Navigating the Future of the Geospatial and Geomatics Sectors

Dr Dorota Grejner-Brzezinska is the incoming president of the Institute of Navigation (ION). She also serves as president of the International Association of Geodesy (IAG) Commission 4, Positioning and Applications. GIM International held an in-depth conversation with Grejner-Brzezinska on the role of the ION, the latest developments and trends in GNSS survey solutions, and the future of GNSS.

The Institute of Navigation (ION) serves a worldwide community including those interested in air, space, marine, land navigation, and position determination. How has the Institute evolved?

The Institute of Navigation was founded in 1945 by a group of practising air navigators, originating from both military and civilian backgrounds. Much of the Institute's energy during the early years was devoted to building an effective organisation that would advance the art and science of navigation by coordinating the knowledge and achievements of practitioners, scientists and developers of navigation equipment. In the 1990s ION really began to flourish as it garnered support from everyone interested in position-determining systems, particularly after GPS had reached full operational capability. Advancements in navigation technology eliminated the need for specialist navigators for most applications; navigation became automated as humans and electromechanical devices were replaced by microcomputers, integrated circuits and sensors. Accuracy and coverage performance for all phases of navigation were rapidly enhanced as today's various GNSSs evolved. The manner in which ION adapted to, and in some cases played a key leadership role in, these changes has accounted for its success.

ION members include cartographers, professional navigators, photogrammetrists, geodesists and surveyors. What are the main membership benefits?

ION membership is an outstanding opportunity to stay connected and informed about what's happing in the field of positioning, navigation and timing (PNT). Membership of professional organisations are considered a 'best practice' for professional and personal development, and ION members gain access to the tools they need to advance in their field. Membership includes a subscription to the quarterly peer-reviewed journal *NAVIGATION* and the quarterly ION Newsletter, and access to the database of more than 13,000 technical papers published in *NAVIGATION* and Proceedings of the many ION meetings. In addition, members receive discounts on meeting registration fees and publication purchases, they have the right to vote and to hold office, and they can participate in the Annual Awards programme. They can also become a Government Fellow. The Government Fellow programme is designed to offer ION members a unique educational experience while providing the government with technical experience and private-sector perspectives that we hope will foster effective public policy on the issues that affect our profession and society as a whole. There are two categories: Congressional Fellowship and Executive Fellowship. A Congressional Fellow serves as a science and technology staffer for a Member of Congress or a Congressional Committee, while an Executive Fellow serves as a science and technology advisor in an Executive Department.

The Institute is well-known for its annual awards programme, such as the Johannes Kepler Award and the Bradford W. Parkinson Award. What do you achieve with these awards, and how do they benefit the navigation industry?

By honouring people who are making a difference, our awards help to focus attention on the field of PNT and serve to foster innovation, excellence, commitment and advancement. This is a perfect role for ION, and our honourees all represent the finest in technical achievement and altruistic dedication to their profession.

ION also sponsors student awards for navigation excellence. Have these students produced any ground-breaking developments?

The vitality of an organisation is preserved by fostering the growth and development of the next generation of professionals and organisational leaders. Many of the leaders in the PNT marketplace and academia are former ION student-paper winners, and several of the ION's past presidents were introduced to the ION through a student programme.

What were the most eye-catching developments at the 2014 edition of ION GNSS+ in Tampa, USA?

One of the highlights of the ION GNSS+ 2014 meeting was the plenary session that, for the first time, this year included several 'ignite talks'. These were brief, high-energy and high-impact presentations focused on the new element on the technical programme – a panel session as part of each technical track. We had panels covering systems, policy, technical visions, commercial products and application developments, and the second indoor positioning panel even featured live demonstrations of the latest technology. These panel sessions really caught the audience's attention; they were very well attended and generated lively discussions. The commercial exhibition was also sparked with innovation. But fundamentally it is the international audience's technical acumen and willingness to share their knowledge that makes it such a unique event.

What new opportunities can surveyors expect from GNSS developments over the next few years?

Multiple constellations of GNSS expected to reach full operation in the next few years will bring new and enhanced capabilities to the surveying community: more signals and more satellites will provide better availability and redundancy, particularly in areas of a limited sky view. However, these will not necessarily always translate into better accuracy, since observation geometry has a strong influence on the final accuracy levels, even if redundant satellites are observed. Triple-frequency configuration will allow formation of additional wide-lane and first-order ionosphere-free linear combinations, as well as a second-order ionosphere-free linear combination that will have a positive impact on the speed and reliability of ambiguity resolution and coordinate accuracy. Availability of the new and modernised civilian signals will significantly improve the accuracy of the Standard Positioning Service (SPS). The US government is in the process of implementing three new signals designed for civilian use: L2C, L5 and L1C. The legacy civilian signal, L1 C/A, will continue broadcasting in the future for a total of four civilian GPS signals. The new civilian signals are phasing in incrementally as new GPS satellites are launched to replace the older ones. Note that most of the new signals will be of limited use until the new constellation reaches the level of 18 to 24 satellites. On 28 April 2014, the Air Force began broadcasting civil navigation messages on the L2C and L5 signals. Fully operational GNSS constellations will be able to provide metre-level (1-10m) positioning accuracy with better coverage and availability than GPS only. The accuracy of GNSS augmented by space-based and ground-based augmentation is at decimetre level (<1m) and carrier-phase-based multi-frequency techniques, including RTK and PPP, are at centimetre level (<10 cm).

The rise of UAS in the geomatics sector seems to be unstoppable. How can the navigation industry contribute to this game-changing development?

The navigation industry has been a game-changer from the onset of the rise of UAS in the geospatial and geomatics sectors by developing portable, low-cost and reliable navigation sensors, such as GPS boards and MEMS IMUs, and GPS/IMU-integrated systems. No UAS can be used in national security, scientific or commercial applications without reliable navigation. The navigation industry has made significant R&D efforts to ensure the availability of accurate, continuous and global PNT to support the growing market of geospatial technology applications, including the UAS market. Even the best information wasn't 'geoinformation' until we attached coordinates and a time stamp to it!

People spend most of their time indoors, where GNSS signals are too weak to be picked up by receivers. How do you view the development of a GNSS-free positioning system for indoor locations?

In recent years, the so-called high-sensitivity GNSS receiver technology has entered the market. These receivers have some indoor reception inside glass or wooden structures, although the accuracy is lower than in clear-line-of-sight navigation. Personal navigation, designed for indoor and generally GNSS-challenged environments, has been of increasing interest among the navigation community for well over a decade. Miniaturised, portable sensors are available on the market, and integration algorithms designed for fusing information from conventional and unconventional sensors (e.g. passive and active imagers and step sensors) have progressed significantly, followed by the improved processing power of portable computers and wireless technology. RF-based systems, such as ultra-wide band (UWB), RFID or WLAN, or a land-based constellation of transceivers that acts as an independent navigation system, such as Australian Locata, are being used for indoor navigation together with MEMS IMUs (inertial measurement units) and image-based navigation. A number of research demonstrations as well as commercial prototypes have been designed and implemented. Global space-based PNT combined with indoor navigation systems, plus the proliferation of wireless technologies, mobile computing devices and mobile internet, has fostered a new and growing interest in location-aware systems and services. It is the fastest-growing location-based commercial market and already generates over 47% of all location-based commercial applications. A typical smartphone houses a GPS chip, digital maps and a number of sensors that can provide navigation information, such as IMUs, Wi-Fi, proximity sensors, cameras, etc. Better exploitation of these sensors will make a smartphone the ultimate personal navigation device of the future.

Today, commercial network-based RTK (NRTK) is an essential GNSS infrastructure for centimetre-level positioning. Meanwhile, precise point positioning (PPP) is rapidly developing as an alternative to NRTK. How do you foresee that accurate positioning will be done in the near future?

I regard NRTK as the next evolutionary step of the differential GPS (DGPS) service which was enabled by the expanding ground-based infrastructure, availability of near-real-time IGS orbits and clocks, increased computing power and ubiquitous Wi-Fi communication, as well as a solid GPS/GNSS constellation that has been offering more than 24 satellites for many years. In PPP mode, the user combines the precise satellite orbits and clocks with dual-frequency GNSS data collected at their location and can calculate coordinates which are absolute rather than relative to a reference station. Dual-frequency data is needed to remove the first-order ionospheric effect. The coordinate accuracy is at centimetre level for static solution and closer to decimetre level for kinematic applications. Dense ground reference networks are available in many parts of the world – Europe, Canada, USA, Japan, etc. – and the availability of high-accuracy error corrections from these permanently tracking networks can, theoretically, be used to support single-frequency users in PPP mode. Static PPP is considered a rather settled approach. For example, Natural Resources Canada offers PPP-based, high-accuracy GPS data processing tools online. Many argue that PPP is the future of precise positioning. I believe that the key is the availability and accuracy of the network-based corrections that provide 'local' or 'regional' resolution of tropospheric and ionospheric corrections and, generally, can provide better accuracy than the global models. Availability of external high-accuracy iono corrections can support faster convergence, which is a primary problem of kinematic PPP. The actual user positioning can be accomplished either as NRTK or PPP, with the benefit of PPP of broadcasting smaller packets of data than NRTK.

What will be the main challenges for the GNSS industry in the coming years?

Firstly, a fiscal challenge – how much are governments willing to spend on GNSS, and will the monetary support be continuous, organised and sufficient? We have seen ups and downs, delays and uncertainties, and it seems to be an ongoing challenge despite the fact that

GNSS is present in virtually every aspect of our lives. For example, the space segment must be updated and replenished at a faster pace than the ongoing GPS and GLONASS modernisation projects. Secondly, the challenge to manage and internationally co-ordinate GNSS in a far-reaching, equitable, transparent and comprehensive way – establishing co-operation via the International Committee on GNSS is an excellent move towards addressing this. Other challenges facing the GNSS industry, but also other industries, include: no back-up system, spectrum protection, interference and jamming, vulnerability to spectrum and cyber attacks, and location privacy. In addressing these challenges, the broader GNSS community must assume the role of a leading enabler, since this amazing, global tool it has created has now become available to many, who may abuse it. Therefore, the GNSS industry, legislators and regulatory agencies must become proactive in addressing these challenges. Otherwise, the GNSS sector and related industries may become reluctant to invest in a market whose sole backbone depends on government policies.

Of course, there are also technological challenges. For example, considering that UAVs are becoming mainstream geospatial data-collection platforms, GNSS and GNSS/IMU/imaging sensors must become not only lightweight but also affordable and more accurate than most of the portable devices currently available. A challenge related to this opportunity is the relatively slow pace of innovation; the industry must step up and close the gap quickly. Another point worth mentioning is the consequence of mergers and consolidations. These may limit competition, creating a market which is shared among a small number of manufacturers or sellers, which can in turn lead to an even slower pace of innovation.

With Europe, China and India actively developing GNSS systems, there are more positioning satellites available today than ever before. How do you see navigation benefiting from this increased availability?

The fastest growing sector of GNSS applications is location-based services (LBS). Aside from the privacy challenge associated with LBS, it brings tremendous opportunities to many markets, with Asia leading the pack. Global GNSS market growth in terms of CAGR is expected to reach approximately 21% over the period 2012-2016, with the GNSS LBS-only revenues expected to reach over EUR80 billion by 2020. At present, the global base of GNSS devices is around 2 billion units, and by 2022 it is expected to grow almost fourfold to seven billion – that's almost one GNSS receiver for every person on the planet!

Self-driving cars is an upcoming application that not only needs reliable GNSS information, but must also ensure that the cars will 'see' their surroundings using a suite of radar and Lidar sensors. Among others, the University of Texas Radionavigation Laboratory has demonstrated centimetre-level positioning accuracy is possible with a smartphone antenna. That's an enabler of high-accuracy and low-cost applications which have so far been served by high-end, costly GNSS equipment. So, the next step to expect is an app for high-accuracy global mapping via crowdsourcing. D.P. Shepard and T.E. Humphreys presented a very interesting vision on high-precision, globally referenced position and attitude via a fusion of visual SLAM, carrier-phase-based GPS and inertial measurements at IEEE/ION PLANS in 2014.

GNSS was originally developed for military purposes, and recent unrest such as in Ukraine, Gaza and Iraq has prominently highlighted its role as a military tool. Do you expect growing tension in international relations to impact on civilian use of GNSS?

The 2004 US space-based PNT policy recognises that the growth in civil and commercial applications continues. However, the positioning, navigation and timing information provided by GPS remains critical to US national security, and its applications are integrated into virtually every facet of US military operations. However, according to the space-based PNT guidelines, the US government is committed to continuous, worldwide provision of GPS civil services, and civil signal design information, free of charge. We can only speculate on whether the US or other governments will decide to impose any restrictions on accuracy or access. With the GPS modernisation programme aimed at separating military and civilian signals, it's fair to expect that no restrictions will be necessary. However, it has been demonstrated how relatively easy it is to spoof a civilian signal, and it seems prudent to focus on protecting vulnerable civilian applications that rely heavily on GNSS (e.g. timing, banking, tolling, emergency response, Earth observation for weather and climate purposes, natural hazards, land-use change, ecosystem health, marine affairs, etc.) from intentional jamming and cyber attacks.

Satellite-based navigation often goes hand-in-hand with inertial navigation. How does your organisation help to improve the use of inertial navigation for its members?

ION is committed to representing a full range of navigation disciplines through its many and varied programs. Inertial navigation courses are taught at several of our conferences; inertial papers can be found in *NAVIGATION* and we host inertial/multi-sensor tracks at all of our conferences.

Biography

Dorota A. Grejner-Brzezinska gained a PhD in Geodetic Science in 1995 from The Ohio State University. She is a professor and chair of the Department of Civil, Environmental and Geodetic Engineering, and director of the Satellite Positioning and Inertial Navigation (SPIN) Laboratory at Ohio State University. Her research interests cover GPS/GNSS algorithms, GPS/inertial and other sensor integration for navigation in GPS-challenged environments, sensors and algorithms for indoor and personal navigation and mobile mapping. She has published over 300 peer-reviewed journal and proceedings papers, numerous technical reports and five book chapters on GPS and navigation. She is an ION Fellow, Fellow of the Royal Institute of Navigation, president of the International Association of Geodesy (IAG) Commission 4, Positioning and Applications, and IAG Fellow. Dorota is currently serving as ION executive vice-president and the incoming president.