes full implementation difficult (i.e. the software needs to support all possible situations). In addition, XML (and thus GML) can be verbose and complex, which makes it impractical for many applications.

There are other solutions that implement the CityGML data model to overcome these problems. One is 3DCityDB, which is an open-source database, built upon Oracle Spatial or PostGIS, to store the CityGML data model in a relational database. Another alternative to CityGML encoding is CityJSON, which is a format that encodes a subset of the CityGML data model using JavaScript Object Notation (JSON). CityJSON was designed with programmers in mind, so that tools and APIs supporting it can be quickly built. It is also designed to be compact, with a compression ▸



▲ *Figure 4: Modelling of trees at different levels of detail, taken from Ortega-Córdova (2018).*

factor of around six when compared to XML-based CityGML files, and is friendly for web and mobile development (i.e. it supports the use of 3D data beyond exchanging data). CityJSON v1.0 was released in 2019 and is supported in several software packages including viewers, 3D modellers, 3D city model generators and GIS software (Figure 5).

CHALLENGE 3: DATA QUALITY

Quality – or lack of it – is another issue that limits the sharing of 3D city models between different software systems and applications. As highlighted by Biljecki et al. (2016), most openly available 3D city models contain many geometric and topological errors, e.g. duplicate vertices, missing surfaces, self-intersecting volumes, etc. Often, these errors are not visible at the scale on which the datasets are visualized or they are not a problem for the specific software in which they are modelled. As a consequence, practitioners are unaware of the issue. However, these errors prevent the datasets from being used in other software and for advanced applications, and that is essential to facilitate 3D data as a platform. All these geometric errors could be prevented if modelling software forced the 3D geometries to comply with ISO 19107, i.e. connecting surfaces, planar surfaces, correct orientation of the surfaces, watertight volumes, etc. Another solution to this problem could be to use automatic repair algorithms. However, these are still often semi-manual, plus it is possible that fixing one error could introduce a new one elsewhere.

CHALLENGE 4: DATA INTEROPERABILITY

The conversion of semantic 3D city models from one format to another is challenging, both from a geometric point of view and because of incompatible semantics. In the case of the IFC standard used in building information modelling (BIM), it is desirable to integrate into a 3D city model the highly detailed models that have already been generated for the design and construction of a building. However, the automatic conversion between IFC models and CityGML models is not straightforward. For a building which is modelled according to both standards, for instance, the mappings between the semantic classes are complex because different semantic information is attached to the geometrical primitives in the two models. Moreover, IFC has many more classes, whereas CityGML contains a limited number of classes structured in a hierarchy. In addition, a simple house can easily be made up of a thousand volumetric elements in IFC, whereas in CityGML it contains just the outer shell and a few other elements such as doors, windows and chimneys. As a consequence of these differences in semantics, coupled with the fact that different software and geometric modelling paradigms are used, it is rather difficult to reuse data from other domains. OGC (2016) and Arroyo Ohori et al. (2018), among others, explain in more detail the issues preventing automation of the process and provide recommendations for better alignment of both standards. This requires a better understanding of how detailed BIM models are needed in GIS-based applications and how GIS-contextual data can be better accessed from BIM software. Deriving the GIS-relevant concepts from a detailed BIM model that can act as an interface between both domains is considered as a crucial step forwards (see Figure 6). In addition, georeferencing of BIM models is needed to be able to locate them in their geographical context.

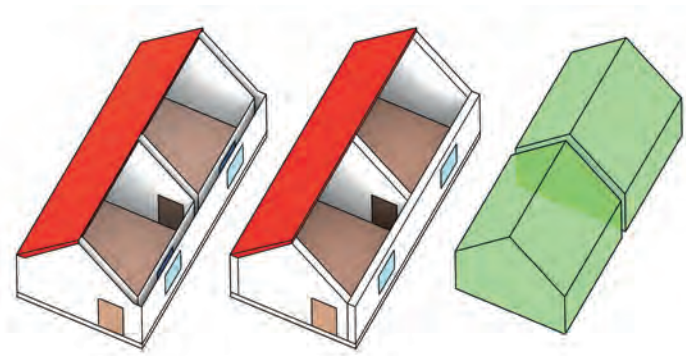
CHALLENGE 5: DATA MAINTENANCE/GOVERNANCE

Many governmental organizations have invested in their own 3D city models. However, despite growing awareness of the importance of up-to-date 3D city models, they often fail to put strategies in place for updating the models and maintaining different versions of the data. One potential method to do so would be to use data about new designs structured in IFC/BIM models. However, this requires good agreements regarding the design data to be submitted and the preprocessing of the IFC/BIM data (e.g. deriving georelevant concepts such as the footprint and outer envelope in a georeferenced context), as well as organizational/institutional agreements (i.e. Who is responsible for the data? How can it be ensured that the IP of the architect/designer is respected?).

CHALLENGE 6: FROM UTOPIAN PILOTS TO REAL-WORLD USE CASES

Technical innovations regarding 3D data usage that look promising in prototypes and pilots may encounter problems in practice. A real-world production setup usually covers larger areas and requires more automation, which can make it more difficult to monitor and control the data quality. In addition, solutions that work well for small test areas are pushed beyond their limits (both in terms of performance and situations they have to cover) when applied to large areas like complete cities or even countries. Further attention is therefore needed to obtain higher-quality 3D city models and building models so that they can indeed form the basis for a 3D data platform serving a wide variety of urban applications. This requires more precise definitions of specifications, as well as validation mechanisms to check whether the 3D data acquired meets those specifications. 'Higher quality' does not necessarily mean 'greater precision'; it means up-to-date 3D data without errors and aligned with the

▲ *Figure 5: The 3D city model of Oberwil (Switzerland) in CityJSON. (Courtesy: The Amt für Geoinformation Basel-Landschaft)*



▲ *Figure 6: Deriving GIS-relevant concepts (spaces) from a collection of volumetric elements in a BIM model.*

specific needs of urban applications rather than serving visualization purposes only.

FURTHER CONSIDERATIONS

Not all challenges facing 3D data as a platform are technical ones. Organizations that want to implement 3D as a platform often lack the latest knowledge and skills to do so. This can range from gaps in their knowledge of issues regarding the acquisition, maintenance and dissemination of 3D data, to a lack of understanding of urban data quality, how to express it in metadata and how data quality impacts on the outcome of urban applications. There are also institutional and organizational issues facing 3D data, e.g. what 3D data should be available, where and how it should be available, who is responsible for updates and maintenance, and how to integrate larger-scale public-sector 3D city models with detailed private-sector architectural models of individual buildings.

CONCLUSIONS AND FUTURE OUTLOOK

More and more 3D city models are becoming available at different levels of detail, for different periods in time and for different applications. It is therefore important to have adequate ways to store such historical collections of 3D city models in a manner that is both standardized and structured with semantics. The ability to translate the physical world into a virtual reality has become a valuable asset in the design, planning, visualization and management of a wide range of urban applications such as noise, heat stress, pollution, etc. However, an increase in complexity (i.e. 3D city modelling beyond visualization) often comes at the expense of usability, interoperability and maintenance. Current practices still show a lack of specific and user-friendly software to deal with 3D city models, as well as several disconnected and inefficient software options, while data integration is an inherent component in 3D city modelling. This integration needs further attention in order for 3D city models to serve as 'digital twins' of reality and provide information for a wide variety of applications. The integration of sensor data in a 3D city model is another area that needs further development to turn 3D city models into dynamic representations of reality. Lastly, the integration of highly detailed and differently structured IFC/BIM models remains an area for further study as well as for further agreements to support integration.

This article has listed the current challenges standing in the way of 3D city models being used for sustainable urban environments. Based on this list, it may seem as though a lot still needs to be done. While that is true, over the past decades there has of course been a huge increase in the number of 3D city models available and many developments in terms of acquiring, modelling, maintaining, using and visualizing them. All of this has laid a foundation for realizing the potential of 3D city models. By tackling the challenges described in this article, another major step can be taken so that the 3D city model indeed will become a powerful information hub that can be used for computer-based urban analysis.

ACKNOWLEDGEMENTS

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 677312 UMnD).

FURTHER READING

- Arroyo Ohori, K, A. Diakité, T. Krijnen, H. Ledoux and J. Stoter, 2018. Processing BIM and GIS models in practice: experiences and recommendations from a GeoBIM project in the Netherlands. ISPRS International Journal of Geo-Information 7(8), August 2018.

- Biljecki, F. H. Ledoux, X. Du, J. Stoter, K. H. Soon and V. H. S. Khoo, 2018. The most common geometric and semantic errors in CityGML datasets.
ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., 2016, pp. 13–22.

- Open Geospatial Consortium inc., 2016. OGC. Future City Pilot-1: Using IFC/CityGML in urban planning engineering report. http://docs.opengeospatial.org/per/16-097.html

- Ortega-Córdova, Lessie M., 2018, Framework for Urban Vegetation 3D Modelling. MSc thesis,, https://repository.tudelft.nl/islandora/object/uuid:8b8967a8-0a0f-498f-9d37-71c6c3e532af?collection=education

- García-Sánchez, Clara, 2017. Quantifying inflow uncertainties for CFD simulations of dispersion in the atmospheric boundary layer, PhD thesis, Antwerp University, Sciences Faculty, https://hdl.handle.net/10067/1460450151162165141

ABOUT THE AUTHORS

Prof Dr Jantien Stoter chairs the 3D Geoinformation research group at Delft University of Technology. She also works as innovations researcher at both Kadaster and Geonovum. Jantien did her PhD on 3D Cadastre (2004), received a personal grant from the Dutch Science Foundation on 5D modelling (2011) and was awarded a grant from the European Research Council for her current research on urban modelling in higher dimensions.
✉ j.e.stoter@tudelft.nl

Dr Ken Arroyo Ohori is a postdoc researcher in the 3D Geoinformation research group. His research interests include higher-dimensional (4D+) GIS representations and algorithms, geometric modelling and processing, GeoBIM integration and automatic data repair.
✉ k.ohori@tudelft.nl

Balázs Dukai, MSc, is a research software engineer in the 3D Geoinformation research group. His focus is on methods for generating datasets, and writing software.
✉ b.dukai@tudelft.nl

Anna Labetski, MSc, is a PhD candidate in the 3D Geoinformation research group, focusing on the generalization of 3D city models. Her research interests include generalization, levels of detail, transportation networks, active transportation and metadata.
✉ a.labetski@tudelft.nl

Kavisha Kumar, MSc, is a PhD candidate in the 3D Geoinformation group. Her research includes compact representation of massive 3D city models for efficient storage and management.
✉ kavisha@tudelft.nl

Stelios Vitalis, MSc, is a PhD candidate in the 3D Geoinformation group. His research interests are versioning of 3D city models, multi-dimensional GIS data, topological data structures and GIS software development.
✉ s.vitalis@tudelft.nl

Dr Hugo Ledoux is an associate professor in the 3D Geoinformation research group. His work is mostly focused on semantic city modelling and computational geometry.
✉ h.ledoux@tudelft.nl

For this 'Ask the Specialist' feature, we invited readers to send us their burning questions about geospatial surveying. We passed the questions on to relevant industry experts who have provided these comprehensive and detailed answers to point geospatial professionals in the right direction.

CONSTRUCTION AND SURVEYING

How can surveyors optimally profit from the digitalization of the construction industry and the trend towards building information modelling (BIM)?

The European construction industry is expanding at a rapid rate and is expected to grow at a CAGR of 4.4% to reach US$ 2,778.3 billion by 2023. To meet these rising demands, it's clear that we need to embrace technology, yet many in the industry are still hesitant to invest. While architects and large contractors are adopting new technology with great enthusiasm, such progressive thinking isn't always replicated among services engineers and small-to-medium-sized contractors. Despite the major benefits, such as increased productivity, reduced rework and improved data handling, many contractors can be reluctant to advance from the traditional, linear methodology. With hardware costs ranging between €15,000 and €40,000, together with the additional time needed to invest in training employees so they can take full advantage of the technology, it's understandable why some contractors don't want to take the risk. This is where surveyors have a big opportunity to profit. By employing a surveyor, contractors are getting both the technology and the experienced skillset of the surveyor. Contractors and surveyors working together is a mutually beneficial relationship; surveyors have great knowledge and understanding of how to run projects and utilize instruments, but don't always know the different trades, applications and construction requirements – so this is where the contractor's knowledge comes in. Also, using a surveyor eliminates the time needed for employees to get to grips with the technology. Developing a good relationship with contractors is how surveyors can succeed. The trend towards BIM is also benefiting surveyors. We're now seeing BIM as not just a benefit, but a requirement. For example, the UK government's Construction Strategy, published in 2011, has had a major impact on the uptake of BIM in the UK. This now means that the government requires fully collaborative 3D BIM – with all project and asset information, documentation and data being electronic – and a minimum of Level 2 BIM is now implemented on all government construction projects. This requirement in the public sector has led to an overall increase in the adoption of BIM processes, with BIM usage levels in the UK now matching those in Singapore, the USA and Scandinavia. Crucially, rather than being a challenge for the industry, this greater adoption of BIM means that the role of surveyors on the construction site is more vital than ever before.

Cesar Mendoza is product manager for vertical construction at Topcon Positioning Group.

FUTURE OF THE SURVEYOR

How will the surveyor's role look in 10 years' time?

Over the next ten years, the surveyor's workflow will become quicker, safer and easier because of new technologies like scanning, mobile mapping and UAS photogrammetry. Virtual layout, aided by the increasing use of augmented reality technologies, will require fewer physical stakes in the ground. Due to the transformation of the physical world into a digital one, digital twins will take centre stage, with surveyors called upon to convey meaningful information from the model back to the physical world. Demand will increase for surveyors' expertise in time-based analysis of changing site conditions, such as monitoring installations for volume-changing and deformation analysis. Surveyors and mappers should also take heed of capital flows into the autonomous vehicle revolution. The tremendous amount of money pouring into that space will continue to improve sensors, onboard processing and vehicle connectivity, essentially resulting in millions of mobile mapping units around the world. That data may provide an abundant resource for spatial information, yet also challenge surveyors to process it into something relevant to their applications. With geospatial-centric data finding its way into more realms of business, surveyors will be needed to ensure data accurately represents the physical world. The layperson will struggle to identify and separate good data from bad, increasing the demand for surveyors – who are legally bound to provide data accuracy and quality. Cutting-edge surveyors will have invested in proven technologies to provide quicker and safer means for data capture, with scanning top of mind. Those who learn to master the powerful software programs used to extract data and automate processes will be most competitive. At the same time, the office-based side of the business will increase and field crews will be expected to understand a wider variety of data capture methods. GNSS and total stations will still have a solid core in day-to-day workflows, yet the growth of the other methods will be important too. A decade from now, we will hopefully have turned our biggest headwind – finding good help – into a tailwind. Land surveying requires a broad skillset touching on numerous disciplines, and through educational initiatives and more outreach to the younger generation I'm optimistic that our industry will generate professionals with mathematics skills, technology capabilities, historical awareness, legal responsibilities and good personalities to boot.

Chris Trevillian is marketing director of Trimble Inc.'s Geospatial GNSS division.

UAV-BASED LIDAR

What are the main reasons for choosing UAV-based Lidar mapping?

Lidar mapping based on unmanned aerial vehicles (UAVs or 'drones') can generally be thought of as a close-range version of manned airborne laser scanning. In brief, lower mobilization costs and much higher spatial resolution are allowing new Lidar mapping use cases in several disciplines, such as forestry, bathymetry, archaeology, infrastructure mapping, hazard management and so on. In general, modern UAV-based Lidar solutions fall into one of the following categories:

(a) Survey-grade sensors featuring narrow laser beams with a beam divergence of <1 mrad, high pulse repetition rates in the MHz range and sophisticated full waveform-based signal processing. These high-end sensors weigh around 1 to 4kg, are typically integrated on multi-copter UAV platforms and are employed whenever both the utmost spatial resolution of more than 500 points/m^2 and measurement precision in the mm range are required.

(b) Ultralight sensors weighing <1kg and typically integrated on either multi-copter or fixed-wing UAV platforms. The lower weight comes with a longer flight endurance and consequently with a higher areal measurement performance. Such sensors are the first choice if (i) decimetre accuracy is sufficient, and (ii) beyond visual line of sight (BVLOS) operation is legally permitted.

(c) Flash Lidar time-of-flight (ToF) cameras. These are the cheapest, most lightweight but at the same time least accurate systems on the market. Flash Lidar cameras are mainly used for applications like collision avoidance, object tracking and augmented reality rather than for traditional mapping tasks.

Compared to UAV photogrammetry using passive RGB camera sensors, survey-grade UAV-Lidar features multi-target capability (i.e. multiple echoes per laser shot) resulting in penetration of semi-transparent objects like vegetation. It also delivers precise geometry as well as radiometry (signal strength). As an active measurement technique, no texture is required and even night-time operation is possible given the respective flight permission. However, compared to image-based UAV mapping, UAV-Lidar relies on direct georeferencing and therefore requires appropriate GNSS/IMU hardware. As opposed to dense image matching, each point of the resulting high-resolution 3D point cloud is individually measured so the follow-up products like DEMs are more reliable. State-of-the-art sensors provide passive cameras and active laser scanners on the same UAV platform, achieving the best of both worlds via data fusion.

Gottfried Mandlburger is a senior researcher in the photogrammetry research group within the Department of Geodesy and Geoinformation at TU Wien.

REAL-TIME MODELLING

How can we address the need for frequent large-scale mapping in order to model real-time change?

My job requires frequent travel, and one thing that regularly strikes me during my trips is that we are living in a time of rapid change. Cities are changing due to growth, rural areas are developing as transportation infrastructure evolves, farmlands are adapting to feed a growing population and our urban areas seem to be multiplying overnight to provide housing. At Hexagon, we are fond of the saying 'You can't manage what you don't measure'. In the context of these changes, 'measure' means 'map'. The challenge with such rapid change is that it outpaces the way we map. We recognize that changes have occurred, start a lengthy process to secure a budget, issue a tender and acquire new data to capture the changes. But the new maps are often too late to be useful to manage the change and simply confirm what we already know. To keep up with our changing world, mapping also needs to change. To achieve this, the old model needs to evolve into programmes that continuously capture and make updated map data easily available. Such 'content as a service' (CaaS) programmes collect data according to consistent specifications and continual refresh schedules, creating a standardized product suitable for many applications. The users of these applications are collectively underwriting the collection cost and can, therefore, pay a significantly reduced price. Using the principle of a sharing economy gives everyone equal access to the same data, and as such, democratizes high-quality aerial data – a previously highly exclusive commodity. The second necessity is more efficient airborne sensing technology which enables the collection of more data in a single flight to reduce the time and cost of making maps. However, the sensor alone does not get the job done. With growing amounts of collected raw data, processing speeds need to be increased in parallel, allowing for the swift delivery of the processed data to the end customer. Hybrid sensors and workflows that capture and process imagery and Lidar data simultaneously will be the driver to map large-scale projects more frequently. At Hexagon, we have invested in making this a reality and will continue to do so. With our network of collection partners, the HxGN Content Program – our CaaS initiative – is now entering its seventh year of continuous collection. The programme has captured 25 million square kilometres of data in North America and Europe which is easily available online via purchase or subscription models. In 2016, we launched the world's first airborne sensor that simultaneously captures nadir and oblique images and Lidar elevation data: the Leica CityMapper and HxMap workflow. And in 2019, we announced a 40% productivity enhancement with the CityMapper-2, allowing airborne mapping companies to collecting more data during every flight.

John Welter is president of geospatial content solutions at Hexagon Geosystems.

SELECTING GEO-DATA ACQUISITION SYSTEMS

How can we choose between the many geodata acquisition systems when our equipment needs replacing or we are expanding due to business success?

This seemingly simple question is surprisingly hard to answer, so I will outline some considerations. Improving workflows focused on a few, well-defined applications entails other concerns than when multiple business fields are covered. If your focus is on sparse point measurements in urban areas, it may be sufficient to extend your total station fleet with high-accuracy GNSS receivers. If you are growing your business through terrestrial laser scanning as a novelty, you should consider questions such as: How will you approach potential clients and retain existing ones? And do you have the necessary in-house expertise to use the new equipment, or should new staff be recruited? The time needed to retrain staff in mastering new equipment and workflows is an often underestimated cost factor. Does the design of the equipment anticipate technological developments that lie ahead? In other words, is the equipment future-proof? Can it be upgraded without high costs, or even booted up at the touch of a button? One example is the GNSS receiver supplied with hundreds of channels for capturing future GNSS signals so that outages in urban canyons and under canopy will steadily diminish over time. What is your company's vision for the future? An aerial survey company that restricts itself to 2D mapping only will have other concerns than one that envisages 3D mapping and other new services. The latter may be interested in camera systems with oblique viewing heads or even a hybrid system equipped with cameras plus Lidar. Equipment and processing software are intertwined like fuel and oxygen in an internal combustion engine. Data formats should allow easy import in subsequent steps in the workflow. Should the transition from one workflow to the other be gradual or sudden? Some topographic agencies may prefer to continue using analytical photogrammetry in parallel, perhaps because the equipment is not yet amortized or the workforce is not yet flexible enough to dive into digital photogrammetry.
Advanced equipment that is not yet in widespread use can give you efficiency gains and hence a competitive advantage without compromising your revenues, especially in the beginning. But buying equipment also means buying the vendor's services and support. When you surrender yourself to a third party, a soft criterion comes into play: trust. In larger organizations, decision-makers may have a non-technical background. Steered by budgetary constraints, their main deciding factor might be the purchase cost. However, what initially seems cheap may turn out to be expensive in the long run... the devil is in the detail.

Mathias Lemmens is an independent geomatics consultant.

SMARTPHONES AS A MAPPING TOOL

To what extent will the smartphone become a professional mapping tool?

Modern smartphones already contain many of the important functions to be used as mapping tools. However, whether they are suitable for use as such professionally depends not only on the built-in sensors, but also on the available computing power, RAM and data storage capacity. For data acquisition, a smartphone usually has two to three cameras, a GNSS sensor, an acceleration sensor and a gyroscope for positioning the system in 3D space. In addition, a smartphone has a magnetometer which displays the orientation or north direction by a compass, and a barometer for measuring altitude. Current-generation smartphones have built-in RGB cameras of up to 108MP (e.g. the Xiaomi Mi Note 10) to take high-resolution photos. However, it is questionable whether so many pixels are generally necessary for mapping applications. Smartphones with mapping functionality have been available on the market for a few years now and there are numerous different options, so I will limit myself to mentioning just a couple of examples here. Back in 2013, ETH Zurich published an article on 'Live Metric 3D Reconstruction on Mobile Phones' presenting an application that allows (rather small) objects to be scanned in real time using a smartphone. A point cloud is generated from photos taken in motion by the smartphone camera and shown on the display during recording, so that the user can continuously check the completeness of the scanning process. Today, the application is marketed by Astrivis and offers an easy-to-use mapping tool for when high accuracy is not the first priority. Another interesting solution is the Spike smart laser measurement solution, which combines a smartphone with a laser distance measuring device developed by IkeGPS. With an add-on laser module, the smartphone is upgraded to a distance measuring instrument for evaluating photos and distance measurements. This takes place within the Spike app and can then be transferred to a GIS, such as ArcGIS, via the Survey123 app from Esri. Spike has many possible applications, particularly in the building and construction sectors. A very similar solution is the Leica BLK3D, which uses photogrammetry to make precise measurements from photographs. The combination of a calibrated stereo camera, advanced algorithms and real-time calculations together with leading electronic distance measurement technology makes it possible to measure exact distances, areas and the like. If smartphones are to gain relevance as professional mapping tools, then other features will also be of importance in addition to the criteria mentioned above. Such features include high-accuracy measurement capabilities, tools for the simple handling of data acquisition and processing, some degree of automation and interactivity in data processing and rapid data transfer via WLAN or Bluetooth to other evaluation systems. The first smartphones with time-of-flight cameras are already available. They use an infrared camera to determine depth information through point-cloud visualization, although the range and precision of these devices is currently limited. Smartphones are in fact already being used today as a supporting mapping tool for controlling other sensors and measuring systems such as terrestrial laser scanners, total stations and also unmanned aerial vehicles (UAVs or 'drones'). The technological development of smartphones continues at a quick pace, and we can expect faster performance and more precise sensors in the future at a reasonable price. Therefore, the use of smartphones as a professional mapping tool is undoubtedly set to increase.

Thomas P. Kersten is a professor of photogrammetry and laser scanning at HafenCity University Hamburg, Germany, where he is also head of the Photogrammetry and Laser Scanning Lab.

LATEST INNOVATIONS AND DEVELOPMENTS

How Geospatial Surveying Is Driving Land Administration

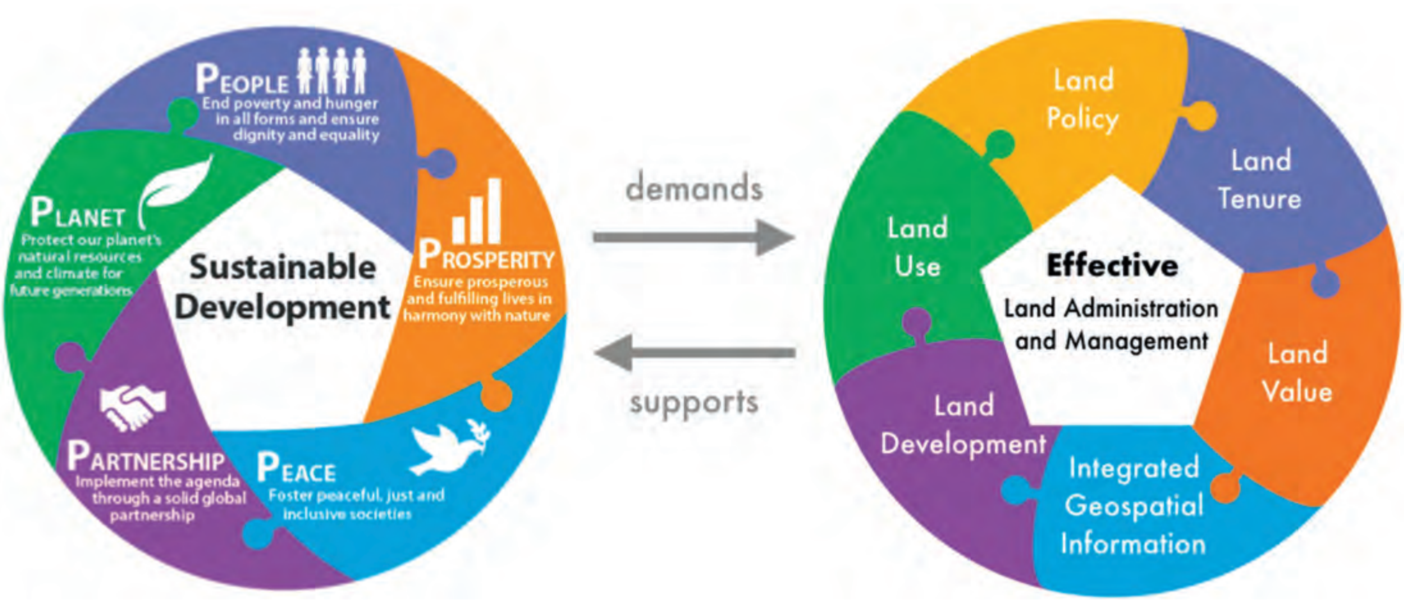
Five years ago, *GIM International* published an article titled 'A New Era in Land Administration Emerges'. It outlined how innovative thinking coupled with quickly maturing, scalable technical approaches could transform land administration globally. To reach fruition, support from policymakers, world-leading private companies, modern geospatial technologies and a new professional mindset would be crucial. So what has happened since? Here, in close cooperation with the geospatial industry, *GIM International* provides a major update, paying special attention to standardization, technical approaches and land data acquisition in the context of global policies.

POLICY GUIDANCE AND UN-GGIM

The national cadastral and topographic mapping agencies from UN member states are represented in the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). The geospatial industry is involved as an observer. UN-GGIM's Expert Group on Land Administration and Management has developed a reference document for developing, reforming, renewing, strengthening or modernizing land administration and management systems. It is called the Framework for Effective Land Administration (FELA). Based on the Integrated Geospatial Information Framework (IGIF), it is currently under global consultation. The document calls for recognition of land tenure, land use, land value and land development data – including elements relating to gender, conflict and disaster – as fundamental geospatial data themes within any jurisdiction. Sustainable development demands effective land administration and management. Likewise, effective land administration and management supports sustainable development, as defined in the Sustainable Development Goals (SDGs) (see Figure 1). FELA recognizes that an enabling environment through the development of policies, standards and regulations may lead towards a cooperative data-creation and data-sharing environment.

INTEROPERABILITY AND OGC

In parallel, the Open Geospatial Consortium (OGC) published a white paper on land administration, providing an overview



▲ *Figure 1: Sustainable development and land administration. (Courtesy: UN-GGIM)*

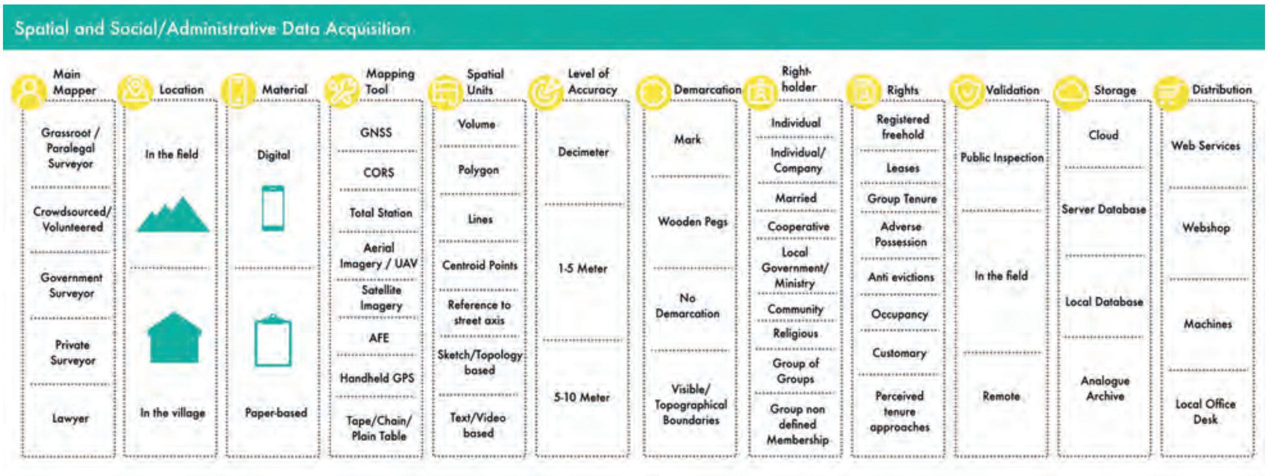
Figure 2: Overview of charter members of the OGC Land Administration Domain Working Group. (Courtesy: OGC)

of the land administration domain and proposing actions needed for the design and development of implementation standards. Close cooperation between OGC and the International Organization for Standardization's TC211 on Geographic Information is expected to accelerate these developments. The charter members (see Figure 2) of the OGC Land Administration Domain Working Group (DWG) seek to identify enabling standards and best practices to guide countries in a programmatic way to establish more cost-effective, efficient and interoperable land administration capabilities. The aim is to support the upgrading of current manual processes to semi-automated ones, and to suggest solutions that are more automated and open to new data sources and technologies. Interoperability is imperative in the field-to-cloud and field-to-office activities.

STANDARDIZATION AND LADM

The Land Administration Domain Model (LADM) has been an ISO standard for seven years and is currently undergoing a review towards a second edition. A road map is under development. The scope of LADM will be extended to include valuation and fiscal representations, which will have an impact on data acquisition methods. Spatial planning and zoning inclusion, with legal implications, is another extension of the scope. Moreover, it is planned to include process models and workflows. Esri continues to invest in LADM for the ArcGIS platform. It has been configured to leverage LADM to meet land

WHAT IS YOUR VISION ON HOW TO SUPPORT LAND ADMINISTRATION (CADASTRE AND LAND REGISTRY) PROCESSES AND SERVICES IN THE FUTURE?	
Esri	Esri has pioneered the world's leading cadastral software. Services-based, the ArcGIS parcel fabric integrates with modern business systems and can ingest data of all types.
Topcon	Many of Topcon's technology solutions for mass data acquisition and processing are ideal for acquisition of cadastre mapping data. For example, since 2016 we have exclusively provided the National Land Survey of Finland (NLS) with its high-precision geomatics solutions, enabling the organization to maintain the highest possible standards of work and data production.
IGNFI/GEOFIT/ INNOLA	IGNI/GEOFIT/INNOLA's solutions are integrated LADM-compliant data management systems based on rule-driven workflows and open for integration and exchange with third-party systems/interfaces. These solutions provide integrated field approaches that offer an all-in-one cadastral mobile office, with survey capacities using any kind of differential global positioning system (DGPS), socio-technical land survey forms with embarked QC capacities, scanning facilities, as well as biometric options for signature and ID generation.
RIEGL	RIEGL fully supports the efforts of UN-GGIM and the EuroGeographics members to modernize and upgrade country information for environmental and economic resilience.
Racurs	In cooperation with our partners, we are working hard on affordable cloud and VR tools which make the process of obtaining cadastral data cheaper and accessible. This will speed up the process of cadastral work.
Meridia	Meridia enables community members to conduct high-quality data acquisition to boost participatory mapping approaches that reduce cost while maintaining quality and strengthening local engagement.
Trimble	Trimble looks at land administration holistically – not as islands of activities, but rather as an integrated ecosystem of actions and reactions. Successful land administration efforts address all aspects of land rights, roles and responsibilities, including stakeholders, workflows, data, sustainability, accessibility, transparency and security.
Cadasta	At Cadasta, the focus is on supporting the individuals and communities left out of formal tenure systems. Globally, and particularly in emerging economies, documented and recognized land tenure and resource rights are the exception, rather than the norm.
Leica Geosystems	Hexagon's vision supports land administration by continuously developing fit-for-purpose data collection sensors, software and autonomous solutions that shape urban and production ecosystems to become fully autonomous and connected. These developments increasingly improve the efficiency and effectiveness of land administration.
Netcad	There are some standards for data acquisition and topology controls in Turkey. These are done by using macros/add-ons. Netcad's mission is to control every process of data acquisition and to eliminate and prevent paper waste by using e-signature technologies.



▲ *Figure 3: Integrated acquisition of spatial and legal/administrative data. Many options and approaches should be available in a flexible way.*

administration system needs across the globe. IGNFI/GEOFIT and Innola Solutions already provide proven national-scale, enterprise-level, LADM-compliant configurabilities, rule-driven systems, based on BPMN workflows. Those open solutions can integrate external services and sources using exposed web services/API (including GIS systems).

QUALITY AND FFPLA

Data capture should fit the purpose of its intended use. In cases where value of land is higher or an intensive level of land use exists, conventional field surveys – using high-precision methods such as high-precision GNSS, total stations or terrestrial laser scanners – can be deployed. Trimble, Leica, Topcon and emerging players offer a wide range of such options. Areas with lower land values can use other approaches including use of aerial imagery, aerial Lidar and even radar. All these approaches are suggested in the Fit for Purpose Land Administration (FFPLA) approach. FFPLA urges cost-effective, time-efficient, transparent, inclusive, scalable and participatory data collection and management, including participatory surveying and volunteered and crowd-sourced land information. This means integrated acquisition of spatial and legal/administrative data. Many options and approaches should be available (see Figure 3). The user interface should be as simple as possible and the kind of measurement used should be recorded. In many situations, it is sufficient to identify visual boundaries in the field using easily understood imagery. By following FFPLA guidelines, land administration systems start from a simple basis and can be incrementally improved over time, whenever necessary or relevant. It is a dynamic process involving adaptation to different contexts, availability of technology and existing integrated/multi-stakeholder approaches. In summary: less accurate measurements can serve the purpose for initial measurements. Higher precision can/should be used for incremental improvement (where needed).

PRODUCTIVITY AND THE PRIVATE SECTOR

The International Federation of Surveyors (FIG) published a report on crowdsourcing (see Figure 4) recognizing that geographic data collection via authoritative professionals only – characterized as the 'top-down' scheme – has been challenged over the past few years. There is now a move towards more bottom-up approaches in which people generate data that is subsequently used as information in various land-related applications and services. This is in line with the FFPLA concept. Esri, IGNFI/GEOFIT and Innola Solutions, Meridia, Trimble and Cadasta now all offer solutions in support of participation. Meridia states that the Meridia°Collect is designed to enable local community members to use advanced spatial and textual surveying features for initial land registration. It scales well (as proven in 50,000+ parcel projects) and is focused on usability and data consistency. Cadasta says that solutions must be adapted to the local context, but at the heart of their work they focus on ensuring data collection and management is done in concert, if not directly, by community members. Trimble states that, if input is required from non-professionals (via crowd-sourcing, for example), tools such as Trimble TerraFlex – a flexible and easy-to-use cloud-based solution for field data collection – also enable attribution. Leica's FFPLA solution, Leica Zeno, provides a very easy-to-use GNSS field

▲ *Figure 4: FIG has published reports on crowdsourcing and 3D land administration.*

▲ *Figure 5: Automated feature extraction (AFE) is under development in various domains. (Courtesy: Crommelinck, Unger, Bennett)*

data collection tool offering scalable accuracy to meet all land administration requirements. Zeno can be used on consumer-grade smartphones or tablets with the high accuracy and precision demanded in land administration.

INNOVATION AND 3D CADASTRES

Another relevant development is that of 3D cadastres. A comprehensive study recently published by FIG (see Figure 4) concluded that ongoing urbanization, increasing complexity of infrastructure and densely built-up areas require better recordation and registration of the legal status. This can only be provided to a limited extent by existing 2D cadastral systems. 3D, including indoor modelling, is required to capture the whole legal and spatial dimension, which further includes the marine environment. A dedicated 'vertical' land administration stream is without any doubt the trend which is requested and fully supported by suppliers. The support may range from assistance during initial registration and documentation of land rights, to deliverance of the full 'vertical' spectrum of land administration services – from field data acquisition, data conversion and data migration, to LADM-compliant data integration

WHAT ARE THE LATEST LAND ADMINISTRATION INNOVATIONS THAT YOU WOULD LIKE TO SHARE?	
Esri	The parcel fabric is the most modern, purpose-built and configurable land administration capability in the market in 15 years. It leverages all the capabilities of the ArcGIS platform supporting distributed, federated, fit-for-purpose and enterprise land systems. Combined with the Esri Geospatial Cloud leveraging the largest global geographic database and extensive services, configurable apps and capabilities, this delivers a complete land administration system.
Topcon	Topcon invests in providing solutions that improve the whole land acquisition workflow, including initial data acquisition, management, provision and maintenance. From Topcon hardware solutions such as the Sirius Pro UAV to Topcon's in-house software such as MAGNET Collage, as well as partnerships with Bentley ContextCapture, Topcon's cutting-edge technology provides invaluable support to those in the land administration community.
IGNFI/GEOFIT/ INNOLA	We are working on the integration of blockchain technology to improve the overall security of our systems.
RIEGL	The introduction of the RIEGL VQ-1560 II dual-channel waveform processing airborne Lidar scanning system for high point density mapping and ultra-wide area mapping is an excellent example of innovation to meet the requirements for efficient and precise data capture for authoritative data needed by the mapping community.
Racurs	At last year's Intergeo, we released the StereoClient: a tool for stereo processing of images from cloud storage. This tool allows stereo measurement with a smartphone, needing only a VR adapter, a keyboard, a mouse and a special app.
Meridia	Meridia provides online and offline-ready sync between multiple data collectors, and traceable field snapping to avoid overlaps and slivers.
Trimble	Recent algorithmic and positioning infrastructure advances allow high-accuracy cadastral boundary surveys with the use of consumer-level hardware. Trimble Catalyst delivers professional-grade positioning to the masses as an on-demand, user-based service. This can enable a scalable and affordable solution for large-scale parcel survey.
Cadasta	At Cadasta, we are working on providing tools for data acquisition, management and maintenance in addition to providing relevant datasets for our partners so that they might maximize their ability to analyse land holdings and make informed land management decisions.
Leica Geosystems	Airborne imaging sensors are ideal for remote sensing projects in land use, agriculture, forestry and the environment. Launched at Intergeo 2019, the Leica CityMapper-2 is specifically designed for airborne urban mapping and offers twice the data collection performance to address this urgent need for 3D data. The world's only hybrid oblique imaging and Lidar airborne sensor captures two nadir (RGB/NIR) and four oblique 150MP images every 0.8 seconds, offering the highest resolution to visualize every corner of a city. Together with a new-generation 2MHz pulse rate Lidar, this sensor breaks all conventional barriers of urban mapping. The release of Leica Zeno also supports professionals collecting data for land administration purposes at the low end.
MGGP Aero	MGGP Aero provides geospatial information based on aerial imagery and Lidar data. Land administration can rely for its use on the resolution, overlaps and precise accuracy provided. For cadastral purposes we only use wide-format photogrammetric cameras and at least 7cm GSD resolution or better. MGGP Aero solutions focus on the use of aerial imagery for land administration (cadastral purposes, stereophotography, 3D mesh models, oblique imagery and regular time sequenced aerial imagery).
Netcad	Netcad solutions include online signature and topology control processes and support in fair property exchanges by using AI technologies. This is of specific complexity in Turkey. Nationwide integrated services are available. Netcad is working on opening CAD data on web browsers and Linux.

and transactional workflow-driven data management and dissemination.

AUTOMATED FEATURE EXTRACTION

Automated feature extraction (AFE) is under development in various domains, including the land administration domain (see Figure 5). The most notable developments are in infrastructure management in urban areas (e.g. transport, buildings) and agriculture (land use). The application to land administration is more recent and should be considered at R&D and pilot level. It is argued that a large number of cadastral boundaries are visible and coincide with natural or human-made physical object boundaries. Imagery-based approaches have been proved as usable for land titling and recordation of all people-to-land relationships in countries such as Ethiopia and Rwanda.

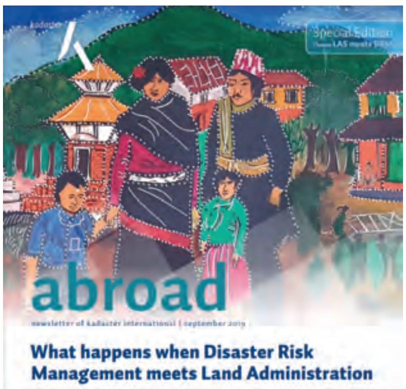
Nevertheless, even in ideal cases, not all visible cadastral boundaries can be automatically detected; certain boundaries require a semi-automated approach, especially in urban areas where the morphology of cadastral boundaries is complex. AFE cannot deliver complete matching; some tenure boundaries are also defined socially or are covered by thick canopy and thus are not visible in imagery. AFE can be a good method for updating a cadastral map or for initial working-draft land recordation. AFE is perhaps on the cusp of going beyond R&D, as all the big vendors are working on it. Linking with those providers for pilots will reveal many lessons, including the viability of the approach in different parts of the landscape. AFE will not be suitable everywhere, but – like UAVs – it will have a niche role to play in both initial capture and updating/maintenance.

DISASTER READINESS

There has been increasing focus on ensuring land administration systems are better able to adapt and respond to both natural disasters and conflicts. It is crucial to gain an overview of areas where conflicts have an impact on land rights. Land administration systems (LASs) are typically built to operate in relatively stable environments. Disaster risk management (DRM) generally assumes a dynamic, if not chaotic, environment. After a disaster occurs, the aim is to quickly assess and triage damage, injury and loss of life, and respond with medicine, food, water, housing and basic infrastructure. New conceptual thinking has established a link between the key LAS constructs of land, people and rights, and the core DRM concepts of hazard, vulnerability and exposure. This theoretical link has been converted into a practical data model by embedding new attributes into the ISO 19152 LADM standard (see Figure 6).

CONCLUDING REMARKS

New-era land administration is being embraced by surveyors, the private sector, policymakers, governments and communities alike. Underpinned by emerging policies such as UN-GGIM's FELA and principles of interoperability (OGC), standardization (LADM) and pragmatism (FFPLA), a range of sustainable and scalable private-sector products and services are being developed. These are enabling innovations and automation in national land administration sectors. Importantly, these technical developments are supplemented – if not enabled – by simple legal procedures and streamlining institutional processes. ◂



▲ *Figure 6: What happens when disaster risk management meets land administration? Special edition of the newsletter* Kadaster Abroad.

POLICIES AND PRINCIPLES OF INTEROPERABILITY, STANDARDIZATION AND PRAGMATISM ARE ENABLING INNOVATIONS AND AUTOMATION IN NATIONAL LAND ADMINISTRATION

The tables show answers from a survey on geospatial innovations and developments relevant for land administration systems. The survey was conducted in close cooperation with *GIM International*. For further results, see: www.gim-international.com.

FURTHER READING

- FIG, 2019, *New Trends in Geospatial Information: The Land Surveyors Role in the Era of Crowdsourcing and VGI*, International Federation of Surveyors, FIG Publication No 73
- FIG, 2018, *FIG publication on Best Practices 3D Cadastres* - Extended version, International Federation of Surveyors, November 2018
- Kadaster, 2019. *Kadaster Abroad*, Special Edition – Theme: LAS meets DRM, Kadaster, September 2019
- OGC, 2018, Open Geospatial Consortium White Paper on Land Administration, OGC, February 2019
- UN GGIM, 2019, Framework for Effective Land Administration. Expert Group on Land Administration and Management United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), July 2019 – Under Consultation
UN-GGIM, 2018, Integrated Geospatial Information Framework

ABOUT THE AUTHORS

Christiaan Lemmen holds a PhD from Delft University. He is a geodetic advisor at Kadaster International, The Netherlands, and a professor of land information modelling at Twente/ITC. He is co-editor of ISO 19152 LADM.
✉ Chrit.Lemmen@kadaster.nl

Eva-Maria Unger holds a PhD from Twente University. She is a geodetic advisor at Kadaster International, The Netherlands, and is a former chair of the FIG Young Surveyors Network.
✉ Eva.Unger@kadaster.nl

Rohan Bennett gained his PhD from the University of Melbourne, Australia. He is a geodetic advisor at Kadaster International, The Netherlands, and an associate professor of information systems with the Swinburne Business School in Melbourne.
✉ Rohan.Bennett@kadaster.nl

Bridging the Gap between Geospatial and Construction

There is certainly a gap in information exchange between the geospatial and construction domains. This is a serious issue, mainly because geospatial systems and engineering surveys are not yet aligned and integrated with building information modelling (BIM). The BIM method is expected to move construction activities from plan-based individual work to model-based collaboration. Such a paradigm shift will bring huge opportunities regarding planning, building and management of the built environment in a more productive, open and sustainable way. Although it is still difficult to entirely close the gap between these two fields, this article shows how that gap can at least be narrowed.

Building information modelling (BIM) is defined as a method using "a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions" (ISO 29481). Despite its underlying diverse and complex structure, BIM is digital, model-based information exchange. Many regional, national and international business and academic networks are currently investigating the gap between the geospatial and construction domains. Two examples are the international working groups from ISO/TC 59/SC 13 – ISO/TC 211 JWG 14 'GIS/BIM interoperability' and from OGC/buildingSMART working group 'Integrated Digital Built Environment' (IDBE). Both compare general modelling concepts as applied for building and geographic information, identify concrete obstacles in the data exchange processes between BIM and GIS and develop proposals for new standards. Still, the implementation, usage and understanding of BIM varies according to the specific expectations of its users, e.g. public and private builders, project developers, general planning companies, construction companies, facility managers, etc. Each actor involved in a construction project brings along their own objectives, expertise and problem understanding. Thus, each stakeholder in an architecture, engineering and construction (AEC) project has specific information requirements.

When geospatial data enters the BIM world (Figure 1), it offers even higher potential. However, such potential also brings unrealistic expectations from stakeholders – expectations that cannot be met by current software implementations, system architectures and related domain cultures. Such technological and administrative hurdles can only be overcome with open standards for data, services and processes. OpenBIM prevents vendor locks and enables market access for small, agile and innovative software companies. The vendor-neutral data model for BIM is defined by the Industry Foundation Classes standard (IFC, ISO 16739). The equivalent for the geospatial world is the Geography Markup Language (GML, ISO 19136). Even though there are many differences between the methods and processes underlying both approaches,

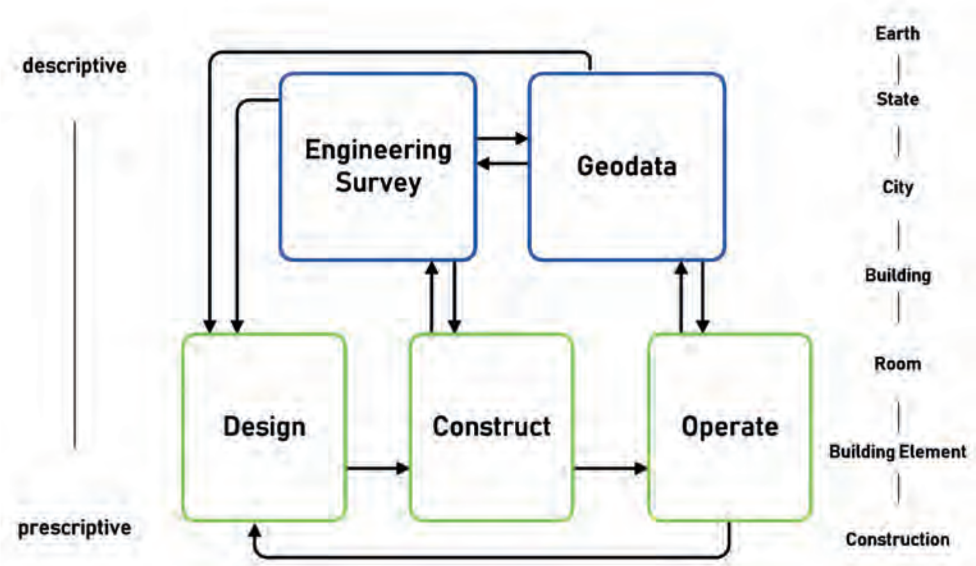


Figure 1: Information flow between the geospatial and construction domains along the life cycle of a built asset.

there is a general tendency of combining them in order to benefit from their cumulated advantages. Reaching such a common vision would bring highly productive outcomes in the field of digital AEC. Indeed, integrating BIM and GIS offers benefits in terms of management of planning processes, notably during the design and construction phases. However, this is not trivial and comes with several challenges: a) an open common data environment for stakeholder collaboration, b) life cycle information, and c) component orientation.

A) OPEN COMMON DATA ENVIRONMENT FOR COLLABORATION

BIM is not a monolithic database that contains all information in a uniformly structured data model with proper semantics. The term ‘common data environment’ (CDE) is deliberately kept generic and can mean either a simple file storage system or a service-oriented, federated infrastructure. Critical functionalities of such a CDE would allow information to be made accessible, assigned to a process, versionable and archivable, filterable and queryable, etc. CEN/TC 442 has initiated a European standardization proposal: ‘OpenCDE’. Its aim is to establish a uniform application programming interface (API) for CDE system architectures, which until now have been exclusively proprietary. The geospatial community can make a major contribution due to its many years of experience with distributed information infrastructures (web map services, web feature services, etc.) and associated metadata services.

B) LIFE CYCLE INFORMATION

It is difficult to achieve consistent and seamless use of the building information along a building’s life cycle. Companies bill their services in the grid of service phases and often have no economic interest in passing on information. However, the owner can benefit greatly from correct, available and well-structured information during the operating phase of the building. It will therefore be important that owners – and especially public owners – design specifications for the continuous transfer of information across all service phases. buildingSMART developed the Information Delivery Manuals (IDM) methodology (ISO 29481) to capture and specify processes and information flow during the lifecycle of a facility. IDM comprises several use cases, being defined as an ensemble of exchange requirements (ER) that detail the geometric and semantic information requirements of the data delivery. For addressing this technically, ERs are developed as ‘model view definitions’ (MVD) to describe only the needed subset of the full IFC Schema. Various aspects of geographic information and engineering surveying must be considered in these documents. For this reason, it is very important for the geospatial community to participate when new BIM regulations are set up.

C) COMPONENT ORIENTATION

The shift from construction drawings to 3D models can be compared to the shift from maps to GIS. The geo-feature concept corresponds (in principle) to the component object. Building objects belong to an IFC class (e.g. IfcWall, IfcWindow, IfcColumn), are identifiable by means of globally unique identifiers (GUIDs), may have no or several geometrical representations, can belong to specific zones, can have topological relations to other objects and may ‘carry’ additional specific properties, defined through IFC property sets. In BIM applications, a building object is characterized by its geometrical representations (one per point of view) and its non-geometrical properties. For example, a wall can be represented either as a segment between two points or as a 3D geometry. Also, a wall’s representation will evolve during the considered building lifecycle phase following the addition of new construction details along with data regarding its engineering, schedule or even cost. The IFC Schema has intentionally been created with a high expressivity. This means – in brief – that the standard contains a huge amount of types for geometry and semantics. On the one

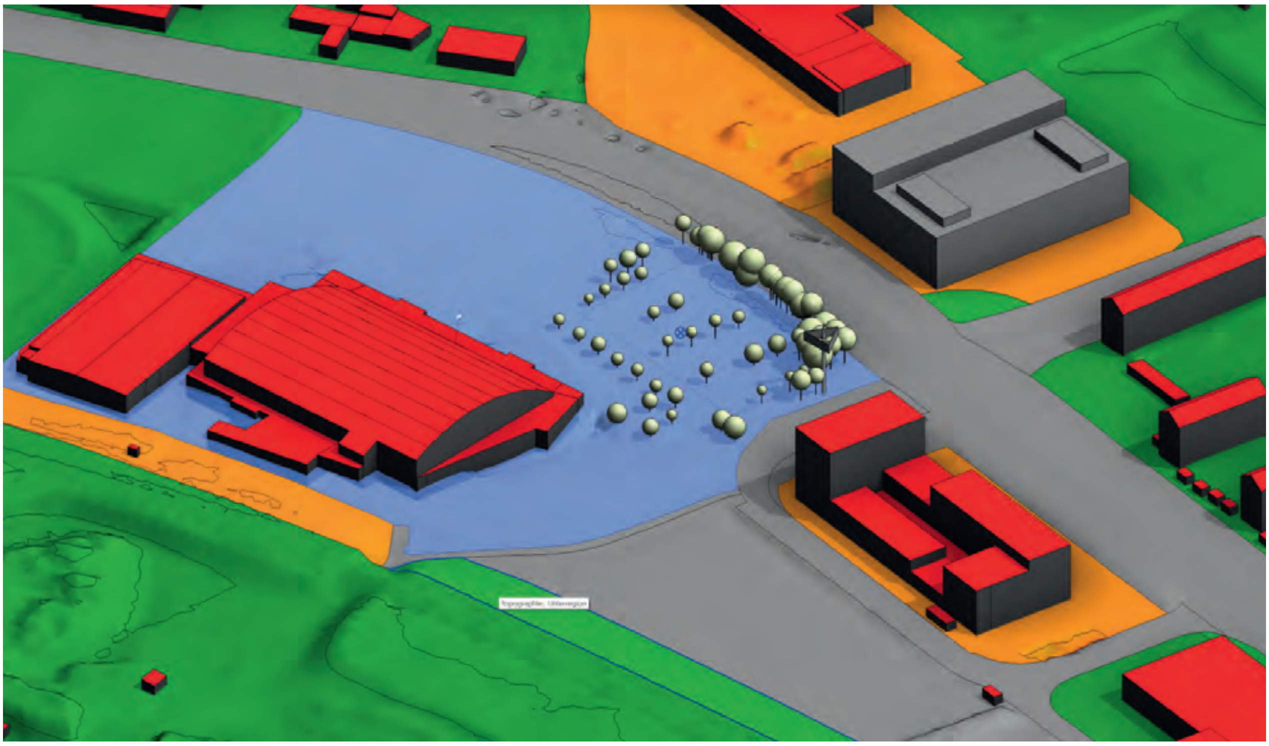


Figure 2: Geospatial datasets in BIM software (city, parcels, terrain and measured survey).

hand, such expressiveness is good because it reduces the potential issues related to software implementation. On the other hand, it gives too much 'freedom' and too many choices for software editors, resulting in numerous different implementations – not all of which are interoperable. The MVD standard is aimed at reducing this complexity by specifying a subset of the IFC Schema that must be checked against specific requirements as related to data delivery scenarios.

BENEFITS OF LINKING GEOSPATIAL AND CONSTRUCTION DOMAINS

Adding information management to model-based geospatial and building data opens up new opportunities for business process optimization. The list of use cases below provides some examples of the benefits of information integration in the various building life cycle phases.

Design and planning phase:

- Visualization of planning variants (Figure 2)
- BIM to geospatial: Use of building models for geospatial analysis, e.g. property and governmental approval, traffic simulation, environmental impact
- Geospatial to BIM: Nearby geographic context of the planned building, e.g. alignment to parcel lines, terrain and soil, location of building connection lines (Figure 3)

Construction work phase:

- Setting out and machine guidance
- Monitoring of work progress
- Area management of construction site (e.g. storage space, traceability)

Operation and maintenance phase:

- Ubiquitous and unified information on indoor assets (architectural model in conjunction with technical equipment in buildings) and outdoor assets (utilities, parcels, trees, paths)
- Reliable and coordinated portfolio management and predictive maintenance
- Combined indoor and outdoor navigation (Figure 4).

MODES OF INFORMATION INTEGRATION

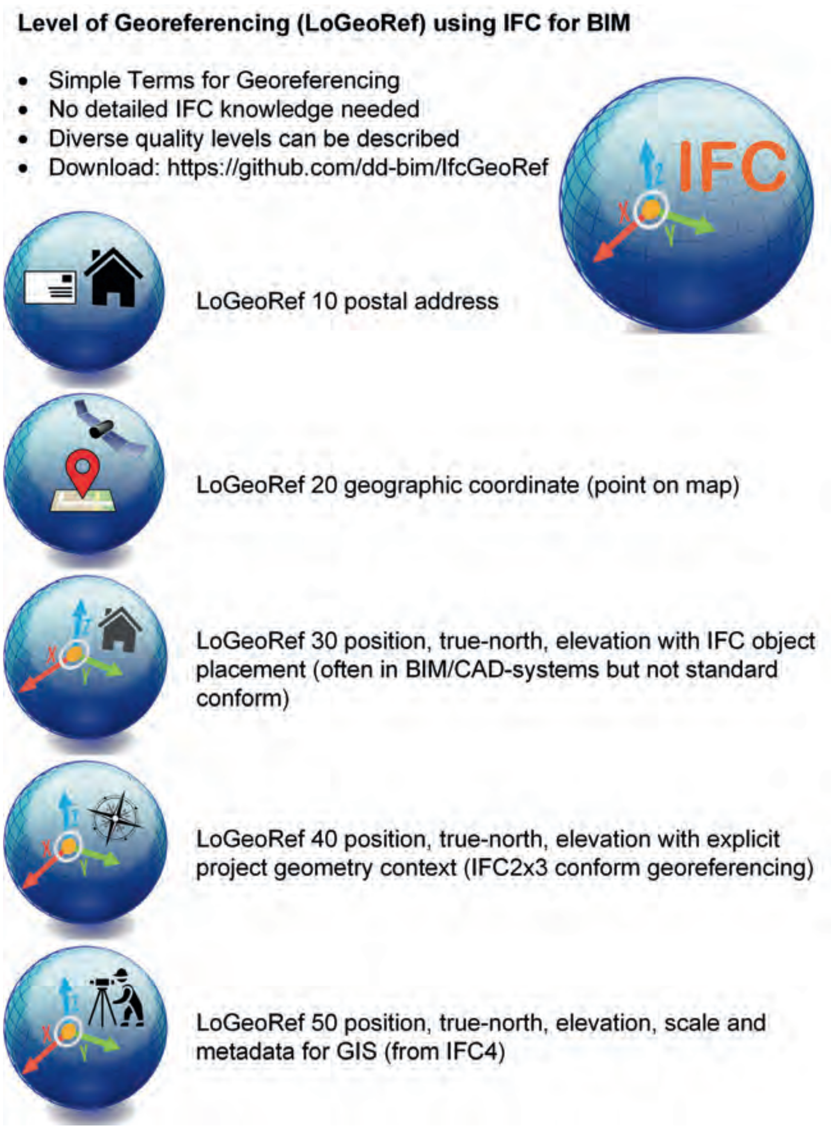
In practical applications, the gap between the geospatial and the construction domains has many facets. These all need to be checked when designing migration processes between geospatial data and construction data, and vice versa. The interoperability of heterogeneous BIM and GIS data sources means it must be possible to analyse (derive) information which could otherwise not be deducted from separated data sources. For ensuring such reasoning over heterogeneous data, the key issue is semantic interoperability. Interoperability can be integrated, unified or federated (ISO 11354). Integrated approaches rely on the definition of a common form, with high expressiveness. All elements from the systems to be integrated must be described according to the common form. Unified approaches rely on a common meta model for the transformation. The meta model itself is not intended for execution and can range from a vocabulary to a complete ontology (knowledge representation with formal semantics). The most interesting, but also challenging, approach is federation. This is to be applied in contexts where the systems are too different to interoperate. The information is kept in the original domain model and can be queried via services by anybody, anywhere and anytime. For example, the Federated Architecture for OWL Ontologies (FOWLA) is an approach for federating independent ontologies and allowing them to be queried

Figure 3: Automatically generated and georeferenced floor plans from open-source BIMserver on Open Street Map (OSM).

all together while keeping query answering time at its lowest (see 'Further Reading' for details of this and the GIS/BIM interoperability problem).

GEOREFERENCING

With the right transformation parameters, a building model can be properly placed in a geodetic coordinate system. The topic of georeferencing plays a decisive role but is nevertheless poorly implemented in practice, i.e. in a manner that does not conform to standards and is technically insufficient, even though IFC (starting version 4) supports good georeferencing capabilities of IFC models. In this matter, software manufacturers must still significantly improve their products. Furthermore, the IFC standards currently lack a clear description of the geodetic scale, a conceptual data model for survey points and the inclusion of GIS-compliant attributes for geodetic datum transformation, e.g. as WKT/proj4 string. In addition to the technical implementation, a detailed specification of the type and implementation of georeferencing in BIM exchange requirements needs to be established, at management level. For this purpose, LoGeoRef could be used to communicate (see Figure 5) and check the required level of georeferencing of an IFC model between information providers and information customers using a simple metric.



▲ *Figure 4: Motivation and metrics for level of georefencing.*

▲ *Figure 5: Integration of geospatial and construction models in a common data environment (CDE). (Courtesy: Korfin)*

SPATIAL REPRESENTATION

A particular challenge in exchanging data among digital building models is the large number of geometric and topological representation types existing in BIM, e.g. boundary representation (B-Rep), constructive solid geometry (CSG), parametric models or hybrid model types. The complexity of adopting the correct geometric representation type is often underestimated. The transformation is not a simple 1:1 schema mapping. Geospatial features are mostly represented as points, lines or surfaces, and these are typically poorly supported (identifiable, visualized, selectable, analysed) by BIM authoring or collaboration tools, mainly because BIM focuses more on parametric solid representation.

DATA TEMPLATES FOR ALIGNED NAMING AND ATTRIBUTION OF SINGLE COMPONENTS

IFC (ISO 16739) provides a semantic model, expressed with a huge range of entity types, type enumerations and predefined property sets. The semantic model can be extended with generic property sets and by using the so-called 'building element proxies'. However, the semantics of this user-defined extension are not standardized. In addition, the IFC is designed for model transfer rather than for expressing information needs. In order to achieve aligned semantics between domains and projects without inflating the IFC and while remaining independent from IFC, several standards for product data templates are currently being developed by

ISO working groups. The evolving standards cover a general taxonomy (ISO 12006-3, buildingSMART data dictionary), the general structure of data templates (ISO 23387), the expert process to describe, author and maintain data templates (ISO 23386), specific data templates and an IFC exchange structure for product data templates (ISO WI442018).

LEVEL OF INFORMATION NEED

In practice, communicating the requirements for the level of detail of the building model regularly leads to misunderstandings because engineers use different terms or because it is not clear what the term 'detailing' actually means. For this reason, a European concept for describing the level of information need (LoIN) is standardized in CEN/TC 442. In the past, the level of geometric detail (LoG) was indirectly 'implied' using the drawing scale. When working with models based on the BIM method, the 'detailing' must be defined in a more complex way: the LoG covers the detailing, dimensionality, spatial reference, graphic representation (appearance) and parametric behavior of the geometric information. In addition, the type of object identification (name, ID) as well as the type and structure of the object classification and attribution must be defined by the level of information (LoI). The level of documentation (DoC) regulates the amount and the scope of the documents that are supplied in addition to the virtual building model.

CONCLUSION

Many of the gaps that occur in practice can be solved with existing technologies but require an awareness of both the possibilities and the systemic difficulties. Open standards developed by OGC, buildingSMART International, ISO and CEN, along with national standardization organizations, will help to bridge the gaps between the construction and the geospatial domains. Last but not least, better training and tutoring has to be provided to professionals, while pushing forward the need for new processes and business models that tackle the issues discussed in this article. ◂

EXAMPLES OF HOW TO NARROW THE GAPS

GIS to BIM

City models are uploaded to BIM in order to visualize the geographic context and use it for BIM/geospatial analysis, such as visibility analysis or calculations for building permits. Besides not supporting the semantics of city models, the spatial representation is very different between the two data models. Most solids in city models, representing a building, are collections of polygons. Currently, there are no quality standards that ensure the generation of watertight solids. However, this is extremely essential for BIM since high numerical precision is required.

BIM to GIS

When uploading simplified building models into GIS in order to check environmental or social impacts on diverse variants in construction and placement, the high diversity of possible BIM geometric representations makes it difficult to transform all objects completely from BIM to GIS. Even deriving a footprint from BIM for GIS is not easy, because the algorithm needs to select and intersect many component elements, e.g. outer walls. Ontologies and semantic web technologies also come in handy for tackling this issue, as they allow the definition of user-specific concepts based on existing ones. The 'building envelope' or the 'highest storey' are examples of concepts that can be defined using semantic rules. Once defined, such concepts can be queried directly.

BIM and engineering surveying

The shape of building elements, given as parametric model or CSG, needs to be recalculated for construction works, because total station surveys, machine guidance and progress monitoring are mostly related to points, not component objects represented as solids. The rules to export points/faces from parametric solids are not uniquely defined, which might lead to inconsistencies. The serialization of derived points in BIM (e.g. for surveying) along with their relation to the components/objects is not part of any standard. However, the major vendors of geodetic instruments provide good support for model-based surveying within their software, also supporting IFC import.

BIM and GIS for operation and maintenance of the built environment

Seamless 3D-Plan/3D-Map for facility management using indoor/outdoor data with the same interface is an important business model. The gap between geospatial and construction appears when the same real-world objects might be stored redundantly in BIM and GIS, e.g. IfcSpace for a room in BIM and a polygon in a geospatial database. There are no standards for expressing that the two geometric representations represent the same real-world object.

FURTHER READING

- Tarcisio Mendes de Farias, Ana Roxin, Christophe Nicolle. FOWLA, A Federated Architecture for Ontologies. International Web Rule Symposium (RuleML 2015), Aug. 2015, Berlin, Germany. pp.97-111.

- Ana Roxin, Elio Hbeich. Semantic Interoperability between BIM and GIS – review of existing standards and depiction of a novel approach. 36th CIB W78 – Information Technology for Construction, Sep. 2019, Newcastle, United Kingdom.

- Christian Clemen, Hendrik Görne: Level of Georeferencing (LoGeoRef) using IFC for BIM, *Journal of Geodesy, Cartography and Cadastre*, 2019, pp.15-20 [Link]

- https://github.com/DD-bim

ABOUT THE AUTHORS

Christian Clemen teaches and researches at HTW Dresden, Germany, on BIM from the perspective of geospatial engineering. His research projects relate to 3D data acquisition and construction progress documentation with terrestrial laser scanning (TLS) as well as 3D city models (CityGML) and land management with BIM. He is a member of BIM standardization at DIN and ISO and is active in NGOs such as the International Federation of Surveyors (FIG).
✉ christian.clemen@htw-dresden.de

Ana Roxin is an associate professor in computer science at the University of Burgundy, France. Her research addresses approaches that allow computers to simulate human reasoning and problem-solving. She has proven experience across semantic web, semantic interoperability, context-aware BIM, GIS and explainable AI. She is a member of several standardization bodies (e.g. AFNOR, CEN, ISO).
✉ ana-maria.roxin@u-bourgogne.fr

-survey
E800
GNSS Receiver
Superior anti-interference ability with magnesium-alu-minum alloy design
E300 Pro
GNSS Receuver
Concealed design for better protection
Web: www.esurvey-gnss.com
E100
GNSS
Receiver
Multi-constellation satellite tracked
P8II
Controller
Protection level IP67, readable in sunlight, touch screen

SOUTH
Target your success
VARIETY MEETS
PERFORMANCE
SOUTH Surveying & Mapping
mail@southsurvey.com
www.southinstrument.com

CHC Navigation

CHCNAV
Make your work more efficient

Founded in 2003, CHC Navigation (CHCNAV) is a publicly listed company creating innovative GNSS navigation and positioning solutions. With a global presence across the world, distributors in over 100 countries and more than 1,300 employees, CHC Navigation is today recognized as one of the fastest-growing companies in geomatics technologies. For CHC Navigation, technological integration means going beyond survey instruments and developing geospatial tools that will provide effective decision-making solutions to the geospatial community. CHCNAV and its affiliates are global providers of integrated solutions, from ground to airborne survey and from traditional GNSS RTK survey to mass data collection with 3D mobile mapping solutions. Examples include the recently introduced Alpha3D, machine control and agriculture auto-steering, all within real-time infrastructures from network RTK solutions to advanced bridge monitoring systems. CHCNAV is rapidly expanding geographically with a growing presence in local markets. The proximity to customers is a key factor in maintaining a clear understanding of geospatial customer requirements in an extremely fast-changing environment. Fundamental research in technologies is making an ever-larger contribution to the company's plans, including advanced tightly integrated positioning algorithms, IoT, cloud-based solutions and simplification of data acquisition workflow processes with carefully designed man-to-machine interfaces. CHCNAV's slogan, 'Make your work more efficient', perfectly summarizes how the company's GNSS positioning and integrated navigation solutions are designed to dramatically improve productivity and provide outstanding return on investment for customers and business partners.

www.chcnav.com | +86-21-54260273 | sales@chcnav.com

ComNav Technology Ltd.

SinoGNSS®
By ComNav Technology Ltd.

Founded in 2012, ComNav Technology is a world-leading high-tech company focused on high-precision BDS/GNSS technologies. ComNav Technology engages in R&D, manufacturing, sales and services to provide worldwide customers with high-precision GNSS chips, modules, terminals, software and solutions across many industries. The company is committed to be an innovator and leader in high-precision BDS/GNSS technologies and applications. ComNav Technology sells its products and solutions in more than 100 countries, amounting to more than 350,000 units of modules (receivers) across ten different industries by the end of 2019. In line with its strong tradition of innovation, ComNav Technology is continuing to invest at least 20% of its annual revenue back into R&D every year to pursue excellence in GNSS technologies and solutions. Its ultimate goal is to provide the best products and solutions to customers worldwide.

www.comnavtech.com | +86 21 64056796 | sales@comnavtech.com

e-Compass

e-survey

Founded in 2005, Shanghai e-Compass Science & Technology Co., Ltd is located in Shanghai. The company is specialized in the surveying and GIS industry, integrating R&D, manufacturing and sales. Its main products include data acquisition and positioning equipment such as high-precision GNSS receivers, GIS data collectors, combined inertial navigation products, UAV positioning products and data application solutions such as displacement monitoring systems, intelligent driving test systems and precision positioning service systems. e-Compass also covers the field of 3D Lidar mobile laser scanning, UAV aerial photogrammetry, machine control systems (BIM), automatic deformation monitoring systems, high-precision location-based services, GIS applications and so on. To extend its business scope, the company is providing more and more products and solutions with a good cost-performance ratio all over the world.

www.esurvey-gnss.com | +86 21 54467213 | info@esurvey-gnss.com

Geo-allen

Geo-allen Co. Ltd. was founded in 2002, in Suzhou, Jiangsu Province, 80km away from Shanghai. Over the past years, Geo-allen has grown to be a world-famous company with an R&D team, a trading department, manufacturing workshops and an after-sales-service team. With the DNV's ISO9001 certificate and its policies of best service/best quality/best prices, Geo-allen is gaining more and more recognition in its field. Geo-allen never stops expanding and developing. Its products now include UAVs, GNSS devices, total stations, theodolites, auto levels, laser instruments and almost all kinds of accessories including tripods, staffs, poles, bipods/tripods and reflecting systems. The company also supplies different kinds of adapters for GNSS controllers, different bags for instruments and accessories, and more. The company holds several approved patents for products it has designed and is in the process of applying for more. With its goal of 'Punctuality, Quality, Rigor and Service (P/Q/R/S)', Geo-allen is looking forward to becoming more involved in the development of the Belt and Road initiative and contributing to an even more beautiful future. In 2020, Geo-allen will be attending Intergeo in Berlin, Germany.

www.geoallen.com / www.geoallen.cn | +86-512-6802-6320 | geoallen@vip.163.com

Hexagon

Hexagon is a global leader in sensor, software and autonomous solutions. Based on the slogan 'Empowering an autonomous future', the company puts data to work to boost efficiency, productivity and quality across industrial, manufacturing, infrastructure, safety and mobility applications. Hexagon's technologies are shaping urban and production ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future. Hexagon (Nasdaq Stockholm: HEXA B) has approximately 20,000 employees in 50 countries and net sales of approximately €3.8 billion. Follow the company on Twitter @HexagonAB.

hexagon.com | +46 8 601 26 20 | info@hexagon.com

Hi-Target

Established in 1999, Hi-Target is the first professional high-precision surveying and mapping instrument brand to be successfully listed in China. Hi-Target produces a wide range of surveying equipment including GNSS receivers, CORS stations, TPS, 3D laser scanners, GIS data collectors, UAV/UAS and hydrographic products to provide complete commercial solutions for various industries. As a leading brand in the geospatial industry, Hi-Target invests heavily in research and development on top of collaborating with more than 100 universities globally to bring the latest positioning technology and innovation for product development. Hi-Target will continue to develop products and technologies to meet the ever-increasing demands of the geospatial arena. Customers can count on Hi-Target to be the best in its field with professional solutions and superior services.

www.hi-target.com.cn | sales@hi-target.com.cn

ImpulseRadar

ImpulseRadar develops and builds ground penetrating radar (GPR) instruments and related software enabling people and organizations to investigate and map subsurface features and structure. In short, the company makes it possible to 'see' through and into all sorts of penetrable non-conductive materials such as the ground (soils and bedrock), concrete, roads, freshwater, snow and ice. A host of associated and established applications can be addressed with ImpulseRadar's technology, and other new application areas have emerged recently, e.g. surveillance systems. The company targets high-margin niches of the GPR market with products based on the latest real-time sampling technology, which offers significant advantages vs existing competitors. The primary target markets are geo-related and 3D imaging, but the offering is also suitable for utility locating and mapping applications. ImpulseRadar focuses its efforts on applications where it can make a clear difference in functionality, user-friendliness and system performance. To build value and stability into the company, ImpulseRadar strives to keep and expand its expertise around core technology and key processes, while outsourcing non-critical tasks. ImpulseRadar's mission is to develop, produce and market high-tech products and control systems.

www.impulseradar.se | +46 953 100 08 | info@impulseradar.se

Phase One Industrial

Phase One Industrial researches, develops and manufactures medium-format digital photography systems, software and imaging solutions for industrial markets. Solutions range from aerial image acquisition to machine vision applications and cultural heritage preservation. Whether mapping the globe, executing industrial inspections or preserving priceless works of art and documents, the focus is on imaging accuracy. Phase One's range of 50MP to 190MP metric cameras are completed with a choice of impressive lenses. In addition, the company offers a powerful controller and software with full compatibility with most flight management systems and GPS receivers. From flight planning to image delivery, Phase One delivers the complete solution. From manned and unmanned platforms, in existing or new settings, Phase One's solutions are diverse. Used on UAVs for surveying and inspecting, in oblique configuration for 3D city applications or in a 4-band setting for agriculture and environmental monitoring and research, the company's products and solutions are designed to answer the needs of the most demanding projects.

industrial.phaseone.com I industrial@phaseone.com

Racurs

Racurs has a 26-year history of success on the Russian and worldwide geoinformatics markets. Since its foundation in 1993, the company has been developing innovative mapping software for processing aerial, space and terrestrial imagery. The flagship product PHOTOMOD was one of the first digital photogrammetric systems on the market designed to work on off-the-shelf PCs. Today, PHOTOMOD is the most popular digital photogrammetric software in Russia and well known all over the world. PHOTOMOD provides a closed production cycle and involves the generation of many kinds of value-added products: digital maps, DEMs, orthomosaics and 3D vectors, all without the use of third-party solutions. The main Racurs business activities are:

- PHOTOMOD development and further integration into Russian and international markets
- Photogrammetric production services using both airborne and satellite imagery
- R&D in the field of RSD processing software, methods, and algorithms
- Remote-sensing data distribution in Russia and the CIS countries.

Racurs has been an ISPRS Sustaining Member since 1998 and a Special Committee I2AC Member since 2016. Racurs organizes the well-known International Scientific and Technical Conference 'From imagery to digital reality: ERS & photogrammetry'.

https://racurs.ru I +7 (495) 720-51-27 I info@racurs.ru

RIEGL

RIEGL is a leading international provider of cutting-edge airborne, mobile, terrestrial, bathymetric and unmanned laser scanning technology for a wide range of applications in surveying. In addition to the headquarters in Horn, Austria – where research & development as well as production are also located – RIEGL provides sales, support and service through its offices in Vienna and Salzburg, RIEGL subsidiaries in the USA, Japan, Australia and China, and its worldwide network of distribution partners. RIEGL has been producing Lidar systems commercially since 1978 and focuses on pulsed time-of-flight laser radar technology in multiple wavelengths. RIEGL's core 'smart waveform' technologies provide pure digital Lidar signal processing, unique methodologies for resolving range ambiguities, multiple targets per laser shots, optimum distribution of measurements, calibrated amplitudes and reflectance estimates, as well as the seamless integration and calibration of systems. RIEGL's various 3D scanners offer a wide array of performance characteristics. The professional advice of the RIEGL experts ensures that each customer finds the optimum solution for their specific applications. From initial purchase to system integration as well as training and support, RIEGL stands out as an industry leader.

www.riegl.com I +43 2982 4211 I office@riegl.com

Satlab Geosolutions

Satlab Geosolutions is a Swedish geospatial solution company with offices around the world. Founded by a group of passionate and pioneering engineers with more than 40 years of experience between them, the management team is made up of veteran industry experts who value customers' needs. Focusing on research and development, Satlab offers unique hardware and software with integrated solutions, with an aim to increase productivity on-site for professional users. In the geospatial world, professionals require accurate surveying and mapping systems to build the future of tomorrow, while preserving the world that we live in. At Satlab Geosolutions, experts are creating and delivering the solutions and products with Swedish engineering and technology to ensure that professionals can rely on them in any circumstances, the moment they power them up. The company's slogan is 'Unlock your mobility'.

www.satlab.com.se I info@satlab.com.se

SBG Systems

SBG Systems is a leading supplier of inertial motion sensing solutions. The company provides a wide range of inertial solutions, from miniature to high accuracy. SBG's inertial navigation sensors deliver roll/pitch, heading and GNSS position. Combined with cutting-edge calibration techniques and advanced embedded algorithms, SBG Systems' products are ideal solutions for surveying applications whether they are aerial, marine or land based. The company has designed a new small, lightweight and low-power inertial navigation system specifically for integration into mobile mapping systems: Quanta. Thanks to the precise orientation and centimetre-level position data delivered in real time and post-processing, this direct georeferencing solution greatly reduces the need for GCPs and overlapping. Qinertia post-processing software completes the Quanta solution with a free one-year subscription. This full-featured software gives access to offline RTK corrections, and processes inertial and GNSS raw data to enhance accuracy and secure the survey. SBG Systems also offers a plug-and-play solution called Navsight. Navsight consists of an inertial measurement unit available at three different performance levels and connected to Navsight, a rugged processing unit embedding the fusion intelligence and the GNSS receiver. This solution has been designed to bring simplicity and versatility in a cost-effective package for surveying applications.

www.sbg-systems.com I +33 1 80 88 45 00 I sales@sbg-systems.com

SOUTH

With 30 years of rapid development, South Group is regarded as a dominant force in the global geoinformation society. One of its key roles is as a global supplier of total stations, electronic theodolites, GNSS receivers and all types of survey accessories. On the basis of large-scale manufacture of conventional survey equipment, the company has stepped into an era with higher-end solutions for the ever-changing needs of the geospatial community such as UAV photogrammetry, mobile laser scanning, indoor mapping navigation, railway engineering works and a variety of GIS applications. Ranked No. 1 among the Top 100 Enterprises in China's geoinformation industry, the company is committed to remaining a world-class survey equipment manufacturer and web-GIS solution provider. With more and more cutting-edge yet affordable products and solutions, the world market can benefit a great deal from this Chinese giant in terms of quality solutions and services at an international level.

www.southinstrument.com I +86-20-23380888 I mail@southsurvey.com

Teledyne Optech

Celebrating over 45 years of innovation, Teledyne Optech's high-precision Lidar sensors provide state-of-the-art solutions for airborne, marine, mobile, UAV and terrestrial mapping. Teledyne Optech's new Compact Lidar suite of products feature exceptional canopy penetration for excellent ground coverage, higher point density for superior results in corridor and power line projects, long-range performance for maximum productivity at UAS ceilings and best-in-class data precision for tight tolerance applications. New innovations in airborne Lidar include the powerful new Galaxy T2000 boasting a true 2MHz point density. Combining two Galaxy T2000 systems for a total of 4MHz in point density, the new G2 sensor system enables FLASH-like point densities with all the advantages of a linear-mode Lidar system. Designed for permanent monitoring applications, the new TLS M3 combines the measurement efficiency of Teledyne Optech's tripod-based Lidar system with a complete internal sensors package and API software. The Maverick sensor is ideal for small-vehicle and back-pack installations and leverages the same automated LMS workflow as that used for airborne operations. The Polaris terrestrial laser scanner provides land surveyors with a user-friendly workflow and long-range performance, at an unprecedented price.

www.teledyneoptech.com | VAU_inquiries@teledyneoptech.com

Trimble Geospatial

Trimble Geospatial provides solutions that facilitate high-quality, productive workflows and information exchange, driving value for a global and diverse customer base of surveyors, engineering and GIS service companies, governments, utilities and transportation authorities. Trimble's innovative technologies include integrated sensors, field applications, real-time communications and office software for processing, modelling and data analytics. Using Trimble solutions, organizations can capture the most accurate spatial data and transform it into intelligence to deliver increased productivity and improved decision-making. Whether enabling more efficient use of natural resources or enhancing the performance and lifecycle of civil infrastructure, timely and reliable geospatial information is at the core of Trimble's solutions to transform the way work is done.

https://geospatial.trimble.com

Vexcel Imaging

Developing cutting-edge digital aerial cameras and photogrammetric processing software with constant product upgrades and world-class support has made Vexcel Imaging a market leader in the geospatial arena. The industry-leading UltraCam aerial sensor portfolio covers all applications in airborne photogrammetry, from nadir to oblique to wide-area data collection. Processing of the UltraCam data is handled by the UltraMap photogrammetric software suite that offers a processing workflow for highly automated generation of exceptional-quality point clouds, DSMs, ortho imagery and 3D-textured TINs. This end-to-end technology is the basis for Vexcel's cloud-based aerial image library providing organizations with location-based insight and intelligence. Industry-leading UltraCam sensors provide up-to-date high-resolution vertical and oblique imagery along with other digital representations of the world, and precision geometry enabling AI and machine learning. The Vexcel Data Program (VDP) allows businesses and organizations to make better strategic decisions through intelligent imagery to uncover crucial location insights. VDP is already powering the Geospatial Intelligence Center (GIC), an initiative launched by the National Insurance Crime Bureau (NICB) to provide its 1,100 members with best-of-breed aerial pre-disaster and post-disaster imagery.

www.vexcel-imaging.com | +43 316 849 0660 | info@vexcel-imaging.com

Zoller + Fröhlich

Zoller + Fröhlich (Z+F) is one of the world's leaders in 2D and 3D laser measurement technology and continues to develop innovative solutions for the surveying industry. The new Z+F MapCam is used in the field of kinematic laser scanning. It collects colour information to subsequently colourize the point cloud. It was specially designed and optimized for using in combination with the Z+F PROFILER 9012. Two different versions are available: Z+F MapCam S and Z+F MapCam C. High precision in colouration with high efficiency on datasets and computing time are the key features. With the Z+F LaserControl module called SynCaT, scan data and navigation data can be processed, colourized, visualized and exported for further application.

www.zf-laser.com | +49 (0) 7522 9308-0 | info@zf-laser.com