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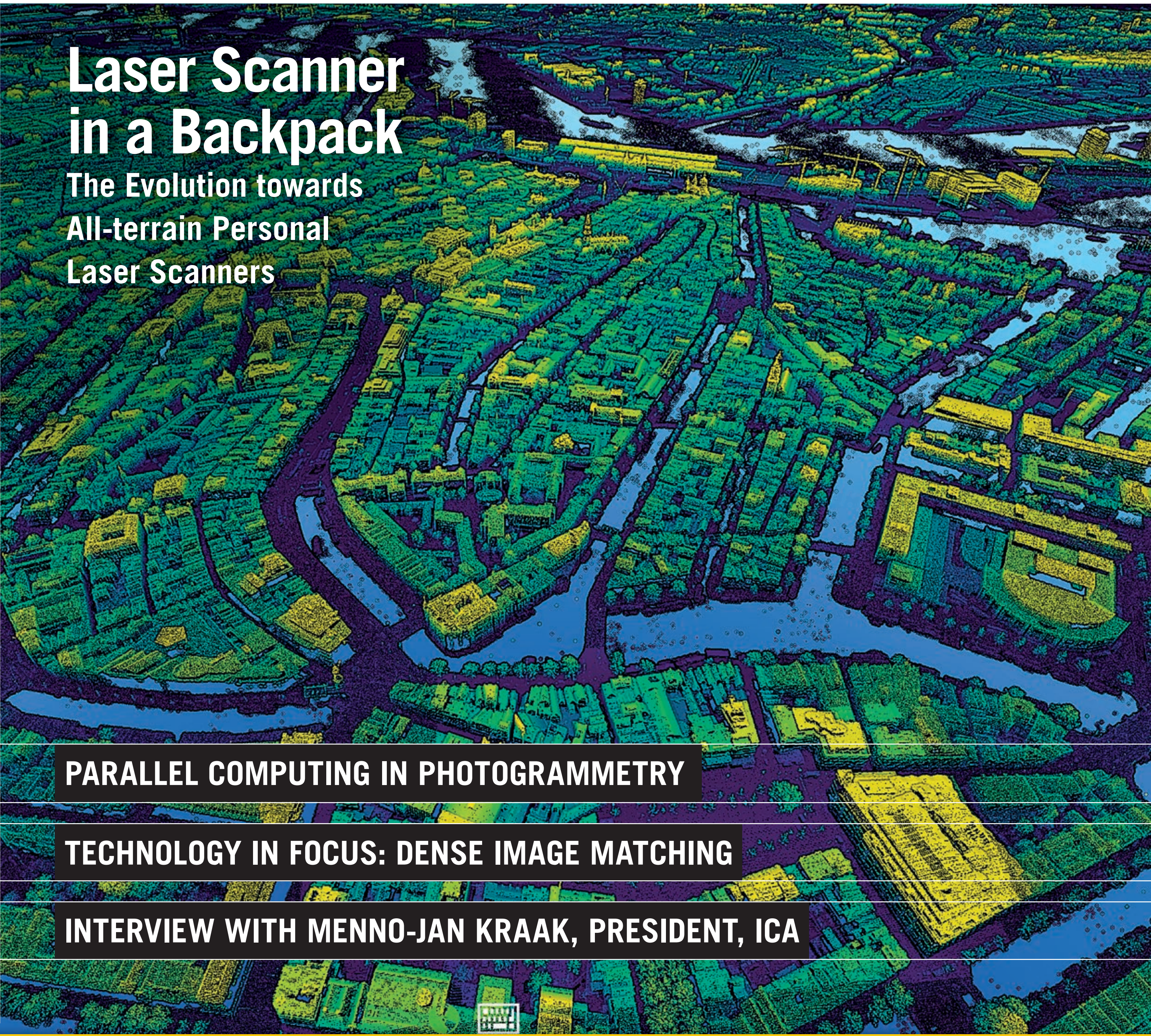

Laser Scanner in a Backpack

The Evolution towards All-terrain Personal Laser Scanners

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TECHNOLOGY IN FOCUS: DENSE IMAGE MATCHING

INTERVIEW WITH MENNO-JAN KRAAK, PRESIDENT, ICA

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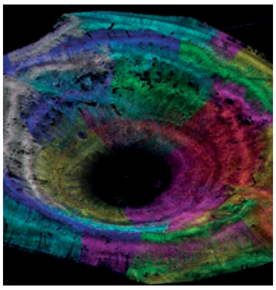

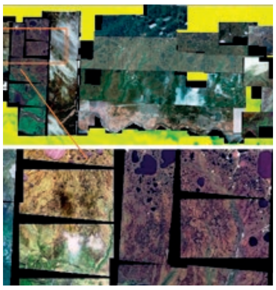

The front cover of the January issue shows point cloud imagery of Amsterdam's famous canals. The visualisation is made possible by the Netherlands eScience Center based on the second national Lidar survey of the Netherlands (AHN2). Dense image matching, photogrammetry and point clouds are keywords in this month's editorial content.

GIM INTERNATIONAL

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Update

This is an issue to remember – not just because it is the first issue of yet another new volume of *GIM International*, but also because we've brought the magazine closer into line with what you want. It is a nice, thick issue filled with articles that will update you on all the latest developments in the field of geomatics worldwide, but which also includes references to our website where you can find more information. *GIM International*'s magazine and website will complement each other more than ever before from now on. You can read the long version in the printed issue, go to our website for accompanying videos and extra illustrations and figures, use the magazine for an update on important trade shows and conferences, and check the website for more photos and an in-depth report.

Our most recent readers' survey (by the way, thanks to all of you who helped us by providing your feedback!) confirmed that many of you still appreciate the printed edition. We've risen to the challenge and – against all publishing trends – we are giving you more instead of less in 2016. We strongly believe there's room for a magazine that informs and educates at a high level, supported by a website that facilitates sharing and interaction within the community of geomatics professionals.

▲ *Durk Haarsma, publishing director*

There have been a few editorial changes too. After almost 200 columns by our senior editor Mathias Lemmens, he will no longer be contributing to 'Endpoint' in the printed edition of *GIM International*. Needless to say, you will still find many in-depth articles and other columns by him and other members of our extensive editorial team, both offline and online. For instance, 'Technology in Focus', a succinct two-page round-up of technology, will appear this year, while 'GIM Perspectives' and 'Insiders View' will give you food for thought on the developments in our field. Meanwhile, our regular 'Young Geo' article focuses on young and enthusiastic new entrants to geomatics who are either still studying or are already working in the industry.

Looking ahead, I believe 2016 is going to be an exciting year. With UAVs approaching maturity and increasingly being applied in mapping and surveying, they will probably change the daily work of many professionals in our field, opening up new opportunities. Crowdsourcing is a topic that still needs to be evaluated and rated on its merits, but this is another area that will undoubtedly advance rapidly in 2016. The ongoing inclusion and penetration of 'geo' in other sectors will boost the importance of our field immensely.

The best way to ensure you are fully up to date on the importance of our industry – and how you can contribute, whether as a company, an academic, a research institute or a geo-passionate individual – is to register for our inaugural GIM International Summit which is being held in the beautiful city of Amsterdam from 10-12 February this year. Visit www.gim-summit.com today to secure your place in shaping the future of geomatics.

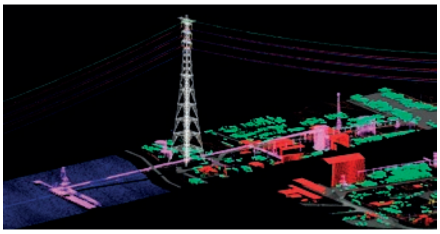
I sincerely hope you have a great 2016 and I wish you all the best, in business and all other matters!

Paris Agreement: Land is a Great Issue!

Surveyors have a role to play in helping the Paris Climate Agreement to become reality. How come? For the first time in history, 195 countries have adopted a universal, legally binding global climate agreement. This happened during the 21st Meeting of the Conference of Parties to the Kyoto Protocol, held in December 2015 in Paris, France. From April onwards the Agreement will be open for ratification. The Agreement will come into force once it has been signed by the 55 countries that account for 55% of global carbon emissions. As you may have read in the media, the commitment is to limit the global temperature rise to a maximum of 2° Celsius (and preferably to 1.5°). But how are we going to do it? That's a good question. Of course, the global Agreement does not go into such details. That's up to the countries themselves. We as surveyors might ask: what contribution will be required from the land sector? Of the total human-induced emissions of about 50 gigatons of CO_2e per annum (i.e. not only carbon but also methane, nitrous oxide, etc.), we know that approximately 9% comes from urban areas and 24% from rural areas. The rest is mainly due to the combustion of fossil fuels. So the land sector must be a major contributor to the reduction of emissions. Unlike the energy sector, land and biomass have the potential to sequester carbon and remove it from the atmosphere! Thus emission reduction and increased storage will definitely help a lot. But were the politicians at the conference aware of this? Yes they were: prior to the conference, 156 countries had already submitted their intended plans. Analysis of these plans reveals that 95 countries included measures on land use, land use change and forestry (LULUCF) as a way to fulfil their commitments. A further 42 countries did not, but they provided assurances that such steps would nevertheless be taken. The rest remained silent on the matter. In total, however, only 36 countries quantified to some extent how the land sector was expected to contribute. This is a relatively low number. Countries appear to be struggling to determine how to manage land use and land use change for the benefit of reduction of emissions and increase of carbon sequestration. This is where we, as surveyors, can put our knowledge and expertise to good use. Matters of land policy, land management and land administration are at the very heart of our profession. The International Federation of Surveyors (FIG) is helping us with its Publication No. 65 on the surveyor's role in monitoring, mitigating and adapting to climate change. Here are a few hints: urban management, infill vacant lands, appropriate management of public spaces, tackling rapid urbanisation and slum upgrading, restoration degraded lands, management of agricultural land use, combating deforestation, land consolidation, nature conservation, resettlement planning in coastal areas, disaster resilience, and land tenure, land tenure security, spatially enabled governance, and the list goes on. In my view, if surveyors can include climate objectives in the management of urban, rural, forest and coastal areas then our contribution could be of paramount importance.

Paul van der Molen.

Lidar Mapping Project Completed in Glacier and Yellowstone National Parks

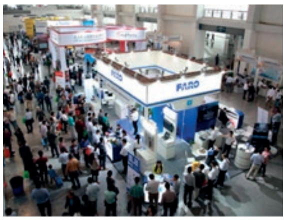


Lidar data collection in two National Parks.

The Sanborn Map Company (Sanborn) has completed mobile Lidar data collection for two corridors in Glacier National Park and one corridor in Yellowstone National Park, USA, totalling approximately 65 linear kilometres. Sanborn was selected for the project to provide data that could be used to determine the level of effort and cost to resurface the roads, which are in dire need of repair. In Yellowstone alone, about 300 kilometres of main roads are in a structurally deficient state, with poor-quality road bases failing under the weight, speed and volume of modern-day traffic. Harsh winter weather and short construction seasons in both parks pose additional challenges.

▸ **http://bit.ly/1TMJk9b**

ChinterGEO 2015 Looks Back on a Successful Event



ChinterGEO 2015.

ChinterGEO 2015 was held in Ningbo, China, from 7-9 November 2015. The event was an opportunity for the international survey instrument industry – manufacturers, distributors and users – to exchange information, display and view new products, learn about the latest technological research, conduct business negotiations and more. A growing number of international companies are finding their way to ChinterGEO each year and now, after 19 years of development, it has become Asia's largest exhibition for geoprofessionals.

▸ **http://bit.ly/1TMJpJV**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GeoSignum Pointer web platform.

New Solution Automatically Processes Massive Lidar Datasets in the Cloud

GeoSignum has launched the GeoSignum Pointer web platform, a solution that automates the processing of Lidar data in the cloud. With the GeoSignum Pointer web platform, users can now immediately access terabytes of Lidar data via a web browser, create and manage an unlimited amount of projects (with download and share functions), extract features and visualise Lidar data in 3D on a high-performance web browser. This enables users to access and manipulate their Lidar datasets anywhere in the world, simultaneously. GeoSignum is committed to bringing accessibility, efficiency and performance to users of Lidar data.

▸ **http://bit.ly/1TMJAoK**

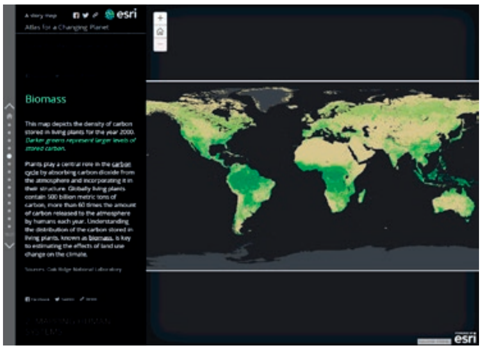
Most shared during the last month from www.gim-international.com

1. How a Well-Functioning Cadastre Can Help Greece to Solve the Crisis - http://bit.ly/1gsLEoC
2. Fast Survey of a High-speed Railway Line - http://bit.ly/1ZepDOx
3. Leapfrogging Urban Problems with Smart Cities - http://bit.ly/1ZepHOr
4. Mapping Liquid Water on Mars - http://bit.ly/1uhs7dr
5. Ford and the Art of Map Maintenance - http://bit.ly/1ZepYkw

Interactive Esri Map Shows Causes and Effects of Climate Change

Esri has released an interactive map illustrating the Earth's natural and human systems and how they have changed – and will change – over time. With the 'Atlas for a Changing Planet' Story Map, scientists, policymakers, planners and activists can examine detailed spatial information that is critical for adapting to a warmer future. Mitigating the effects of climate change is a global, geographic challenge, said Jack Dangermond, president of Esri. Understanding how the Earth's systems interact and transform is an essential first step in measuring the threat of climate change and making informed decisions to reduce it.

▸ **http://bit.ly/1TMJHAE**



'Atlas for a Changing Planet' Story Map.

Key Players Sign UAS Photogrammetric Software Partner Agreement

Topcon Positioning Group has entered into a new partnership with digital photogrammetric solution provider Agisoft. The aim of the agreement is to further expand the Topcon solutions portfolio for mass data collection (MDC). Agisoft is a leading company in the processing of digital imagery in order to generate high-accuracy 3D spatial data using photogrammetric and computer vision techniques, and has been developing imaging solutions for nearly ten years. Topcon will provide the Agisoft Photogrammetric Kit for Topcon – Professional Edition software for post-processing of data collected using the Falcon 8 and Sirius Pro UASs.

▸ **http://bit.ly/1TMJvkP**

FIG and Dutch Kadaster Launch Land Consolidation Event

FIG and The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster), in cooperation with FAO, have announced that they will be holding a Symposium on 'Land Consolidation and Readjustment for Sustainable Development – Designing Resilient Landscapes and Empowering Communities'. This event will take place in The Netherlands in November 2016. The Symposium is aimed at scientists and practitioners from all over the world working in the field of land consolidation and land readjustment. The event is being organised to mark the celebration of 100 years of land consolidation in The Netherlands in 2016.

▸ **http://bit.ly/1TMJIEI**

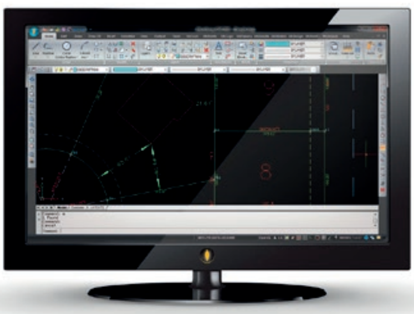
High-performance Mobile Mapping System for Forest Road Mapping

Siteco's versatile mobile mapping system.

Back in 2012, Siteco – an Italian developer of Lidar mapping systems – won the Friuli Venezia Giulia Region tender in its home country by designing and developing a special model of Road-Scanner, a flexible system that can be installed on pickups and quads. The Forest Operational Survey Department wanted to enable its engineering staff to catalogue and update the forest roads in order to develop maintenance programmes and create an inventory of the road network. To achieve this, it issued a tender for the supply of a very versatile mobile mapping system (MMS) that would allow the organisation to update its system dynamically.

▸ **http://bit.ly/1TMJ0fq**

Intuitive New Point Cloud Tools Added to MicroSurvey CAD 2016



MicroSurvey CAD 2016.

MicroSurvey has released MicroSurvey CAD 2016, the newest generation of the flagship desktop survey and design program for land surveyors and civil engineers. Powered by a new IntelliCAD 8.1a engine and enhanced with a suite of new point cloud management tools, the software makes high-impact drafting and design fast and intuitive. The new release includes significant enhancements for working with point clouds. The Ultimate and Studio versions of the software are now powered by the same point cloud engine that drives Leica Cyclone and CloudWorx software, making it possible to directly import Leica Cyclone and Leica JetStream databases using Cyclone dialogues. Users can view panoramic photographs captured by the laser scanner and snap to points directly from the photographs in a TruSpace window. Point cloud data is now displayed directly within the CAD model space, and users can also snap to the point cloud points using standard CAD tools.

▸ http://bit.ly/1TMLsOG

GEO Business 2016 Launches Call for Papers

GEO Business logo

The organisers GEO Business 2016 have issued a call to those working at the cutting edge of geospatial developments to submit their abstracts for the next conference, which will be held at the Business Design Centre in London, UK, from 24-25 May 2016.The conference committee is seeking revolutionary and thought-provoking abstracts that truly demonstrate the remarkable impact geospatial technologies and solutions are having on the global environment. Over the two-day conference, expert presenters will explore how geospatial solutions have enabled projects to run more efficiently, ensuring that they are delivered on time, whilst saving money and reducing risk.

▸ http://bit.ly/1TMKVMa

Capturing Reality Forum Whets the Appetite for More

The first Capturing Reality Forum, held in Salzburg, Austria, from 23-25 November 2015, has been welcomed as a great addition to the geomatics industry by its audience of international delegates and visitors. The event focused on the use of laser scanning, 3D imaging and Lidar to support infrastructure development, BIM, transport, urban and coastal zone mapping, asset management, 3D visualisation and GIS applications.

▸ http://bit.ly/1TMK12b

CHC Navigation Launches i80 GNSS Receiver Worldwide

CHC, based in Shanghai, China, has announced the availability of its new flagship GNSS receiver, the i80. With the ability to compute a true Triple Frequency RTK tilted pole solution using all four worldwide and multiple regional constellations, the i80 receiver is the most advanced receiver available in the market today. The i80 GNSS receiver brings a future-proof sub-centimetre RTK solution to surveyors and contractors everywhere.

http://bit.ly/1TbWVXy

i80 GNSS Receiver.

UN-GGIM Europe to Determine Global Fundamental Geospatial Data Themes

UN-GGIM Europe is to lead work to seek global fundamental geospatial data themes. The mandate to develop this work, which is critical for supporting sustainability, disaster response, land management and environmental resilience, was given to UN-GGIM Europe during the 5th Session of the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). It comes as UN-GGIM Europe adopts its work plan for 2015 to 2018.

▸ http://bit.ly/1TMKIIQ

GIM INTERNATIONAL SUMMIT 2016

Amsterdam - 10-12 February 2016

Time is ticking... secure your place at the GIM International Summit!

2016 has just begun and the *GIM International* team wishes you a happy, healthy and inspiring New Year! Talking about inspiring... why not seize the opportunity to participate in the GIM International Summit? This brand new event – taking place from 10-12 February in Amsterdam, The Netherlands – will immerse you in state-of-the-art geomatics from a different perspective. This unique conference connects the geospatial sector with the challenges faced by modern society.

Top speakers such as Hans Rosling, Morten Jerven, Vanessa Watson and Ed Parsons will each deliver a keynote. In addition, thanks to the interactive workshop programme – including topics like urban planning, climate change, agriculture and infrastructure for geo-IT – delegates will learn about the latest geomatics technologies that can help to tackle society's challenges. Take part in the GIM International Summit to benefit from vital knowledge that will support your organisation's future.

There is only a space for a limited number of delegates, so don't delay and risk missing out on the last few remaining places.
Visit www.gimsummit.com to sign up now!

What others say

James Kavanagh, Director of RICS (Royal Institution of Chartered Surveyors)

"Our geospatial industries have many threats and opportunities before them and one of the best ways to help develop our future profession is through collaboration and knowledge transfer. There are numerous geo-specific conferences and events around the world but we believe that, by reaching out to kindred sectors such as housing, planning, technologists and future trendsetters, the forthcoming GIM International Summit is taking a tentative but brave step in this direction. It's time to start a serious conversation with our client base and we believe the GIM International Summit can help to provide this platform. RICS has no hesitation in supporting and taking part in this ground-breaking event. Fortune always favours the brave."

Prof Tom Veldkamp, Dean of ITC, University of Twente

"At ITC we are very proud to partner with the GIM International Summit. For the past 65 years we've sought to inspire generations of students and to build capacity relating to the use of geospatial information and Earth observation technologies. Our work has always been driven by the demands of society. We believe that geospatial tools play a key role in improving people's livelihoods and the health of the planet. The GIM International Summit puts today's most pressing issues on the agenda: food security, water management, infrastructure provision, climate change and social justice. Let's learn from experts in these domains, and explore how our sector can truly make a difference."

Roger Longhorn, Secretary-general of GSDI (Global Spatial Data Infrastructure)

"The Global Spatial Data Infrastructure (GSDI) Association has a long-standing partnership with GIM International, which has published our monthly GSDI column for several years now. Implementing SDI requires a wide range of skills, tools and technologies from across the geomatics industry and other government sectors. Although Europe has made great advances in the SDI arena since 2007 with publication of the INSPIRE Directive and the implementing EC Regulations, there is still very much work to be done as well as some very valuable lessons to be learned in overcoming the many challenges facing SDI implementers. Therefore, we are very happy to fully endorse this exciting new initiative – the GIM International Summit 2016. We are looking forward to actively participating in the event, both as an association and with our members from Europe and the rest of the world."

GIM INTERNATIONAL INTERVIEWS MENNO-JAN KRAAK

Let's Make the **World a Better Place** with Maps

Menno-Jan Kraak is the newly elected president of the International Cartographic Association (ICA). Cartographer Kraak is a professor in Geovisual Analytics and Cartography at the University of Twente/ITC in The Netherlands, and is a long-standing and active member of the organisation he now heads up. Over the next four years, Kraak will shape the policy of the ICA, striving to make further progress on the steps taken by his predecessor Georg Gartner while naturally also introducing some ideas of his own. His goal is to make the world a better place through maps. He recently shared his thoughts with *GIM International*.

You've just become the new president of ICA. What are your goals?
I've got four main focal points for my period as president. First of all, the map! We covered that with the 'Year of the Map', of course, in which the map plays a central role. Secondly and thirdly, our internal and external relationships. Internally, we have quite a 'bottom-up' organisation; all working groups are initiated by members, and the work has to be done by them as well. I would like to see how we can make that process work even better. The same goes for external relationships; we have immensely increased our commitment in the last few years, especially through the Joint Board of Geospatial Societies but also through UN-GGIM, which has recognised and endorsed our International Map Year. That puts a responsibility on our shoulders. The fourth area of focus is membership. We have around 70 members – i.e. national organisations – but the potential is 200, so there's plenty of scope to expand our number of members.

What's the main benefit for new members? Why should they join?
Most importantly, membership provides them with a gateway to ICA's global network. There's a lot of information exchange between members and possibilities to work together and learn from each other. Basically they are gaining access to knowledge within the association. I know that is difficult to measure, which is why it's often hard to convince member states or national organisations to become members. By the way, a lot of that knowledge is provided to students or young researchers, for instance, in the form of a grant or a reimbursement for visiting a conference. Such benefits are of course very easy to measure.

Do you see a changing role for learned societies like ICA?
Well, just as membership no longer goes without saying nowadays, as an association you should always keep an open mind about your own role. But I still believe that if you want to promote your profession, coming together in real life is most effective. Even virtual contact via Skype or other tools doesn't work half as well. The 'platform role' of ICA remains a very important aspect, enabling people – from many different backgrounds but all united by an interest in the cartography profession – to come together. From commissions and working groups to conferences and congresses, attendance can vary from a few dozen to thousands.

IF YOU WANT TO PROMOTE YOUR PROFESSION, COMING TOGETHER IN REAL LIFE IS MOST EFFECTIVE

What was your main motivation behind taking on this role?
My love for the profession! I've been active in ICA for such a long time. I've acted as vice-chair and chair in several commissions and I was vice-president for eight years. My professional life has been intertwined with the association, so I guess this was a logical step. But I must stress that it's also a great honour!

What are the biggest changes in GIScience and cartography right now?
That's a difficult one… story mapping is very much a hot topic these days and the newest GIS techniques are perfect for portraying a story in a map. However, in the early days of my career, and even before that, a map was published in a booklet or atlas including a small text explaining the map. In my view, that was the same as story mapping. Today's IT tools are making it easier, fancier and more accessible for everybody, but the concept of story mapping, i.e. telling a story through a map, has been around for many years. I don't see any Nobel Prize-winning discoveries, but what is gradually changing is the individualisation and personification of

maps on the one hand and how the individual responds to the map on the other.

In GIM International we keep highlighting the fact that 75% of land-citizen relationships are not documented. Is that another hot topic in your world?

To be honest, when it comes to the art of making maps, a cadastral map is not the most challenging job for a cartographer and none of our commissions are covering that right now. The United Nations' Sustainable Development Goals take the relationships between citizens and the Earth a little further, and I believe that maps as outputs of data can make a difference in that respect.

How do you envisage the role of the 'modern-day' cartographer?

One of the most important characteristics of a modern-day cartographer is the ability to listen to, and to be in touch with, the user of the map in order to establish a user-centred design. The modern-day cartographer needs to ask – and receive answers to – questions like: What does this user want? Which question does the map need to answer? Which story must it tell? And the cartographer must then be able to translate those questions and answers into the right map. Another important thing is to analyse data quickly to find out whether the data contains the answers.

Your presidency starts in the International Year of the Map. What is the main goal of this themed year?

We want to create awareness about maps. We're doing that via UN-GGIM and hence all our sister organisations like FIG, ISPRS and GSDI will see a lot of maps and explanations of what maps can do for them. We've launched a dedicated website where projects and organisations can present their work. We've written a book on maps, titled *The World of Maps* (http://mapyear.org/the-world-of-maps-overview/) which has already been downloaded more than 15,000 times so I believe we are succeeding in creating more awareness.

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What other projects is ICA working on?
We are planning to support the UN in their efforts to achieve the new sustainability goals, by sharing best practices of how maps can help them provide insight into the goals and monitor the world's progress. We've also launched a new journal with publishing company Taylor and Francis, called the *International Journal of Cartography*, and we have become a member of the International Council for Science (www.icsu.org). We are involved in a lot of OpenGeo activities and also with Maps4All. All our commissions are very 'alive and kicking'. A lot of those things were all in place when I came; I've inherited a very healthy and active organisation so credit is due to our former president and my predecessor Georg Gartner who did a great job!

What message do you want to share with our readers?
A map can help you solve a lot of problems: from 'How to get from A to B' to 'How can I reduce poverty?'. First of all I want to create awareness among professionals and map users about the problem-solving ability of maps in particular and the field of cartography in general. I've even tried to coin a catchphrase: 'Let's make the world a better place with maps'. ◂

I WANT TO CREATE AWARENESS ABOUT THE PROBLEM-SOLVING ABILITY OF MAPS IN PARTICULAR AND THE FIELD OF CARTOGRAPHY IN GENERAL

MENNO-JAN KRAAK

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THE EVOLUTION TOWARDS ALL-TERRAIN PERSONAL LASER SCANNERS

Laser Scanner in a **Backpack**

Laser scanning systems have gone through a major evolution in the past decade. After the initial breakthrough of airborne laser scanners (ALS), other types of laser scanning systems have emerged, most notably terrestrial laser scanners (TLS) and mobile laser scanners (MLS). While these three main types of Lidar systems together serve a large number of applications, none of them are optimised for fast and flexible scanning in challenging locations, rugged terrain and complicated urban structures. Personal laser scanners (PLS) fill this void and are now evolving towards compact, agile and flexible solutions for mapping complex environments. This article explains the new Akhka R2 PLS and illustrates its use in various applications.

Many applications require 3D data of objects and their surroundings. Examples can be found in civil and industrial engineering, road construction and maintenance, urban planning, environmental analysis and precision forestry. Lidar has been widely used throughout the years to scan objects or map the environment in 3D to support these applications. The ALS, TLS and MLS types of Lidar systems each have their own applications and advantages and disadvantages. However, there are situations in which none of these Lidar systems can be used. For example, fences, curbs or the orientation of a passageway may prevent access with an MLS, or the terrain may be too rough or too spatially limited. A TLS, on the other hand, may be suitable for the terrain but may be inadequate due to the limited number of viewpoints and the requirement of excessive data redundancy for successful scan registration. Therefore, the growing need to model and monitor objects in complex environments is challenging the industry to develop new 3D data collection tools that are even more complete, accurate and efficient.

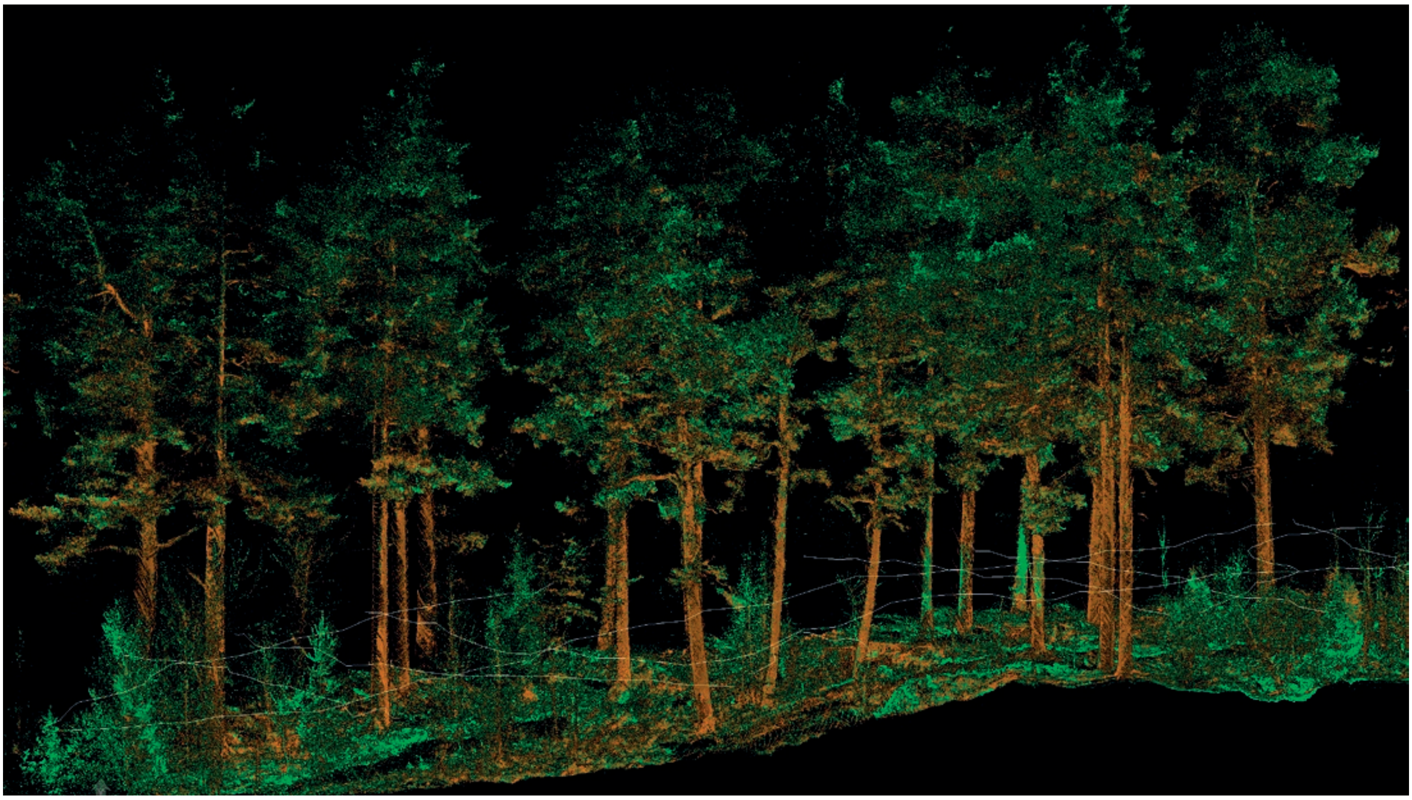
▲ *Figure 1, The Akhka R2 PLS system is suitable for detailed mapping of rugged terrain and complex scenes such as forests. The system consists of a laser scanner, GNSS-IMU navigation system, a tablet computer for data recording and a support structure, all carried as a backpack for flexible operation.*

HEAVY PROTOTYPE

The need for an agile field MLS for large-scale geomorphological landform surveys was the driving force behind the development of the backpack mobile laser scanning system called Akhka that is described in this article. This PLS essentially has similar mapping capabilities to an MLS. The first prototype of the Akhka PLS was built in early 2011 and it was operated in the Finnish Arctic region for mapping point bars (inside-bend river deposits) and palsa landforms (Arctic frost heaves). The prototype proved to be functional and a good starting point for further improvement. One feature still requiring a lot of attention, however, was the weight of the system, since it was too heavy to be worn comfortably for long periods. Nevertheless, operators could easily complete two-to-three-hour mapping runs on loose sand and rugged terrain.

AKHKA REVISION

The current production version of the Akhka PLS, Akhka R2 (Revision 2), now has a much lighter scanner unit and a more robust solution for the trajectory determination with multi-constellation global navigation satellite systems (GNSS) coupled to a fibre optic gyroscope (FOG) inertial measurement unit (IMU). The basic version uses the FARO Focus3D 120S scanner operating at 905-nanometre laser wavelength. The laser scanner on the system operates on profiling mode scanning cross-



▲ Figure 2, Forestry data collected with the Akhka R2X. The system captures not only the ground surface and dominant trees for stem and canopy modelling, but also the secondary forest layer. The PLS allows for easy access to and complete data coverage of complex environments. Image colouring is based on laser intensity while the white line shows fractions of the data collection trajectory.

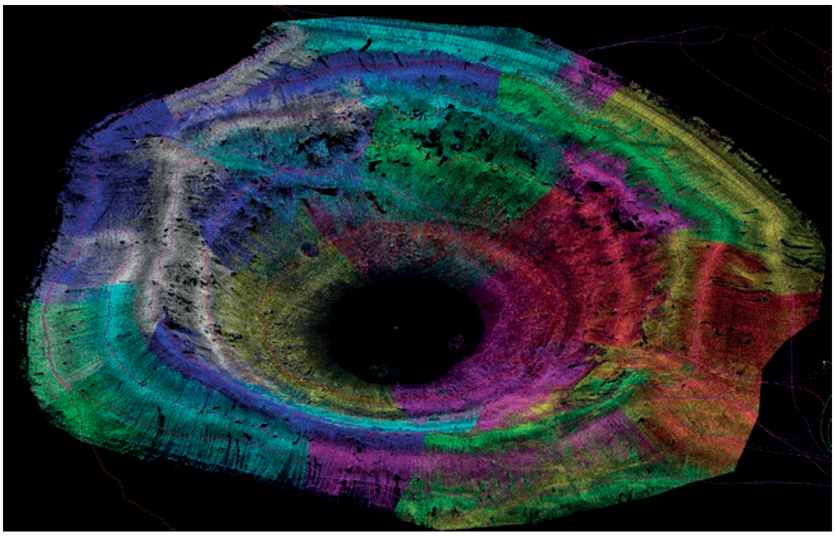
track profiles behind the operator with slightly forward tilt. In Figure 1, the GNSS antenna (white plate) is seen on top and the IMU is found below the scanner. A rugged tablet computer is used to store the positioning and timing data; the scanner data is stored on SD memory cards in the scanner. Table 1 gives a summary of the Akhka R2 sensors.

EASY MOUNTING

The whole scanning system is designed as one backpack-sized sensor pack. The idea of the sensor pack is to have all the sensors mounted rigidly onto a single and compact bundle to maximise robustness and minimise platform distortions and the need for calibration. The R2X version of the Akhka PLS is a slightly modified version of the Akhka R2, which uses 1,550 nanometre laser light for ranging. This category includes the long-range versions of the FARO Focus3D family of scanners, such as the X330 with an ambiguity range of about 300 metres but also the X130 model with a ranging ability of up to 150 metres. These scanners essentially have the same physical dimensions as the 120S version, so mounting any of them to the Akhka R2 platform is straightforward. The structural design of the sensor pack supports the option for vehicle mount as well, allowing even more versatility in different environments and for various data needs.

PRECISE FOREST COVERAGE

The PLS allows the operator to move in and around the scene while capturing the environment with millimetre precision. This is an essential feature when mapping a forest. Figure 2 shows a forest scene captured with the Akhka R2X system. The plot was collected by walking through the forest in different directions to create a dataset with complete coverage. The data shows detailed features of the forest stand (a collection of trees with similar characteristics) and terrain for precise tree stem count, volume



▲ Figure 3, Thinned point cloud representation of the Kaali impact structure computed from the Akhka R2 data. Point colouring represents the point intensity and order of data collection in terms of block number (0-42). The rim of the 25m-deep crater is 110m in diameter. Data collection trajectories are plotted in blue for the post-processed GNSS-IMU and in red for the one corrected based on target data.

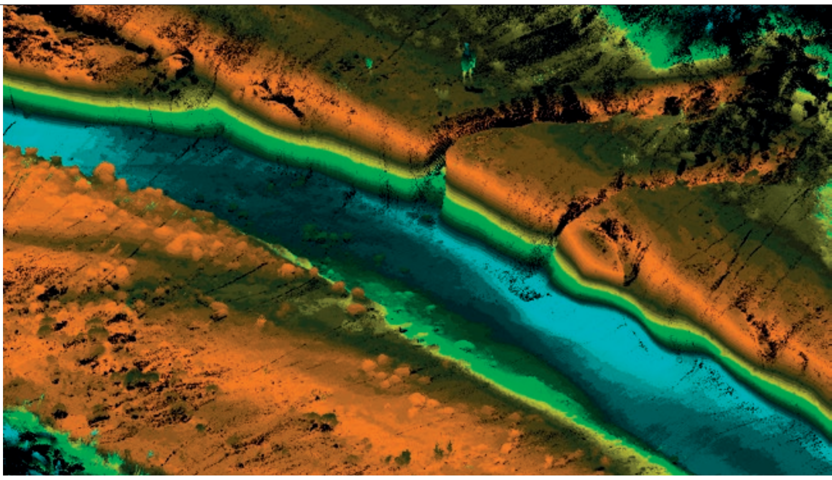


Figure 4, Section of Rambla de la Viuda in Spain representing the erosion ravine induced by a flooding event. The scene is captured with the Akhka R2. The data acquired with the backpack scanning platform can be used as input data for hydraulic modelling. The point colouring represents the ground elevation. To show the scale of the scene, the person captured in 3D in the top centre of the image is 1.8m tall.

and canopy cover estimation and biomass calculation.

IMPACT CRATERS

Acquiring data with a PLS makes it possible to capture all terrain details that are needed for the analysis and understanding of specialised activities like impact cratering and planetary analogue missions. In addition, PLS systems can be used to supplement data or to validate data from smaller-scale sensor systems. Figure 3 illustrates a point cloud collected from the Kaali impact crater in Saaremaa, Estonia, to map the 3D shape and size of the crater. Along with the overall model created from the point cloud, the high-density scan data could also be used to relate the crater features to the size of the impactor.

FLOODING

In fields such as fluvial geomorphology and other natural processes generated by water, wind, frost or ice, a PLS can produce detailed data for relating the extent of change in 3D to other monitored processes such as flooding or wind (speed and direction). For example, the hydraulic modelling of a riverine system benefits greatly from a detailed reconstruction of flooding periods to relate discharge and river bed characteristics. A small ravine eroded by a flooding event (Figure 4) at Rambla de la Viuda, Valencia, Spain, was captured with Akhka R2 to reconstruct the changes induced by the flooding and to derive environmental parameters (such as surface roughness) for hydraulic modelling.

URBAN MAPPING

Furthermore, a PLS can be used for urban mapping and industrial engineering. The PLS can capture the fine details of structures thanks to its high level of mobility. The speed of data collection helps in precise scheduling of tasks. In addition, the PLS minimises the need for process breaks, thus making it ideal when conducting surveys in busy streets and industrial environments. The 3D reconstruction of urban areas (Figure 5) can be used for as-built documentation and planning of new structures and buildings in great detail.

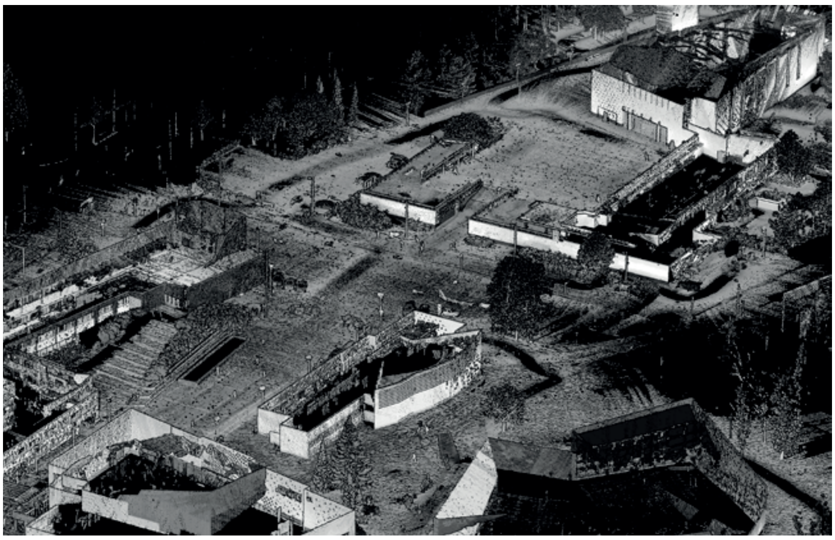


Figure 5, Urban scene mapped with a PLS. The PLS enables collection of complete data from the built environment (e.g. for management and renovation purposes). The operator could use stairs and gateways to reach sections not visible from the street.

FUTURE

It is expected that PLS systems, essentially the 'MLS in a backpack', will be used extensively for a wide range of applications that require data with a high level of detail for structural reconstruction and analysis. Sensor technology is making systems smaller and smaller, thus aiding operations both in the field and indoors, provided that integrated computational technologies evolve sufficiently to also enable accurate positioning in GNSS-denied environments. There are some very interesting small sensors already available in the market and integrated systems are being launched on a commercial basis. However, the main factors to be considered in the system design for a given application are point and line measurement rates, ranging capability and resolution along with angular resolution. There is much still to be done in terms of finding the optimal sensor layout and performance levels for each and every application, but personal laser scanning is definitely a technology to keep an eye on. ◂

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SEAMLESS ORTHOMOSAIC CREATION FROM MASSIVE IMAGERY

Parallel Computing in **Photogrammetry**

The race between data production and processing capacity has been going on for many decades, with data production usually on the winning team. This is also true for airborne and space-borne imagery, as the amount of images captured by satellite sensors and aerial cameras is growing not only steadily but also rapidly. How can the abundance of pixels be processed into photogrammetric products quickly and effectively? The answer lies in parallel computing. Today, computer clusters enable fast and affordable processing of photogrammetric tasks. The author shows how parallelism speeds up the creation of seamless orthomosaics.

Traditionally, software has been written for serial computation. The algorithm is put into operation as a series of instructions which are executed on a central processing unit (CPU), one instruction at a time in succession. Parallel computing – a dominant research area in computer architecture aimed at speeding up computation – is mainly implemented through multi-core processors. The use of multiple CPUs enables many calculations to be conducted simultaneously. As a result, complex computational tasks are broken down into smaller components which can be processed at the same time. Each CPU executes its part of the process simultaneously with and independently of the others. The results are combined afterwards. Photogrammetric processing of massive volumes of images may also benefit from parallel computing. To illustrate the massiveness of the amount of data produced by spatial and airborne sensors, European Pleiades-1A and Pleiades-1B satellites have the capacity to acquire 2,000,000km^2 per day, while the VisionMap A3 Edge aerial camera captures 5,000km^2/hour of imagery with a GSD of 20cm.

SEAMLESS MOSAICS

The creation of seamless orthomosaics consists of several steps, including (Figure 1):

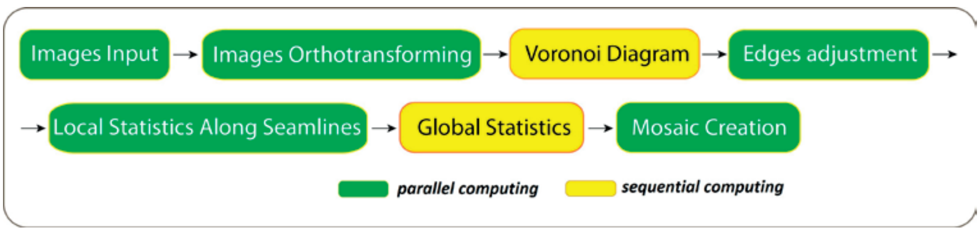
1. project creation and reading the images from storage devices
2. ortho creation of each image using the corresponding digital terrain model (DTM)
3. determination of seamlines
4. image statistic gathering for brightness adjustment
5. seamless orthomosaic computation and storage in separate sheets.

The time taken to download images from a provider of satellite images or from an aerial camera storage unit will be disregarded in the present considerations. Ortho creation of each image, called 'images orthotransforming' in Figure 1, can be conducted in parallel. Seamlines are the edges which constitute the outline of the part of the image used for the creation of the orthomosaic. The determination of seamlines consists of two steps. First an initial seamline is created based on simple topological relationships, particularly the Voronoi diagram. This ensures that the nadir part of all images is preferably selected. This step cannot be done in parallel, but it is completed very quickly. Next, each edge of the Voronoi diagram is automatically refined based on the image content so that the edges of the outline curve around buildings and do not cross roads at right angles. This step can be performed in parallel.

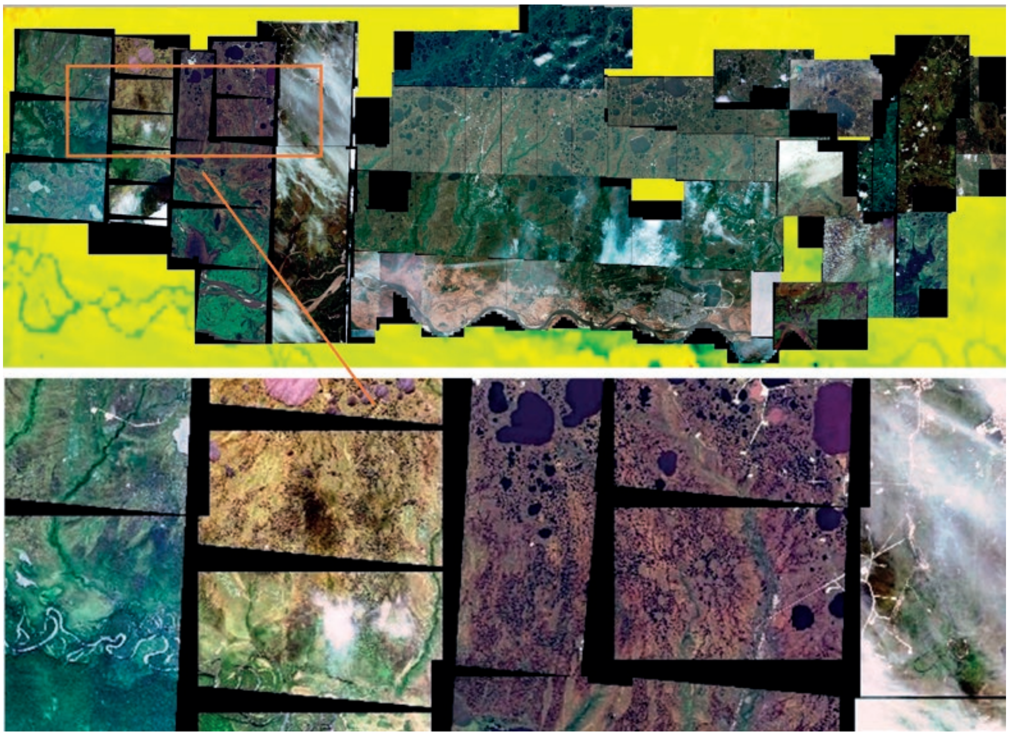
Brightness adjustment is mathematically complex and consists of several stages including collection of image statistics, such as brightness histograms, and global brightness adjustment. Global brightness adjustment cannot be conducted in parallel, but the local brightness adjustment can be done per tile and along seamlines, thus through parallel computing. The last step stitches the images together in one mosaic. This process is carried out on a separate CPU.

TEST

To test the time efficiency of the process developed, the blue, green and red bands of multispectral satellite images were used with a ground sampling distance (GSD) of 1m covering a total area of 37,234km^2 in Khanty-Mansi Autonomous Okrug, Russia. The diverse images were taken during

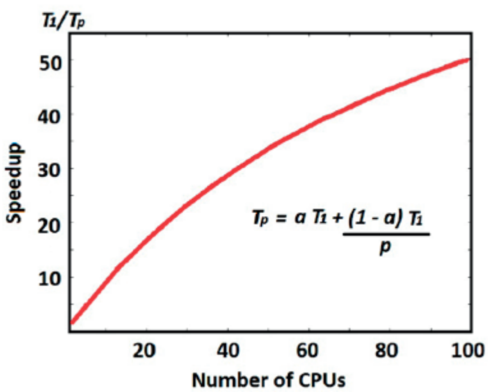


▲ *Figure 1, Flow diagram of the orthomosaic creation process.*



▸ *Figure 2, Block of around 200 GeoEye images on a background representing the DTM and detail (bottom).*

different seasons and under a variety of light conditions (Figure 2). The varying conditions particularly challenged the brightness adjustment part of the process. The method was also tested on 510 true-colour aerial images captured with the Microsoft UltraCam digital camera. Very-high-resolution satellite images are delivered in tiles. The area these tiles cover and the storage requirements depend on the sensor type. For the purpose of parallel processing, the tiles as delivered were rearranged into 1GB tiles. It is preferable to store images at different scales (pyramid levels) to speed up visualisation and the computation of image statistics at reduced images sizes. Each of the 1GB tiles forms separate inputs for the different CPUs.



▴ *Figure 3, Speed-up using multiple CPUs: T1 and Tp are computing time on one and p CPUs, respectively; a is a nonparallel ratio.*

SPEED-UP

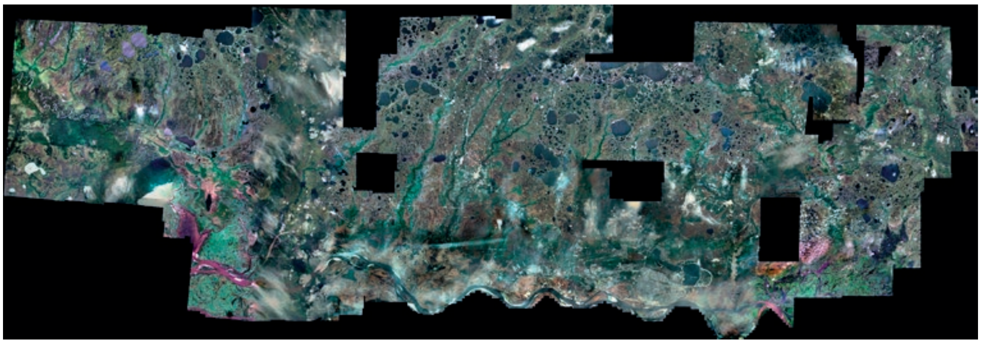
The total computation speed-up using parallel computing is a function of the computing time needed when using a single CPU, the computation time on multiple CPUs and a ratio that expresses the effects of the parts of the process that are not carried out in parallel (Figure 3). As experiments show that the nonparallel ratio of the process never exceeds 1% for large aerial and satellite tiles, computer clusters equipped with 100 to 200 CPUs will be efficient for mosaic production. In this test a computing cluster was used with 96 CPUs (Xeon E5-2695v2). On a single CPU computer the mosaicking of the 1m GSD satellite images took 60 hours while parallel processing on 96 CPUs took just 50 minutes, resulting in a speed-up factor of 72. Figure 4 shows the resulting orthomosaic. Mosaicking of the 510 aerial images required around 100 hours on a single CPU core and 101 minutes in parallel processing using the Xeon E5-2695v2 – a speed-up factor of 60. Hence parallel computing may speed up the creation of an orthomosaic from three to five days to around just one hour.

PARALLEL I/O

In the above-mentioned test, the reading and writing part (I/O) of the orthoimage creation process were conducted sequentially. However, parallelism can be employed not only in computing by expanding the number of CPUs but also in storing the data. RAIDs (Redundant Arrays of Independent Disks) make it possible to speed up reading and writing of files by combining various storage devices into one logical unit.
How the data is distributed across the devices – usually hard disk drives (HDDs) – depends on (1) the level of redundancy required to avoid loss of data due to sector read errors or disk failures (reliability); (2) speed of reading and writing (performance); and (3) available capacity. An extension number from 0 onwards indicates the balance between these goals. Two principles underlie a RAID: stripping and mirroring. Stripping allows writing in parallel to a storage device by splitting huge amounts of data into smaller parts and pushing these parts to different HDDs simultaneously. Mirroring is storing the same data on several HDDs to improve reliability of data storage and also to speed up reading, as the data can be read from different HDDs simultaneously. Typical RAIDs have 300MB/s sequential access throughput and do not constrain CPU usage.

RANDOM ACCESS

The data needs to be transported from the RAIDs to the CPUs and back through a local area network (LAN). Therefore, the reading and writing times also depend on the LAN throughput. The I/O time is roughly linearly related to the array speed, i.e. a 300MB/s array is around three times faster than a 100MB/s array based on the same LAN speed. The authors' experiments show, however, that a 600MB/s array connected to 4GB/s LAN is only two times faster than a 300MB/s array connected to a 4GB/s LAN. This is also true for a 100MB/s array connected to a 2 GB/s LAN. This configuration is four times faster than a 20MB/s to 30MB/s array connected to a 1GB/s LAN, although one would expect performance to be eight times better. Hence, the array and LAN speed alone do not tell the whole story. The reason is that some photogrammetric algorithms require random data access for which modern HDD-based RAID storage systems will give low throughput. Furthermore, the experiments show that using solid state drives (SDDs) instead of HDDs improves the reading performance even when only stripping is used.



▲ *Figure 4, GeoEye orthomosaic – over 600 sheets have been produced at scale 1:10,000.*

CONCLUDING REMARKS

Photogrammetric algorithms can be effectively run on computer clusters with 100 to 200 CPUs. A fast data retrieval and storage system and high LAN throughput ensure the highest productivity. ◀

More information
https://youtu.be/f0STI3xTd-E

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USING NIGHT-TIME ILLUMINATION IMAGES TO MONITOR LOCAL CHANGES OVER TIME

Measuring **Spatial Developments** in the Czech Republic

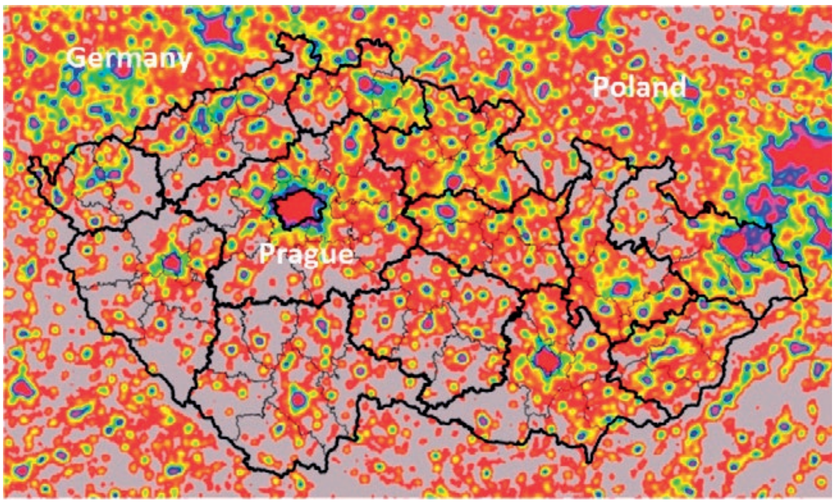
A country's local spatial development can be derived from socio-economic indicators assigned to administrative units. Proper management and monitoring often require statistics at a more detailed level. However, it is difficult if not impossible to sub-aggregate the statistics to smaller areas than administrative units. A reliable alternative is to measure the intensity and extent of night-time illumination and the changes over time. The authors have developed two indicators derived from satellite night-time images for monitoring local spatial developments in the Czech Republic.

Based on analysis of satellite images of the Czech Republic captured at night, the first development indicator identifies the increase or decrease in the amount of light over time and the second indicator identifies year-on-year changes. As the amount of night-time light is computed per grid cell covering an area of 0.55km^2, which can be aggregated into any spatial extent and thus spatial detail, the indicators can be computed for small spatial units (Figure 1). Both indicators enable the determination of intraregional development over time but do not allow interregional comparisons.

DATA

NOAA's National Centers for Environmental Information (NCEI, formerly the National Geophysical Data Center) captures and processes night-time light images taken by satellite sensors, one of which being the Operational Linescan System (OLS) which orbits at 830km above the Earth surface. The spatial resolution of the data is 2.7km and the dynamic range is 6 bits, i.e. the digital numbers (DN) range from 0 to 63. Time series of annual cloud-free composite night-time images have been available since 1992. OLS can detect visible and near-infrared light of which the intensity is one million times weaker than most other satellite sensors and this allows the detection of artificial light. The 14 orbits per day enable the planet to be captured between latitudes 75° north and 65° south between 20:30 and 22:00 hours.

INFLUENCES OF LIGHT FROM THE SUN AND THE MOON ARE REMOVED, AS ARE AURORA, FIRES, LASER LIGHT AND OTHER UNDESIRABLE LIGHT SOURCES



▲ *Figure 1, In contrast to socio-economic statistics, space imagery of nocturnal light emissions enables development spots to be identified within administrative units.*

Influences of light from the sun and the moon are removed, as are aurora, fires, laser light and other undesirable light sources. Areas obscured by cloud cover are also excluded. From the data captured by six

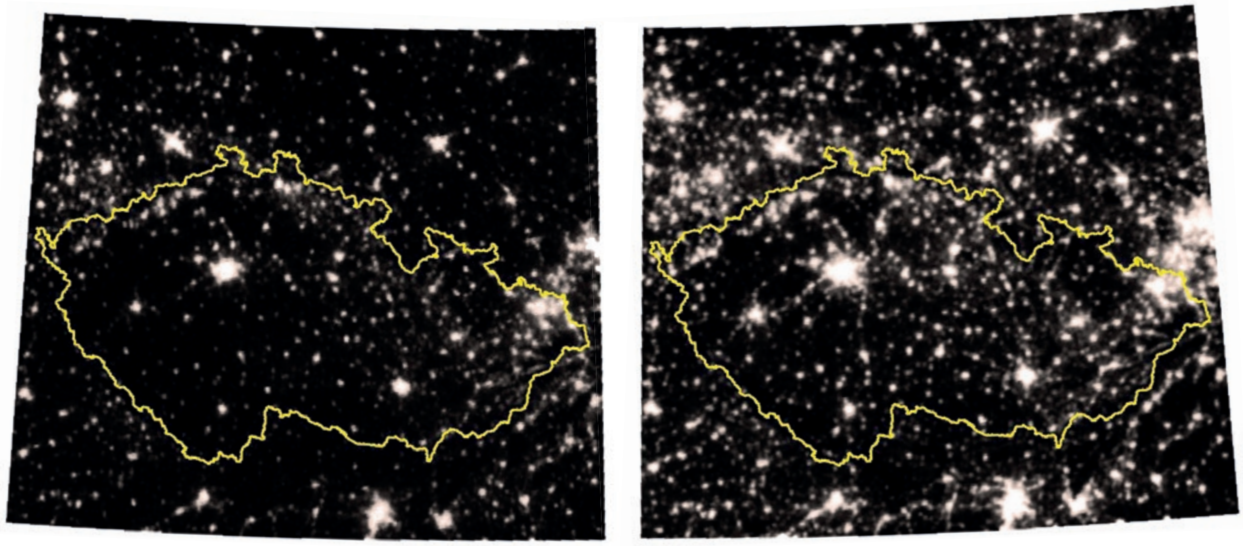


Figure 2, Night-time light development in the Czech Republic from 1992 (left) to 2013.

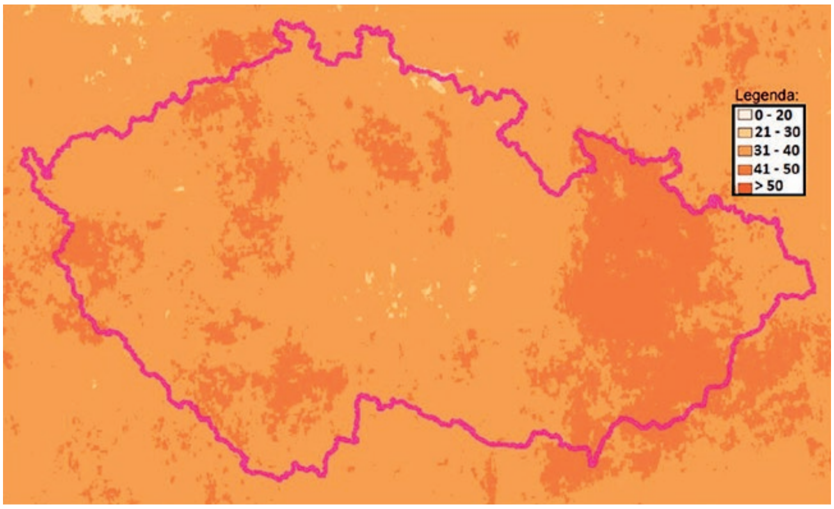


Figure 3, Number of observations used in the calculations.

satellites in the period of 1992-2013, a time series of 34 annual cloud-free night-time composites of the Czech Republic was generated, with each pixel covering an area of 0.55km^2. Figure 2 gives a first impression of the changes in nocturnal light emissions over the course of the two decades. A metadata file contains the number of observations used for each grid cell to calculate the annual values (Figure 3).

CALIBRATION

To monitor the long-term trend, it is necessary to equalise the radiometry of images from the six sensors taken during a time span of over 20 years. The results of the standard radiometric calibration did not enable proper calculation of the development over time. Therefore, the authors developed their own calibration approach based on robust regression using a second-order polynomial instead of linear regression. This enabled the successful minimisation of the differences in the sum of light values for the entire country derived from the night-time images acquired by the diverse sensors over the course of one

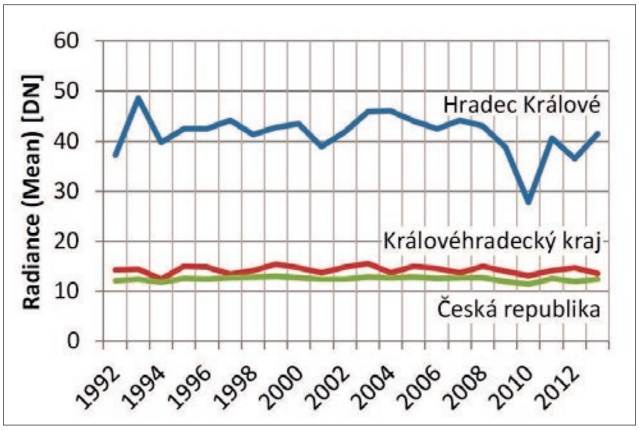


Figure 4, Trends of nocturnal light emissions in two Czech municipalities and in the Czech Republic as a whole.

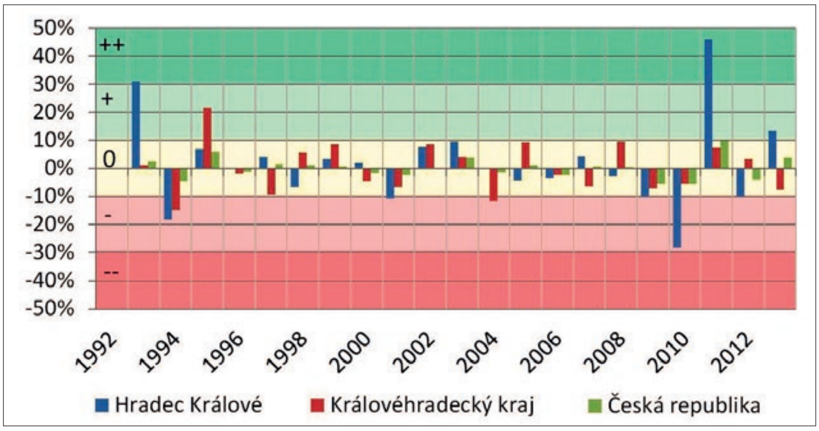


Figure 5, Annual changes in nocturnal light emissions.

year. The corrected light values were used to calculate the two indicators.

INDICATORS AND RESULTS

The trend indicator computes the annual mean of light emission per grid cell. To arrive at a value per region, the means of the grid cells are added together and divided by the area of the region. Figure 4 shows a graph of the trends in two Czech municipalities and in the Czech Republic as a whole. Fluctuations over time may be due to investments, building projects, economic recession, depopulation or other socio-economic factors. Of course, changes in types of light sources may also affect the trend. Since the values do not take into account the degree of urbanisation, this indicator does not allow interregional comparisons of developments. The annual change indicator computes the annual changes as the differences between the means of two consecutive years divided by the mean of the first year. This percentage provides a measure for the proportional change in the given year compared with the year before. Figure 5 shows an example: + indicates sustainable development; ++ means a fast, unviable development; 0 represents stagnation or little development; - means a slight decline; and – indicates a major decline.

Figure 5 also shows that Hradec Králové suffered from the financial recession in the period 2008-2010. In 2011 a recovery commenced as a result of new investment projects. ◀

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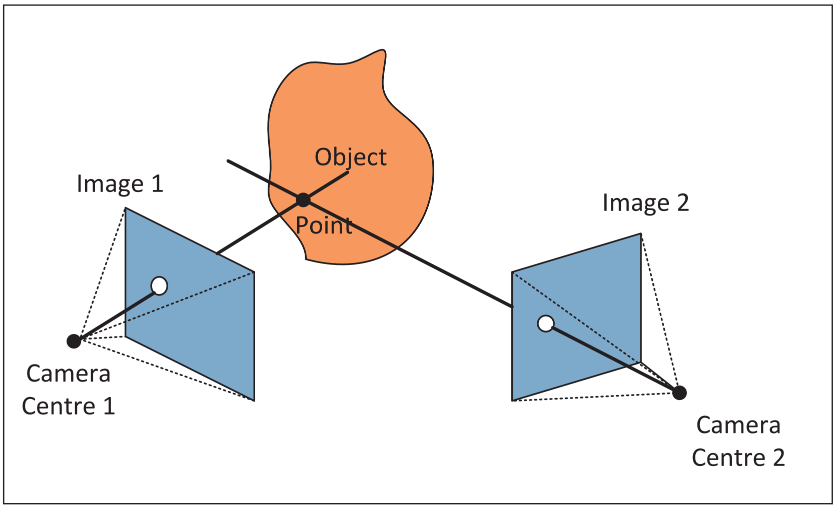
Dense Image **Matching**

Point clouds are increasingly a prime data source for 3D information. For many years, Lidar systems have been the primary way to create point clouds. More recently, advances in the field of computer vision have allowed for the generation of detailed and reliable point clouds from images – not only from traditional aerial photographs but also from uncalibrated photos from consumer-grade cameras. Dense image matching is the powerful technology underpinning this development.

A good understanding of dense image matching requires insight into the way photogrammetry works. Photogrammetry in itself is not a new technology; it has been applied in practice for decades without many changes to its fundamental concepts. In photogrammetry, 3D geometry is obtained by creating images of the same object from different positions. This makes a single point on the object visible as a pixel in multiple images. For each image, a straight line can be drawn from the camera centre through the pixel in the image. These lines will intersect at one point, which is the 3D location of the object point (Figure 1).

However, this requires the position and orientation of each image to be known. To this end, so-called tie points are used to link all the images together. Each tie point is a well-recognisable point that is identified in all images where it occurs. Sufficient tie points allow for the reconstruction of the relative position of all images. Additionally, known points or ground control points (GCPs) with 3D world coordinates should be added to obtain scale and absolute coordinates.

Technology in Focus
Over recent decades, many of the geomatics processes which were previously performed by humans have been automated. Software modules running on powerful computers are now doing much of the work. What are the principles behind the algorithms? Which concepts underpin these techniques? The Technology in Focus article provides you with a bimonthly, in-depth insight into the complex underlying technology.



▲ *Figure 1, The principle of 3D point reconstruction from two images.*

Tie points and GCPs are combined in a bundle block adjustment, resulting in the 3D coordinates of all tie points and, more importantly, the position and orientation of each image.

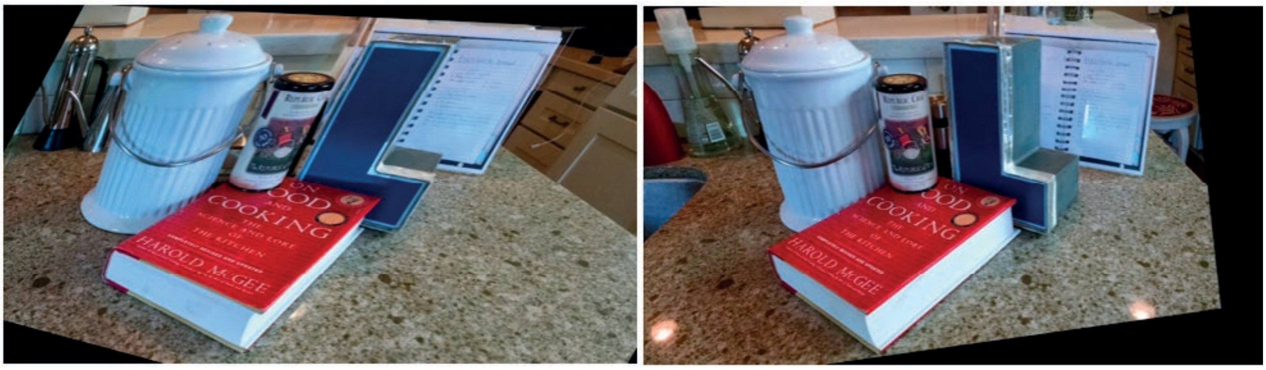
FINDING CORRESPONDING POINTS

In the old days of analogue aerial photogrammetry, tie points were physically identified by pinning small holes through the image at the tie-point location. When digital photogrammetry emerged, much of the manual labour was replaced by automated tie-point search software which can easily detect hundreds of reliable corresponding points in multiple images. Feature-based matching is often applied for this purpose. The algorithm attempts to detect well-recognisable features – such as a road marking, a building edge or any other strong change in contrast – in each individual image. Once all the features have been found, the algorithm proceeds to detect corresponding features in multiple images. This results in highly reliable corresponding points that are very suitable as tie points.

To obtain a dense point cloud, a corresponding point is needed for almost every pixel in the image. The feature-based matching approach is not suitable for this purpose since not every pixel in the image corresponds to a well-recognisable feature. Many pixels will represent a greyish surface of a road or pavement or a green patch of vegetation. These pixels cannot be automatically linked to a feature and will be missed by the feature-based matching approach.

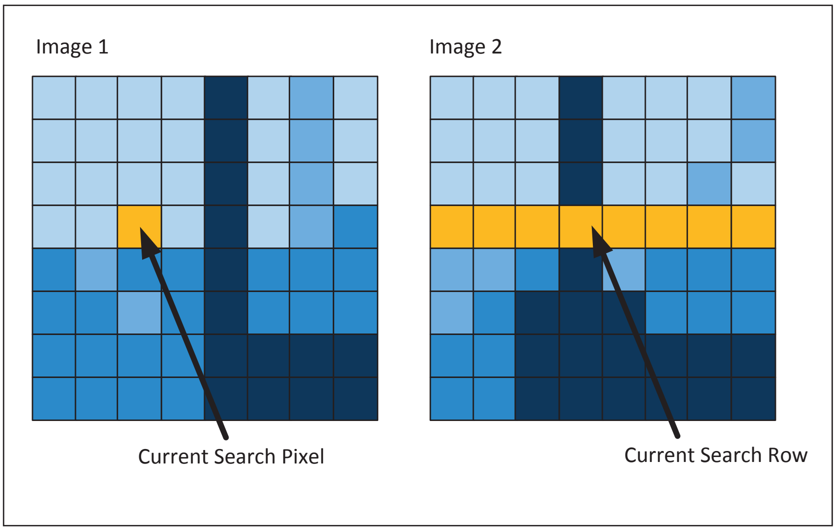
SEARCHING ROW BY ROW

Dense image matching takes an alternative approach to obtain a corresponding



◀ *Figure 2, Two images rectified to create corresponding rows.*

point for almost every pixel in the image. Rather than searching the entire image for features, it will compare two overlapping images row by row. Essentially, this reduces the problem to a much simpler one-dimensional search. This requires an image-rectification step before the matching starts. The images need to be warped in such a way that each row of pixels in one image corresponds exactly to one row in the other image, i.e. in technical terms the rows of the images should be parallel to the epipolar line. In the case of aerial images that are captured in long flight lines, there is usually a good correspondence between the rows so only a small correction is needed. Terrestrial and oblique images, however, may require significant adjustment to achieve this row-by-row property. From a computational point of view, this can be achieved with a simple perspective transformation. To the human eye, the resulting images can appear highly distorted (Figure 2).



▲ *Figure 3, Searching row by row in two images.*

Now, the algorithm can work row by row and pixel by pixel (Figure 3). For each pixel, it will search in the corresponding row for the pixel that is most likely to represent the same point in the real world. It will do this by comparing the colour or grey value of the pixel and its neighbours. At the same time, a constraint is set to ensure a certain amount of smoothness in the result. When a pixel is found in the second image that is a good match to the same pixel in the first image, the location of that pixel is stored. Once two corresponding pixels are known, traditional photogrammetric techniques can be used to compute the 3D intersection for the pixel.

SEMI-GLOBAL MATCHING

The row-by-row approach to images is efficient but, since each row is handled entirely independently, there is a risk of a disconnect between the results. This effect is called streaking. To overcome this disadvantage, the semi-global matching approach was proposed. This method not only evaluates horizontally row by row but it also traverses the image in 16 different directions. This produces 16 matching results which are then combined in a weighted sum to achieve a final result that has much less noise. Furthermore, this approach may add other images that also have overlap for an even better result.

DENSE IMAGE MATCHING IS AN ESSENTIAL TECHNOLOGY FOR MANY RECENT INNOVATIONS IN THE FIELD OF GEOINFORMATION

CONCLUDING REMARKS

There are many adaptations and alternatives to the matching approach presented in this article. Alternative implementations may improve memory efficiency, speed or reliability. Often, the algorithms do not store the corresponding pixels but rather the parallax between them as this is more memory efficient. Dense image matching is an essential technology for many recent innovations in the field of geoinformation. It is used to generate point clouds from aerial images, drone images, spherical images, etc. It can also increasingly be found in consumer-oriented products such as mobile apps for fast modelling of 3D objects. ◀

EXPLORING COLOUR AND GEOMETRICAL PROPERTIES

Semantically Enriching **Point Clouds**

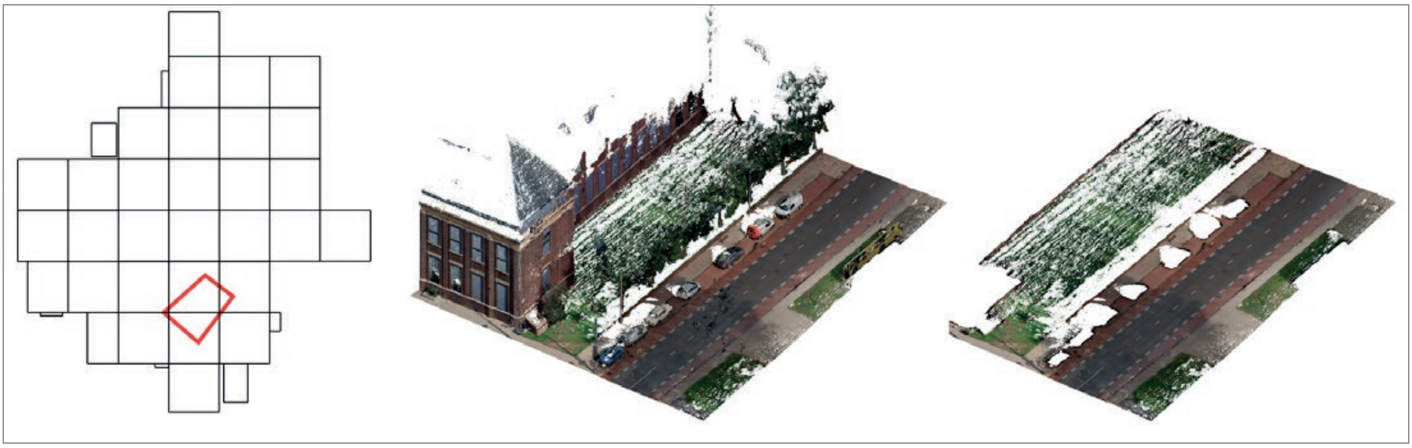
The Geomatics master programme at Delft University of Technology focuses on geographical information science. Geomatics in Delft differs from other geomatics programmes in its close connection to the Faculty of Architecture and the Built Environment. In their second – and final – year of study, the geomatics students embarked on a 10-week Geomatics Synthesis Project as a group. The objective was to undertake a small but real-world research project where experience could be gained in the entire geoinformatics chain (acquisition, processing and application).

For the 2015 Geomatics Synthesis Project at Delft University of Technology (TU Delft), five students were asked to explore new ways for the direct use of point clouds in order to fully exploit the data. In addition to geometry, the point cloud data holds colour information that is derived from matched terrestrial images, better describing the data collection environment. Other information usually available in point clouds, e.g. intensity, is not present due to the nature of the acquisition technique. Until now, point clouds have mainly been used for 3D modelling. In most cases the contextual data is never utilised and is simply discarded at the end of the project.

From the students' perspective, increasing the usability of point clouds was a matter of incorporating semantics into the original xyz data. This means that the points are enriched with meaning derived from their urban environment. These additional point attributes can highly increase the value of the data by making it more descriptive. Features and parts of the data can be extracted more precisely, then shared and analysed for more applications and users. This approach creates new possibilities such as high-resolution map creation, water infiltration capacity analysis and other ways of studying the urban environment.

In this project, different approaches and techniques to adding semantics were explored and an optimal workflow was

▲ *Figure 1, The Geomatics Synthesis Project group, in front of the Cyclomedia mobile mapper.*



▲ *Figure 2, The selected scene, before and after the ground filtering process.*

created by combining the best practices. These best practices consisted of indexing, colour transformation, region growing, region classification and the smoothing of the results. The focus in this workflow was on ground points since the street level around buildings is usually omitted in 3D models.

LABEL DEFINITION

Designing a workflow that would extract the road information and its surroundings first required the definition of relevant classes for the application. In this case road extraction and material detection at street level were examined. The relevant subcategories used were: Grass, Road, Cycle path and Footpath. These categories represent how people generally interpret the street level. For more specific applications (e.g. the surface infiltration capacity), where the composition of materials is needed, a specialist would benefit from a classified point cloud with the classes of asphalt, grass and tiles.

DATA ACQUISITION AND INDEXING

The data acquisition was performed in collaboration with Cyclomedia using their mobile mappers. The mappers acquire panoramic images that are used in a stereo imaging process to create a coloured point cloud. The mobile mapper was driven around the Faculty of Architecture, collecting 93,436,125 points.

A subsection of the data was processed for the project and ground points were extracted. These points were indexed using a kd-tree for fast nearest neighbour search and the calculation of the geometrical properties. Current research in object recognition from point clouds is mainly focused on making use of the geometric properties of the point and its environment. For ground points, however, a labelling process on geometrical properties only is more complex, as all ground points generally lie on the same plane. This is especially true for a flat country like The Netherlands. Therefore, the colour properties of the individual points were used to differentiate between neighbouring points and identify which belong to the same class.

REGION GROWING AND COLOUR SIMILARITY MATCHING

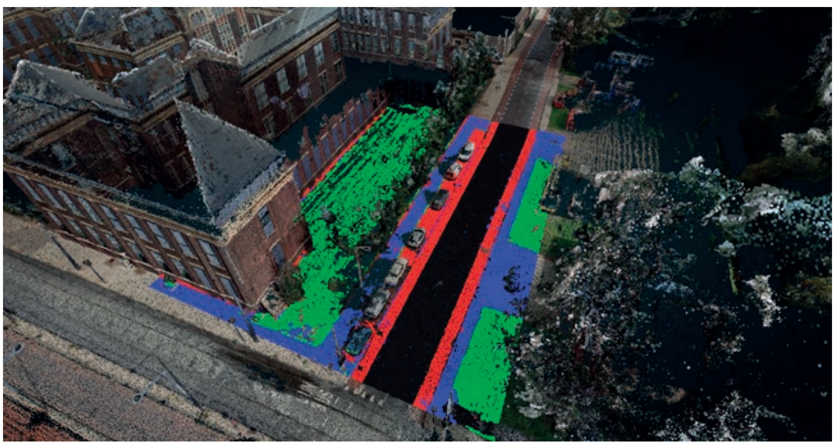
In order to create groups of points with similar properties, a region growing algorithm was developed. The algorithm groups neighbouring points with similar colour and geometrical properties, the normal and curvature, using a predefined threshold of similarity. The colour information was transformed beforehand into a different colour space. A colour space is a colour indexing framework that assigns coordinates to colours based on their position in the colour space, like RGB (a 3D colour space). This transformation was done in order to make the data more suitable for spatial operations and especially for colour matching. After experimenting with different colour spaces, the CIELab colour space was selected.

SUPERVISED CLASSIFICATION

In the classification algorithm, the grown regions were given a semantic meaning by making use of supervised classification. This approach required a set of training sample data that had labels associated with it. This sample data came from prior knowledge about the scene. This meant that for the area of interest, samples were collected that belonged to the Road, Cycle Path, Footpath and Grass. A Gaussian distribution of the colour properties was assumed to define the data classification algorithm. A 99% confidence level was chosen, as this gave the most optimal results.

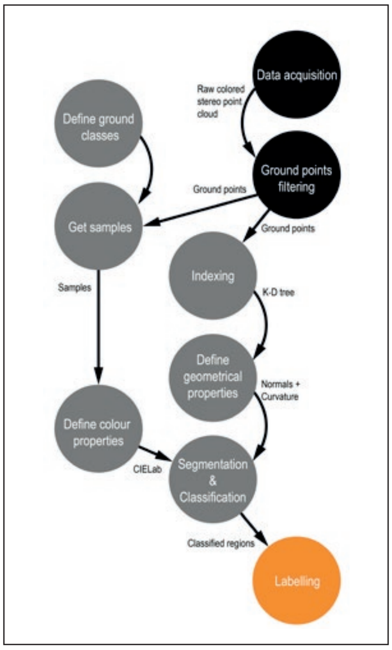
SMOOTHING ALGORITHM

To handle the noise generated from the supervised classification, a smoothing algorithm was developed. This method was based on image smoothing filters for noise



▲ *Figure 3, The classified points, whereby each colour represents a different class.*

removal. The algorithm traverses all points in the classified point cloud. For every point it checks its k-nearest neighbours and calculates the most frequent class among these neighbours. The point is then reclassified if the original classification differs from the most prevalent class of its neighbours. This process offered both a visual and accuracy advantage to the final result.



▲ *Figure 4, Workflow of the classification process.*

CONCLUSION

The use of colour in combination with geometrical properties in today's point cloud processing procedures can offer invaluable assistance in classifying objects. Normals and curvature are used for region growing, but not for directly labelling the point cloud. While most of the procedure can be automated, this approach still requires human interpretation in selecting training samples. Using external data, such as the position of the car, could help in further automating the process.

ACKNOWLEDGEMENTS

The group members Adrie Rovers, Tim Nagelkerke, Irene de Vreede, Stella Psomadaki and Merwin Rook would like to acknowledge the support of Bart Beers from Cyclomedia as well as thank their mentor, Wilko Quak. ◀

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STELLA PSOMADAKI

Stella Psomadaki is a Geomatics master student at TU Delft. She holds a BSc in Rural and Surveying Engineering from the National Technical University of Athens, Greece, where she graduated top of her year. She is currently working on her graduation project on investigating the possibilities of integrating space and time in point clouds using a database management system.

Young Geo in Focus

'Young Geo in Focus' offers recent graduates or postdocs the opportunity to share their experiences with our worldwide audience. If you've just completed an innovative project with your first employer or finalised your PhD research with results that are of interest to practitioners feel free to contact the editorial manager at wim.van.wegen@geomares.nl.

Urban Planning, Management and Decision-Making in the Cloud

SmarterBetterCities is a software company located in Zurich, Switzerland, which creates CloudCities (https://cloudciti.es): a cloud platform for smart city planning and smarter urban management. In line with the SmarterBetterCities' mission – 'to replace an army of specialists with a single web platform' – CloudCities is a simple, smart and attractive platform for urban planning, putting decision-making at your fingertips. Users can upload 3D city models using various file formats and show off their projects and significant context data, e.g. energy consumption, floor areas or renovation potential, by just using a web browser. Smart tools such as SmarterBetterCities' 3D Cities Libraries offer solutions for instant city modelling and energy demand assessment.

Together with current CTO Jan Halatsch, Antje Kunze founded SmarterBetterCities in December 2012 as an ETH Zurich spin-off. Before then, the duo had been working as research scientists since 2006 on several pan-European research projects. Most of their activities strongly involved investigating how information technology can facilitate sustainable urban planning. Their ties with ETH Zurich enabled them to gain exposure both locally and internationally and gave them access to professional networks around the globe.

There is still an enormous gap between the GIS and BIM industries nowadays, and great ideas are often lost in today's interdisciplinary design process. That starts with the lack of tools to communicate thoughts and concepts. Just visualising the actual situation of a city is a time-consuming process, and the situation tends to worsen when data is exchanged (and unfortunately also lost) frequently between the project partners involved. Furthermore, during a design session it is typically difficult to include relevant key metrics such as the direct assessment of urban design scenarios with regard to costs, floor area and energy demands.

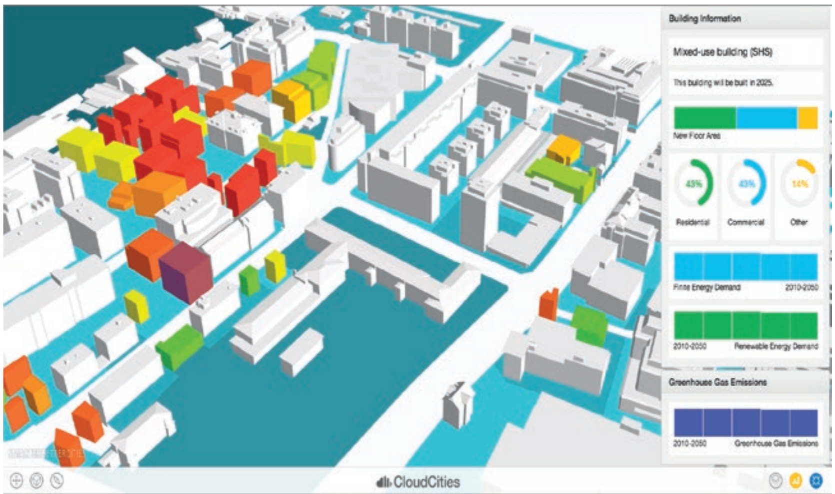
Every month *GIM International* invites a company to introduce itself in these pages. The resulting article, entitled Company's View, is subject to the usual copy editing procedures, but the publisher takes no responsibility for the content and the views expressed are not necessarily those of the magazine.

CITY MODELLING

ETH Zurich has been at the forefront of technology for many years, continuously striving to tackle the above-mentioned issues using advanced technology. In early 2006, Antje Kunze and Jan Halatsch started to work with a tool called CityEngine, which had just been invented by Pascal Mueller and his peers at the ETH Zurich Computer Vision Laboratory. The tool offered exciting potential for urban planning applications. It was suddenly possible to recreate whole, realistic-looking cities in 3D using tiny computer scripts. These little scripts subsequently evolved into sophisticated programs which not only visualise highly detailed cityscapes but also translate complex zoning regulations and energy demand calculations into understandable urban forms. Interest was aroused from both the private and the public sectors. In the meantime, Esri acquired the start-up Procedural AG that released the commercial version of CityEngine. Hence, the CityEngine technology became part of the wide universe of the Esri ArcGIS platform, thus accelerating the demand. The company SmarterBetterCities was launched in response to the growing number of requests for custom solutions based on CityEngine modelling technology.

SMART ZONING

One of the company's first major contracts was to implement the city of Zurich's zoning laws, which resulted in the SmartZoning product. This is a procedural 3D city model that creates legally solid 3D building envelope shapes. The city is using SmartZoning on a daily base. Firstly, parcel and land use data is uploaded as GIS layers. Then SmartZoning automatically triggers the procedural rules to generate the regular building envelopes for the underlying land use zone. The building envelopes precisely follow thresholds such as building dimensions, floor area ratios, open space requirements and setback information. The researchers were keen to develop solutions that would make a difference on a large scale, so from an early stage the focus was on innovative tools for urban planning which would offer benefits to many cities (and people). European Union funding within the framework of Climate-KIC projects, which support products that can significantly lower the release of greenhouse gases, further accelerated the commercialisation of the



CloudCities makes it easy to create clear visualisations out of complex GIS and CAD data.

SmartZoning tool and facilitated the development of an entirely new cloud service named CloudCities.

CLOUD-BASED SERVICE

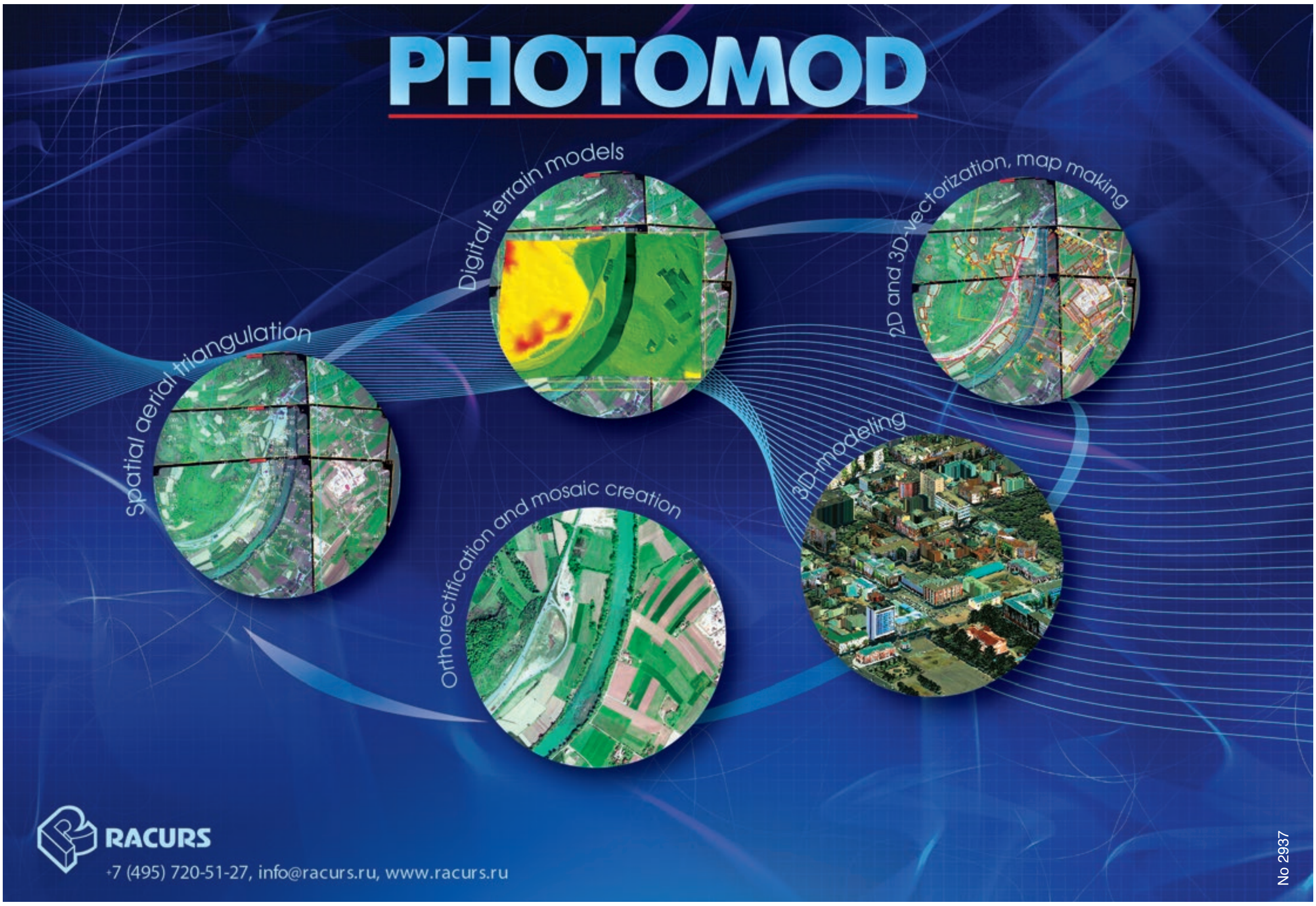
CloudCities is intended to replace sophisticated and complex urban planning and management tools that can only be handled by highly educated users. Thanks to CloudCities, cities with between 10,000 and 100,000 inhabitants that cannot afford a full 3D GIS stack but still want to become livable, lean and efficient 'smart cities' can upload and share their design scenarios using just a web browser on any modern device – computer, smartphone or tablet. CloudCities makes it easy to create clear visualisations out of complex GIS and CAD data. Users can customise dashboards using drag and drop to highlight the key metrics of their design or even the current state of their city. Moreover, within CloudCities it is possible to create cameras and animation paths that can guide people through vast urban scenarios. Various aspects of a construction project can be explored using intuitive controls through the information layers, and search features ensure that no details are lost. Sliders, toggle buttons and radio buttons give multiple control options for the display of information, including time ranges such as to illustrate the progress of a construction project. Once the preparations are complete, the online presentation can either be left inside CloudCities or it can be embedded directly in an external project web page or a project app. The end users of CloudCities range from individual citizens (public engagement) to CFOs of large government organisations.

In the most recent December release, support was added for Google Earth data (.kmz, .kml) and Collada (.dae). The Q1/16 release will include direct support for Autodesk FBX, Esri Multipatch (.shp and .gdb), Trimble SketchUp (.skp) and CityGML. These are all file formats which are heavily used in urban planning and management but typically in very different departments. CloudCities bridges the gap between them and enables the interaction between project partners by using and integrating digital data from all project parties.

FUTURE

Future releases of CloudCities 2016 will further increase the interoperability of features. Other plans include to ultimately integrate SmartZoning and 3D Cities Libraries into the cloud service. This will enable cities to quickly create 3D zoning plans, including sophisticated energy cost assessments, online by simply uploading their 2D cadastre maps to CloudCities and by applying SmartZoning to the parcel information. In turn, architects could validate their designs against the present zoning for a given parcel lot, for instance, and real estate developers could gain a better understanding of the real market value of land. A third-party data provider will provide direct access to vector maps, 3D buildings and climate, sensor and traffic data from within CloudCities.

More information
www.smarterbettercities.ch



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Review of FIG Workshops in Autumn 2015

Crowdsourcing of Land Information

Is crowdsourcing feasible for capturing evidence of land rights and can it help to rapidly shrink the security of tenure chasm? These were the central questions during a FIG (Commissions 3 and 7) workshop on Crowdsourcing of Land Information in Malta from 16-20 November 2015.

The United Nations' 2030 Agenda for Sustainable Development includes new Sustainable Development Goals, with six of the goals having a significant land component mentioned in the targets. For example, Goal 1 calls for ending poverty in all its forms everywhere, and Target 4 states that by 2030 all men and women should have equal rights to ownership and control over land and other forms of property. These goals and targets will never be achieved without having good land governance and well-functioning, countrywide land administration systems in place. Conventional approaches in land administration have failed so far in developing countries, and there is a need for new and scalable approaches in land administration. The workshop showcased the innovative crowdsourcing approaches emerging as one of the potential solutions to reducing the global land tenure divide.

Although the crowdsourcing solutions presented at the workshop have not yet gone to scale, they have clearly demonstrated success in piloting environments. Examples include the USAID Mobile Application to Secure Tenure project in Tanzania, the Landapp pilots in Ghana and Indonesia to support smallholder farmers, and the Kadaster/Esri/Trimble pilot in Columbia. The approach is certainly proven from a technical and ICT perspective: apps for the collection of land administrative data are available for mobiles with GPS, extensions are available for positioning with lightweight GNSS devices with sub-metre accuracy, and software tools are available to share the collected data in the cloud for transparent access and for maintenance purposes.

Services were presented where countries or communities can store and manage land data and organise access to that land data. Key issues were discussed around standards, certification for apps, formalisation of crowdsourced land rights, trusted intermediaries within communities and business models to sustain the crowdsourcing initiatives. There was agreement that 'legitimate land rights' and related spatial units can be integrated into formal land administration solutions in step-by-step approaches. It is possible to integrate crowdsourcing with the fit-for-purpose approach to land administration. However, the concept of crowdsourcing needs to gain society's trust to be ultimately accepted and adopted.

FIG-ISPRS Workshop: Role of Land Professionals and SDI in Disaster Risk Reduction

The programme of this workshop, held in Kathmandu, Nepal, from 25-27 November 2015, covered the various aspects of spatial technologies and the role of spatial data infrastructure in the context of disaster risk reduction. It gave a rich picture of the Nepal post-2015 earthquake experiences and the lessons learned, including innovative and unique approaches and tools developed in this context. The keynote speakers were well chosen, adding high value by placing the Nepal experiences in a global and scientific context. Former FIG president Chee Hai Teo attended the workshop and addressed the audience during the plenary session on the last day.


Satellite image of Malta.

Disaster risk reduction is a unique knowledge domain and has its own particular issues, own approaches and own technologies. To include disaster risk reduction in the curriculum of the surveyor and land professional means allocating enough quality time and thinking carefully about the set-up and content of the programme and the teaching approaches. There will be more on disaster risk reduction at the FIG Working Week in New Zealand in May 2016. For more information, see www.fig.net/fig2016. ◄

More information
www.fig.net

GSDI 15 World Conference Announced

The Global Spatial Data Infrastructure (GSDI) Association has been holding SDI conferences around the world since 1996. We are pleased to announce that the GSDI 15 World Conference will be held in Taipei, Taiwan (Rep. of China), from 28 November to 2 December 2016 at the Taipei Nangang Exhibition Center. The theme of GSDI 15 is 'Spatial Enablement in the Smart Homeland'. The conference will be co-hosted by GSDI and our Taiwan-based members, the Taiwan Association of Disaster Prevention Industry (TADPI) and Taiwan Geographic Information System Center (TGIC), with financial support from Ministry of the Interior of the government of Taiwan.

Dr David Coleman, president of GSDI, says: "Since 1996, 14 GSDI Conferences have brought together geospatial community leaders and persons of influence from government, industry and academia to highlight new developments, discuss emerging concerns and share lessons learned. GSDI 15 will continue a tradition of staying ahead of the ►

curve by highlighting how services built atop the infrastructure are helping shape the smart communities of tomorrow. On behalf of the GSDI Association Executive and our very capable and enthusiastic team of local organisers, I am delighted to welcome you to Taipei next November for GSDI 15."

▲ *GSDI 14 plenary session, UNECA, Addis Ababa, Ethiopia.*

GSDI World Conferences are the place to hear and meet global players in the geomatics and spatial data infrastructure world. Past keynote speakers have included Jack Dangermond (Esri president), Dr Barbara Ryan (director of the GEO Secretariat), Jacqueline McGlade (former executive director of the European Environment Agency), plus many senior officials from European institutions, the World Bank and other global organisations. Attendance and networking at GSDI Conferences is one of the key benefits that a recent survey of our membership (and prior conference attendees) ranked highly.

GSDI 11 (2009, Rotterdam) was held in parallel with the EU's annual INSPIRE Conference and the national Dutch SDI conference. GSDI 12 (2010, Singapore) was in parallel with the PCGIAP (Permanent Committee for GI in Asia-Pacific) and the ISCGM (International Steering Committee for the Global Map) meetings. GSDI 13 (2012, Quebec) was held in parallel with the Canadian national GEOIDE conference. GSDI 14 (2013, Addis Ababa, Ethiopia) included AfricaGIS 2013 and featured the launch of the AfriGEOSS initiative of GEO. ◀

For more information about GSDI 15, contact Roger Longhorn, GSDI secretary-general, at secgen@gsdi.org or David Coleman, GSDI president, at president@gsdi.org or visit the GSDI Association website.

Learn more about the GSDI Association at gsdiassociation.org.

More information
www.gsdi.org

New IAG Executive Committee Meets in San Francisco

The first meeting of the IAG Executive Committee (IAG-EC) since the conclusion of the International Union of Geodesy & Geophysics' General Assembly in Prague took place on 12 December 2015 in San Francisco, USA, on the margins of the annual meeting of the American Geophysical Union (AGU).

The IAG-EC comprises the IAG president, IAG vice president, secretary general, past IAG president, presidents of the four Commissions, Communications & Outreach Branch and Inter-Commission Committee on Theory, chair of the Global Geodetic Observing System, three representatives of the Services and two members-at-large. In this article we introduce some of the members of the IAG-EC.

IAG President: Harald Schuh
Prof Harald Schuh was VP of IAG during the last quadrennium period. Besides many other duties and positions in international organisations, he was the chair of the International VLBI Service for Geodesy and Astrometry (IVS) from 2007 to 2013. Harald has been engaged in space geodetic research for more than 30 years with special focus on VLBI (Very Long Baseline Interferometry) and Earth Rotation. Since 2012, he has been director of Department 1 'Geodesy and Remote Sensing' at the GFZ German Research Centre for Geosciences in Potsdam, Germany.

IAG Vice-President: Zuheir Altamimi
Zuheir Altamimi is a research director at IGN, France. His principal research focus is the theory and realisation of terrestrial reference systems. Zuheir has formerly served as president of IAG Commission 1 'Reference

▲ *Members of the IAG Executive Committee, 2015-2019.*

Frames' (2007-2011). He is currently head of the International Terrestrial Reference System Center and active in several IAG services (IERS, IVS, ILRS, IGS, IDS). He is member of the IERS Directing and the IGS Governing Boards.

IAG Secretary General: Hermann Drewes
Hermann Drewes has been IAG secretary general since 2007. He was formerly the director of the German Geodetic Research Institute (DGFI) and is currently an honorary professor of the Technical University of Munich (TUM). His main research interests and activities since 1970 are gravimetry and geoid determination, geodynamics (Earth rotation, plate kinematics, crustal deformation), and regional and global reference frames. Hermann has held many positions, including president of Commission VIII 'CSTG' (2003-2007) and president of Commission 1 'Reference Frames' (2003-2007).

President of Communication & Outreach Branch: József Ádám
József Ádám has been president of the COB since 2003. He is a professor in the Department of Geodesy and Surveying at Budapest University of Technology & Economics. Since 1991 József has been the IAG national correspondent of Hungary. His research interests include VLBI for astrometry and geodesy, geodetic datum transformations and GNSS applications.

President of Commission 1 'Reference Frames': Geoffrey Blewitt
Geoff Blewitt's experience is firmly grounded in his research interests in reference frame theory, advanced geodetic techniques, GNSS technology and the practice of frame realisation. With over 10 years' prior experience on the IGS Board, he is familiar with how the IAG Services value and rely on the work of Commission 1.

President of Commission 2 'Gravity Field': Roland Pail
Since 2010 Roland Pail has been a professor of astronomical and physical geodesy at the TUM and is currently dean of the Department of Civil, Geo and Environmental Engineering. His fields of research are physical and satellite geodesy, global and regional Earth gravity field modelling, cal/val of satellite observations, inverse problems, applications of the gravity field in the Earth sciences and studies on future gravity field mission constellations.

President of Commission 3 'Earth Rotation and Geodynamics': Manabu Hashimoto
Manabu Hashimoto is a professor at the Disaster Prevention Research Institute, Kyoto University. His research interests include the study of crustal deformation using geodetic data such as triangulation, trilateration, levelling, GNSS and SAR. He currently contributes to several national projects of earthquake hazard evaluation including the largest possible earthquake along the Nankai trough.

President of Commission 4 'Positioning and Applications': Marcelo Santos
Marcelo Santos is a professor in the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada, where he is currently department chair. He has served IAG in different capacities, most recently in his second term as president of Sub-Commission 4.3 on 'Remote Sensing and Modelling of the Atmosphere'. His research interests include the gravity field and geodetic applications of GNSS. ◀

More information
www.iag-aig.org

Working towards the Sustainable Development Goals

The quadrennial elections of a new Executive Committee (EC), of Commissions and Working Groups, and their chairs, and the appointment of other officers, are the ideal opportunity for ICA to reinvigorate itself with a fresh start for the 2015-2019 period. This was initiated with a meeting of all at the beginning of November 2015, hosted by the past-president at the Technical University of Vienna, Austria.

Secretary-general Laszlo Zentai informed the ICA Commissions and Working Groups how they are supposed to operate, based on the statutes and by-laws. This included information on how to organise a Commission, how to communicate within ICA, options for publication of results, activities related to the International Cartographic Conferences and financial support. The Commission office holders were then asked to revisit their Terms of Reference and decide which of those would be their focus point for the next four years. The possibilities of sharing flagship projects with other Commissions and running other joint events and activities were highlighted.

The second session started with short presentations by EC members of ICA's various 'instruments', including the Strategic Plan, the ICA Directory, Publications, the Research Agenda, Scholarships, and ICA external relations with the Joint Board of GIS and the ICSU-based GeoUnions. Opportunities for discussion allowed Commission chairs to present their opinions and suggestions for ICA's improved operation with respect to such mechanisms.

Following these 'inward-looking' sessions, the third part of the workshop encouraged participants to look internationally at two major initiatives. The Commissions' contributions to the International Map Year (IMY), the UN-endorsed programme of worldwide engagement with maps in all areas of human life, were solicited. The newly proposed UN ▶

▲ *ICA office holders wearing IMY T-shirts in Vienna, November 2015.*

sustainability goals (sustainabledevelopment.un.org) were then introduced into the meeting and the participants were asked to suggest how ICA can make an impact. Each of the 17 goals has a specific objective – for instance, Goal 4 on Education is to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" – and a number of targets (for example: "By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes"). Multiple indicators, mainly quantitative, have been defined (such as "Completion rate (primary, lower secondary, upper secondary [schools]") and these can be mapped, either as individual variables or in combination. As part of the IMY, ICA will organise a cartographic exhibition at the next UN-GGIM meeting in New York, USA, in August 2016. A set of 17 posters will be created demonstrating how maps can help to provide insight into each goal. The plan is not just to create a single map for each goal; instead, the idea is to offer different cartographic perspectives on these goals via story maps. These perspectives will be offered by the ICA Commissions. Each of the 17 goals has been adopted by two Commissions, and together they will map a goal based on their skill set. For example, the poster that involves the Commission on Visual Analytics might show how, in an exploratory environment, one can combine different indicators to reveal trends, while the poster involving the Commission on Mountain Cartography could show how the landscape influences the distribution of certain phenomena. The final goal of this exercise is to create an atlas of best practices for mapping the sustainability goals.

Menno-Jan Kraak, ICA president

More information
www.icaci.org

XXIII ISPRS Congress: From Human History to the Future with Spatial Information

Now that we have entered the year 2016, the XXIII ISPRS Congress is clearly visible on the horizon. The event is taking place from 12-19 July this year in Prague, Czech Republic.

When preparing for the Congress we are not only relying on the Local Organising and Programme Committees, on whose shoulders this task rests, but we are also benefiting from the knowledge of hundreds of experts from all over the world. The Congress information system already contains a long list of Full Paper and Abstract authors, and they have completed the first part of the process. January is the month in which the Congress Reviewers take over the relay baton. Their reviews will enable us to select pieces that will form the varied mosaic of the final Congress programme. In other words, we have a large group of volunteers who will devote a lot of time to their important work. I would like to thank all of those who have agreed to help us by becoming members of this group. They are anonymous to the authors, who are in turn anonymous to them. However, they are all working with the same goal in mind: a successful congress.

▲ *Prague will host the XXIII ISPRS Congress.*

We would like to invite you to stay up to date on the latest news about the Congress by referring to http://www.isprs2016-prague.com, Facebook, Twitter and our newsletters. During the event, you will be able to choose from 9 plenary speakers, 60 Technical Sessions, 18 Theme Sessions, 18 Special Sessions, 10 Tutorials, the National Mapping Agency Forum, Space Agency Forum, Youth Forum, the technical exhibition, the Summer School, many accommodation options, concert and theatre performances, a boat trip on the Vltava River under the Prague Castle, Technical Tours both within or beyond Prague – such as to Germany, Austria and Poland – and optional trips to beautiful places of the Czech Republic.

For a chance to win a ticket to the Congress Gala Dinner, simply visit www.isprs2016-prague.com and install the Congress App on your mobile device. Using the Official Mobile Application of the XIII ISPRS 2016 – Prague Congress, you can plan your agenda, meet, network and have the latest information about everything!

More information
www.isprs.org

FUTURE EVENTS

JANUARY

SKYTECH 2016
London, UK
from 27-28 January
For more information:
W: www.skytechevent.com

FEBRUARY

TUSEXPO
The Hague, The Netherlands
from 02-04 February
For more information:
W: www.tusexpo.com

15. OLDENBURGER 3D-TAGE
Oldenburg, Germany
from 03-04 February
For more information:
W: http://bit.ly/1NoX4ox
E: schumacher@jade-hs.de

GIM INTERNATIONAL SUMMIT
Amsterdam, The Netherlands
from 10-12 February
For more information:
E: wim.van.wegen@geomares.nl
W: www.gimsummit.com

EUROCOW 2016
Lausanne, Switzerland
from 10-12 February
For more information:
W: www.eurocow.org

INTERNATIONAL LIDAR MAPPING FORUM 2016
Denver, CO, USA
from 22-24 February
For more information:
E: lhernandez@divcom.com
W: www.lidarmap.org/international

AAG ANNUAL MEETING
San Francisco, CA, USA
29 March-02 April
For more information:
W: www.aag.org/cs/annualmeeting

APRIL

INTEREXPO GEO-SIBERIA
Novosibirsk, Russia
from 20-22 April
For more information:
W: www.expo-geo.ru

GISTAM 2016
Rome, Italy
from 26-27 April
For more information:
E: gistam.secretariat@insticc.org
W: www.gistam.org

MAY

FIG WORKING WEEK 2016
Christchurch, New Zealand
from 02-06 May
For more information:
E: nzis@surveyors.org.nz
W: www.fig.net/fig2016

GEO BUSINESS 2016
London, UK
from 24-25 May
For more information:
E: info@Geobusinessshow.com
W: www.geobusinessshow.com

JULY

XXIII ISPRS CONGRESS
Prague, Czech Republic
from 12-19 July
For more information:
E: info@isprs2016-prague.com
W: www.isprs2016-prague.com

OCTOBER

INTERGEO
Hamburg, Germany
from 11-13 October
Fore more information:
W: www.intergeo.de

CALENDAR NOTICES

Please send notices at least 3 months before the event date to: Trea Fledderus, marketing assistant, email: trea.fledderus@geomares.nl

For extended information on the shows mentioned on this page, see our website: www.gim-international.com.