GIM INTERNATIONAL

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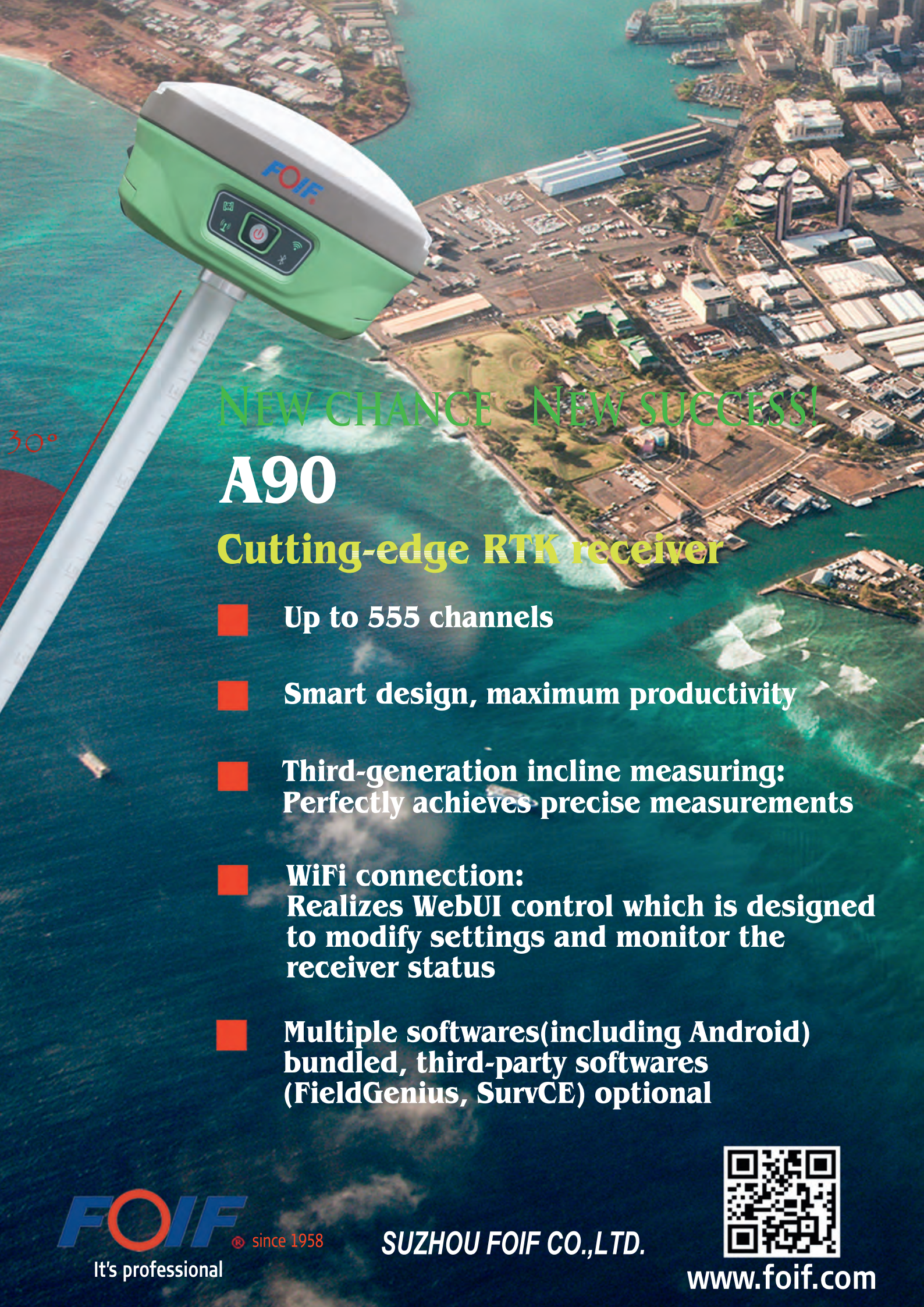
Earth Observation Data and Image Processing for High-level Humanitarian Support

An Efficient Approach for Estimating Refugee Camp Populations

DRIVING INNOVATION FOR EUROPE'S EARTH OBSERVATION PROGRAMME

UAV MAPPING OF A GREENLAND GLACIER

POINT CLOUDS FROM SMARTPHONES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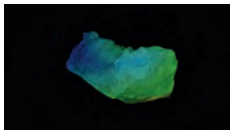

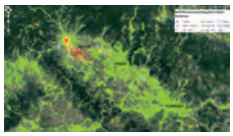

COVER STORY

Copernicus, Europe's Earth observation (EO) programme, generates ten petabytes of free EO data a year. Big data from space holds great potential for ideas and solutions in many sectors. The front cover of this issue of GIM International shows a satellite image of the Yukon Delta on the west coast of the US state of Alaska. The image contains Copernicus Sentinel data (2017) that has been processed by the European Space Agency (ESA).

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Water/Dust Rating	IP67
Shock	1.2m fall onto concrete
Handheld	
Type	HCE320
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Water/Dust Rating	IP67
Shock	1.2m fall onto concrete

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New mindset

"The geospatial business needs a new mindset, together with agile concepts in order to provide new business models for the geospatial work." One could easily miss this statement when flipping through this new edition of *GIM International*. It is tucked away towards the end of 'Bright Perspectives: Some Thoughts on the Future of the Geospatial Business', the column by Hansjörg Kutterer, president of DVW in Germany, on page 6. But I advise you to read this piece, because it is truly something to chew on with a view to the near future. Technological trends like artificial intelligence (AI), virtual reality (VR) and big 3D data – the mere fact that our whole lives are becoming digital – are shifting the landscape and giving geodata the opportunity to become crucial in all kinds of decisions related to planning and managing assets and resources. Inventing new business models is not a luxury, but a necessity. If you want to be in the driver's seat, it is hugely beneficial to be able to adjust instantly to changing technological and business environments.

Durk Haarsma, director strategy & business development

Self-surveyed cadastre builds trust

The Sustainable Development Goals (SDGs) talk about land rights for all by 2030 – so there's plenty of work to be done, especially in the developing world. Today, field data collected about cadastral boundaries can be sent to a cloud-based GIS. The community can follow the fieldwork remotely. Farmers walk the perimeters of their spatial units. They set the vertex points using an antenna. Grassroots surveyors record the observations in an app. The perimeter of the spatial unit is stored as a closed polygon. This is combined with a photo of the claimant(s), and with a photo of their proof-of-identity document(s). The perimeters identify one cadastral boundary from two sides. If those are within the tolerance ranges, it indicates agreement. The approach can use handheld antennas or something more precise, depending on people's perception. It can be done in an analogue way too. An alternative is that claimants set the boundary points in an office, overlaid on a digital or analogue image. That approach is accepted in some countries, but not in others. The professional surveyor organises both the awareness campaign and the fieldwork. The agreement on boundaries can be confirmed during a public inspection. People trust the results because they have surveyed the boundaries themselves. They accept differences with previously published parcels. They reach agreement with neighbours indirectly – both neighbours set all their boundary points individually and the results are compared. That works fine – and fast – in practice in many places, plus it is affordable because the people do the work themselves, at no cost. It builds trust between people within communities, and between citizens and governments. Citizens are happy if government representatives show their face in the field to bring land titles. Trust is the foundation for development, and taxation is far more accepted if based on self-collected data.

Christiaan Lemmen, contributing editor

Solving societal problems

Our planet is facing many complex challenges right now. Climate change is causing floods and – at the other extreme – droughts. Droughts lead to political unrest and conflicts, a potent combination which triggers migration. People forced to leave their homes due to natural disasters or war often end up in camps packed with thousands of other refugees. Although circumstances are far from optimal, they receive aid from non-governmental organisations (NGOs) who at least guarantee that they have food, shelter and medical assistance. A very interesting article on page 40 of this issue of *GIM International* teaches us how high-resolution satellite Earth observation data and image processing software are key ingredients for estimating camp populations, providing essential information so that NGOs can manage their operations as efficiently and effectively as possible. Another interesting read that also touches on this topic is 'Geomatics Helps Relief to Reach More Refugees', which can be found on our website (www.gim-international.com). The article zooms in on the role of GPS, GIS and UAVs in humanitarian aid, and this insight into how the power of geo-ICT is used to help communities of refugees is a truly inspiring story.

Wim van Wegen, content manager

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Bright Perspectives: Some Thoughts on the Future of the Geospatial Business

Digital transformation of our professional and personal lives is a megatrend which is stimulated by technological innovation and driven by the needs of economy and society. Politics and administration are working on legislation, infrastructure and services required to organise and promote digital applications of any kind. Industry and commercial service providers are developing attractive business models which make use of the new opportunities.

By its very nature, geospatial information plays a key role in this process as we live in a 3D world and 'everything happens somewhere'. During the last two decades, significant advances in technological development have paved the way to comprehensive digitalisation of our world. In the geospatial business this is closely linked with the broad use of new techniques in the acquisition, management, processing, visualisation and use of digital geospatial data. Rapid scanning devices and digital imagery, increasingly mounted on unmanned aerial vehicles (UAVs), provide huge amounts of 3D data ('big 3D data') almost instantaneously. This data needs to be efficiently organised, processed, distributed and effectively used in order to exploit its full potential.

ABOUT THE AUTHOR

Hansjörg Kutterer is director general of the German National Mapping Agency (BKG). He received his Dipl.-Ing. and doctoral degrees in geodesy from the University of Karlsruhe. After 20 years of an academic career he moved to BKG in 2011. He holds (and has held) positions in various committees and organisations such as vice president of EuroGeographics, and is president of the German Society for Geodesy, Geoinformation and Land Management (DVW).

✉ hansjoerg.kutterer@bkg.bund.de

Smart technologies are key for meeting these challenges as they comprise data acquisition and integration, comprehensive connectivity of objects and cloud computing. On the one hand this refers to miniaturised devices such as smartphones or tablet computers which allow ubiquitous access to information for use in a wide range of applications. On the other, and as illustrative and reasonably complex application examples, smart cities, villages or ports are urban, rural or industrial areas that use smart technology to collect and supply geospatial information which is needed to manage assets and resources efficiently. Geospatial referencing – both outdoors and indoors based on wireless techniques such as GNSS or Wi-Fi – provides the immediate link to the digital geospatial world of objects and users alike.

The digital twins of our 3D environment enriched with georeferenced factual or specialist information are provided for use in a multitude of applications such as urban or rural planning, structural monitoring as well as hazard mitigation and civil protection. Advanced technological developments lower the entry threshold to digital geospatial applications for non-expert users. This holds true particularly for artificial intelligence (AI) techniques which allow automation of standard processes using image analysis and pattern recognition. There is a multitude of applications, such as smart farming in agriculture, road surface inspection in quality control or autonomous navigation in mobility. Visualisation of geospatial data is increasingly based on high-resolution photorealistic virtual reality (VR) applications benefiting from cutting-edge imaging and scanning techniques. This is enhanced by augmented reality (AR) applications that provide direct access to site-specific factual information which is merged with the 3D digital representation of the environment in a geographically consistent way. As an evident progress, decisions are informed by the latest available geospatial data represented in visual scenarios.

The fundamental 'digital by default' requirement in geospatial applications leads to a disruptive concept of work in the geospatial business in terms of working basis, processes and results: 'Work 4.0'. Accordingly, induced by the developments mentioned above, a new mindset is needed together with agile concepts in order to provide new business models for the geospatial work. As this process is still at its very beginning, the geospatial community is advised to actively discuss and promote it.

In conclusion, a visit to Intergeo 2018 is an excellent opportunity to find out more about the megatrend of digital transformation and the bright perspectives for the geospatial business. Intergeo is the world's largest conference and trade fair for geodesy, geoinformation and land management and hence an outstanding professional platform, forum and networking opportunity. The 2018 edition will be held in Frankfurt/Main, Germany, from 16 to 18 October. ◀

Cyril Halter Becomes New COO of Wingtra

Cyril Halter.

Wingtra, a Swiss manufacturer of professional vertical take-off and landing (VTOL) drones, has appointed Cyril Halter as its new COO. Cyril will be taking over Wingtra's operations with a focus on the industrialisation and the ramp-up of production to enable forecasted triple-digit growth over the next years. Commenting on his new position, Cyril said that Wingtra inspired him with its technologically outstanding VTOL system and the passionate team behind the company's wheel. He stated he has followed their work for a long time and believes that Wingtra has a huge potential to grow even further. Wingtra's successful market entry last year, fundraising and rapid international growth were a clear incentive for him to get on board and push the industrialisation process.

▸ **https://bit.ly/2K6CzkN**

Trimble Launches New Field Solutions for Land and Construction Surveying

Trimble has introduced the Trimble TSC7 controller, a new field solution for land and civil construction surveyors. The TSC7, combined with specialised software, defines the next generation of data collection and computing for mobile workers. The Trimble TSC7 brings powerful enhancements to the field and was designed based on customer feedback. It provides a tablet experience with a physical keyboard and a sunlight-readable 7-inch touchscreen that supports pinch, tap and slide gestures. Users can interact with the TSC7 intuitively, easily zooming, panning and selecting items on the large touchscreen. Front- and rear-facing cameras allow users to videoconference their office from the field for on-the-job support, and capture high-definition videos and images that provide valuable context to their data and clients.

▸ **https://bit.ly/2JjiA1i**

Application of the Trimble TSC7.

European Space Agency Upgrades to OGC Strategic Membership

The European Space Agency (ESA) has raised its Open Geospatial Consortium (OGC) membership level from Technical to Strategic – OGC's highest level of membership. As a Strategic Member, ESA will participate in OGC's Planning Committee to provide leadership through the exploration of market and technology trends to ensure that OGC's activities remain effective and agile in a changing technology environment. ESA will also participate in final approval decisions for all OGC standards and nominations to the Board of Directors. Further, ESA will work with other Strategic Members as part of an OGC Strategic Member Advisory Committee to help identify and advance high-priority areas of interoperability concern.

▸ **https://bit.ly/2HmsRgB**

senseFly Appoints New CEO

Gilles Labossière.

senseFly, a Switzerland-based provider of professional mapping drones and a commercial drone subsidiary of Parrot Group, has confirmed the appointment of its new CEO, Gilles Labossière. Labossière is the executive vice president and COO of Parrot Group, a position he will continue to hold as he focuses on boosting senseFly's growth in the professional drone space. Labossière said he is excited by the chance to build upon senseFly's leading position in the fixed-wing UAV market. As CEO, his focus will be on continuing to grow the company's share of the professional drone market and on leveraging the team's outstanding geospatial and agricultural expertise across the wider Parrot Group. senseFly will, in turn, benefit from the ongoing strengthening of the group's Business Solutions portfolio, which comprises dedicated drone hardware, software and services.

▸ **https://bit.ly/2vIVWxi**

Racurs Honoured with Prestigious Russian Award

Honoured with the Feodosy Nikolaevich Krasovsky Award.

On 5 March 2018, the central board of the Russian Society of Geodesy, Cartography and Land Management chose Racurs as the recipient of the Feodosy Nikolaevich Krasovsky Award. The accolade, which recognises the best scientific and technical developments in geodesy and cartography, was awarded to the company's founders – Victor Adrov, Alexander Chekurin, Andrey Sechin and Alexander Smirnov – for the creation of the PHOTOMOD digital photogrammetric system.

Back in 1993 the creators/developers of PHOTOMOD offered the market a digital photogrammetric system for personal computers. Almost 25 years have passed since then, and today PHOTOMOD is not only the most popular photogrammetric system in Russia but is also used successfully in 80 countries around the world.

▸ **https://bit.ly/2qUQKI8**

New SR3 Underground Laser Scanner from Maptek

Maptek has launched its new I-Site SR3 600m-range laser scanner, developed to become the mine measurement standard for underground operations, both for general underground survey and detailed geological face mapping. The SR3 follows the extra-long-range XR3 and long-range LR3, which came onto the market in 2017. The R3 series is 30% smaller and 25% lighter, with 2.5 times faster data acquisition than the earlier I-Site 8000 scanners. Survey teams can work faster and smarter, with confidence that accurate, current topographic and volumetric data is guiding mine planning and geotechnical investigations. The new laser scanner weighs 9.6kg and is accurate to 4mm. This enables surveyors to measure stopes, drives and tunnels with ease. High-resolution laser scans collect detailed data for geological and geotechnical face mapping. High-fidelity imagery captured underground at the same time as scanning provides context and support for analysis and communication.

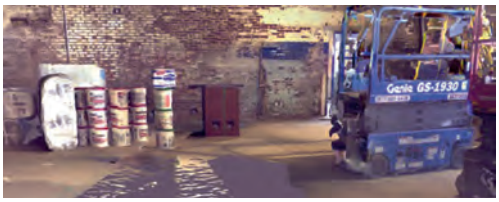
▸ **https://bit.ly/2HmN85A**

Maptek I-Site SR3 laser scanner.

Rapid 3D Reality Capture Solution with Integrated Photorealism

Kaarta has made another leap forward in the advance of rapid 3D reality capture with the launch of Kaarta Reality Layer. This augments its already geometrically accurate and robust spatial capture with the richness of colour information, running the gamut from point cloud to surface mesh and from RGB point cloud to rich photorealistic model. These integrated colourisation capabilities make it possible to quickly capture and process just the level of colour detail needed for a wide range of built-environment applications, from planning and design to construction, ongoing operations and maintenance. In addition, the ability to automatically generate photorealistic 3D models promises to make a host of new mixed-reality applications possible.

▸ **https://bit.ly/2Hnj1Ln**



Reality Layer photorealistic 3D model of a construction site.

New Miniature INS Module with External GNSS Receiver

Xsens has expanded its MTi product portfolio by introducing the MTi-7, a miniature inertial navigation system (INS) module which uses input from an external GNSS receiver to provide an accurate, real-time position, velocity and orientation data stream. The MTi-7 module, which has a compact 12mm x 12mm footprint and weighs less than 1g, consumes under 100mW, making it ideal for use in space- and power-constrained devices such as unmanned aerial vehicles (UAVs) as well as autonomous or remote-controlled mapping and imaging equipment.

▸ **https://bit.ly/2HTZZJq**

Xsens MTi-7 module.

Klau Geomatics Launches PPK Positioning Kits for UAVs in Japan

SkyLink will distribute KlauPPK kits in Japan.

Australian technology company Klau Geomatics has announced the launch of its KlauPPK kits in Japan in partnership with SkyLink to distribute to the Japanese surveying, engineering and construction markets. The KlauPPK technology enables users to create highly accurate, reliable and repeatable mapping data without ground control points, transforming the capabilities of drones for construction, infrastructure, mining, telecommunications and other sectors. SkyLink, the leading DJI distributor in Japan, will be importing and supporting the system for Japanese customers. The company has independently verified the accuracy of KlauPPK on various DJI drones carrying cameras from DJI, Sony and Phase One.

▸ **https://bit.ly/2HUD68H**

Intergeo 2018: Geoinformation as the DNA of Digitalisation

Digital through and through, and it's all thanks to geoinformation. True to its slogan 'Geoinformation – the DNA of digitalisation', Intergeo has announced a pioneering conference programme. As the live platform for this truly dynamic high-tech sector, Intergeo is showcasing top speakers and cutting-edge topics in digitalisation and its technologies – from cloud solutions and artificial intelligence to the applications and processes of virtual and augmented reality. This year's Intergeo event is focusing on the digital transformation of business and society. From 16 to 18 October 2018, the Intergeo conference in Frankfurt will contextualise key developments and scenarios for a geoinformation-based digital future.

▸ **https://bit.ly/2HquDJw**

Intergeo 2018 will take place in Frankfurt.

Phase One Industrial and Aerialtronics Enter into Partnership

Phase One Industrial, a provider of medium-format metric cameras and imaging solutions for aerial applications, has signed an agreement with Aerialtronics DV, a developer of end-to-end aerial data capture solutions. Together, these companies aim to open up new opportunities in high-accuracy mapping and inspection markets with their high-end products. Under this agreement, the companies will cooperate to deliver aerial solutions comprising Aerialtronics DV Altura Zenith UAV integrated solutions with Phase One Industrial's medium-format aerial camera systems, Schneider-Kreuznach and Rodenstock lenses and related software solutions to clients worldwide.

▸ https://bit.ly/2HLaO2Y

Aerialtronics Altura Zenith UAV.

Copernicus Masters: An Important Innovation Driver for Earth Observation

Copernicus is Europe's most ambitious Earth observation (EO) programme and provides full free and open access to data for the development of applications in a wide variety of domains. The Copernicus Masters awards recognise applications and ideas that are using Copernicus data to tackle important challenges faced by business and society. Until 30 June, Copernicus Masters participants can submit their innovative EO ideas for solving any of the 16 challenges offered by the largest number of world-class partners since the competition started. It is estimated that investments in the programme will increase to €7.5 billion by 2020, while the economic benefit is expected to double in value. Every euro invested in Copernicus activities by public authorities results in a €1.4 benefit to the whole economy.

▸ https://bit.ly/2HoHmfJ

Satellite imagery from TripleSat.

Airbus Strengthens Earth Observation Portfolio with TripleSat Satellite Data

Airbus has entered into an agreement with Twenty First Century Aerospace Technology Co. Ltd (21AT), a Chinese commercial satellite operator, for the distribution of the images acquired by its TripleSat constellation. TripleSat consists of three identical high-resolution Earth observation satellites set 120° apart, travelling around the same orbit. They offer daily monitoring of any place on Earth, revealing details as small as 80 centimetres. The satellites were specifically designed to map large-area coverage and will therefore reinforce the Pléiades and SPOT satellite capacities, improving access to information in critical situations.

▸ https://bit.ly/2vGAKbd

NavVis Introduces New Indoor Mobile Mapping System

NavVis M6.

NavVis, a Germany-based specialist in mobile indoor mapping, visualisation and navigation, has launched the M6, a next-generation indoor mobile mapping system that aims to overcome the scalability and data-quality constraints of today's reality capture technology. Surveyors and AEC professionals can now use reality capture technology for demanding applications, such as large-scale indoor mapping projects, factory planning, creating and updating as-built BIM models and construction monitoring. The NavVis M6 is an all-in-one system that captures 360-degree immersive imagery, photorealistic point clouds, Bluetooth beacons, Wi-Fi signals and magnetic field data. The NavVis M6 features a mobile Lidar system that, according to the company, enables it to scan up to 30 times faster than stationary devices, letting users capture up to 30,000 square metres in a day. Worth some special attention is the 6D simultaneous localisation and mapping (SLAM) technology, which significantly improves the quality of data captured.

▸ https://bit.ly/2qXKdoO

Tersus Makes Strides in Surveying with David GNSS Receiver

Tersus GNSS, a leading provider of centimetre-accuracy GNSS RTK solutions, is taking surveying applications to the next level with the global launch of Tersus David, a GNSS receiver. For surveyors, the David receiver and the components create an affordable solution delivering higher-precision signal reception, integrated in a smaller and lighter package. The David GNSS receiver supports GPS L1/L2, GLONASS G1/G2 and BeiDou B1/B2. With this GNSS receiver, users can take full advantage of common platforms such as smartphones, tablets or traditional handheld modules to collect data. Coupled with an external antenna, survey app and post-processing software, the David GNSS receiver is a low-cost solution for all survey applications, including real-time RTK positioning and data collection for PPK.

Tersus David GNSS receiver.

▸ https://bit.ly/2HovCd3

Which **Societal and Technological Developments** Will Most Impact the Geospatial Industry?

To gain real insight into today's geospatial business landscape, *GIM International* regularly asks experts from some of the sector's most influential companies for their opinions. This time we zoom in on the current and future state of the geomatics market from two perspectives: societal and technological.

WHICH **SOCIETAL** DEVELOPMENTS WILL INFLUENCE YOUR SHARE OF THE GEOMATICS MARKET THE MOST IN THE COMING YEARS? HOW AND WHY?

JÜRGEN DOLD, PRESIDENT HEXAGON/LEICA GEOSYSTEMS

As population around the globe increases, we know contractors will need to be more efficient on construction sites. As more people move into cities, we know city planners will need to create smarter cities. And as more land is used for urban needs, we know farmers will need to be more productive with crop yields. Our focus is to provide 'smart digital realities' by capturing all variables in real time fused with advanced analytics and powerful visualisations. The smart digital reality is what enables the digital transformation of somewhat less than efficient systems in order to address these critical challenges.

CLINT BROWN, DIRECTOR OF PRODUCT ENGINEERING, ESRI

GIS has evolved into an essential information technology and will be at the centre of major advances in computing. Geospatial systems and expertise will be essential for our planet's future. In the past decade, GIS has been expanding far beyond the professional GIS community. With the advent of apps, people everywhere began to use online maps – the foundation for shared GIS. Almost overnight, everyone began to recognise the power of GIS as an enabling information platform for improved understanding, decision-making, efficiency, communication and collaboration. GIS provides a geospatial framework to integrate and interpret results. Over the past few decades, the mass adoption of the internet has led to a glut of information that we have come to know as big data. GIS provides a geographic context to make sense of it all – while also providing the capability and the context to analyse that data in real time.

RON BISIO, VICE PRESIDENT OF GEOSPATIAL, TRIMBLE

Geospatial information is no longer solely the domain of professionals but is evolving for the broader population. Digitalisation, mobility and global connectivity are increasing the importance of geospatial data. Some of the world's top thinkers believe artificial intelligence (AI) will change everything in society by enabling machines to interpret and respond to our environment more quickly than the human mind. One example of societal benefit comes from using AI to interpret data collected in real time from transportation infrastructure so roadside damage can be detected and corrected before it puts public safety at risk. Innovations in the professional market are leading to innovations in the consumer market as well, including autonomous vehicles, drones and virtual reality systems.

VICTOR ADROV, CEO, RACURS

Nowadays, methods and technologies of spatial data acquisition as well as new business models like software as a service (SaaS) are becoming increasingly available for non-professionals. For instance, the growing UAS market generates many start-ups which offer aerial survey and UAS data processing. Such businesses need user-friendly and inexpensive solutions, so the target for software developers is to decrease prices and increase possibilities. These efforts, for sure, expand the market opportunities.

CHRISTIAN SEVCIK, MANAGER FOR STRATEGIC SOFTWARE ALLIANCES, RIEGL

The societal development that will influence and shape our brand the most over the coming years is Lidar becoming more widely known and used throughout the world. As Lidar becomes more of a 'household name', so to speak, and people generally gain more knowledge of what it is, what it does, what it is capable of and how it affects their daily life, that will really give us a larger share and greater visibility in the geomatics market and in the public eye.

AIDAN MERCER, INDUSTRY MARKETING DIRECTOR FOR AEC, BENTLEY

The world's population is growing by a staggering 200,000 people every day. By 2025, the global population is expected to reach over eight billion people and by 2040 this number could hit nine billion. Experts predict such rapid growth will increase the population to a massive 11 billion people by the turn of the century. Urban expansion is driving new ways of working and a heavy reliance on technology. We've made great progress with our reality modelling applications, in particular ContextCapture CONNECT Edition, which rapidly captures existing site conditions through digital photographs or laser scanning data. This is helping urban planners develop space for new housing, develop new roadways, expand water capacity and understand how to deal with future growth, to name but a few use cases, because of its ability to capture assets or entire cities. It is slowly becoming the must-have technology and we are excited about the contribution it provides to society.

IAN STILGOE, VICE PRESIDENT OF GEOPOSITIONING, TOPCON EUROPE POSITIONING

According to Standard and Poors, there is a US $36 trillion deficit between the amount we need to spend on infrastructure globally and the amount of capacity currently available within the industry. Increasing urbanisation, growing economies and aging post-war infrastructure in Europe mean there are huge demands to create and maintain infrastructure. We believe we're at the crunch point where as an industry we need to work collaboratively to be able to meet this shortfall between capacity and demand. It's a key focus for our business, as we work to create and help our clients implement technology to increase efficiency and maximise capacity.

CHASE FLY, GEOSPATIAL PRODUCT MANAGER, DELAIR

Drones, and more importantly the huge data generated by drones, will enable companies to digitise their physical assets, which will provide exciting new insights into what happens in the world around us. Combining these exciting new insights and huge datasets with big data analysis and machine learning techniques will also open new opportunities in the area of predictive solutions. This is likely to lead to a future where physical objects and infrastructure is built to last longer and could also enable a wealth of new business models around servicing physical objects. Delair's UAVs lend themselves well to large-area mapping projects and flying BVLOS, and a 3G/4G communication link is used as one solution for this. The expansion of cellular data network coverage in rural and unpopulated areas throughout the world, where companies frequently have assets they want to map, will enhance the value of the technology Delair is building into its drones.

WHICH **TECHNOLOGICAL** DEVELOPMENTS WILL AFFECT YOUR PRODUCT/ SERVICE PORTFOLIO THE MOST IN THE COMING YEARS?

JÜRGEN DOLD, PRESIDENT HEXAGON/LEICA GEOSYSTEMS

Edge computing is quickly becoming a guiding development for our solutions. From laser scanning to machine control, we are working to make processing the reality captured data happen more in real time and in the field, to dramatically increase efficiencies. Although we've been on this path of giving users the ability to do more in the field for some years, I am convinced that our customers will recognise the advantage of edge computing in the future.

RON BISIO, VICE PRESIDENT OF GEOSPATIAL, TRIMBLE

All of the key IT trends in the world today require precise data. Autonomous vehicles, mixed reality and sensor fusion are just a few of the data-driven technological advances shaping geospatial innovation. Autonomous vehicle development is elevating the geospatial industry's role in capturing roadside assets and accurate data. Emerging mixed-reality solutions are poised to transform the industry by making it easy to place and align digital assets in the physical environment so that road crews, for example, can dig with greater assurance they won't hit utilities. By merging multiple sensor types into unified data collection and analysis tools we can maximise their collective benefits while minimising their collective weaknesses. Innovation will also focus on collaborative environments such as Trimble Connect, which unifies data from different hardware and software solutions so multiple stakeholders can work together with disparate tools.

CLINT BROWN, DIRECTOR OF PRODUCT ENGINEERING, ESRI

Cloud computing is enabling an instrumented world where computing can be harnessed to analyse and respond to virtually any issue. We envision that GIS will be recognised as a key enabling information technology for most big IT initiatives in the coming years – essentially integrating location intelligence into large to massive enterprise and cloud-based systems and hybrid systems. GIS provides a comprehensive approach for working with virtually all information sources. Further, the data in each individual organisational GIS is being brought together virtually to create a comprehensive GIS of the world in the cloud. Each of us are creating and maintaining our own layers, and because all GIS layers register onto the Earth, we are also contributing to and assembling a larger societal GIS for our planet – our individual GIS systems of record are being integrated, extended and deployed as systems for insight as well as communal systems for engagement.

AIDAN MERCER, INDUSTRY MARKETING DIRECTOR FOR AEC, BENTLEY

One of the most exciting developments at Bentley are Microsoft Azure-based cloud services that enable our users to achieve better project delivery and asset performance. This is known as our CONNECT Edition portfolio. This next generation of software is helping firms in 'going digital' – this is the ability for data residing in applications to interact with data in other applications in a fully digital environment, one we may describe as 'connected'. The benefits are unbounded, e.g. performance improvements, scalability, efficiency gains, accessibility and more. The ability for our users to access on-premise or cloud-based services gives them choices and flexibility as well as exciting new features like '365 Services' and a range of CONNECT Edition applications.

VICTOR ADROV, CEO, RACURS

Racurs' main business activities are PHOTOMOD development and photogrammetric production services, so evolution of remote sensing technologies – both aerial and spaceborne – and computing facilities have the most influence on our business. We rise to this challenge with a high level of automation and distributed processing for main photogrammetric operations. Furthermore, cloud technologies seem promising, which is why we offer our solutions in several cloud services.

CHASE FLY, GEOSPATIAL PRODUCT MANAGER, DELAIR

Key technological developments that will impact Delair solutions in the coming years include deep learning, Internet of Things (IoT), telecommunications and cloud technology. Delair provides hardware and software products that form complete aerial data acquisition and analysis solutions which deliver business intelligence. Deep learning algorithms enable Delair to continuously improve the quality and quantity of data analytics which are applied to aerial imagery, such as change detection. Delair's UAVs (drones) are being equipped with advanced telecommunications systems that include cellular connectivity and onboard data processing capabilities in order to extend the range of drones to support beyond visual line of sight (BVLOS) flights and open the door to IoT applications.

CHRISTIAN SEVCIK, MANAGER FOR STRATEGIC SOFTWARE ALLIANCES, RIEGL

Some of the technological developments that will affect our product/service portfolio and business the most over the coming years are advances such as automation, robotics, driverless vehicles, the cloud, and the Internet of Things, to name but a few. While these may not affect our business with a direct impact, we do feel the effects of them in the industry and are watching them starting to shape how the industry works and new products that are being introduced to the market. We are seeing how these new pushes of technology are working their way into affecting new products and services that we may end up offering to the market, if they are needed.

IAN STILGOE, VICE PRESIDENT OF GEOPOSITIONING, TOPCON EUROPE POSITIONING

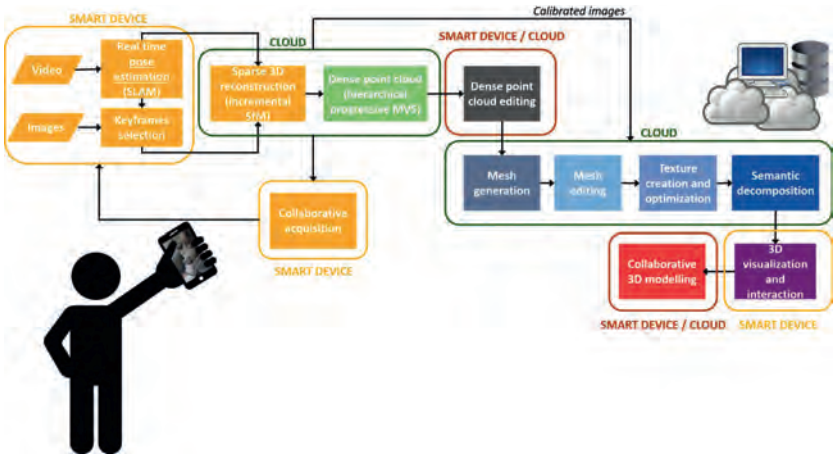
Trends that are going mainstream in consumer technology, such as the Internet of Things (IOT), are impacting the way we work on site and in the office on construction projects. This pace of change is widening our user base and speeding up the adoption of automation and connectivity across the whole workflow – from the site to the office, and from excavating initial foundations to asset monitoring. This is helping our customers to work smarter – meaning real-time communication between all stakeholders involved on a project as well as less waste and less time-consuming processes. The fast pace of technological development has shaped the way we work with our customers. We have developed long-standing relationships with the likes of Autodesk, Bentley and Intel. We are always open to working with the right partner to complement our hardware and software offering. This helps to ensure we have the best package of expertise and technology for the specific requirements of a project.

COLLABORATION ENABLES CHEAP AND RAPID 3D MODELLING

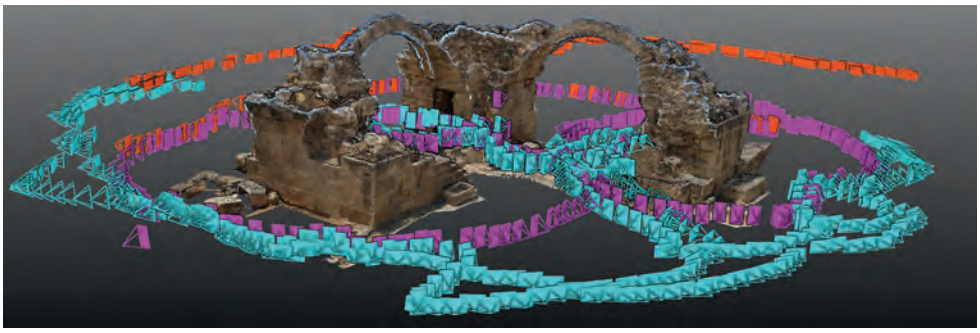
Point Clouds from **Smartphones**

Smartphones are omnipresent, and many people can no longer do without them. Smartphone cameras capture images suited for generating point clouds and 3D models. Apps running on smartphones and software running on a remote server enable easy 3D modelling from multiple images. The challenge is to train and guide laymen through a proper image capture strategy using their smartphones. The authors of this article investigated the potential use of smartphones for cheap and rapid generation of point clouds and 3D models exploiting a collaborative approach.

Today's smartphone images are higher in quality than they were a few years ago. Images and videos captured by smartphone cameras can be processed on a remote server to create dense and accurate point clouds. This puts easy 3D modelling from multiple smartphone images within reach for applications such as 3D documentation and modelling in cultural heritage and the creative industry. Disaster management may also benefit from this approach for documenting, monitoring and inspecting hazardous environments.



▲ *Figure 1: REPLICATE pipeline jointly done on smartphones and the HPC remote server.*



▲ *Figure 2: RGB dense point cloud of Saranta Kolones; coloured pyramids indicate position and orientation of the keyframes.*

'REPLICATE' PROJECT

The popularity of 3D modelling from images has soared in many applications over the last decade, mainly because of the availability of high-quality, affordable photographic tools and easy-to-use software enabling automatic 3D reconstruction. The creation of 3D content has become common for professionals and the general public alike because of the widespread availability of digital media, 3D printing, and extended reality. For example, apps that generate 3D models (e.g. ItSeez3D, TRNIO) on smartphones can nowadays be downloaded from app stores. Thanks to faster communications and better network coverage, alternative solutions are exploring how to effectively split the digitisation process between the smartphone and a high-performance computing (HPC) remote server. The images or videos are captured by smartphones while the heavy computation required by SfM, DIM and meshing is done on the remote server (Figure 1). Next, the 3D model is accessible through the smartphone.

TODAY'S SMARTPHONE APPS IMPLEMENT SFM, DIM AND MESHING FOR 3D MODELS

	# videos	Smartphone	Resolution (pixel)	# keyframes	Smartphone orientation
Saranta Kolones	3	Huawei P9	1920x1080	152/154/210	Landscape & Portrait
	4	OnePlus One	1920x1080	117/105/59/44	Portrait
	3	Samsung S6	3840x20160	84/57/56	Landscape & Portrait
Piazza Duomo	1	LG Nexus 5X	1920x1080	64	Landscape & Portrait
	1	Samsung Galaxy Alpha	640x480	91	Landscape & Portrait
	1	SonyZ5	1920x1080	74	Landscape
Caffe Italia	1	LG Nexus 5X	1920x1080	175	Landscape & Portrait
	1	Samsung Galaxy Alpha	640x480	218	Landscape & Portrait
	1	SonyZ5	1920x1080	107	Landscape & Portrait

▲ *Table 1: Main characteristics of the images captured at the three test sites.*

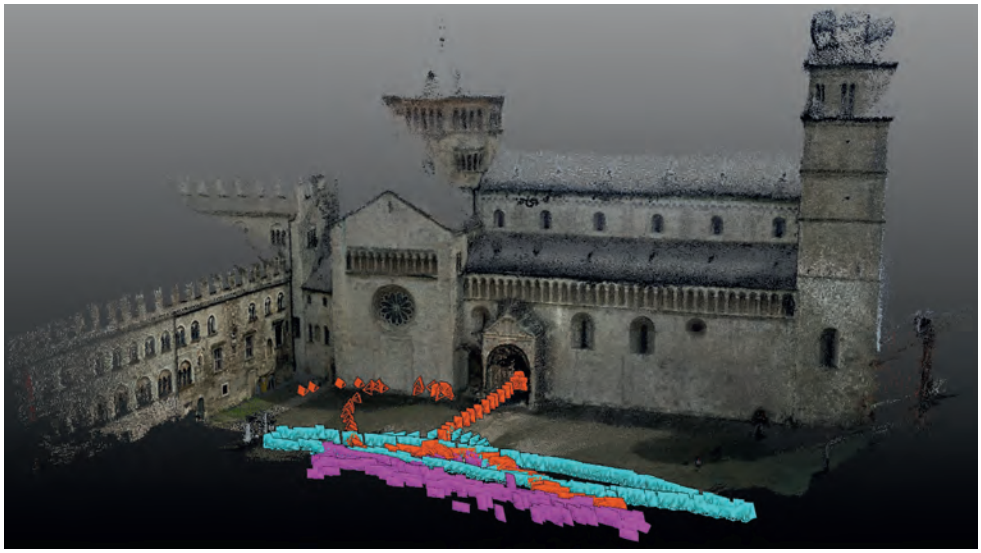
This idea of such a hybrid 3D modelling pipeline is what is scrutinised in the EU H2020 REPLICATE project. The research focuses on guiding multiple smartphone users, called 'replicators', through the image capture stage, the editing of the 3D model and its conversion into 3D media content.

FROM VIDEO STREAM TO 3D MODEL

Smartphone users can capture images individually or in groups, either at the same time or at different moments. Authorised replicators can use an app – such as Replicorder, developed by the authors – to extract and select keyframes and then upload them together with the GNSS position and acceleration data to the remote server. Keyframes are selected based on frame quality, such as sharpness, and overlap with previous frames. The overlap is estimated from the number of newly extracted and matched feature points with respect to the previously selected frames. To avoid gaps, the time span between two keyframes, regardless of their quality, should not exceed a certain time interval. On the server, first an incremental SfM algorithm is applied on the overlapping frames to process images captured by multiple individuals at different times. The sparse point cloud, processed at the server, can be displayed on the smartphone during frame acquisition. Newly uploaded keyframes are matched with keyframes already used for reconstruction. When the frame acquisition is completed, a global bundle adjustment (BA) is executed to refine the camera parameters and sparse point cloud. Next, DIM is carried out to build a dense point cloud from the sparse cloud imposing photoconsistency constraints across pairs of frames. All users can simultaneously visualise the progress of the 3D modelling in a preview window in the smartphone app. Users can also interact with the 3D modelling session via a web page.

TESTS

Six off-the-shelf Android smartphones captured single or multiple video streams (Table 1) of three cultural heritage sites. Each site was captured by three smartphones by



▲ *Figure 3: RGB dense point cloud of Piazza Duomo; coloured pyramids indicate position and orientation of the keyframes.*

▲ *Figure 4: RGB dense point cloud of Caffe Italia; coloured pyramids indicate position and orientation of the keyframes.*

different users to simulate a collaborative 3D documentation approach. The first site, the 'Saranta Kolones' monument at Paphos, Cyprus, measuring about 16m x 16m x 5m, is on the UNESCO World Heritage list. The dimensions and complexity are major challenges. The videos were taken throughout the day resulting in varying lighting conditions (Figure 2). The second site was the north-facing façade of the cathedral on 'Piazza Duomo' in Trento, Italy, which has a length of 100m and a height of 30m (Figure 3). The third site was the south-facing façade of a painted building measuring 30m x 15m and housing 'Caffe Italia' in Trento. These sites were simultaneously captured by three replicators (Figures 2 to 4). Challenges of these sites were the flat geometry of the facades and the presence of people, cars, trucks and other moving objects.

CHALLENGES WERE THE PRESENCE OF PEOPLE, CARS, TRUCKS AND OTHER MOVING OBJECTS

RESULTS

The metric potentialities of the pipeline were examined by comparing the dense point clouds with reference data acquired with professional digital single lens reflex (DSLR) cameras equipped with fixed focal length lenses and processed with state-of-the-art commercial software. For the 'Saranta Kolones' dataset, 176 images were captured with the DSLR; it was possible to achieve a final root mean square (RMS) error better than 5mm using 20 checkpoints. For the 'Piazza Duomo' and 'Caffe Italia', 359 images were captured; comparison with 18 checkpoints resulted in an RMS error better than 10mm. Before comparison, noisy elements were removed from the point clouds generated with REPLICATE and then aligned to the reference data in a local reference system, through the iterative closest point (ICP) algorithm with scale factor registration method (CloudCompare). The comparison showed that the global geometry of the structures features deviations up to ten times the average point cloud resolution, respectively 5mm, 15mm and 10mm for the three datasets, making the proposed approach suitable for 3D documentation and modelling for the creative industry.

CONCLUDING REMARKS

You are invited to access the datasets of the three test sites, including reference data, through http://tev.fbk.eu/collaborative3D.

ACKNOWLEDGMENTS

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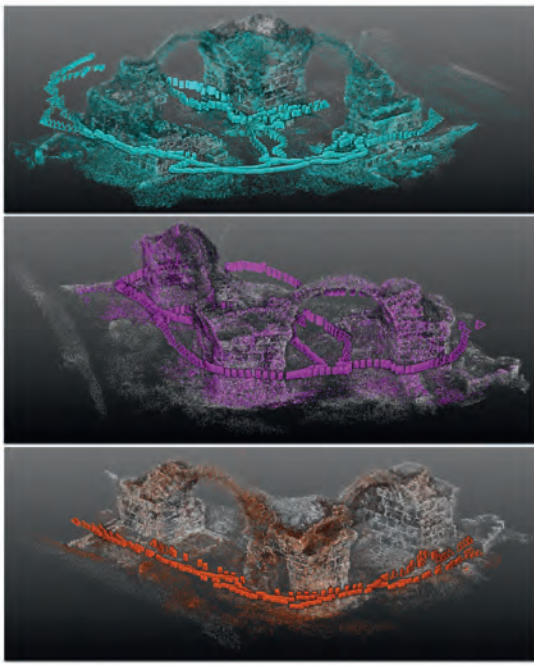

Figure 5: Three sparse point clouds of Saranta Kolones (coloured) generated from the three smartphones; grey inidcates the entire point cloud.

FURTHER READING

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CAVITY MAPPING ABOVE COLLAPSED TUNNEL

Underground 3D Scanning in Bhutan

Surveying cavities in underground excavation projects can be difficult and dangerous. The collapse of a roof inside the main access tunnel at a hydroelectric dam construction site in Bhutan resulted in loss of life and a significant delay in progress. Project participants could not move forward with the tunnel work until they could ascertain the size and condition of the cavity that remained above the caved-in debris blocking the chamber. An Indian technology application company deployed a laser scanner specially designed for cavity measurement to accurately determine the volume and dimension of the inaccessible space.

▲ *The ceiling in the main tunnel collapsed, completely blocking the tunnel and forming a cavity of unknown size and shape above.*

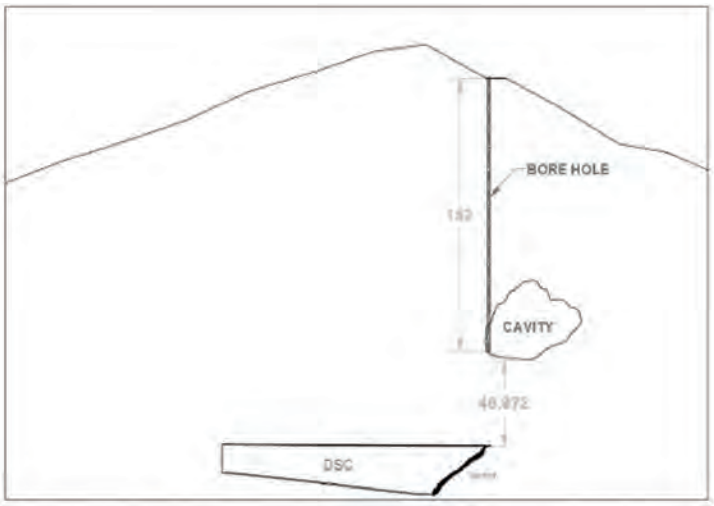
In 2008, the governments of Bhutan and India committed to working jointly on the development of a multi-billion-dollar hydroelectric project in Bhutan's Punatsangchhu region, along the river of the same name. With an original completion date of 2020, the entire endeavour would generate 10,000MW of power and supply electricity to millions of homes in Bhutan and India.

The two governments set up the PHPA, an autonomous body involving organisations from both countries, to work on the massive undertaking. The centrepiece of the second phase of the project (called Punatsangchhu-II or 'PHPA-II') would be a dam of 86 metres high and 213.5 metres wide at the top. A series of tunnels, desilting chambers, surge and pressure shafts and an underground power station would be constructed, extending several kilometres from the dam site.

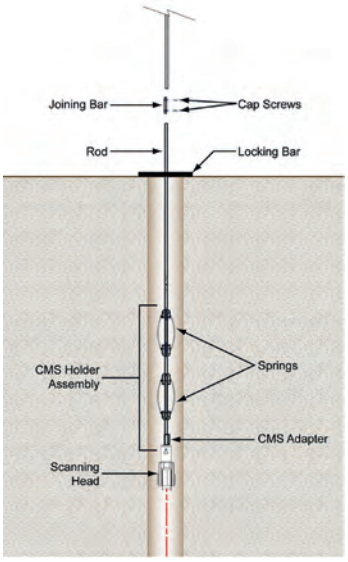
A DEADLY COLLAPSE

Excavation of a downstream surge chamber in the power station complex encountered a subterranean shear zone which resulted in a roof collapse in the main tunnel, leaving it completely blocked. This delayed the project for 1.5 years while PHPA evaluated the risk and determined how to proceed. The unplanned postponement created cost overruns and disruption to the proposed start of power delivery to customers.

The problem was a lack of information about the cavity formed by the collapse of debris



▲ *Diagram showing the relative locations of the borehole and cavity.*



▲ *The vertical insertion package (VIP) keeps the CMS steady and centred as it is lowered into a vertical borehole.*

down into the tunnel. Before proceeding with excavation of the rubble, PHPA wanted to survey the precise location of the cavity, measure its height, width and length, and determine the overall volume of the space. In addition, project engineers hoped to gain details of the structural stability of the void area. This information would assist PHPA in evaluating the risk of digging into the soil and rock blocking the tunnel. Having already experienced loss of life in the workforce, participants feared an additional cave-in and landslide would occur if the situation was approached incorrectly.

IDENTIFIED CHALLENGES

PHPA retained the services of Ansari Precision Instruments Private Limited (APIPL), part of the ROTER Group of Companies, established since 1936 in India. With a core focus on the surveying of land, mines and irrigation networks, APIPL is known for its expertise in utilising the latest in high-tech surveying and mapping products. The company evaluated the options for surveying the interior of the deep, inaccessible cavern.

A nearly vertical 150m-long borehole with a diameter of 205mm (the widest diameter possible with the boring equipment available to PHPA) had been drilled from the exterior down into the cavity, providing some insight for PHPA. Several challenges were identified:

- The cavity was too deep to use ground penetrating radar.
- The borehole was too narrow for common laser scanners or cameras to be lowered into the space.
- The bore had not been drilled perfectly straight, making insertion of any device difficult.
- There was evidence that the interior of the bore was unconsolidated, greatly increasing the chance an instrument could become trapped once lowered into place.

DEVISING A 3D MODELLING PLAN

APIPL recognised that one viable solution for accurately surveying the space was to use the cavity monitoring system (CMS) developed by Teledyne Optech specifically to scan the interiors of underground areas too dangerous or difficult for personnel to reach. The laser scanner, which includes a built-in camera and integrated three-axis inclinometer, quickly collects thousands of points inside mines, caverns and other subterranean features to generate georeferenced 3D models and calculate their size, orientation and volume.

Fortuitously, an upgrade of the CMS instrument, the V500, had just been introduced at the time of this project with a slimmer profile (130mm) which would fit easily inside the 205mm borehole. But despite the suitability of the cavity scanner, challenges remained. Uncertainty related to possible curves in the bore, and the unconsolidated nature of its interior walls, led APIPL to determine the existing hole was too risky. A second borehole was drilled vertically into the chamber below, taking great care to keep the drilling straight. As an added precaution, the interior of the hole was lined with steel casing. These conditions would contribute to the safe insertion and extraction of the CMS V500.

PREPARING THE CMS V500 SCANNER

The surveying engineers devised a plan for deploying the scanner in a way that would capture the desired data from the cavity while also ensuring the instrument would not be lost. The first concern was the depth of the target area. At 150 metres, it was likely too deep for the device to wirelessly transmit the scan data and video data to the surface via Wi-Fi. Real-time wireless data transmission is an important capability of the CMS because wires and cables must be kept to a minimum when operating in subterranean environments, where a snag can potentially result in the loss of an instrument. While the engineers did not want to risk losing the device, nor did they want to take chances that data might be lost if the Wi-Fi failed to operate at such a depth.

The decision was made to set up a custom fibre-optic cable from the instrument to a tablet computer on the surface. Not only would the laser scan data be captured and monitored in real time, but live imagery from the camera would also assist the operator in proper insertion. As an added safeguard, the surveyors opted to use a vertical insertion package (VIP) offered with the CMS by Optech. The VIP's

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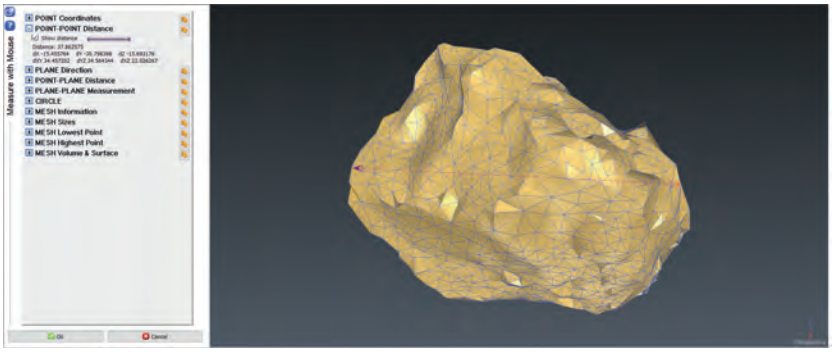
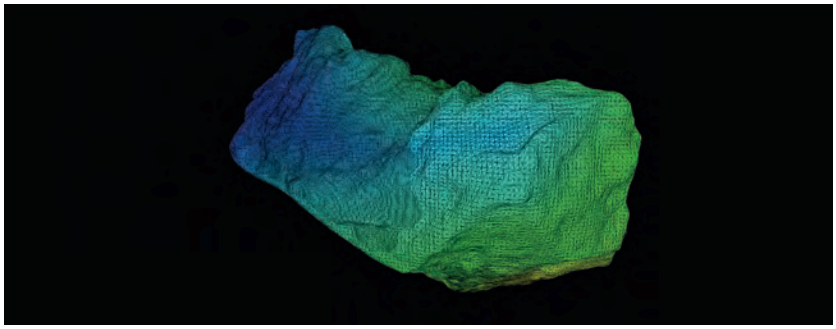
The new toggle under the CAD drawing controls tab called 3D point labels causes point labels to be drawn at the same elevation as the point node.

▲ *The on-site team prepares to lower the CMS into the borehole, a process that took several hours.*



▲ *3D model created from the scan point cloud was measured to determine the dimensions and volume of the cavity.*



▲ *Scan data collected by the CMS created an accurate 3D model of the cavity.*

leaf-spring mechanism would keep the device steady and centred in the casing as it was lowered safely into the borehole.

CAPTURING SURVEY DATA

In preparation for the cavity scan, the surveyors first used the CMS in terrestrial mode mounted on a tripod inside the tunnel. They collected five scans of the tunnel starting at the point where the cave-in occurred and then moving outward to the entrance: a total of 773.6199 metres. This information would be vital for representing the cavity in the correct orientation and location relative to the entire underground tunnel complex. At the location of the debris pile, the tunnel was 31.194m high and 18m wide.

The survey team used a total station to measure ground control points both outside and inside the tunnel to tie the captured 3D scan data into the project coordinate system. They also surveyed the surface location of the borehole. Engineers used this planning data to create a 3D model of the tunnel for incorporation into an existing terrain model of the entire site.

SCANNING THE CAVITY

Prior to CMS insertion, a stand-alone inclinometer was attached to the VIP, which was lowered into the borehole by a winch on the surface over the opening. The inclinometer captured precise orientation and location data as it descended into the borehole before reaching the cavity at a depth of 152m. This test data would be cross-referenced later with the CMS scans and integrated inclinometer data to ensure the positional accuracy.

Next, the system was attached to the VIP for the all-important scan collection. As the apparatus was lowered by winch, the camera-equipped CMS captured images and low-resolution scans inside the borehole, which were transmitted in real time via the fibre-optic cable to the surface.

Crew members examined the imagery on a tablet as they slowly guided the device downward one metre at a time. A time stamp was made at each metre mark so the CMS scan data could be correlated with the recordings of inclinometer positional data.

Once inside the cavern at 152m deep, the CMS was switched to 'fine scanning' mode in which it acquired thousands of laser measurements. Each scan captured a point cloud with a 360 x 320-degree field of view in the void space. The inclinometer tracked the position of the scanner during each scan, and a total station mounted above the borehole surveyed the location of the VIP as the CMS was lowered.

CREATING A 3D MODEL

After safe extraction of the devices, Optech CMS Desktop processing software was used to remove noise from the scan data before merging the scans into a 3D point cloud representing the entire cavity. Data from the inclinometer and total station was used to register the scans to each other and then georeference the point cloud to the coordinate system of the project site.

As expected, the point cloud revealed a large cavity with undulating walls and an undefined shape. The CMS took thousands of measurements inside the cavity and the software determined its overall volume. The coordinate data precisely located the void space in the existing 3D model of the project site. This information gave the engineers a better understanding of the conditions in the area where the collapse had occurred and enabled them to begin formulating a plan to resume excavation in the main tunnel. ◀

ABOUT THE AUTHOR

Sajid Mukhtar is a third-generation entrepreneur with a demonstrated history in the field of surveying instrument design, development and manufacture. He is skilled in AutoCAD, operations management, highways, earthworks and computer-aided design (CAD), and is particularly strong in the fields of GNSS, Lidar and geospatial.
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A FLEXIBLE LOW-COST SOLUTION FOR RECORDING LAND RIGHTS

The Social Tenure Domain Model

High-end technology-driven solutions often create serious implementation constraints in land administration. Furthermore, despite the developments and advances in geo-ICT, there is still a gap in the development of tools that model people-to-land relationships independently from the legality of those relationships. This article explains why the Social Tenure Domain Model (STDM) is a powerful and effective land information system to arrive at locally engineered solutions for improving tenure security.

Land administration plays a crucial macroeconomic role in the collection, management and dissemination of information about land tenure rights, land use and value. However, high-end technology-driven solutions often create serious implementation constraints where issues such as those related to licence costs of proprietary software have been reported to land administration programmes. In addition, despite the developments and advances in geo-ICT, there still exists a gap in the development of tools that model people-to-land relationships independently from the level of formalisation, or legality, of these relationships. The Social Tenure Domain Model (STDM) was designed to specifically address these challenges.

PARTICIPATORY

The STDM is a pro-poor, participatory, flexible and affordable land tool for representing people-to-land relationships along the 'continuum of land rights', independently of the level of formalisation and legality of those relationships. The basic way of defining any form of land right represented through the STDM is that a party has a social tenure relationship with a spatial unit supported by evidence-based source documents (Figure 1), and this also applies to related restrictions and responsibilities. A party can be a person, household or a cooperative society, whereas a parcel, informal structure, natural resources or building can be used to represent a spatial unit. The STDM is an initiative of the Global Land Tool Network (GLTN) in collaboration with its partners to support pro-poor land administration.

Its practical implementation involves participatory enumeration – a survey method which aims to gain better knowledge of the needs and priorities of a community through the administration of appropriate data collection tools. The STDM offers a practical way to address land administration problems related to recognising and recording land rights on the continuum.

STDM TOOL

The STDM tool is a desktop-based application which is designed to fully comply with the conceptual model in Figure 1. It brings together mature and stable open-source software projects through a consistent, easy-to-use interface, which allows non-specialised users to define and manage tenure information, visualise spatial units as well as support the creation of reports.

CUSTOMISATION OF TENURE CONTEXT

The STDM tool provides a data management interface for designing tables and corresponding attributes to meet the data requirements of different application contexts. The current release, version 1.7, enables the definition of compound tenure relationships

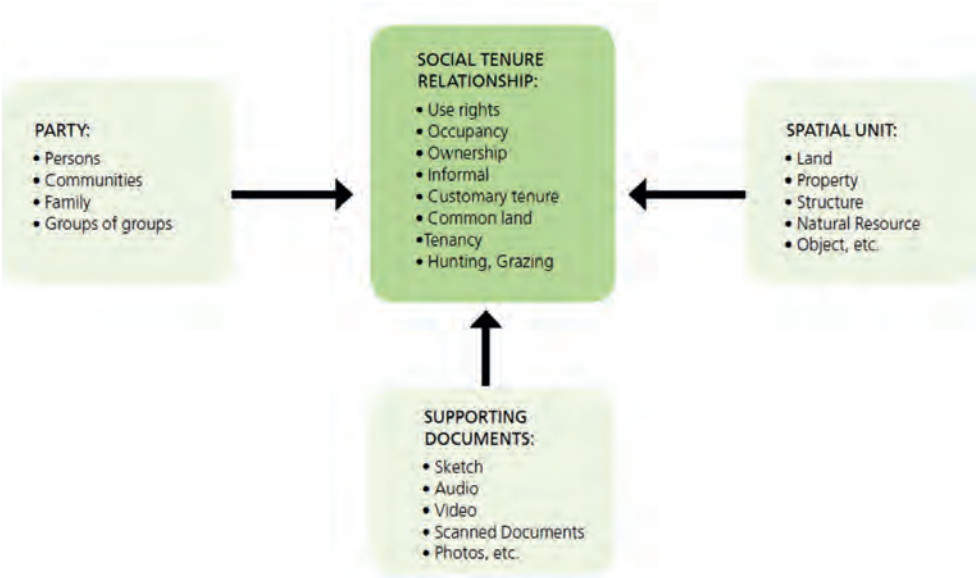
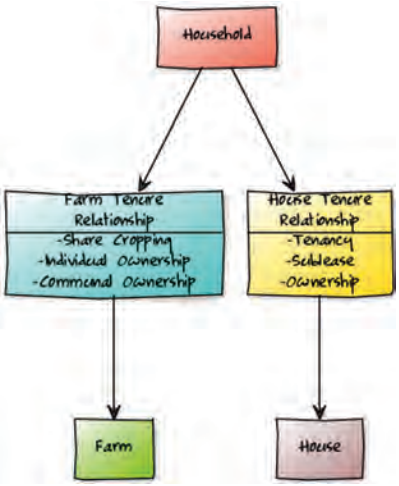
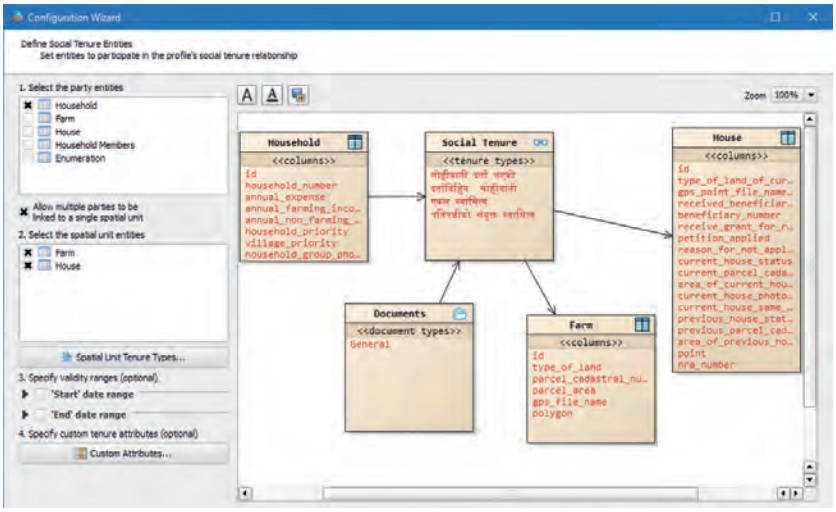


Figure 1: The STDM conceptual model illustrates the relationship between a party and spatial unit through the social tenure relationship, supported by relevant evidence-based documents.

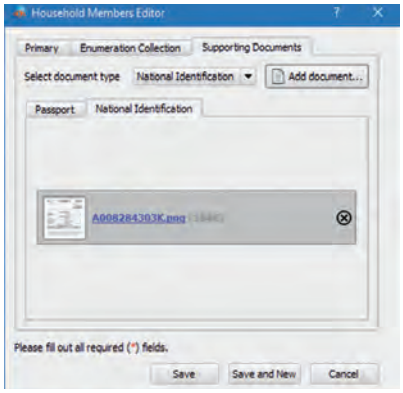


▲ *Figure 2: Conceptual illustration of a party having separate tenure relations with multiple spatial units.*



▲ *Figure 3: Definition of social tenure relationship in the STDM tool based on an example of post-disaster application context in Nepal.*

such as different party types having tenure relationships with a given spatial unit type, or a party type having separate tenure relationships with different spatial units, e.g. a household having different sets of tenure relations with a house and farm respectively (Figure 2). Figure 3 shows this implementation in the STDM tool.



▲ *Figure 4: Attaching supporting documents in an auto-generated data input form.*

▲ *Figure 5: Draft process for applying and issuing customary occupancy certificates in Mungule Chiefdom, Zambia. This was developed using participatory approaches involving local leaders, PPHPZ, Huairou Commission and GLTN.*

By default, every tenure relation between a party and spatial unit includes a percentage share of the right as well as information on start and end dates representing the duration for which the relation is valid. In addition, custom tenure-specific attributes, such as the identification number of tenure supporting documents, can be defined depending on the tenure context.

DATA MANAGEMENT

All the spatial and attribute information in the STDM is stored in a PostgreSQL/PostGIS database, with the user interface hosted as a QGIS extension, also known as a plug-in. The use of PostgreSQL and PostGIS software components enables the STDM to be deployed as a stand-alone installation or in a client-server environment. The former is mostly applicable in those areas where internet infrastructure does not exist or might be too costly to set up for the given programme, such as in urban informal settlements or rural areas.

EVIDENCE-BASED SUPPORTING DOCUMENTS

The STDM provides an intuitive interface which enables the attachment of supporting documents for every record stored in the data repository (Figure 4). These documents provide proof or support claims within the given context. Such evidence from the field can be photographs or scanned documents which are subsequently uploaded into the software when defining the primary textual information. Examples of these can be photos of people or households, scanned copies of utility bills or even hand-written tenancy agreements in urban informal settlements.

The types of source documents that are applicable for each entity can be specified using the data management interface during the initial stage of defining the structure of the data profile.

EXTENSION BY DEVELOPERS

The STDM is designed to be a flexible platform which enables software developers to extend, modify or integrate with existing enterprise systems in order to meet the functional requirements of their own applications. Its application programming interface (API) provides various extensibility points from definition of custom data types, data storage back ends, widgets for data types, document management back ends and data importation formatting to report design items and production.
The STDM is written in Python programming language and the developer community can participate in the open-source project on GitHub.

THE IMPLEMENTATION PROCESS

The application of the STDM promotes inclusiveness and continuous capacity development amongst all key stakeholders, from the initial inception up to the deployment and rollout stages. At the core of the implementation is the active participation of the local community leaders and members, who must be continuously engaged throughout the whole process.

▲ *Figure 6: Officers from Lusaka City Council and community members from Kanyama Settlement familiarise themselves with the use of handheld GPS receivers.*

▲ *Figure 7: Training of county government officials on the use of the STDM-based Land Information System developed for Turkana County Government, Kenya.*

The key activities include planning and consultations amongst the stakeholders where key issues pertaining to tenure security are discussed; this process also includes identifying the main areas where GLTN tools (i.e. continuum of land rights approach, gender evaluation criteria, STDM, participatory enumerations) can be applied. An implementation plan is developed which incorporates agreement on the roles and responsibilities of the different stakeholders (Figure 5). This is followed by an extensive mobilisation and sensitisation process which involves local government authorities as well as community leaders and members.

DATA COLLECTION

The data requirements of the project are identified and customised in the STDM to fit the local context. This is an iterative process which is considered final once all the stakeholders have reached agreement on the data attribution to be captured, using either digital or paper-based surveys. Data collection involves conducting interviews and plot or structure mapping, and the enumeration teams are usually accompanied by local leaders and local government officials. The mapping can be done using handheld GPS receivers (Figure 6) and/or high-resolution satellite images depending on the context. All the collected data, documents and photographs are entered into the STDM tool. In some instances, the initial digital maps are also updated at this stage. The enumerators are also trained to analyse the data and produce reports using the tool.

In the final stage, community members validate the collected data before it is subsequently updated in the STDM database. This validation process is critical as it improves the credibility of the overall process. Afterwards, the community members and local government officials agree on modalities of how to continue updating the data and sustaining the process, with backstopping provided by GLTN. Manuals, guidelines and process documents are produced, and translated if applicable, as part of standard outputs from these interventions.

MOVING FORWARD

As the STDM continues to evolve technically based on the convergence of new technologies with emerging country needs, GLTN is exploring new opportunities based on the strategic guidance provided by the STDM Advisory Committee. Examples of such opportunities include: establishing data-sharing mechanisms from community level to national level in line with fit-for-purpose principles of 'incremental upgrading'; developing a sustainable business model; submitting the tool to the OSGeo Incubator programme; promoting the development of Open Geospatial Consortium (OGC) standards related to land administration through the LandAdmin Domain Working Group (DWG) and supporting the implementation of the Sustainable Development Goals (SDGs) – particularly 1, 2, 5 and 11 – in land tenure projects at country level. The use and application of the STDM in these strategic areas of interest will be closely aligned with GLTN's Phase III strategy which is currently under development.

CONCLUDING REMARKS

The capability of the STDM to further incorporate participatory approaches makes it a powerful and effective land information system to arrive at locally engineered solutions for improving tenure security. The uptake of the STDM has in some instances led to inclusion of the STDM-generated information in government initiatives such as the Transforming Settlements of the Urban Poor in Uganda project (TSUPU), establishment of a land information system to manage urban and customary land in Turkana County (Figure 7), and in the Kenya Informal Settlement Improvement Project (KISIP) in Kenya. The STDM is now seen as a significant tool that local governments can adopt for development objectives like inclusive planning, tenure security improvement, provision of basic services and infrastructure. A future article will focus on experiences and lessons learnt from implementations. ◀

FURTHER READING

https://github.com/gltn/stdm
https://stdm.gltn.net

ABOUT THE AUTHORS

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DRONES AND ICE SHEET DYNAMICS

UAV Mapping of a Greenland Glacier

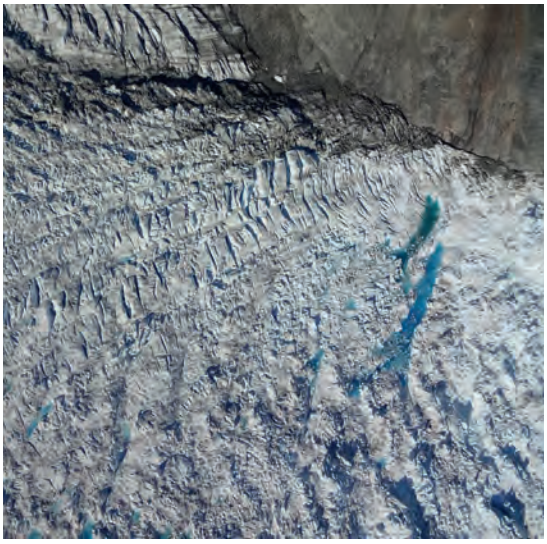
Mapping polar regions can be a challenging yet vital mission, helping scientists and researchers to better understand how the planet and its climate are changing. Traditionally, terrestrial and ground-based techniques have limited the scope of activity and the quality of data. In this article, the author discusses how unmanned aerial vehicle (UAV or 'drone') solutions have been used in Greenland to successfully monitor the formation of crevasses and the behaviour of ice flow on the Eqip Glacier, providing previously impossible levels of insight.

The status of polar regions has risen to the forefront of public awareness in recent decades, with rapid climate-driven changes to glaciers and ice caps capturing the attention of scientists and the general population alike. It has become increasingly important to gather data that can be used to gain a better understanding of these areas and the mechanisms behind their extreme transitions. However, in conditions that are amongst the most hostile on the planet, such missions can be challenging. The use of UAVs has proven to be instrumental in facilitating research in this area, not only helping to overcome significant safety and logistical challenges, but also providing greater insights for professionals in the field.

A research group at the University of Zurich led by Dr Andreas Vieli, head of glaciology and geomorphodynamics in the

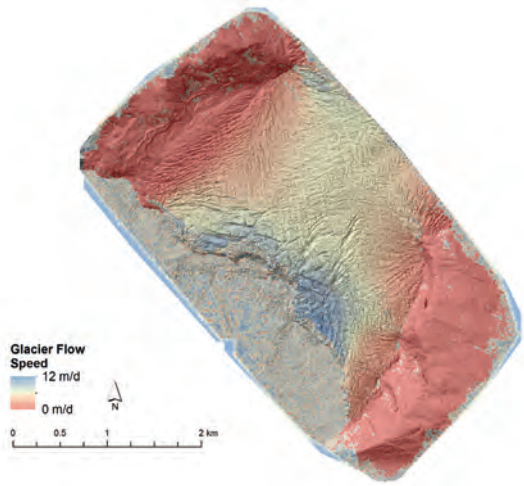
Figure 1: The Eqip Glacier is one of the island's most active pcean-terminating glaciers, with large chunks of ice breaking off at regular intervals every day.

▲ *Figure 2: The integrated eBee drone solution was selected to map, and gather insights from, the Eqip Glacier.*



▲ *Figure 3: With an average time of 25 minutes per flight, Dr Vieli and his team acquired a total of 625 images across the six flights.*

Department of Geography, has been using UAV technology to achieve just that at the Eqip Glacier (also known as 'Eqip Sermia'), an outlet glacier of the Greenland ice sheet. Located in West Greenland, this ocean-terminating glacier is one of the island's most active, with large chunks of ice breaking off at regular intervals every day (Figure 1). As part of a project funded by the Swiss National Science Foundation (SNSF) between 2015 and 2017, Dr Vieli and his associates collected data to monitor how the glacier geometry and ice flow speed evolved over time. The team aimed to use this data to investigate the formation of crevasses and the process of calving – the mechanism of icebergs breaking off into the sea – in order to improve the ability to predict the future retreat and mass loss of such marine-terminating glaciers.



▲ *Figure 4: The team found out that the glacier is flowing 12m a day, and obtained new insights into the structure of the flow field.*

ASSESSING THE OPTIONS

Given the hostility of polar regions, historically it has proven difficult for research groups like Dr Vieli's to map such terrains. Based on experience from similar projects, the team knew that traditional, terrestrial techniques like laser scanning or remote sensing methods using satellites would not be able to provide the breadth and quality of insights required. While satellite imagery offers a wide view of the terrain, the images captured are typically of low temporal and spatial resolution, making it difficult to obtain data that reaches acceptable standards for studying detailed processes. When using the terrestrial approach of laser scanning in the Alps, Dr Vieli's team found that processing was often difficult and the resulting data was affected by shadows. In addition, such ground-based approaches are time and labour intensive – something ideally avoided in harsh, hostile climates like those found in the Arctic region.

Following these challenges with terrestrial equipment, and in view of the need to collect highly accurate data from which to create comparative digital elevation models (DEMs), Dr Vieli and his team concluded that UAVs offered the most effective and efficient solution. An aerial approach offered significant logistical and safety advantages, meaning the team could securely map a previously inaccessible side of the glacier and gather higher-resolution data on demand.

Having previously used the senseFly eBee drone in a range of projects, including in high Alpine environments, the team selected this integrated solution to map, and gather insights from, the Eqip Glacier (Figure 2). A fully autonomous, easy-to-use professional mapping drone, the eBee weighs just 700g and is capable of covering up to 12km^2 in a single flight, enabling Vieli and his associates to be in the air within a matter of minutes. True-colour RGB payloads were used, with the Sony WX camera able to capture high-resolution aerial photography, creating accurate and detailed DEMs at decimetre resolution. In addition, the eBee's pre-installed global positioning system (GPS) capabilities enabled the team to avoid the necessity of compass navigation and therefore minimise the impact of the weak magnetic field in Greenland.

TAKING FLIGHT

A total of six flights were required to create one DEM of the entire glacier tongue, and this process was conducted eight times between 2015 and 2017. Prior to each flight, the in-built eMotion software allowed the team to assess the feasibility of the project, plan their flight route and load elevation data in advance, helping to streamline processes and optimise the time spent analysing data. With such a challenging environment to navigate, the team had to consider weather conditions and altitude in the area surrounding the glacier ahead of the flight. For instance, as the glacier is only accessible on one side, if winds blow the drone too far out of reach it may not be possible to retrieve it. In addition to potentially impacting the safety and success of operations, the limited

accessibility also had a knock-on effect on the team's ability to establish ground control points (GCPs). However, prior flights in the area meant that some GCPs had been previously established and could be used in this mission.

To map the 20km^2 calving front area of the Eqip Glacier, one to two members of the research team were deployed to the site for each DEM acquisition mission. Missions were repeated every four to five days depending on weather conditions. With an average time of 25 minutes per flight, Dr Vieli and his team acquired a total of 625 images across the six flights (Figure 3). This data was first processed using Pix4DMapper software to create the highly detailed DEMs and subsequently used to derive elevation change maps. In addition, the research team's own cross-correlation software used the data to monitor how the flow fields on the glacier's surface evolve year on year. From this analysis, the team found that the glacier is flowing 12m a day – a significant speed – and obtained new insights into the structure of the flow field which, ultimately, will help them to better understand the process of calving (Figure 4).

INTEGRATED INSIGHTS

Using the senseFly eBee as part of an integrated, end-to-end approach, Dr Vieli and his team from the University of Zurich were able to collect highly accurate, professional aerial data of the Eqip Glacier in under three weeks in each year of the project – a feat which would have been impossible using alternative satellite imagery or terrestrial techniques. The data collected using the eBee has already significantly contributed to furthering the team's research, complementing additional lower-resolution satellite imagery, to provide a comprehensive view of the area and the acting processes. With more UAV flights scheduled for the summer of 2018, the team also has future plans to extend its research to mapping debris-covered glaciers in Alpine terrain using innovative thermal camera mapping technology. Having access to these detailed, integrated insights will help the team continue to broaden their understanding of some of the most remote, hostile environments on the planet. ◂

All images are courtesy of the University of Zurich.

ABOUT THE AUTHOR

Francois Gervaix is surveying product manager at senseFly. A qualified geomatics engineer, Gervaix has worked for Leica Geosystems, specialising in airborne sensors, Lidar, GPS and inertial units, and as a professor at the Technical University for Applied Sciences Western Switzerland (HES-SO), where he was in charge of photogrammetry and geospatial imagery. In 2010, Gervaix launched project R-Pod, Photogrammetry on Demand, using senseFly drones and Pix4D software for R&D and to provide teaching materials. Then, in 2012, he founded Easy2map, a drone-based photogrammetry service provider that is active across Switzerland and overseas. He joined senseFly in February 2016 and was president of the Swiss Society of Photogrammetry and Remote Sensing from 2011-2017.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BY **FRÉDÉRIQUE COUMANS**, CONTRIBUTING EDITOR, GIM INTERNATIONAL

Innovative Ways to **Monitor Land Displacement**

When people think about landslides, they usually imagine large mud streams which cause considerable loss of life. Whereas such large-scale disasters are rare, smaller landslides are a much more frequent occurrence and pose a danger for traffic and housing in thousands of cities worldwide. In Italy, Google News is used to calibrate the 24-hour prediction models and slope-instability risk maps are produced every six days based on Sentinel-1 radar images. In fact, Prof Nicola Casagli from Florence University has high hopes for a geostationary European InSAR satellite which will enable the daily production of a map for assessing ground displacements of 1mm.

Can one predict with certainty where and when a landslide will occur? Prof Nicola Casagli, from Italy's Florence University, has no doubt about the answer: "Landslides caused by earthquakes are impossible to predict, but all other types of landslides are predictable. You can forecast the time of failure even using simple models. You do need to have a continuous series of accurate monitoring data." He adds, laughing: "But it is quite common to do the prediction after the event." The art and science of predicting is never easy, but climate change is making things even more complicated nowadays. Casagli can handle it, though; his renowned Centre of Competence for geohydrological hazards is supported by 60 multi-disciplinary experts.

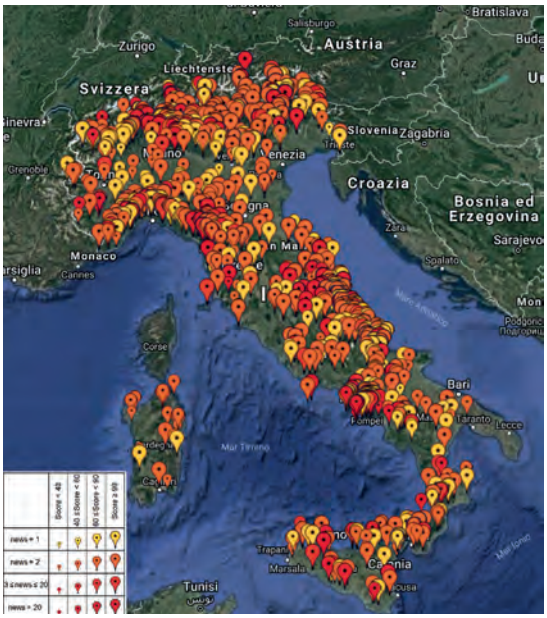
FLASH FLOODS

In the south of Europe, climate change is causing rising temperatures and a gradual reduction in the average yearly rainfall. Besides that, the precipitation increasingly occurs in more concentrated periods of heavy rainfall, triggering debris flows and shallow landslides – small, but very fast and dangerous. These landslides are increasingly being accompanied by flash floods: a large volume of water building up in one place in a very short space of time. This mixture of geological and hydrological phenomena is difficult to predict. Casagli: "You can monitor slow-moving, large landslides with satellites combined with ground based instrumentation for measurement of the exact displacements. Those are very easy to predict. For very fast landslides – debris flows, debris avalanches – triggered by intense rainfall, it is more difficult. The movement before failure is zero, but when heavy rain occurs they start to accelerate in seconds. The only way to predict them is to predict the rainfall."

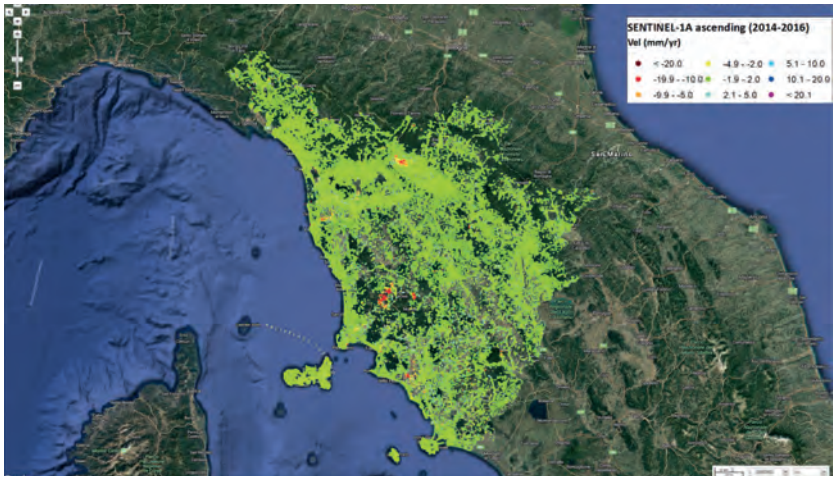
Besides the normal 24-hour weather forecast, data is also collected from rain gauges. These are in place throughout the whole country, with different defined thresholds per zone based on normal rainfall characteristics, bedrock lithology and landscape morphology. When a threshold is exceeded, the regional landslide early-warning system issues a moderate or high alert, spatially limited to the authorities of that zone. Of course, there must be certainty that those thresholds are correct so that no false alarms are raised or the alert fails to be issued when it should be. To ensure this, Casagli uses spatial data mining techniques. A semantic engine analyses Google News for reports of landslides that occurred in the previous week. By comparing the reported events with the rain-gauge data – all rainfall parameters (intensity, duration, amount, etc.) are stored in a database management system (DBMS) – the thresholds are kept up to date and the alerts provide trusted input for the landslide prediction model.

2,000 LANDSLIDES REPORTED LAST YEAR

Casagli explains the importance of Google News. "To predict landslides caused by precipitation, you need information on



▲ *Landslide news items retrieved from Google News and ANSA in 2017 (2,174 items in total). The news items are ranked by number and by relevance (the score is related to the importance of the source).*



▲ *Persistent scatter map for the Tuscany region updated every six days using ESA's Sentinel-1 radar satellites. Points show the ground displacement along a satellite's line of sight.*

landslides as well as weather predictions and data from rain gauges. If I predict a landslide will occur tomorrow based upon precipitation, I subsequently need to know whether a landslide did actually occur on that day. We match the data with rainfall data and refine the prediction. The more data we have on landslides, the better our predictions become."

The semantic engine analyses all the news reports about landslides (and about the 34 synonyms for 'landslide' that exist in the Italian language) that really occurred. Last year there were more than 2,000 such news items. In fact, this manner of calibrating landslide prediction models is a digital follow-up. In the 1980s, scientists in Italy started to compile large databases of newspaper data on floods and landslides, until the government cut all funding in 2002. But since 2010 the scientists have been using spatial data mining techniques. The semantic engine now analyses all the news in Google News and in the database of ANSA, the national press agency. Many reports of minor landslides go to local or regional newspapers rather than to ANSA, but they are all on Google News, as are most of the digital-only local newspapers.

WARNINGS EVERY 24 HOURS

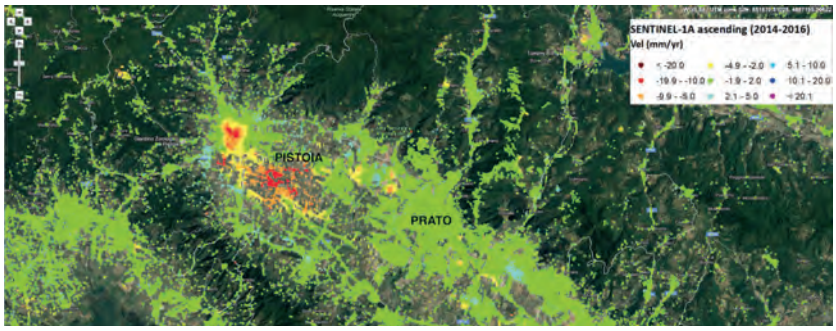
To actually predict landslides, all the data is input into several models that are used simultaneously. Experts within the National Civil Protection service and in the regions evaluate the outcomes every day and make a decision. That is then translated into a map showing expected landslides and floods, which is made publicly available on the National Civil Protection service's website.

On a nice sunny day in February, almost the whole of Italy is shown in green on the map with yellow indicating a low probability of landslides or floods in just a few places. "The national warning system gives warnings every 24 hours. That is enough for most problems, but not for all. Sometimes we would need 'now-casting' of heavy rainfall (*as opposed to the normal 24-hour 'forecasting', Ed.*), but hourly prediction is still in the research phase; the degree of uncertainty is still to high."

Uncertainty also plays a role at the local level. Casagli is a member of the National Risk Commission and sees the struggle the mayors face whenever the map turns red or orange in their territory, because this means the mayor has to take action as a local authority of civil protection. Every municipality has a civil-protection action plan and should know what to do in the case of each colour. "Here in Tuscany the colour red occurs two or three times per year. Then, schools are closed, some offices are closed, houses near rivers are evacuated and firefighters get ready. But orange is a problem; it's the mayor's responsibility to decide what to do. You might have 10-12 orange alerts per year, and if you evacuate nine times without anything happening… So many mayors of larger cities waited too long and they are being charged with manslaughter. But it is not easy. In many cities, urban planning was non-existent during the time Italy became a richer country and we built whatever we liked. For instance, many rivers were put away under concrete and are now causing serious problems when floods occur. In our research group we now want to add an expert on risk communication."

SENTINEL-1 FOR MONITORING

The Italian authorities are also provided, every six days, with scatter maps on the risk of slope instability, again based on applications developed and maintained by Casagli and his team. Sentinel-1 satellites belonging to the European Space Agency (ESA) have proved crucial. Casagli started using radar satellites to map and monitor landslides in the 1990s. With interferometry in all variations, the measurements of ground displacements over large areas can be extracted from the radar images. "Sentinel-1 is such a big step forward, it is like the change from a photograph to a movie." With the previously available satellites, the revisiting time was at best 24 days. Now, Sentinel-1A and B revisit each part of the Earth every six days with the same line of sight – plus it is free. This opened up the possibility to use satellites for monitoring as well as mapping. Now, all the authorities can update their risk map with interferometric data. In Italy there are five levels of risk, from R0 (no risk) to R4 (extremely high risk). No building is permitted in the case of R3 or R4 codes. The district authorities decide on the exact



▲ *Zooming in on the flood plains of the cities of Florence, Prato and Pistoia showing high subsidence rates (shown in red) in the north-western part.*

boundaries. Changing a boundary or a level has a considerable effect on property value, so there is always great pressure from the owners. And of course, not all the authorities are happy to learn that they have to take action right away to solve a serious problem with a road or a building. But the satellite data provides quantitative information, and the pressure is reduced; it is not only based on an expert's opinion. Casagli: "We are already doing completely new mapping every six days for two Italian regions. You can see on the scatter web maps which points are red, with significant ground displacements. Most of them correspond to R4 in urban areas."

EUROPEAN STATIONARY INSAR SATELLITE

There still are limitations to the use of Sentinel-1. The main problem is the resolution of 14x5m. "That resolution is a problem when you want to build a warning system based on satellites only; you cannot detect all the relevant phenomena. We are now applying, with all the major radar-interferometry research institutions in Europe, for the third time to ESA for a geostationary radar satellite. Each day, one map image with an accuracy between 1 and 2mm will be composed out of all the interferograms. With one satellite it would be possible to map a circle with a 2,000km radius: more than half of Europe. We suggest a cooperation with ESA because they have good ground segmentation. By using that, we are certain to get an image of the same area every day. The application is ready. The satellite would cost €500 million. The same satellite can also be used for other applications such telecommunications and television. But in the European institutions, applications for smart cities, oceans, coastlines or desertification are more popular than natural hazards. It is a pity, because it is cheap and it can save lives. As a comparison: our four-satellite Italian system, COSMO-SkyMed, cost €800 million. The data is excellent (3x3m) but it is not free, and the standard revisiting time is 16 days."

"Europe has been the leader in radar Earth observation since the 1990s; it had the vision to launch the satellites and to build an archive, which was crucial for new business to develop. But if ESA doesn't take a step forward, Amazon or Tesla will take over its role and provide a new impulse. I would love to talk to Mr Musk. The information we would produce is crucial for traffic safety; if you drive in a self-driving car, you trust the authorities to keep the roads safe." ◂

Image: Jeroen van Berkel

▲ *Prof Dr Nicola Casagli: "I would love to talk to Mr Musk. The information we would produce is crucial for traffic safety. If you drive in a self-driving car, you trust the authorities to keep the roads safe."*

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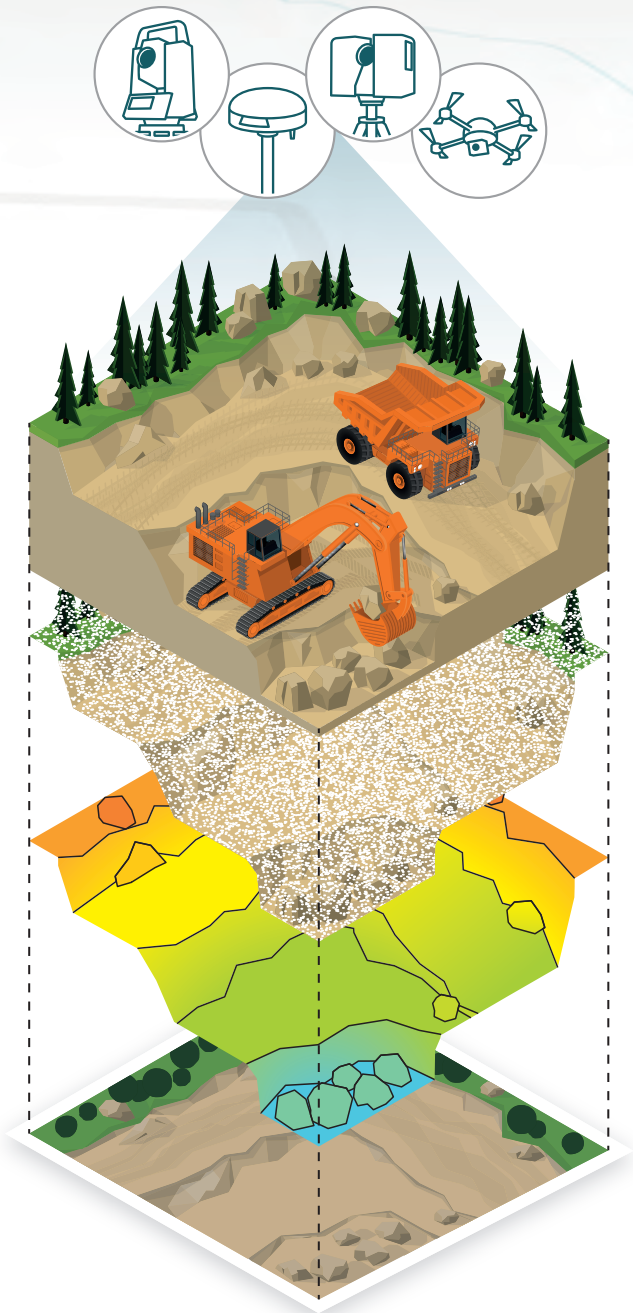

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ANALYSE, MANAGE & MONITOR

Copernicus Masters: Driving Innovation for Europe's Earth Observation Programme

Copernicus, Europe's most ambitious Earth observation (EO) programme to date, provides space data and services for Europe and its citizens. Ten petabytes of free EO data is generated by Copernicus every year. Big data from space holds great potential for ideas and solutions in many sectors. These kind of solutions are driven by the Copernicus Masters – Europe's leading competition dedicated to EO applications. In this column, Thorsten Rudolph, managing director of AZO Anwendungszentrum GmbH Oberpfaffenhofen which organises the Copernicus Masters, highlights the successful development of Copernicus. Moreover, he explores how the Copernicus Masters competition functions as a deal flow pipeline and innovation driver.

The incredible development of EO's commercialisation got a big boost seven years ago when we started to work together with our Copernicus Masters initiating partners: Josef Aschbacher, director of ESA's Earth Observation programmes, and Dr Thomas Beer, Copernicus policy coordinator at ESA. Back then, Copernicus did not exist in its present form; it was called the Global Monitoring for Environment and Security (GMES) programme. In terms of commercial EO-based applications, there was not much out there at that time.

Currently, six Sentinels are in orbit, and Sentinel-3B will join them on 25 April this year. Copernicus has literally skyrocketed, and so has the first innovation competition dedicated to respective solutions – the Copernicus Masters.

I would like to stress some key aspects about Europe's EO programme to give a better understanding of the role of the Copernicus Masters. Copernicus provides full free and open access to data for the development of applications in a wide diversity of domains. This enables the Copernicus services to deliver near-real-time data on a global level. Investments in the programme will increase to €7.5 billion by 2020, while the economic benefit is expected to double in value. That's quite impressive, isn't it?

And this is exactly where the Copernicus Masters comes into play. Its mission is to foster the user uptake of the Copernicus programme as well as to look at our planet and its environment for the ultimate benefit of European citizens. With more than 450 participants from 38 countries in 2017, the Copernicus Masters competition affirms the importance of EO. The competition website illustrates the vast variety of application fields. This year, the competition is bigger than ever: 16 challenges with exciting topics tackling global societal and business-related issues, including the Internet of Things (IoT), artificial intelligence (AI), machine learning, energy, health, sustainable living, smart farming, disaster management and digital transportation.

The active role of the Copernicus Masters in the commercialisation of EO makes me proud. It demonstrates how this innovation competition functions as a European deal flow pipeline for EO and drives innovation worldwide.

The partners of the 2018 edition are the European Space Agency (ESA), the European Commission (EC), the German Aerospace Center (DLR), CGI, Planet Inc., BayWa AG, Stevenson Astrosat Ltd., Airbus, Satellite Applications Catapult Ltd. and the German Federal Ministry of Transport and Digital Infrastructure (BMVI).

Participants can enter the competition with their innovative EO ideas until 30 June. Besides cash prizes, challenge winners receive access to an international network of leading EO organisations, substantial satellite data quotas and a crowd investing platform, as well as business development support worth more than €600,000 in total. Additionally, the overall winner receives a VIP trip to a satellite launch in Kourou valued at €10,000.

I encourage all participants of the Copernicus Masters to submit their best ideas. They can actually make an impact on society and business. ◂

ABOUT THORSTEN RUDOLPH

Thorsten Rudolph is the founder and managing director of AZO Anwendungszentrum GmbH Oberpfaffenhofen. AZO is an international networking and branding company for space-related innovation competitions with about 15,000 participants and over 160 industrial, public-sector and international stakeholders. AZO's Masters Series comprises four leading European innovation competitions in the fields of satellite navigation, Earth observation, new space economy, and Low Earth Orbit (LEO), the moon, Mars and beyond.

AN EFFICIENT APPROACH FOR ESTIMATING REFUGEE CAMP POPULATIONS

Earth Observation Data and Image Processing for High-level Humanitarian Support

Over the past decade, the world has witnessed a steady increase in the number of people forced away from their homes by natural disasters or political unrest. They often end up in camps that hold tens of thousands of refugees. The camps are supported by non-governmental organisations (NGOs) that provide food, shelter and medical assistance. To manage their operations, NGOs and other agencies need to know how many people are in a given camp. This article explains how a combination of high-resolution satellite Earth observation data and image processing software provides an efficient approach for estimating camp populations.

The refugee population is growing rapidly. Recent estimates from the United Nations indicate that nearly 68 million people fled their homes in 2016, up from 64 million in the previous year. Often located near war zones, the largest camps hold more than 200,000 people. When essential services such as food, clean water and sanitation are in short supply, malnutrition and sickness can take hold. Financial and material support is limited, though, and a camp's infrastructure is often overtaxed. Because of their limited funding, NGOs have become adept at planning and resource allocation. Information on population size and trends for a given camp helps the NGOs to optimise the return on their spending. Producing good data, however, is not easy. Aircraft – including unmanned aerial vehicles (UAVs or 'drones') – and satellites can capture aerial images of the camps, but manually extracting reliable population data from these photos can be painfully slow and expensive. Médecins Sans Frontières (MSF), an NGO supporting refugee camps, teamed up with experts at the University of Salzburg's Department of Geoinformatics (Z_GIS) to find a solution. Z_GIS conducts research into the use of satellite imagery with advanced image processing techniques to monitor populations. One of its key objectives is developing automated approaches to extract population information from satellite images of refugee camps.

▲ *Satellite image of the Dadaab camp in Kenya taken in June 2015, when the camp was home to more than 400,000 Somali refugees. Image courtesy: DigitalGlobe.*

ACCURATE COUNTS

To measure the populations, Z_GIS obtains very-high-resolution (VHR) imagery (less than 1 metre per pixel) from commercial suppliers such as DigitalGlobe and Airbus (Pleiades). The images are processed using Trimble's eCognition software to produce estimates on the number of physical dwelling units in

▲ *eCognition automated classification of structures at the Minawao camp in Cameroon.*

a camp. The results can be displayed using tools such as ArcGIS or Google Earth to provide geographic context. Teams can then add ground data about the average number of residents per dwelling, enabling them to estimate the size and distribution of the population. The process can be repeated to quantify population change and movement within a camp. The ability to repeat the population analysis quickly is important, since rapid changes can occur in a camp during a crisis.

RULE SETS

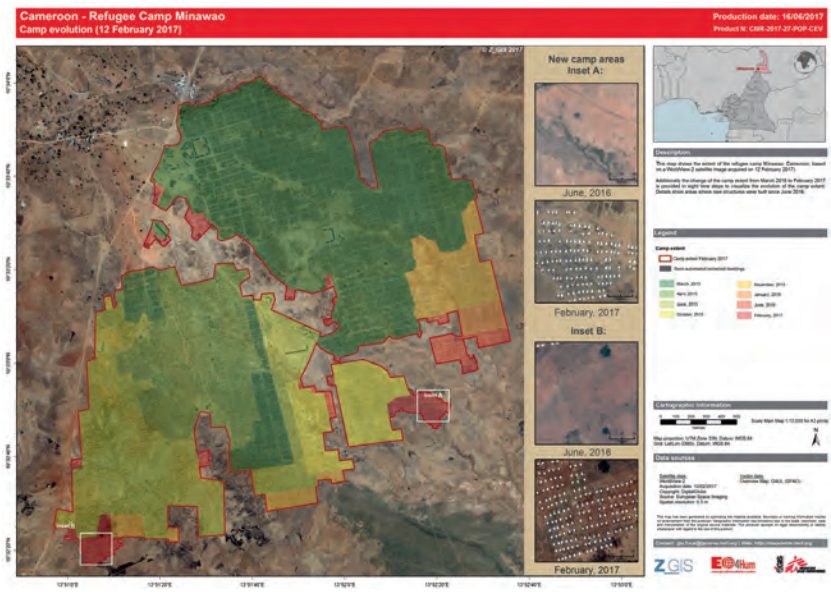
Object-based image analysis (OBIA), a method available in eCognition, is used to identify and classify features in an image. According to Dr Dirk Tiede of Z_GIS, OBIA offers greater flexibility and efficiency than pixel-based analysis techniques. Tiede develops customised processes (known as 'rule sets') that effectively train eCognition to recognise and classify individual features within an image. The objective is to identify man-made structures and to differentiate dwellings from other camp buildings such as food stations and medical facilities.

The rule sets use edge detection algorithms to delineate camp margins and to classify man-made features. Spatial characteristics of different dwelling types, along with relative spectral differences between objects, enable the rule sets to distinguish light-coloured dwelling structures from darker buildings and fences. The system determines the spectral values in order to separate dwelling types as well as areas with and without vegetation. The comparison is based on specific spectral ranges or vegetation indices such as the Normalised Difference Vegetation Index (NDVI). These values are saved as variables within the rule set and can be combined with other independent spectral parameters. Once a rule set is constructed, it can be transferred and adapted to work in different camps, or at different times in the same camp when the environment has changed.

HYBRID APPROACH

The initial rule set was developed using archived QuickBird imagery of the Zam Zam camp in Darfur, Sudan. To test transferability, the rule set was applied to a series of QuickBird images taken in the years prior to and following the original dataset. Additional tests used GeoEye-1 imagery at camps in Darfur. During these tests, Z_GIS found that the primary challenges came from varying vegetation at new sites as well as differences in characteristics of various satellite sensors.

Complex situations occur when camps show a very diverse set of structures or several development phases. In addition, local conditions may change the appearance of structures over time. For example, in some camps brightly coloured tents are used, which are relatively easily recognisable. However, when a sandstorm passes over



▲ *Map prepared by Z_GIS showing population distribution and changes in dwelling density at Minawao refugee camp from March 2015 to February 2017.*

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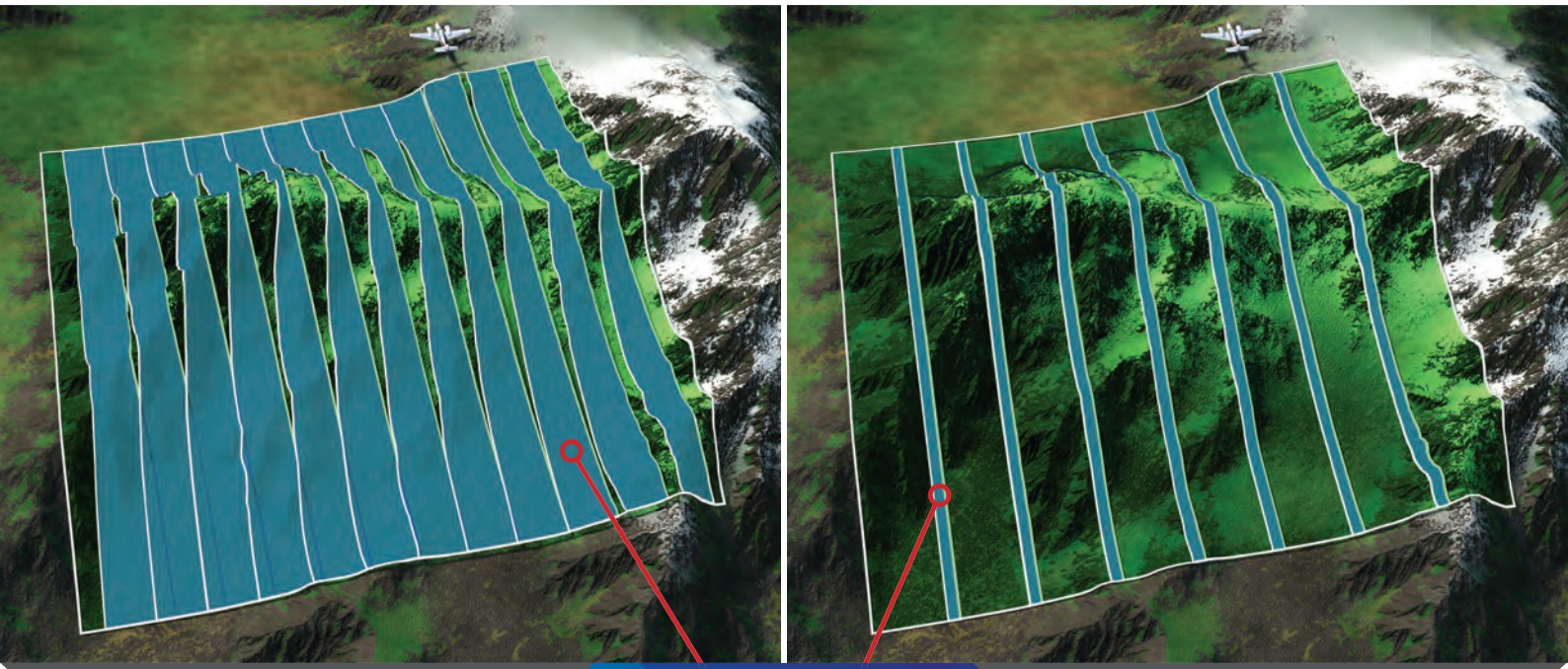

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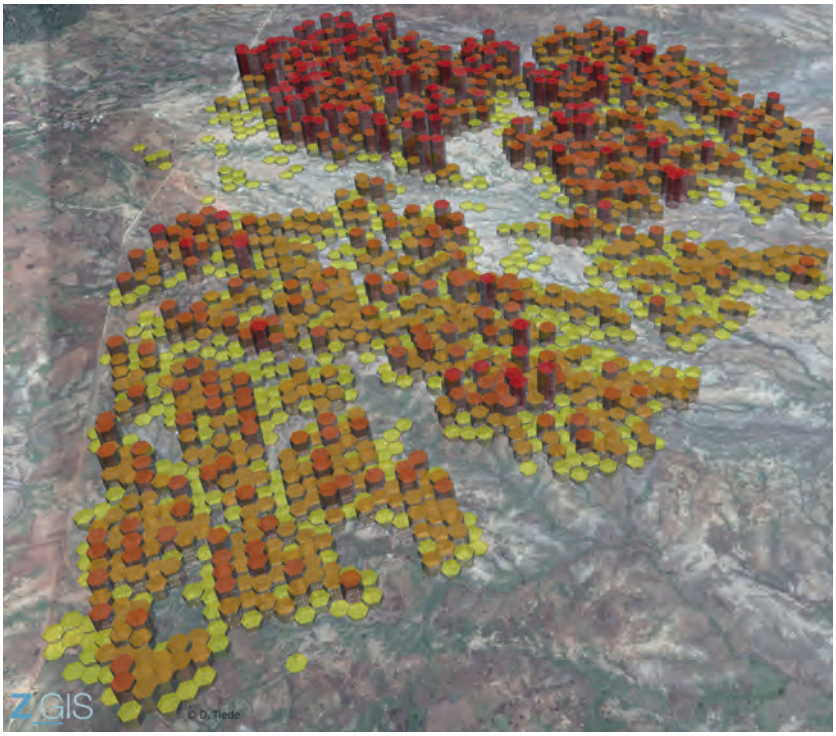

▲ *Population density visualised as hexagons (created by eCognition and shown in Google Earth). Different colours depict variations in population density at Minawao refugee camp.*

and covers everything in a brownish dust, the given rule set may need to be adapted quickly. Therefore, a hybrid approach was applied that combines the automated solution with manual image interpretation for analysis and quality checking. The tests performed by Z_GIS showed that the rule sets could be adapted successfully using visual inspection on the computer screen to redefine the spectral thresholds for structures.

POPULATION DYNAMICS

Effective population monitoring relies on rapid acquisition and processing of satellite data. Once imagery is acquired, the main bottleneck occurs in image processing.

▲ *A typical dwelling at the Minawao refugee camp in Cameroon. Image processing helps to distinguish residential structures from other buildings in the camp. Image courtesy: Louise Annaud, MSF.*

Using more efficient algorithms and faster computing technology (including the distributed computing ability of eCognition Server), it is possible to analyse an entire VHR satellite scene in just a few minutes.

To further reduce the time and staffing level required for analysis, Tiede and his colleagues are working to improve workflows around the automated processes. They are developing applications and solutions with the goal of producing initial data for a camp very quickly. From there, the team can build on the results to produce temporal information on population dynamics.

NEW APPLICATIONS

Satellite imagery supports NGOs in more than just population estimates. For example, organisations want to avoid the expensive and risky practice of trucking water to the camps. Using lower-resolution imagery from Sentinel or Landsat satellites, Z_GIS can develop an overview map of a camp's geohydrological situation to identify possible well sites. Natural disaster aid efforts also benefit from satellite imagery in analysing the extent and nature of damage for first responders and longer-term recovery. After the devastating 2010 earthquake in Haiti, Z_GIS produced a damage map within two days of the event. In emergency situations, the turnaround time is critical. The urgency is usually not as great for refugee camps, but timeliness does matter for highly dynamic situations such as the Rohingya crisis in Bangladesh.

The humanitarian team at Z_GIS continues to work closely with MSF and other NGOs, including the Red Cross movement, SOS Children's Villages and Action Against Hunger. Their work has produced a stable, operational service to support humanitarian organisations. It is an illustrative example of the value of Earth observation and image analysis in humanitarian aid. Natural disasters and other crises will continue. Putting advanced tools in the hands of dedicated specialists helps to provide better and faster relief to those in need. ◀

ABOUT THE AUTHOR

John Stenmark is an independent writer and consultant working in the geospatial, AEC and associated industries. He has more than 25 years of experience in applying advanced technology to surveying and related disciplines.

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BY **JAMES KAVANAGH**, RICS LAND GROUP, UNITED KINGDOM

International Land Measurement Standards: A Perfect Fit

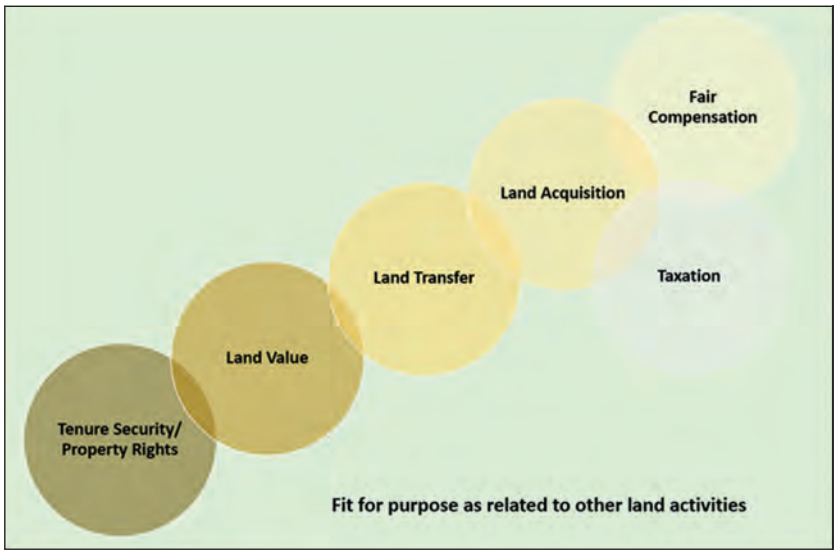
The International Land Measurement Standards are in consultation and are being prepared for launch later this year. In this article James Kavanagh, chair of the ILMS Coalition, discusses how they can make the process of land and property transactions consistent around the world.

We have almost reached the end of a long road; the International Land Measurement Standards (ILMS) have undergone an open, global consultation and draft versions have been downloaded hundreds of times. The consultation has not only helped the coalition of more than 30 national and international organisations and institutions gather global market insight and commentary, but also to inform the wider finance, legal, land acquisition and investment professions about the ILMS and the impact they will have on their work. Furthermore, the consultation has opened the debate on some new major global guides from UN agencies and helped embed ILMS in them. When the coalition was formed in June 2016 at the UN Food and Agriculture Organization (FAO) headquarters in Rome, Italy, it was agreed that ILMS would be international, principle-based standards for recording and reporting information relevant to land and property transfers. The standards aim to reduce the risks in such transactions by ensuring consistency and supporting land governance, robust conveyancing, secure lending and land registration. Global consistency is provided by standards for classifying, defining, measuring, analysing, presenting and reporting land information, which can be applied at project, regional, state, national and/or international levels. ILMS are therefore both the standards themselves and a framework for reporting. During the consultation, it has also become apparent that their flexible and non-prescriptive quality is a powerful incentive for adopting them, linking them directly to the concept of being fit for purpose . Their non-prescriptive nature means the ILMS are aspirational rather than rigid, which is especially important where high levels of informal land ownership and land use occurs.

WHAT ILMS ALLOW

ILMS will apply across the globe, although many high-income nations will comply with the standards already. This suggests that the essential land data elements of ILMS are now available, but during land acquisition, assembly and referencing, processes can differ between agencies and create a confusing mix of authoritative data. Devising a primary, basic data standard for each land parcel or an assembly of them better enables land acquisition, valuation and compensation processes – an essential and costly element of all infrastructure projects.

High-income countries are better positioned to carry out land referencing, the formal investigation of rights held in land through the collection of data relating to ownership, environmental reports and land plans and deeds, among other factors. Referencing also enables land assembly, and ILMS support this process by helping practitioners and clients understand the potential risks in the data elements. Low- and middle-income nations cannot afford the fees demanded by many professionals in the West, however, so a new combined way of thinking and practising is needed to support large-scale acquisition and development across the globe. ILMS match this need perfectly, as does the new RICS Land pathway.



▲ *Land professionals work in a continuum of land-related processes, each of which relies on the others, but not necessarily sequentially. A land valuation, a taxation receipt or both can be used to establish tenure security without the need for formalisation and titling. Land-based financing is now seen as a crucial element of the New Urban Agenda.*

DUE DILIGENCE

The final standards should be reliable, expose the risk inherent in data elements, and ensure the integrity of the due diligence process in whatever context. The land transfer and reporting standard consists of seven key elements required during due diligence to enable the process and minimise risks:

- land tenure
- parcel boundary identification
- site or land area
- land use
- services
- building
- land value or transfer price.

This creates a data feedback loop, where elements such as valuation can be improved as land data becomes available. ILMS also contain an agreed geospatial survey accuracy table, which for the first time outlines what is

globally agreed in terms of geospatial output, its relationship to scale and achievable accuracy – an enormous milestone.

Each land data element contained in the ILMS can be used to facilitate land administration standards, enable governance, enhance policy, support tenure security and help to benchmark nations against each other in line with The World Bank's 'Ease of Doing Business' index.

THE STANDARD SETTING COMMITTEE

The independent Standard Setting Committee (SSC) was formed by the coalition in January 2017 to develop the ILMS, and included technical specialists from 18 countries and a combined expertise covering more than a hundred different markets. The SSC largely worked together online, although some met in person at the World Bank Land and Poverty Conference in Washington DC in March last year, at the FIG Working Week in Helsinki in June, and in Berlin in September.

The final consultation document went to 25 drafts, some with small, nuanced changes and others with major edits. However, this was a cathartic and necessary process for what can be a national and localised profession. The final standards are, we believe, exactly what the coalition requested and the SSC has done an amazing job, requiring diplomacy and doggedness to achieve global consensus.

This initial consultation process ended in February this year and the ILMS were presented at the World Bank Land Conference in Washington in March. The conference brought together more than a thousand land professionals, academics and international agency staff. Further comments and thoughts will be incorporated, ready for the ILMS to be featured at the FIG Congress in Istanbul in May. Another 'exposure draft' consultation will take place during this summer, with a final launch date pencilled in for November 2018.

OTHER INITIATIVES

Land formalisation and tenure security initiatives have been in operation for many years, with The World Bank providing billions of dollars in funding, and two major international agreements have made them even more significant. UN member states endorsed the 2030 UN Agenda and committed to implementing both the Sustainable Development Goals (SDGs) and the New Urban Agenda at the World Urban Forum in February. RICS, like many international organisations, is keen to engrain the SDGs in national and international initiatives, and ILMS are directly linked to SDGs 1, 2, 5, 9, 11, 15 and 16. The Land Portal has also developed an online resource bringing land-based indicators and targets together.

The ILMS are also directly linked to the new UN FAO publication Valuing Land Tenure Rights: Technical Guide 11. This covers the issues associated with identifying and valuing tenure rights for different purposes, and offers guidance on how to ensure that valuations are undertaken in a fair, reliable and transparent manner complying with international norms.

Other important developments include the UN Habitat Global Land Tool Network's soon-to-be-published guide on the valuation of unregistered land, and the UN Global Geospatial Information Management's work with the UN Economic Commission for Europe on basic land parcel definitions, both of which have referenced ILMS, and the forthcoming RICS research paper on the valuation of unregistered land. As both initiatives feature ILMS, this underlines the standards' future role in land-based financing and the establishment of land markets. ◀

Property Address/Identifier:

	Component	Basis	Date (dd/mm/yy)	Conveyancer Verification (Formal/ Informal)	Documentary Support	ILMS Status	Risk Status
1	Land Tenure						
2	Parcel Identification (Boundaries)						
3	Site/Land Area						
4	Land Use						
5	Services						
6	Building						
7	Land Valuation (Transfer Price)						

▲ *The ILMS land transfer and reporting standard consists of seven key elements required during a due diligence process.*

FURTHER READING

https://consultations.intstandards.org/consult.ti/ilms/consultationHome

'Setting global standards', *Land Journal* (RICS), February/March 2018, pp.10-11 (http://www.rics.org/Global/Land_Journal_February_March_2018.pdf)

New Urban Agenda (http://bit.ly/2C8VF4K)

The World Bank's 'Ease of Doing Business' index (www.doingbusiness.org)

The Land Portal's online resource 'Land and the Sustainable Development Goals' (https://landportal.org/book/sdgs/)

UN FAO, Valuing Land Tenure Rights: Technical Guide 11 (https://shar.es/1N9OQZ)

UN Habitat Global Land Tool Network's guide on the valuation of unregistered land (http://bit.ly/2nPvtYq)

UN-GGIM's work on basic land parcel definitions (http://bit.ly/2H1FkCx)

ABOUT THE AUTHOR

James Kavanagh is director of the RICS Land Group and chair of the ILMS Coalition. He is a chartered land surveyor and chartered geographer with over 25 years of experience in civil engineering, land issues and surveying. He has worked on some of the largest civil engineering projects in Europe and spent several years mapping Palestinian refugee camps in the Middle East while working for the United Nations.

✉ jkavanagh@rics.org

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LADM2018 and 6th Croatian Congress on Cadastre

The 7th Land Administration Domain Model Workshop(LADM2018) was held recently in conjunction with the 6th Croatian Congress on Cadastre (VI. HKK). This international event was organised and hosted by the Croatian Geodetic Society and took place in Zagreb, Croatia, from 11-13 April 2018. It was attended by 600 participants from more than 20 countries.

Prof Chryssy Potsiou, president of FIG, gave an inspiring keynote on preparing surveyors for the future. The focus was on the contribution of surveyors to the implementation of the sustainable development goals. The chair of the FIG Commission 7, Ms Gerda Schennach, presented her view on the future of the land profession. She introduced a changing paradigm: "Cadastre will be more and more created by society – where land owners become active information providers". Stakeholders will be decision-makers in this context and citizens will be shareholders. Kees de Zeeuw, co-chair of the UN-GGIM Expert Group on Land Administration, spoke about standardisation as a basis for sustainability in land administration. He gave a fascinating view of the impact of future innovations.

Proceedings of the 7th Land Administration Domain Workshop.

The LADM standard ISO 19152 is very much alive and being considered, developed and implemented in more and more countries. A second edition will be developed, with inclusion of functionality for valuation. More comprehensive support for 3D and 4D cadastre is required. In order to better support implementations, technical model/encodings (BIM/IFC, INTERLIS, RDF, InfraGML, CityGML) are also proposed. The possibility of a blockchain in support of transactions will be considered as well as the inclusion of processes using imagery. App-based solutions are another relevant development. Very important will be the piloting of LADM implementations in real-world environments. This will be organised by the Open Geospatial Consortium's Land Administration Domain Working Group.

The proposal is that FIG submits a New Work Item Proposal (NWIP) to ISO Technical Committee 211 on Geographic Information in order to develop the second edition in close cooperation with global stakeholders and member organisations.

The chair of the Organising Committee (Prof Rinaldo Paar), the chair of the Scientific Committee VI.HKK (Prof Miodrag Roić), the co-chairs of the LADM2018 Programme Committee (Prof Christiaan Lemmen and Prof Peter van Oosterom) and all participants can look back on a successful event.

More information
www.fig.net

Centennial Celebration of the Finnish Geodetic Institute

The Finnish Geodetic Institute (FGI) was established on 5 July 1918, just seven months after Finland gained its independence. The main task of FGI was the basic mapping of Finland, later to include precise levelling for the national height system, gravimetric measurements for the gravity system, and extensive research in the field of geodesy.

The first-order triangulation had to start from scratch, requiring the selection and reconnaissance of the measurement sites, construction of towers, measurements and computation, astronomical measurements for positioning the network, and baseline measurements to determine the scale of the network. The measurements were started in May 1919, with the last measurements taken in 1987 in Northern Lapland. Ten years after the last triangulation observations, the geodetic control network was replaced by a network of permanent GNSS stations – FinnRef – which nowadays forms the basis of the national reference frame created and maintained by FGI.

Due to the Fennoscandian postglacial rebound, land uplift is almost 1cm per year on the west coast of Finland. Hence the national height system had to be renewed every few decades utilising precise levelling techniques. Nowadays, uplift can be measured using the time series obtained from the GNSS stations of the FinnRef network.

FGI initiated gravity measurements in 1924 using pendulum instruments. Later relative gravity measurements were made using spring gravimeters, and since the late 1980s with an absolute gravimeter. A total of 35,000 gravity points have been measured and this database is now used for computation of the gravimetric geoid. The world-famous work of Professor Veikko A. Heiskanen, who later became the director of the Geodetic Institute at the Ohio State University in 1950, on isostasy and global geoid was also a reason why FGI became well-known within the geodetic community. Although Heiskanen was for only the director of FGI for a short time, his influence on geodesy in Finland has been considerable.

Over decades FGI has conducted or participated in several important national and international measurement campaigns. Metsähovi Observatory was established and SLR observations were started in 1978. Gradually, Metsähovi developed into a comprehensive geodetic research station with a GPS receiver in the IGS network, a DORIS beacon, a gravity lab, and auxiliary and environmental monitoring instruments. In 2012, using special investment funds, a programme commenced to modernise all major instruments, including the SLR and the superconducting gravimeter. A new VLBI radio telescope is under construction, and is expected to be operational in 2019.

The new millennium ushered in significant changes at FGI. Four new departments replacing the old ones were established in 2001: Geodesy & Geodynamics, Geoinformatics & Cartography, Remote Sensing & Photogrammetry, and Navigation & Positioning. The number of personnel has grown from about 45 in 1995 to 140 in 2018. The strategic research areas were defined to be Reference Systems, Mobile Geomatics, Spatial Data Infrastructures, and Changing Earth. The biggest change occurred in 2015 when FGI merged with the National Land Survey (NLS) of Finland. At the same time the name was changed to the Finnish Geospatial Research Institute, preserving the well-known abbreviation FGI. FGI has become a research unit within NLS, and is now stronger than ever – ready for the challenges of this new century.

More information
www.iag-aig.org

FGI's Metsähovi Geodetic Research Station. (Image courtesy: M. Poutanen / FGI)

Spanning the Globe

Two cartographic events in September this year will demonstrate the global span of our discipline; at contraposed points on our planet, there are concurrent cartographic conferences which, although national in organisation, are recommended as being internationally significant.

GeoCart2018 is the biennial national cartographic conference of the New Zealand Cartographic Society (NZCS), and is scheduled for 5-7 September 2018. This wide-ranging event, which is presented in conjunction with the Australia and New Zealand Map Society (ANZMS) , will take place at the National Library of New Zealand, in the capital of Wellington. It aims to bring together a wide cross-section of professionals, researchers and enthusiasts engaged in cartography, map curatorship and research, geovisualisation and GIScience. With international keynote speakers and a full programme devoted to cartographic practice within the country, the conference – with its title 'Cartographies of Change: Then, Now and Tomorrow' – is a widely anticipated event. The proceedings of previous conferences have resulted in valuable additions to the NZCS list of publications available.

In an Antipodean nation to New Zealand (the UK), another capital city (London) will host the UK Mapping Festival during the same time period. This event involves professional bodies, learned societies, government agencies, commercial companies, educational bodies, interest groups and enthusiasts, collaborating on a series of events from 2-7 September 2018. The overall aim of the festival is to increase awareness of mapping in its many forms, providing forums for learning how to use maps, training in the latest techniques for creating, managing and displaying maps, and educating young and old into the great diversity and rich heritage of maps past and present. The formal part of the programme will be in three parts: GeoSpatial theme run by the Association of Geographic Information (AGI)/ GeoForum (4 September); Mapping and Cartography theme run by the British Cartographic Society (BCS)/Society of Cartographers (SoC) (5 September); and Imagery theme run by the British Association of Remote Sensing Companies (BARSC)/ Remote Sensing and Photogrammetric Society (RSPSoc) (6 September). Other activities will include a Geomob/social event, workshops and a HotOSM mapathon.

More information
www.icaci.org

Two cartographic conferences on opposite sides of the globe in September 2018.

3D Spatial Information Science – The Engine of Change

The world's population is predicted to reach 7.5 billion in 2018, and 9.7 billion by 2050. Managing the social and economic changes brought on by this increasing population will require new ideas and spatial information decision-making tools. Moreover, the pressures placed on the usage of spaces where people live and work in will necessitate decisions that are based on 3D and higher dimension spatial data. These pose significant challenges to researchers, data holders, software developers and stakeholders. Besides research and development, much more collaboration and cooperation is required between disciplines, researchers and practitioners, industry and academics to support the progress on spatial information.

One highlight of ISPRS Technical Commission IV 'Spatial Information Sciences' is the Commission Symposium which aims to provide a forum where researchers and practitioners can come together and share their work and ideas in the spatial information sciences, and propose new developments for this important field for the progress of humanity. The 2018 Symposium will be held in Delft, The Netherlands, from 1-5 October. Based around the theme of '3D Spatial Information Science – The Engine of Change', it will be an opportunity to examine and evaluate the state of the art in all aspects of 3D modelling through the work of the ten working groups.

Papers should be submitted online via EasyChair.

DEADLINES

Full paper submission	1 May
Abstract submission	30 May
Notifications of authors	15 June
Final paper submission	15 July

The ISPRS symposium will be hosted at Delft University of Technology and will be a part of the Geo Delft 2018 joint event, which will also host the 3D Geoinfo, 3Dcadatsres and SDSC conferences.

More information
www2.isprs.org/commissions/comm4.html
www.isprs.org/tc4-symposium2018

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