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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Privacy and ethics

under the gaze of eyes in the sky

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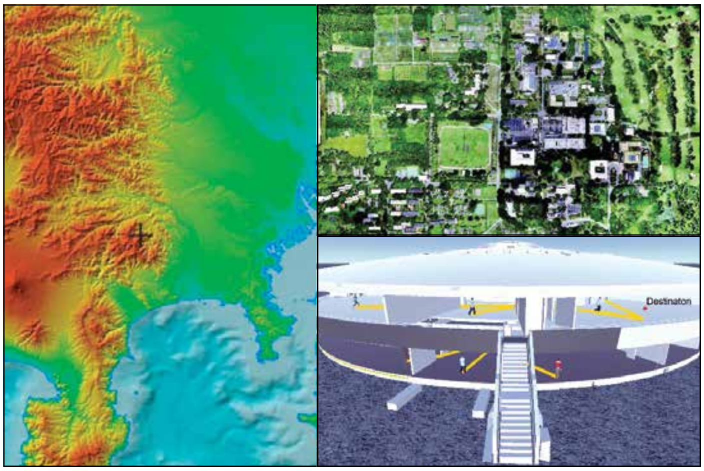

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Protecting privacy

When a trade off is made

Between convenience and personal information

We not only underestimate the value of the information

But many a times underestimate its potential exploitation, as well

And we do not realize when and how

The technology that otherwise is pushed as a facilitator,

Turns into a surveillance tool.

Is it true that in bio-techno sphere

Where we live in,

The privacy that was precious for many

Has become privilege for some?

Read Prof George Cho (page 6).

Bal Krishna, Editor
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Privacy and ethics under the gaze of eyes in the sky

Data protection and by extension privacy is a universal value may be attainable, not merely aspirational

George Cho
University of Canberra, Australia

Conceptions of privacy under the gaze of earth observations (EO) and satellite technology is now exposed to the full array of other means of capturing data from unmanned aerial vehicles through to in situ fixed CCTV cameras and sensors in indoor lighting systems. This statement is not to spread fear and foreboding that our privacy is being incessantly invaded by all and sundry. Whilst, privacy is a fundamental human right recognised internationally this 'right' has been poorly understood and the very term privacy itself cannot be precisely defined.[1]

Typologies of privacy

Any analysis of privacy could begin by analysing different conceptual frameworks and typologies. Privacy can also be looked at from a legal point of view, from aspects of the common law in addition to civil law rights and protections. From a jurisprudential point of view, legal frameworks and theories add a further complexity to our understandings of privacy obligations. These obligations include trespass and property law; confidentiality and data protection; environmental law; tort liability and nuisance.

The idea of privacy is that it has a series of interlocking themes including bodily privacy, such as invasive procedures on one's body or other covert forms; informational privacy, in regards to data about the person, the privacy of secure and confidential communications; and locational privacy, in terms of intrusions to one's domestic abodes, work places and shopping journeys.

> Whilst, privacy is a fundamental human right recognised internationally this 'right' has been poorly understood and the very term privacy itself cannot be precisely defined

The typology is summarised as to who we are, what we know, what we say and where we are that encompasses all thematic, temporal and spatial aspects of our existence. These also suggest the continuum of zones of privacy of personal and public spaces that are both inherent surrounding us and above us, that change over time and are relative to wealth, culture and ideology.

Privacy as a prism

The multidimensional prismatic nature of EO and other invasive technologies and the complexity of the privacy question has been a huge impediment to the development of an appropriate and holistic privacy protection program. For instance, there is no active "personal" jurisdiction in this regard nor is there a truly international geospatial jurisprudence for privacy rights and obligations in so far as EO is concerned.

Earth observation satellite cameras and sensors capture everything in its wake as the extra-terrestrial vehicle circles the globe. Advertent or otherwise all activities on the ground are captured on a regular and cyclical basis. When analysed such images may show single scenes or scenes over time. When mixed in with with other spatial and thematic information and increasingly 'big data', the images are truly a rich trove of data.

Technology has now been developed where in situ CCTVs are able to capture and recognise people's faces. In these instances, the worry at the back of many people's minds is the loss of "privacy", whatever one conceives of it. Whereas in the past to invade one's privacy is to physically cross social and property boundaries.

Lemma 1: At what point does the aggregation of spatially enabled data encroach on our privacy interests and who decides this?

The inference is that the conflicts and uncertainty is made more complex when one attempts to separate the identification of the individual and that of the identification of private property. Identification, *per se*, may not be an issue but identification coupled with extra information may raise serious privacy concerns.

An image of a person is of not much value but when it is linked to places, everyday patterns and other contextual information the picture may tell more than is apparent. This linked information network presents privacy issues in an age of automated data processing. The "new" problem for privacy in its wider information technology context reduces the ability of an individual to control one's own information and it is this aspect of personal privacy that is placed at risk by high powered computer analytics.

The "new" problem for privacy in its wider information technology context reduces the ability of an individual to control one's own information and it is this aspect of personal privacy that is placed at risk by high powered computer analytics

But, the privacy question is also relative in temporal terms. For instance, there may be inter-generational differences in what and how people reveal information about themselves. The gen-Y children may be quite happy to share their lives through new social media such as Twitter and Facebook as contrasted to the "baby-boomers" of the sixties who might be more reticent and "conservative". Social networks now challenge the very fabric of what is "private" and what is secret.

Business model

The business model with social media providers such as Google, Instagram and Facebook is that users are asked to give up some personal information in exchange for free use of software and services. This business model has worked very well as witnessed by the success of these platforms, the numbers of users and the monetization of the data. The data harvested from users of these services have spawned a whole new industry in which third party buyers and sellers of data use these for their marketing and advertising campaigns. It seems that the business model is a win-win for everyone involved.

Lemma 2: The one question that arises from such activity is how much information can anyone afford to give away, which, once released, is irreversible.[2]

This business model has seemingly been successful in a liberal, democratic market economy of the developed world in the West. However, other newly developed economies in the East have used such a model in their governance with equally greater impact. The Aadhaar biometric identification system in India and the social credit system in China have taken the business model a few innovative steps forward.[3]

The Aadhaar system is a data-driven model of governance where citizens are given digital identities to enable them to access government services such as welfare benefits.[4] The Aadhaar or unique identity number project (UID) has made it mandatory for all citizens to obtain an UID since 2012. The system has been lauded by major news outlets such as the BBC for giving the poor a presence and the ability to access welfare benefits.[5] Access to social services, banking and food subsidies have now become possible for the masses as the national online system can verify the UIDs anywhere, anytime and in seconds.

Whilst there are challenges to the UID process from possible privacy and human rights violations such as, the risk of fake online identities, weak institutional measures and data breaches, the undocumented sections of society now have the right to an identity where previously they had none.

Perversely there are some sectors of the Indian society, who are privileged group of land-owning peasants, now wish to be classified in the 'other backward classes' in order to guarantee them government jobs and university places.

The UID has guaranteed citizens the right to an identity, to become visible and to be active in the public and market sphere. In some ways this system has provided the means to overcome the parallel illicit economies controlled by the rice mafia, the fuel mafia and the border mafia – the latter intercepting welfare goods before these reach the shops.

The first privacy law in India was installed only in 2017 as a solution to data protection issues. Indeed, in India the Hindi word for privacy is *nijta*, a term not usually used in local languages. This suggests that privacy protection may not be important and that privacy is culturally and economically relative.

By contrast the social credit system in China is where a citizen's financial record, online shopping data, social media behaviour and employment history are used to produce a score. Such scores provide a measure of a citizen's trustworthiness. China's leading technological innovation with a datafied system is deployed by the government to promote social safety, financial inclusion and citizen participation. The "give and take" business model is evident here.

The business model with social media providers such as Google, Instagram and Facebook is that users are asked to give up some personal information in exchange for free use of software and services

Ironically, the social credit system is not novel nor new. The "sesame credit" system used by the AliBaba group, launched in 2015, has close to 520 million users.[6] While the points credit system is differently configured, better scores gain special privileges and has even been used as a status symbol on dating and match making sites.

Under the social credit system, the sharing of social, political and economic information between private enterprise and public authorities appear to work well. AliBaba data are used for designing smart cities, BeiDou GNSS data for autonomous vehicle navigation systems, and Tencent for medical imaging. Similarly, AliPay and WeChat Wallet provide an alternate to traditional banking practices as these provide access to nearly everyone where trust is paramount.[7]

The social credit system also assists in providing data-driven social order and citizen tracking. While citizen tracking might be an anathema in the developed world, in China personal security and safety are provided in return to greater dataveillance.[8] Disparities in social inclusion, representation and minority rights may fracture Chinese communities and interpreted as the oppression of individual freedom of expression, but the prospect of payoffs in economic development, social betterment and good governance has proven to be more attractive.

Lemma 3: The business models above suggest that privacy protection should be understood and accepted to be the "process of finding appropriate balance between privacy and multiple competing interests" in light of different interpretations by the free market economy and the totalitarian state.[9]

Data protection

Privacy protection may be a misnomer. More correctly, we should be speaking of data protection as this terminology lends itself to better definition and clarity and is a much broader term. The Latin root *privare* which means "to separate". To want privacy is to want to be separate, to be an individual and *privare* also means to deprive, to take, to rob or to leave something behind.[10] This latter usage might be more apposite in the age of electronic tracking and surveillance with the 'taking' of information advertent or otherwise, with or without consent, and at any time and any place.

In the U.S. the origins of the privacy right may be traced to a law review article by Warren and Brandeis (1890) where the right to be left alone has held sway for over a century.[11] Added to this are nuisance laws linked to property rights and the freedom of expression, all ensconced within the U.S. Constitution.

Thus, with reference to EO and UAVs, U.S. property law encompasses a zone theory where there is an upper strata and the lower zone in which land owners enjoy effective possession and use, the unused airspace that denies ownership to land owners, the use of and ownership of upward space (for navigation) and nuisance theory where recourse is only afforded to those who have suffered actual interference. Thus, to offer protection is to guard the use of the underlying data.

In a news report that Google pledges to keep secrets, it was suggested that privacy is the company's achilles heel.[12] Such a statement comes following the penalty imposed by the U.S. Federal Trade Commission of USD $22 million in 2012 for misrepresentation on the use of tracking information. In 2019 Facebook is faced with the prospect of a USD $5 billion fine for not protecting users' data in the light of the Cambridge Analytica episode.[13]

Facebook has more than 2.7 billion users worldwide of its family of 'apps' – Facebook, Messenger, Instagram and WhatsApp among others. Facebook's founder and CEO Mark Zuckerberg has welcomed more regulation. The rationale being that there are unintended consequences when technology creates applications and in most instances without ethical considerations. In re-designing the platforms Zuckerberg has declared that 'the future is private'.[14] By this is meant that the private social platforms become more like digital town squares where users are in private conversations that are un-shareable and encrypted. This is radically different from the current sharing economy.

Unintended consequences beg ethical considerations. As with the trolley problem that raises ethical questions of whom to preserve in a potential collision, the issue with dataveillance is the question of how to design technological ecosystems that behave responsibly.

An algorithmic solution promoted by Zuckerberg is that of an integrated

Unintended consequences beg ethical considerations. As with the trolley problem that raises ethical questions of whom to preserve in a potential collision, the issue with dataveillance is the question of how to design technological ecosystems that behave responsibly

identity. Whilst we may have multiple identities in our daily lives – that of self, parent, lecturer, sports person, advocate and the rest – the one identity proposed aligns with authenticity and a universal profile. But the intractable issue is how third parties may churn data from this universal profile for profit.[15]

The next issue is that the loss of identity may be the price one pays for living in a digital age where a digital trail of data is left behind everywhere we venture. The problem with geospatial technology generally, and EO technology in particular, is to balance the rights of individuals against the rights of the general public to the advantage of all.

On the one hand, a more lasting impact on consumer privacy is to make it mandatory through legislation for large corporations like Facebook to curb its ability to share data with its business partners. On the other, legislative and ethical tools should promote measures that inform consumers when and how it collects and shares data.

Slonecker *et al.* (1998) have suggested that there is a dire need for ethical guidelines to provide the moral philosophy to data and privacy protection in the absence of a global comprehensive legal and policy framework.[16] The invasion of privacy and data breaches both advertent and inadvertent can be difficult to identify, protect and police.

Lemma 4: Indeed, how does a person maintain "privacy" in a public place?

A cynical view is that perhaps the right to be left alone has been steamrolled by the rush of the digital revolution. In so doing privacy may only be available to those who can afford to pay for it.[17] Similarly it has been said that privacy is not a right but a privilege, a luxury afforded by wealth and enforced by custom. However, some people are prepared to trade a bit of privacy for convenience – to save time and money – to divulge personal information in return for discounts, ease of future access and to save time. This is the operation of the business model *par excellence.*

That privacy is a luxury should no longer be in contemplation. Whilst we do have a right and an entitlement to privacy in the Western liberal world, digital technology has eased the access of marginalised peoples around the world to have an identity, and to participate in the political and socio-economic life. Privacy is no longer culturally relative but is normative.

Further research questions

It may be that the advancement of technology and demands of modern business and government have made the traditional ideas of privacy anachronistic.[18] In addition, netizens in the Web 2.0 generation in which things happen by mass action of the crowds, the solutions may be embedded in ethical, technical and social standards and not solely through those in legal avenues.

That data protection and by extension privacy is a universal value may be attainable, not merely aspirational.

> Whilst we do have a right and an entitlement to privacy in the Western liberal world, digital technology has eased the access of marginalised peoples around the world to have an identity, and to participate in the political and socio-economic life

Fundamental to individual dignity, the research question is whether dataveillance balanced with benign paternalism may overcome the resistance to datafied governance models of the totalitarian kind or to adopt the business model of large corporations as proxies of the government. The aims of both governance models are the same but the means of getting there may be different.

Footnotes

[1] UDHR 1948 *Universal Declaration of Human Rights*, December 10, 1948, Article 12 at http://www.un.org/Overview/rights.html and Article 17 of the ICCPR 1976 *International Covenant on Civil and Political Rights* (New York, United Nations) at http://www.privacy.org/pi/intl_orgs/un/internatioinal_covenant_civil_political_rights.txt.

[2] The implementation of the EU GDPR legislation has a provision with the 'right to be digitally forgotten' that prescribes how this irreversibility may be countered. See Commission of the European Communities 2016 Regulation (EU) 2016/679 of the European Parliament and of the Council 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation).

[3] Arora, P & H Stevens 2019 Data driven models of governance across borders: Datafication from the local to the global, *First Monday* V.24(1) 1 April 2019; Bang Xiao 2019 Chinese surveillance app reverse-engineered by the HRW highlights monitoring of Xianjiang residents, ABC News 2 May 2019 at https://www.abc.net.au/news/2019-05-02/chinese-surveillance-app-reverse-engineered-by-rights-group/11062670.

[4] See Arora, P 2019 Benign dataveillance: Examining novel data-driven governance systems in India and China, *First Monday*, v.24(4), 1 April 2019.

[5] Arora, P 2016 The bottom of the data pyramid: Bid data and the Global South, *International Journal of Communication*, V.10 pp. 1681-1699 and at https://ijoc.org/index.php/ijoc/article,view/4297.

[6] Kostka, G 2018 China's social credit systems are highly popular – for now, *Mercator Institute for China Studies* at https://www.merics.org/en/blog/china-social-systems-are-highly-popular-now.

[7] Alipay is a third-party mobile and online payment platform, established in Hangzhou, China in February 2004 by AliBaba Group and its founder Jack Ma. See https://intl.alipay.com/. WeChat Wallet is a way to manage payments with a smart phone by adding debit or credit cards, to send money and pay for goods and services. See https://www.citcon.com.

[8] Dataveillance, a portmanteau of data and surveillance, refers to the practice of monitoring digital data relating to personal details or online activities on social media and mobile applications.

> The loss of identity may be the price one pays for living in a digital age where a digital trail of data is left behind everywhere we venture

[9] Roger Clarke, "Privacy: More wobble-board than balance-beam", at http://www.rogerclarke.com/DV/Wobble.html.

[10] See Beckman Center for Internet and Society – "Privacy in Cyberspace" at http://eon.law.harvard.edu/privacy99/syllabus.html.

[11] Warren, S & Brandeis, L (1890) "The Right to Privacy" in 4 *Harvard Law Review* 193.

[12] Griffiths, C 2019 Google pledges to keep secrets, The Australian 9 May 2019, p. 14.

[13] Issac, M & C Kang 2019 Facebook expects to be fined up to $5 billion by FTC over privacy issues at https://www.nytimes.com/2019/04/24/technology-facebook-ftc-fine-privacy.html. See also Cambridge Analytica was a British political consulting firm which combined data mining, data brokerage and data analysis with strategic communication during the U.S. Presidential elections in 2013. See https://www.theguardian.com/news/series/cambridge-analytica-files.

[14] The Times 2019 Facebook finally discovers privacy, *The Australian* 2 May 2019, p. 3.

[15] Brusseau, J 2019 Ethics of identity in the time of big data, *First Monday*, V.24(5) 6 May 2019.

[16] Slonecker, ET, Shaw, DM & Lillesand, TM (1998) Emerging legal and ethical issues in advanced remote sensing technology, *Photogrammetry Engineering and Remote Sensing*, V.64(6), pp, 589-595.

[17] Given, J (2009) "Privacy is over, get used to it", in *The Australian Literary Review*, March 4, 2009, p. 10-11.

[18] Philipson, G (208) "Privacy the price of super communication. If you want instant movies, music and phone calls you have no privacy. Get over it", *Sydney Morning Herald Next*, July 15 2008, p. 29.

Advancement in GNSS technology in India

Opportunities and challenges

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The emergence of Global Navigation Satellite System (GNSS) has provided a remarkable opportunity to determine and manage position and time information with precision, for various purposes, ranging from day-to-day navigation to tracking military assets. GNSS constellations deployed by various nations serve as essential infrastructures for navigation and timekeeping. The availability of multiple GNSS, for example, Global Positioning System (GPS), Galileo, GLONASS, Beidou has improved the robustness and reliability of the GNSS-based navigation solution. Recently India has deployed a Regional Navigation Satellite System (RNSS) called Navigation using Indian Constellation (NavIC) to enhance the nation's Position, Navigation and Timing (PNT) capability.

Modern critical infrastructures such as airports, railways, banking and finance, power grid and communication systems are increasingly becoming dependent on the GNSS Position, Navigation and Timing (PNT) services. GNSS is directly benefiting the economy and transforming our daily life. It has also created an accidental system of seemingly unrelated systems which is enormous in scale and extremely complex. Hence focused national-level research on the advancement of GNSS technology, innovative applications as well as vulnerability analysis and mitigation is of vital importance.

National status

As mentioned earlier, the indigenous space-based navigation system NavIC has reached full operational capability. The space segment of NavIC consists of 7 satellites in geosynchronous and geostationary orbits. The coverage area of this system is 1500 km beyond the Indian territory and the estimated horizontal position accuracy is 20m. NavIC satellites transmit signals in L5 and S-band, and provides both Standard Positioning Service (SPS) for civil applications and Restricted Service for defence applications. It should be noted that even before the deployment of NavIC, India contributed towards global navigation services by establishing Satellite Based Augmentation System (SBAS) named GPS Aided GEO Augmented Navigation (GAGAN). GAGAN ensures the integrity of the GPS service as well as increases the navigation accuracy for safety-critical applications, for example, civil aviation in the Indian subcontinent.

While, Indian Space Research Organisation (ISRO) took the daunting task of establishing the space and ground segments of the satellite navigation system, Indian academic research in this area has been restricted to predominantly at the application level. Several research groups are working on positioning performance analysis of multi-GNSS receivers, NTRIP server development and ionospheric studies. Academic research in GNSS from geomatics and space weather perspective is important. However, there is a strong need for diversifying the research scopes within the GNSS domain, to address immediate national requirements.

One such immediate requirement is the development of a low-cost general-purpose NavIC receiver. Although ISRO and the Ministry of Electronics and Information Technology are partnering with commercial manufacturers for the development and deployment of NavIC receivers, the Indian academic research community can also play a major role in this context. One of the major challenges in the user-segment development sub-domain is designing a low-power GPS-NavIC integrated receiver. The flexibility of the academic research environment can be of advantage in developing innovative hardware and software solutions to this problem. Adding further to the details, research in the direction of reducing the acquisition time and computational resources, reducing the Time to First Fix (TTFF) of NavIC receiver is extremely important to enhance the user experience and performance of the receiver. Another direction can be the development of special correlators for acquiring weak NavIC signals.

Having discussed some direct research trends and outlining plausible research directions, it is now important to discuss the vulnerability of GNSS. As previously mentioned, GNSS connects various otherwise independent critical systems and thus also acts as a single point of failure to this system of systems. GNSS signals are extremely weak by design and can be susceptible to intentional or unintentional interference. This may lead to GNSS service disruption and result in catastrophic failure of multiple critical infrastructures at a single instance. A similar threat is imminent to NavIC as well. NavIC S-band signal was designed to avoid unintentional interference. However, it has been recently observed that the WIFI signal may interfere with the S-band signal. Hence it is of paramount importance to peruse active research in the area of GNSS and NavIC interference source detection, localization and mitigation.

Opportunities

GNSS technology has unfolded various research and entrepreneurship opportunities to improve the overall quality of life. With the availability of NavIC, India has become self-reliant on PNT services in the Indian subcontinent. Hence, application of NavIC standard positioning service is expected to be penetrated in a diverse set of existing services. Also, this will facilitate some emerging applications like precision agriculture and reflectometry.

> There are very few academic institutes in India which provide full-fledged courses on GNSS technology in undergraduate and masters level. Hence, it is necessary to offer more rigorous courses on GNSS signal processing, receiver architecture and navigation algorithms

Automated, timely and efficient execution of various farming tasks sit at the core of precision agriculture and these often depend on spatial information where GNSS service plays a key role. On the other hand, there is an opportunity to repurpose the reflected GNSS/RNSS satellite signals to extract information about various important environmental parameters such as soil moisture, wind speed at the ocean surface, water-body area etc. This method has proved to be very cost effective compared to the conventional remote sensing techniques and known as GNSS-Reflectometry (GNSS-R). There is significant untapped potential in exploiting synchronized S-band and L5 band signals transmitted by NavIC to develop new approaches that can improve the resolution and accuracy of the reflectometry-based solution of various environmental parameter estimations. To facilitate strong national research capability in this emerging area, it is necessary to develop reflectometry capable GNSS/RNSS receiver as well.

Challenges

Although the availability of GNSS and NavIC services created an abundance of opportunities, there are many challenges which must be addressed to facilitate impactful and relevant outcomes in the field of GNSS technology. It is well known that the academic research groups working on GNSS technology in India is very sparse and hence it is imperative that more researchers are needed to be attracted in this research field. Establishment of a national GNSS research society can help the cause.

A substantial amount of efficient workforce is also needed for efficient development, nationwide deployment and maintenance of NavIC receivers. Efforts have been put for workforce development through short courses. However, there are very few academic institutes in India which provide full-fledged courses on GNSS technology in undergraduate and masters level. Hence, it is also necessary to offer more rigorous courses on GNSS signal processing, receiver architecture and navigation algorithms.

Another major challenge is there are very few Indian Original Equipment Manufacturers (OEM) who provide GNSS/NavIC receivers, spares and related supports. More OEMs will allow a diverse range of technological solutions as well as expedite the research and development in this field. Government of India is encouraging the process through the “Make in India” and “Digital India” initiatives.

Conclusion

GNSS technology has opened various possibilities of technological advancements and will play a key role in shaping the society of the coming age. The emergence of NavIC has marked India’s self-reliance on PNT-services and is just the beginning of a technological transformation. It is anticipated that in future NavIC will support critical infrastructures such as airports, railroads, power grids and finance sector, will play a major role in the development of next-generation intelligent transport systems and Internet of Things applications. At this crucial juncture, the Indian academic research communities from various disciplines must assume a pivotal role in GNSS technology development, technology transfer and workforce development.

Building a low cost long range mapping drone

This study is focused on custom building a low-cost fixed wing drone for long range mapping applications under 2000 USD which significantly reduce the cost for the hardware

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Drones are becoming popular day by day in professional applications of mapping in the fields of surveying, agriculture, mining, structural inspection, etc. When it comes to mapping, drones are proven to provide accurate and very high-resolution products at low cost compared to other traditional remote sensing or surveying techniques. Today's consumer grade multirotor drones which cost below 2000 USD for the hardware are capable of using for small area mapping applications. The major issue of multirotors in mapping applications is less flying time (approximately 30 mins) so it requires multiple flights and frequent change of batteries, which makes the mapping coverage significantly reduced. Using a fixed wing drone for mapping will solve this issue as fixed wings have high endurance. Considering the advantages of mapping with fixed wing drones, pioneering companies in the geomatics industry such as Sensefly, Trimble, and Leica have introduced survey grade drones to the market specifically for mapping purposes. These survey grade drones come as a reliable end to end package and with a very high price tag above 15000 USD.

This study is focused on custom building a low-cost fixed wing drone for long range mapping applications under 2000 USD which significantly reduce the cost for the hardware. The drone is equipped with a GNSS unit and intelligent flight controller, which provide the capability of executing autonomous missions, improving the reliability and adding the crucial safety functions as return to home. Free-sky open source radio system is used for the radio link. The Propulsion system is optimized in such a way to add the the proper amount of thrust to the airframe carrying a high-resolution camera as the payload. The landing of the drone is a well-known problem for fixed wing category and it is addressed by integrating a parachute with automatic deployment function. The drone was successfully tested by mapping 1km^2 area in a single flight, flying over 45 mins. The resulting 3cm resolution map has a verified planimetric accuracy of 34 cm without using GCPs. It was concluded that it is possible to custom build a long-range mapping UAV with a significantly reduced price yet resulting accurate and high-resolution maps.

Introduction

UAVs (Unmanned Aerial Vehicles) which are commonly known as Drones are new technology that revolutionized the field of remote sensing. With the increased popularity of drones among the community, their uses and importance are growing rapidly. Drones have already proven to be beneficial in Remote Sensing and GIS applications as they can fly autonomously and collect high quality imagery within a short acquisition period, which can be processed in to high accurate and high-resolution map products such as Orthomosaics, 3D points clouds, Digital surface models, 3D meshes, Contour maps, index maps, etc. Remotely sensed data obtained from drones are suited for various applications of mapping in both 2D and 3D domains. Few examples are environmental surveying, forest monitoring, agricultural mapping, terrain analysis, infrastructure monitoring, feasibility surveys, archaeology and cultural heritage mapping. Even drones are used for military purposes in the early stages, now it has been a common consumer tool in many fields.

Current status of drones in mapping

Today's consumer grade drones are capable enough of obtaining data for many mapping applications. DJI's Phantom series, which are the most popular consumer grade drones are now widely being used to map small areas at very low costs. These consumer grade drones are mainly purposed for photography and videography, so they come with stabilized, high quality cameras. Most of the consumer grade drones are also equipped with GNSS guided navigation system, intelligent flight controller and safety features such as return to home function which makes these drones "hardware ready" to be used in mapping. With the help of freely available third-party flight planning software, consumer grade drones can make very high-resolution maps yet saving the money for a survey grade UAV. Studies show that a 1000 USD DJI phantom 3 professional drone can tie up with 15000 USD survey grade Sensefly eBee, in terms of geolocation accuracy and resolution.

On the other hand, survey grade drones which come as a complete mapping solution is developed specifically for applications in geomatics ensuring the accuracy of the products.

Limitations of today's drones in mapping

The main limitation of the consumer grade drones in mapping application is that the low flight time. Almost all the consumer grade drones which can be used for mapping are multi rotors which consist of multiple motors that power propellers to take flight and maneuvers the aircraft. The most common configuration, quadcopters have four rotors, but they can have as many as six or eight rotors (hexacopter and octocopter). As there are multiple motors constantly running to provide direct upthrust, the flying time of multirotors become significantly low which limits them only to be used in small area mapping.

The survey grade drones such as Sensefly eBee, Trimble UX 5 are using fixed wing airframes well designed to cover a large area in a single flight. They come as a complete mapping solution including proprietary flight planning software. The main purpose of survey grade drones is to collect high accurate data which guarantee the accuracy of the map products. Drones such as eBee RTK, eBee X, WingtraOne are equipped with RTK/PPK GNSS units which results stunning accuracy down to 3cm without ground control. In terms of accuracy, quality and productivity, today's survey grade drones show maximum capabilities in mapping but limiting the number of users due to the high price. Most of the survey grade drones in the market are priced above 15000 USD. The cost of a survey grade drone adds up to the cost of maintenance, labour, and photogrammetric processing software which makes them only viable for large scale projects. DroneDeploy, a photogrammetric processing service provider reveals that 90% of commercial drone mapping customors use consumer grade drones that cost less than 1500 USD. One major reason behind the fact users choose consumer grade drones over survey grade drones is the high price of survey grade drones.

Problem statement

When analysing today's drones, consumer grade drones are affordable and can be used in most of small area mapping applications resulting acceptable accuracy. But, there are no drones in the current market with a similar price which can be used in large area mapping.

Objective

Develop a low cost, long range, prototype drone under 2000 USD which is capable of mapping a large area

Methodology

The primary task of a mapping drone is to take the imaging system up in the air and accurately navigate through the desired flight path and facilitating the camera to collect images without an onboard pilot. There are 6 major aspects to focus on when custom building such UAV.

Figure1 : Completed Custom Made Drone – "FX79 Berunda"

1. Airframe
2. Flight Controller
3. Positioning System
4. Propulsion System
5. Failsafe systems
6. Imaging system

Airframe

The airframe was selected considering five main factors i.e. safety, aerodynamic stability, range, payload, and cost. There are several categories of airframes available for drones. After analysing the options for airframes, fixed wing type is selected as it's the most suitable to fulfil the objective of the study. The main limitation of the multi rotor is the low flying time. Helicopters and hybrid drones have considerable flying time, but they pose a risk to the public upon a crash as propellers are facing forward and the body is solid. Single rotors and hybrid drones are easy to operate when they are built perfect but the aerodynamic and control systems are sophisticated. When considering the fixed wing design, its relatively simple and lift is generated by the airflow passing in sides of aerofoil shape of the wings. So the energy is utilized efficiently compared to quad copters. Using a fixed wing increases the flying time and range which opens the possibility for long range mapping.

The airframe we have selected is Zeta FX-79. The airframe is designed and made by Zeta, a Chinese based manufacture in RC aircrafts and its available worldwide. It is made with EPO (Expanded Polyolefin) which is a lightweight, mouldable foam which makes the FX-79 safe to operate in public locations as it does not threat human life or property. The propulsion system is at the rear of the drone which adds additional safety to the public. The material is durable to withstand skid landing or few low speed crash landings but will be torn apart upon high impact. Minor damages can be easily repaired using a contact adhesive. The FX 79 is a large wing with 2-meter wingspan provides lift for accompany all additional payload required for mapping. Front of the aircraft is modified to enclose the parachute system and strengthened with fiberglass tape.

This airframe is mostly popular with in the FPV (First Person View) community as a slow flying, stable long-range wing, which makes it a great candidate for aerial mapping. Stability in slow speeds is vital for the imaging system to take clear and crisp images and to obtain an accurate position at the exact time of the camera trigger. In general, when compared to traditional airframe design, the flying wings only have 2 control surfaces (elevons) to control all movements in roll, pitch, and yaw which makes the design simple but trading off the aerodynamic stability. However, the FX 79's large wing span and vertical stabilizers make very stable flight performance with the help of the flight controller.

Table 1:Specifications and features of FX 79 airframe

Specifications		Features
Design	Flying Wing	+ Removable wings + Stable flight performance + Large interior space for the payload - Moderate aerodynamic efficiency - Difficult to hand launch & land
Wingspan	2m	
Airframe weight	1.2kg	
Maximum take-off weight	3.5kg	
Price	$150	
Maximum reported distance	116km	

Flight controller

The flight controller is the brain of the drone which controls the airplane's control surfaces based on sensor outputs and it also focuses on assisting or taking full control of a vehicle. Manoeuvring the plane to follow a reference trajectory while keeping the airframe steady by regulating the control surfaces is done by this device. Autopilots systems for drones have evolved significantly over time, capable of performing fully automated missions.

PIXHAWK 2.1 Cube

Pixhawk is an open-hardware which established a standard for readily-available, high-quality and low-cost autopilot hardware designs for the academic, recreation and developer communities. For this study, Pixhawk 2.1 flight controller is chosen considering its reliability and functions.

The Pixhawk 2.1 is designed to be a fully integrated single board flight controller with sufficient I/O for the most demanding of applications. In addition, the sensor performance and reliability have greatly been improved, with triple redundant IMU's, and the capability to use up to 2 GPS modules. Through smart design, the cost for materials has been reduced which keeps the overall design simple, affordable and extremely light at only 75g per board.

Figure 2: Pixhawk 2.1 Cube Flight Controller

The flight controller is loaded with the with the Ardupilot firmware which is the defines the functions and behaviour of the flight controller. Ardupilot open source firmware is matured and reliable for stable flight performance which also has great documentation and community support. Mission Planner is chosen as the ground control software, which monitors the drone during the flight.

Beside the stable flying, a mapping drone should have two vital functions.
1. Ability to execute a flight plan
2. Accurately trigger the camera at the desired location

The data requirement to make an accurate map using photogrammetric method is good quality images with sufficient overlap. To obtain such data, the drone should follow a precisely determined flight path which is calculated according to the required resolution of the map, overlap, and camera internal parameters.

The Ardupilot firmware supports flight planning out of the box where the tools are provided in MissionPlanner software. During a flight mission, the flight controller takes full control of the drone and navigates autonomously along the flight path. Pixhawk signals the camera using predefined PWM (pulse width modulation) signal at the exact moment where the photographs are needed to be taken and record the location at the time of trigger. After the flight, images are post processed with the flight log to precisely georeference the images with the location of capture.

Positioning system

The GNSS positional module of the drone plays an important role in navigation and Geotagging the images. The drone is equipped with a navigation grade GNSS unit developed by HEX Technologies. The unit is named 'HERE GNSS' which is powered by a u-blox Neo M8N GNSS receiver and Honywell's latest high precision 3-axis digital magnetometer (HMC5883L). Its sophisticated RF-architecture and interference suppression mitigates multipath effects and ensures good navigation performance. As the GNSS unit is placed away from the other electronics of the drone, the magnetometer in the HERE unit is assigned to be the primary magnetometer which has the minimum interference from other electronics. The features of here GNSS unit are as follows:

Concurrent reception	: Up to 3 GNSS constellation
GNSS constellations support	: GPS, GLONASS, QZSS, SBAS, Galileo ready
Horizontal position accuracy	: Single Point 2.5m | SBAS 2.0m
Navigation update rate	: Up to 10 Hz
Velocity accuracy	: 0.05 ms^{-1}
Heading accuracy	: 0.3 degrees

Figure 3: HERE GNSS unit

Propulsion system

The propulsion system includes motor, propeller and ESC (electronic speed controller). Among the wide variety of available components, the propulsion system is carefully selected to balance between price, power, and efficiency based on the specification of the FX 79 airframe. Folding propellers are used to avoid damage to the motor and mount in case of a hard landing. Dual 3 cell LiPo (Lithium Polymer) batteries in parallel with a total capacity of 10400mAh are used to power the propulsion system and other components of the drone.

Fail safe Systems

Return to launch function

The Pixhawk flight controller with Ardupilot firmware has a built in return to launch function in case of emergency. Home location is set to the location where the drone is turned on. Return to home is initiated automatically when the drone's battery level is critical or if the connection between the receiver and the remote controller is lost.

Real time monitoring system

Real time monitoring of the drone is done by ground control station and live video feed back of the drone using FPV (first person view) Transmission. Telemetry data is transmitted to the ground control station using long range 433MHZ radio. The real time location, attitude, battery level, and speed are continuously monitored during manual and autonomous flights. For additional safety, a Fatshark FPV camera system is installed to the drone which provides live video feedback. After the initial prototyping, the FPV system can be removed from the drone to save power.

Parachute deployment

The landing of the drone is done by a parachute. In case of emergency, the parachute can be deployed manually using the remote controller. The remote controller is programmed to avoid deploying the parachute by accident by adding a safety switch to the deployment switch.

Imaging system

Selection of proper camera plays an important role in building a mapping drone. Ultimate data provided by drone for mapping purpose are the images so the quality of the images directly affects the quality of the map products. Several parameters are considered when choosing the camera for the drone. Which are the resolution, resolving power, sensor size, shutter speed, focusing compatibility, PWM triggering compatibility, weight, and price. Two camera models were selected for different applications.

1. **Sony RX 100 M3** - For high resolution and high quality maps
2. **GitUp Git 2 Pro** - For medium resolution medium quality maps with increased coverage and rapid processing

Landing system

Landing of the drone is a well known issue in the fixed wing category and it's a critical phase of each mission. Conventional manual landing requires large open space. Commercial survey grade drones use controlled deep stall landing with the help of advanced sensor integration such as range finders and optical flow sensors. For this drone, a simple yet effective parachute system is used for landing where the available landing space is limited. The front of the airframe is modified to open a hatch and parachute is placed on an elastic bed which throws the parachute out when the hatch is opened. The parachute can either be deployed by the flight controller automatically or manually using the remote controller.

The size of the parachute was calculated using the following equation. The velocity of the drop is set to $3ms^{-1}$.

$$Radius = \sqrt{\frac{2.m.g}{\pi C_d \rho V^2}}$$

m- Mass of the drone C_d- Coefficient of drag
ρ- Density of air g – Gravitational acceleration
V- Velocity of drop

Table 2: Specification of Cameras

	 Sony RX 100 M3	 GitUp Git 2 Pro
Sensor	20.1 MP Exmor R BSI-CMOS sensor	16MP Panasonic MN34120PA16
Min shutter speed	1/2000s	1/30s
Maximum aperture	f/1.8	f/2.5
Focal length	8.8 - 25.7mm	3.87mm
Field of view	34 – 88 deg	170 deg
Trigger mechanism	Seagull MAP 2 connected to Sony Multi port	Direct PWM signal from the flight controller
weight	290g	64g

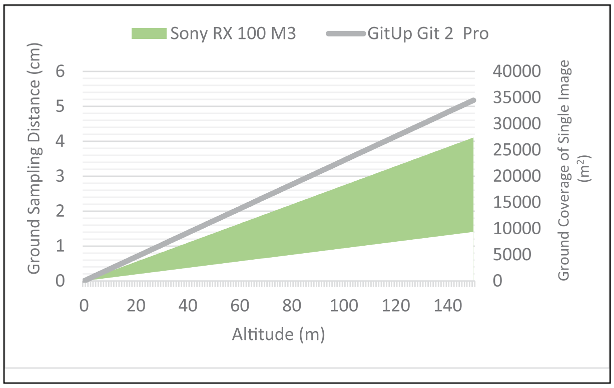

Figure 4: Relationship between Altitude, GSD, and coverage of a single image of the imaging system

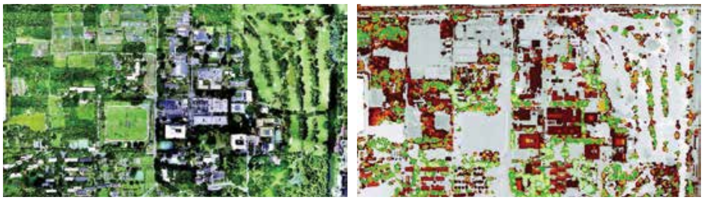

Figure 6: High Resolution Orthomap and DSM (Digital Surface Model)

Flight performance

The flight performance of the drone is initially tested with 10 flights for evaluating the stability, imaging system, parachute landing and to tune the parameters i.e. control surface trim, PID gains. Nine out of ten flights performed perfectly but single flight ended up with crash landing without any damage, due to an error in deploying the parachute.

Two flights were performed to precisely test the power consumption, by using single 5200mAh LiPo battery. Power consumption is calculated after each flight by charging up the battery to its full capacity by precisely measuring the consumed electric charge. The analysis shows that the drone consumes an average of 214mAh battery capacity to fly 1km distance. Which means the drone can fly at 15ms^{-1} ideal speed for 50 minutes in single flight covering 45km distance with spare 10% of battery.

Table 3: Flight performance of two test flights

Flight No	Weather	Average Ground Speed (ms^{-1})	Battery Consumption (mAh)	Distance (km)	Battery Consumption per kilometre (mAh)	Flying Time (min)
1	Light wind	15	3530	15.76	224	18
2	Light wind	16	3344	16.37	204	18

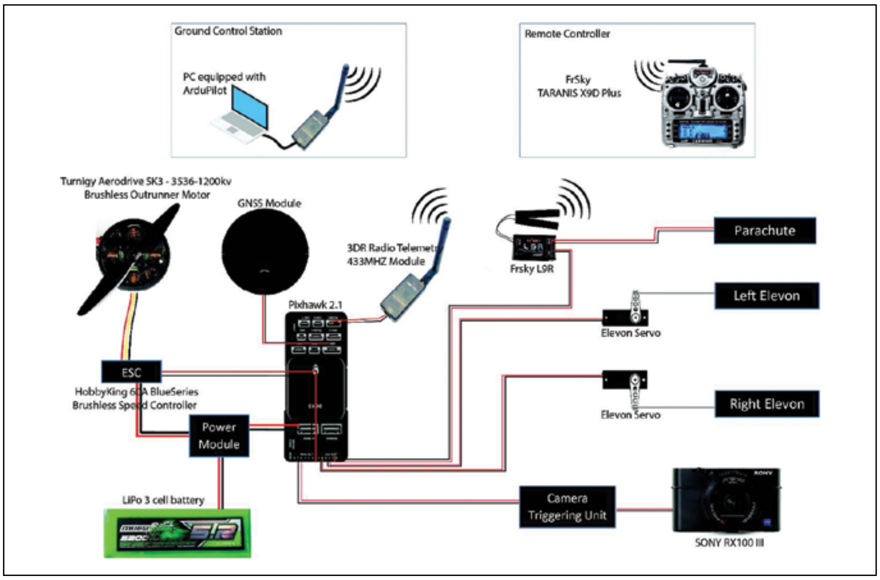

Figure 5: Diagram of Internal Components

Table 4: Configuration for Testing the Mapping Performance

Area	1km^2
Forward and side overlap	80%
Flying height	120m
Total flying time	35 mins
Camera	Sony DSC-RX100 MIII
Average GSD (Ground Sampling Distance)	3.286cm
Number of images	727

Figure 7: Visualization of Standalone Accuracy

Mapping performance

The drone's performance in mapping is assessed by mapping a total area of 1km^2 in Asian Institute of Technology, Thailand. Prior to the flight, ground control is established using RTK GNSS method to assess the geolocation accuracy of the maps. For the ground control, well distributed 10 ground control points and 15 checkpoints were established with 5cm accuracy. The flight planning was done using the Mission Planner software.

The images are post processed with the flight log to extract the location at the time of exposure. The geotagged images are photogrammetricaly processed into orthomap and DSM using the Pix4D software, resulting a

Table 5:Geolocation Accuracy

	Horizontal Accuracy (cm)		Vertical Accuracy (cm)		Total Accuracy (cm)	
	Absolute	Relative	Absolute	Relative	Absolute	Relative
Without GCPs	34	13	-	71	-	72
With GCPs	7	7	11	17	14	18

This study proves that it is possible to build a long-range mapping drone under 2000USD which can perform mapping to a planimetric accuracy of 34cm and sub meter in 3D. Further improvements can be made to upgrade the positioning system to RTK/PPK capable receiver to increase the standalone mapping accuracy.

high resolution (3.3 cm) orthomap and DSM. Two sets of maps were made during the process by using the ground control for georeferencing and without using the ground control but direct georeferencing only by the image geotags.

The absolute accuracy is assessed by comparing the map coordinates with the actual ground coordinates measured by survey grade RTK GNSS receiver. The relative accuracy is for the map measurements relative to a point on the map. The analysis shows that the custom made drone can make 2D maps to an accuracy of 34cm without the aid of a ground control.

Comparison

The drone's performance in mapping is compared with phantom 3 & phantom 4 which are DJIs consumer grade drones and with Wingtra One, Trimble UX5, DATAhawk & eBee X which are popular survey grade drones. The most significant advantage of the custom-made drone over other commercial drones is the price. The total build including two cameras only cost 1989 USD for the hardware. Its 10 times cheaper than the average price of a survey grade drone. Also, the drone is capable of covering an area of 3ha with a single flight which ties up with the survey grade drones. The trade offs are the accuracy and operational complexity. The drone only uses SBUS aided GNSS positioning which brings the standalone horizontal accuracy of the products to 34cm. 3D accuracy further drops to 72cm which is less accurate than the survey grade drones. Also at the current stage, it is very difficult for others to understand how to operate the drone except for the people who built it, which makes the operational complexity, extreme.

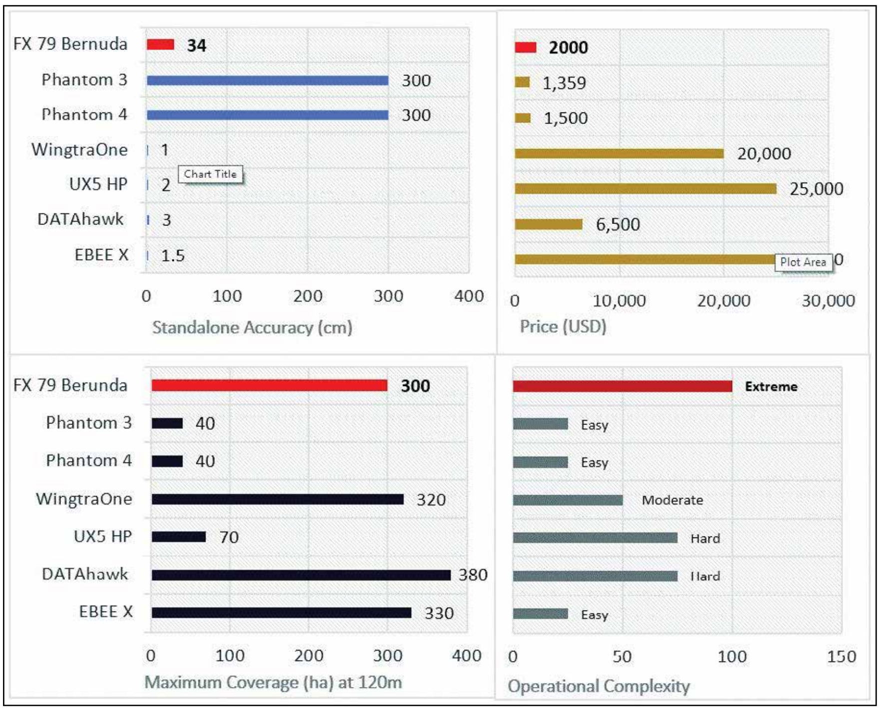

Figure 8: Comparison between common commercial drones

Discussion

This study proves that it is possible to build a long-range mapping drone under 2000USD which can perform mapping to a planimetric accuracy of 34cm and sub meter in 3D. Further improvements can be made to upgrade the positioning system to RTK/PPK capable receiver to increase the standalone mapping accuracy.

The power consumption can be reduced by fine tuning the internal parameters of the flight controller which requires a significant amount of flight data in multiple flights. When compared to the survey grade drones in the market, the custom-built FX-79 "Berunda" is a very affordable drone solution for long range mapping where it matches with the accuracy requirements as the accuracy is always governed by the application.

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Driving force of historically land use changes in the part of Tokyo city

The old maps, aerial photographs and continuous surveying will be able to explain the driving forces of land use changes and to lead to the well understanding of growth or prosperity of cities

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Tokyo metropolitan city is divided into 23 wards. Shibuya-ward is one of them and is in the western part of central Tokyo area. It is now famous for pop-culture and information technology companies complex. But when the Meiji-restoration about 150 years ago was done, about half of Shibuya-ward area was a kind of farm belt. The rest of farm region in Shibuya-ward was the “Samurai”, a warrior, house district. The land-use in this area was at first transformed to dairy and pasture, horticulture farm growing tea leaves or mulberry leaves for silkworms. It is because of abolition of Samurai warrior class and abrogation of feudal load’s alternating “Edo”, the old name of Tokyo, residence. In addition, there were changes in eating habits also. There are changes in diet from fish and soy beans into meat and dairy products. After that, there are some opportunities to change the land use in this area, such as construction and opening of railway to the central area, tap water supply, the “Kanto” region great earthquake, increasing populations, World-War-II and its damages, changes of industrial structure, the Tokyo-Olympic-Games, the miraculously swift growth of the economy, etc. The old maps, aerial photographs and continuous surveying, will be able to explain the driving forces of land use changes and to lead to the well understanding of growth or prosperity of cities. Photointerpretation is the key to obtain a cause of such kind of land use changes. The web-based Geographic Information Technology is the way how to hold in common among the people.

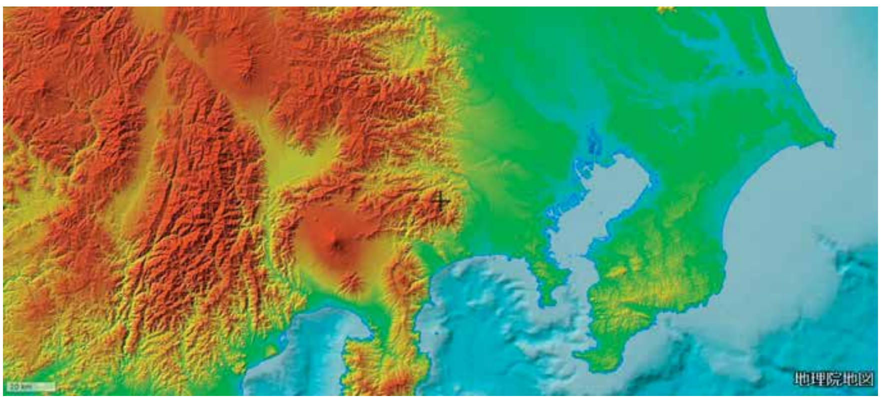

Fig.1 Topography map around Tokyo area from Mt. Fuji to Pacific Ocean

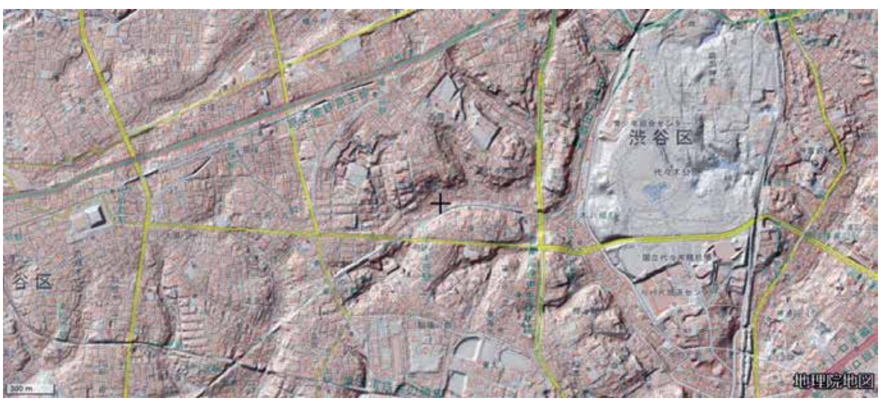

Fig.2 Research Area (North-Western part of Shibuya-ward of Tokyo)

Introduction

Tokyo metropolitan city is divided into 23 wards. Shibuya-ward is one of them and is in the western part of central Tokyo area. The JR-Shibuya railway station is one of the major terminal stations in Tokyo metropolitan city. The concerning area is the north-west part of Shibuya-ward, Yoyogi-Nishihara, Yoyogi-Uehara, Yoyogi-Tomigaya, Yoyogi-Ohyama, Yoyogi-Sotowa.

There is a high-class residential street, many public facilities in this area next to Yoyogi park and the Meiji Shrine. But only about 150 years ago, this area was a thickly wooded area and cultivated fields. The land use was changed into cultivated area, residential street or public facilities by the social environment after many changes during last 150 years.

The Meiji restoration, the end of the Tokugawa Shogunate

Chronological table	1868 the Meiji Restoration, changed the era name
	1887 the start of electricity supply by the thermal power plant
	1889 opening of the whole "Tolaido" Main Line of railway (from Shinbashi to Osaka through Shizuoka, Nagoya)

The Edo-era, the Tokugawa Shogunate times, most of Yoyogi village was farmer's fields. The Koshu highway, main road from Edo to Kofu, where was the backyard of Edo and very important place for the Tokugawa Shogunate. So this main road was one of the main routes of transportation of goods. The north edge of Yoyogi village was along this Koshu main road. The eastern part of Yoyogi village was Samurai warrior's residential area. There were some housing grounds for the lords of feudal clan the in the Edo era. Yoyogi-Shibuya area was the second or the third residences for them. The land-use in this area was at first transformed to dairy and pasture, horticulture farm growing tea leaves or mulberry leaves for silkworms. It is because of abolition of Samurai warrior class and abrogation of feudal load's alternating Edo residence. In addition there were changes of eating habits also.

But the population of Tokyo was soon restored and increased. Samurai warrior's residential areas were converted into the Emperor's milking farm, school yards, Red Cross hospital and military drill field. The land use of western part of Yoyogi village was milking farm for the central Tokyo inhabitants and tea farm and vegetables farm. The milling industry of wheat and rice polishing using water wheels along the Tamagawa or Mita agricultural water way. After the Tokaido railway line was opened and electricity power supply was started, tea leaves came from Shizuoka along the Tokaido railway. The tea farm and water wheels milling industry declined.

People had kept away from meat-eating life influenced by Buddism until the Meiji Restoraion. After the Meiji Restortion, people's eating habits were changed into the Western style, such as drinking milk, eating dairy products, and meat-eating. There were much of dairy farms in the north-western part of Shibuya-ward, but those were relocated to the suburbs soon after housing-land development. There were also many factories along the "Koshu" main road. And there was the water supply open channel, "the old Tamagawa aqueduct" and its new waterway in the Hatagaya area, the north part of Koshu main road. (The Yoyogi village was located at the southern Koshu main road area and in the southern Tamagawa old aqueduct.) This "new-Tamagawa water supply open channnel" divided into two regions of Hatagaya area. The Yoyogi-Oyama, Nishihara, Uehara area were owned by the few landholders, such as Mr. Takayoshi Kido, one of the statesmen who made an outstanding contribution to the Meiji Restoration. They dreamt to run a large farm as a Western-style farm management. Those factors influenced the growth of the Yoyogi village. Some followers of Mr. Kido possessed those region for a large scale of land. They were the captain of the industry.

Progressing economy and construction of private railways

Chronological table	1915 the "Keio" electric railway opened between "Shinjuku" and "Sasazuka".
	1923 the "Kanto" great earthquake occurred
	1927 the "Odakyu" electric railway opened between "Shinjuku" and "Odawara"
	1931 the tap water supplied by the "Yoyohata" town waterworks bureau the "Yoyogi-Oyama" region sold by a private company as a residential lots

The private railway lines, such as "Keio" and "Odakyu", set up railway transportation service after about 50 years from the Meiji Restoration and public water supply started by the municipal government. Because Yoyogi village combined with the next village, Hatagaya village and it formed Yoyohaya Town, but not the old Tokyo city area. The Kanto great earthquake also occurred during this time. This region is suitable for residential area as a western edge of the central Tokyo city and the solid ground.

Figure 3: Topographic map of 1909

Topographic map of 1921

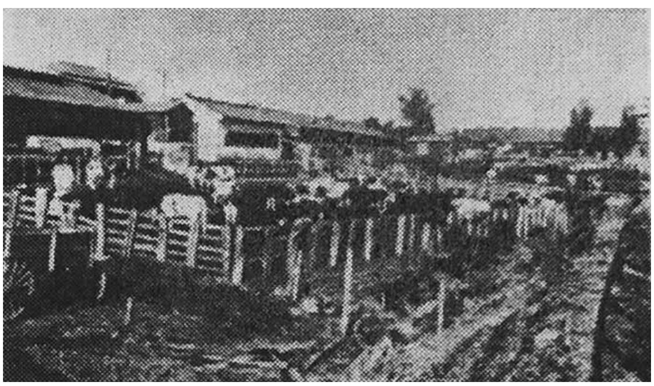

Figure 4: Hagoromosha dairy farm at Yoyogi-Nishihara in about 1910-1930

Some places were sold in parcels as residential areas. Those housing lots were comparatively large. Because most parts of this area were owned by the large-scale landowner above mentioned. Besides that, most of the new residents of sale of the land were returnees from the overseas, such as European countries and The United States. They built Western style houses with a bathroom, bed-room, air-conditioner and garage, sometimes with a swimming pool and lawn tennis in the yard, maybe without Japanese "Tatami" floor.

Figure 5: Aerial photograph about 1936 (before World War II)

Figure 6: Burned area by the large-scale air-attacks of napalm bomb at World War II (The red color means the burned area)

Figure 7: The requisitioned houses by GHQ around Yoyogi-Oyama, Shoto And a part of the burned area and escaped a fire map by the air attacks

Figure 8: Aerial Photograph about 1945 (after the World War II)

Large scale air attack of the World War II and the many houses requisitioned for occupation forces (GHQ-SCAP =General Headquarters of the supreme commander for the allied powers)

Large scale air attacks by napalm bomb happend during March, April and May in 1945 to Tokyo city. But the western Yoyogi area (Oyama, Nishihara, Uehara, Tomigaya) were not burned by the bomb. Because this area was sparse and covered with rich green and most of the houses were of Western style and near the Washington-heights, the residence barracks of middle-ranking officers. So many houses (over 200) were requisitioned for occupation forces (GHQ-SCAP).

Japanese inhabitants might feel the gap between the rich life of Americans and poor Japanese. Because they lived in the big house with bathrooms, air-conditioners, swimming pool or tennis court and kept a big dog. After the military occupation, there were many company-owned apartments in this area. the companies included large enterprises.

The residents were including returnees from overseas, such as European countries and United States as like before the war. They brought progressive and go-ahead spirit from overseas. This reformed the "Shibuya" stylish temperament in the present.

Tokyo Olympic game and high-rate economic growth

The last time Tokyo Olympic Game was held in 1964 and high-rate economic growth was continuing. The sewerage system was installed very quickly before the Olympic game in this area. The Washington-heights was return to Japan; The Olympic athlete village and Yoyogi Olympic Gymnasium was constructed there. Some Olympic roads, wide streets, were constructed in this area. The high-rate economic growth brought increase in population and the construction of apartment houses resulted in this area.

There was a dormitory for the Indonesian students studying in Japan supported by the Japanese government as the compensation of World War II at Yoyogi-Oyama. Because there might be the Tokyo Mosque near the dormitory.

Findings and conclusion

The driving forces of land use changes in this area are (1) Agricultural land use change by the drastic transition of eating

Fig.9 Aerial Photograph about 1960 (before Tokyo Olympic game)

Fig. 10 Aerial Photogragh 1974 (during high-rate economic growth)

Fig.11 Aerial Photograph 1988

Fig.12 Tokyo Camii (mosque) and Turkish Culture Center

habits in the beginning of Meiji Restoration, (2) Construction of railway and increasing demand of housing after the Kanto great earthquake (3) Large-scale air-attack of World War II and requisitioned houses by GHQ (4) Hosting Tokyo Olympic Game and high-rate economic growth. The author can find land use changes and its driving force by the historically social-economic growth through the analysis in this part of Tokyo metropolitan area. But the similar land use change can be happened in the South-Eastern Asia. It can generalize a conclusion drawn from such highly specific analysis in the specific land use changes.

If the georeferenced aerial photography and old maps in tine-series are overlaid and we could see such image and maps in the same browser just like Geospatial Information Authority of Japan Web Map, we could analyze the factor of land use change in another region, another city.

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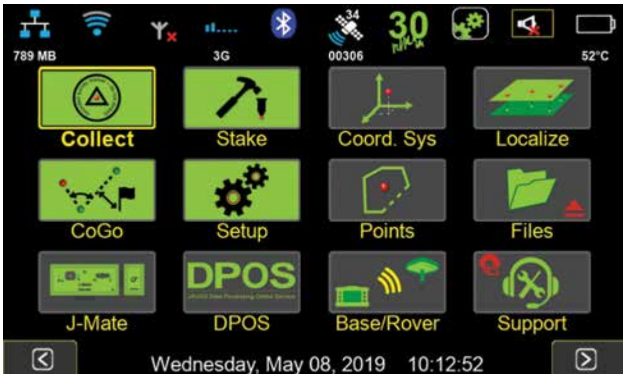
Introduction

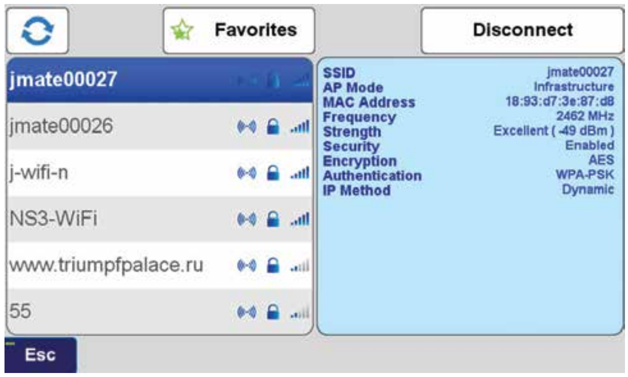
Let's set the record straight: J-Mate is not a total-station. **J-Mate and TRIUMPH-LS together** make the **"Total Solution"** which is a combination of GNSS, encoder and laser range measurements that **together do a lot more than a total station**. For long distances you use GNSS and for short distances (maximum of 100 meters) you use the J-Mate along with the TRIUMPH-LS. Together they provide RTK level accuracy (few centimeters) in ranges **from zero to infinity**.

As with the TRIUMPH-LS, with the J-Mate we also provide software improvement updates regularly and free of charge. Download the J-Mate update in your TRIUMPH-LS and then inject it to the J-Mate. The J-Mate SSID will be in this format JMatexxx, where xxx is your J-Mate's serial number. After a Wi-Fi connection is established, click the J-Mate icon and then click Setup. When you are prompted to connect to the J-Mate, click yes and then follow the remaining prompts.

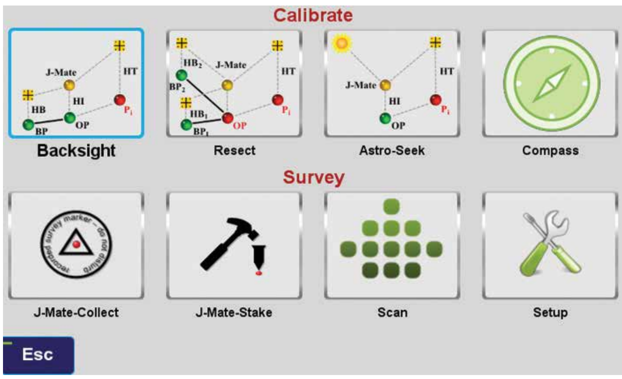
Connecting the TRIUMPH-LS to the J-Mate

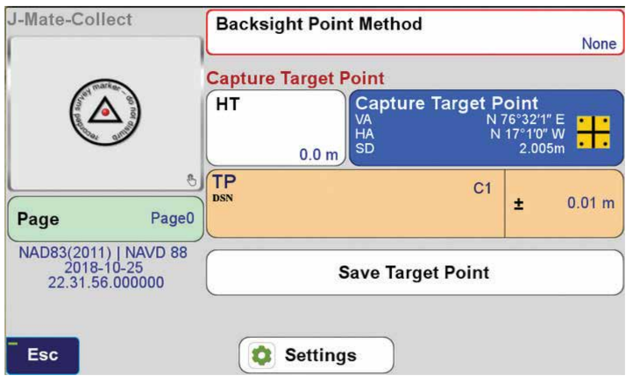
TRIUMPH-LS communicates with the J-Mate through Wi-Fi. Turn on both the TRIUMPH-LS and the J-Mate. Click the Wi-Fi icon on the TRIUMPH-LS Home screen to connect to the J-Mate, much the same way as you connect TRIUMPH-LS to your Wi-Fi access point.





After connection, click the J-Mate icon on the TRIUMPH-LS Home screen and then J-Mate/ J-Mate Collect/Capture Target Point to get familiar with the Main J-Mate screen.





Main J-Mate Screen

This is the Main J-Mate Screen. Click button **"7"** in Figure 1 to switch some controls as shown above. Below are explanations of some buttons of these screens.

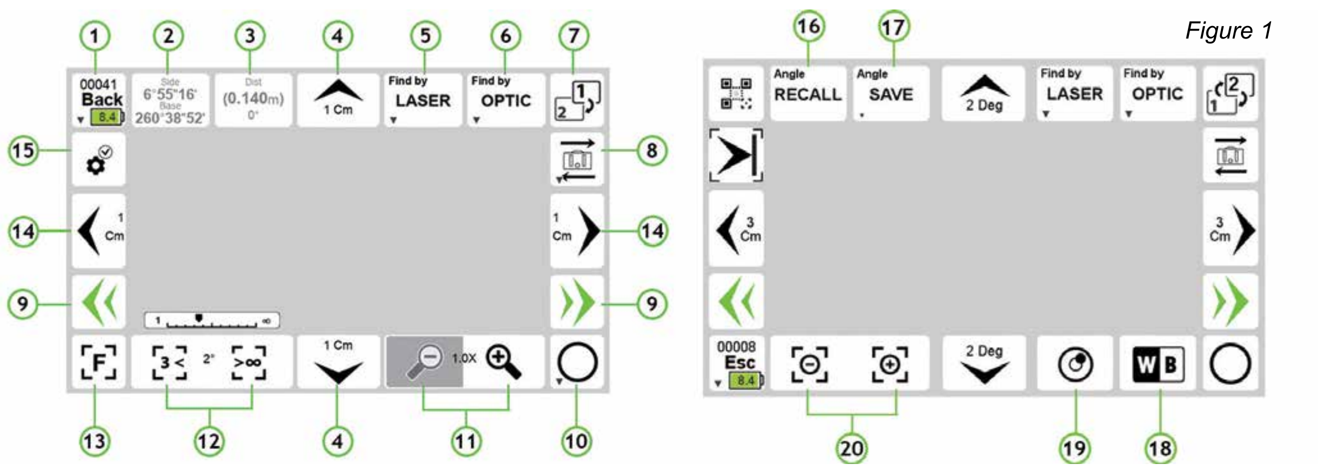


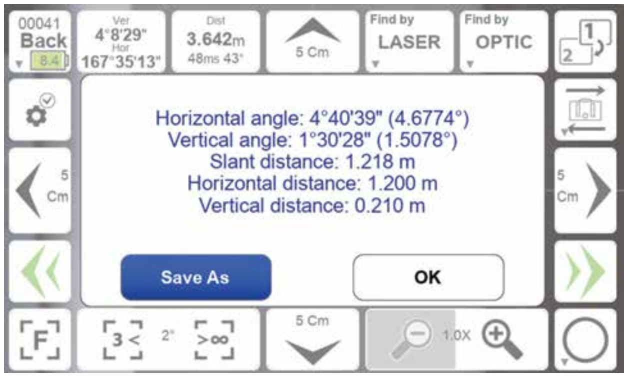
Figure 1

Aiming at targets manually

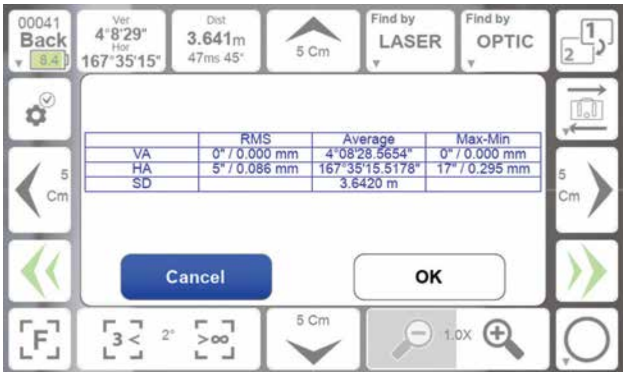
You can find targets manually or automatically.

Measure angles between two points:

Aim at the first point and click button **“2”** of Fig. 1. Then Aim to the second point and click this button again. You will see the horizontal angles between the two points. You can save the measured angles in clip boards and use it elsewhere when you need.



Taking a point



Aim at your target and click **“10”**. J-Mate will take 10 readings and average them. The average, RMS and spread of the ten readings are shown. Optionally, you can specify four points around the target point to be measured too, to ensure that you have aimed at the desired target. To specify the distance of the four points around the target, hold **“10”**.

Instantaneous angular and range measurements are shown in boxes **“2”** and **“3”** in Fig. 1.

Camera operation and settings

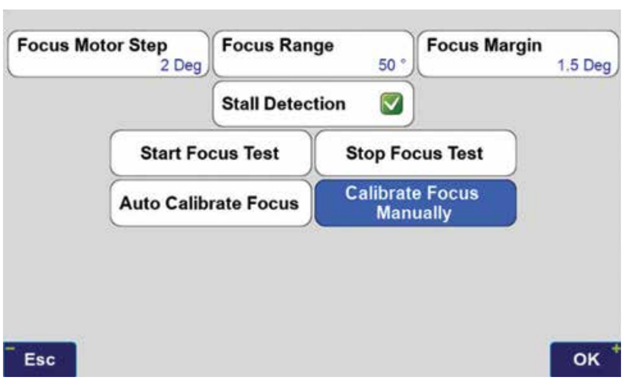
White balancing the J-Mate camera when the light setting changes: 1)Put a white paper in front of the J-Mate camera about few meters away, such that it covers at least half of the viewing angle of the camera. 2) Click **“18”** to start white balancing. It will take about 10 seconds to finish.

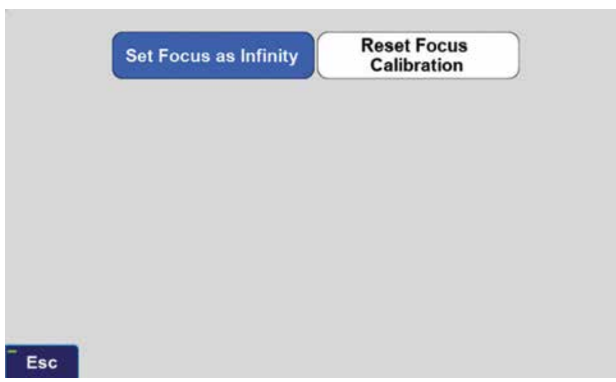
Zoom buttons: **“11”**

Contrast/Brightness buttons: **“20”**

Focus: use buttons **“12”** to focus manually. Click **“13”** for autofocus on the subject.

Occasionally you may need to calibrate the Focus motor. Click Setup **“15”** → “Focus” → “Auto Calibrate Focus” or “Calibrate Focus Manually”. In Manual focus, 1)click “Rest Focus Calibration”, 2) using **“12”** buttons, focus to infinity, 3) Click “Set Focus as Infinity”.





Searching and finding objects by laser and Object types

Hold the Laser button (**"5"**) to see the setup screen for laser target selection and parameters. If you know the approximate distance to the target, click the check box and enter the distance and accuracy percentage. This will help J-Mate to ignore targets that are outside the range.

Horizontal and Vertical Limits are the limits that J-Mate will search around the starting point to find targets. In this example is 15 degrees on left and right, and 5 degrees up and down.

"Keep Fixed Height" check box, scans horizontally on fixed target height. You may rarely need to use this feature. It will reduce the scanning speed by a factor of 2.

In Target Selection screen, the following targets are defined:

- **J-Target** is a printed pattern glued to 166x166 mm plywood of about 25 mm thick. It can be attached to a 226x226 mm plywood of 10 mm which provides flaps around the pattern. Select check boxes related to Sides, Top and Bottom flaps, if they exist and you want J-Mate to consider the depth of the flap (about 25 mm).
- If the J-Target is not sitting on another object and its bottom boundary is clear, then check the box Measure to Bottom. If not checked, J-Mate will measure to the top and will come down half of the height to aim at center. This feature applies to other target types too.
- In laser scanning and finding, the pattern on the J-Target has no effect.

J-Target Custom: This option allows you to build your custom J-Target type.

TRIUMPH-LS Back: searching for an object similar to the back of TRIUMPH-LS.

Search Tube: Searches to find a tube with given diameter and height. If Measure to Bottom is not checked, it will go to the top of the tube and then come down half of the specified height, irrespective of the actual height of the tube.

Measure Tube: Searches for a tube that has the given width and then it measures the tube depth.

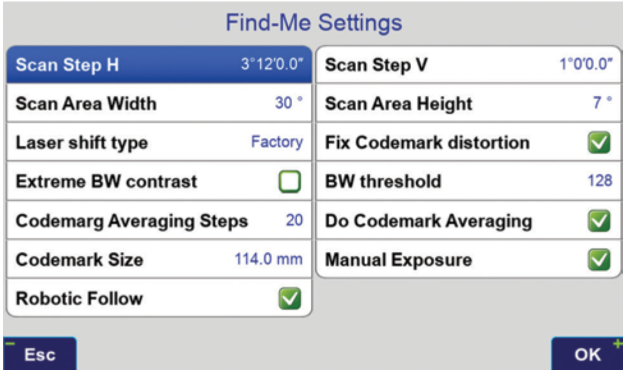
Corner identifies an abrupt change on a flat surface.

Snap: scans with the resolution given in "Step" and stops when range changes by "Edge Depth".

Scan: Scans according with the resolution given in "Step" and saves the scanned files if the box is checked. The scanned files can be viewed in the Main screen / File icon.

Selected objects and their parameters can be saved and recalled by **"Save"** button on this and **"Recall"** button of the previous screen.

Follow me and robotic operation



J-Mate can search and find the J-Target and robotically follow it. J-Mate also measures the distance to the Target optically, and shows distance and tilt on top and the bottom of the J-Target image.

For J-Mate to follow the J-Target robotically, check the **"Follow Me"** box in the OPTIC set up (hold **6** to reach its setup).

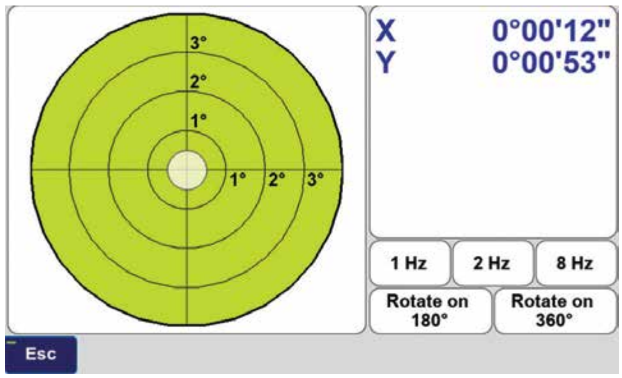
J-Mate can also optically search and find the "Zebra Cylinder" Target. It will target the center of the Zebra Target (Half the specified height from the top). If you don't check the "Measure to bottom" box, you can make the Zebra Cylinder of any height and J-Mate will aim half of the specified "Target Height" from the top of the cylinder. The Zebra Cylinder is omnidirectional and you can hold it in any direction towards the J-Mate.

Calibrating the J-Mate laser and camera offset.

1. Select an area where range changes between 2 to 10 meters when J-Mate rotates.

2. Hold **"15"**, select "Advanced" → "Calibration" → "User Calibration" and click "Start". It will take about 10 minutes to finish calibration. This will be adjust the laser cross hair identification to where it should be.

Viewing the inclinometer



Hold button **"8"** or click button **"19"** of Figure 1 to see the embedded 0.001-degree electronic inclinometer of the J-Mate as shown in Figure 3. It updates 10 times per second.

The embedded inclinometer monitors and corrects for tilts automatically.

Saving and recalling orientation of J-Mate

Click **"17"** to save the current orientation of the J-Mate to a scratch pad.

Click **"16"** and select the scratch pad orientation that you want to orient to.

Laser time limit

The time that it takes for a laser measurement depends on the reflective surface of the target and weather conditions (dust and moisture in the air).

On a good white reflective surface and in clean air, it takes about 50 milliseconds to have a laser reading. If there is no reflective surface, or the reflective surface is black, it may take up to 4 seconds to have a laser reading.

If the surface of the object that you want to scan is a good reflective surface, limit the laser time to a fraction of a second. This will cause the laser to skip points that do not reflect enough energy in the time limit that you specified. This will significantly increase the scan speed and will ignore points that are not possibly your target and reduces the chance of identifying a wrong object.

Hold "LASER" (**"5"**) to set the laser time limit.

Option to Help J-Mate to find you

At Occupation point, click the J-Target icon (**"21"** of the Figure 1). You will be guided through the following steps for J-Mate to aim at you holding the TRIUMPH-LS with the J-Target, when going to the Backsight, for example.

1. At Occupation point, put the TRIUMPH-LS on top of J-Mate (or slightly above it, but at the same orientation as the J-Mate, to be far from the motor magnets of the J-Mate) and click Next.

This step will transfer the compass reading of the TRIUMPH-LS to the J-Mate encoders.

2. Go to your target, Put the J-Target on top of the TRIUMPH-LS and aim the TRIUMPH-LS towards the J-Mate (with the help of the TRIUMPH-LS camera) and click Next.

This will help the J-Mate to know the general direction to the target and limit its search range. You can go back to previous step to fine tune view of the J-Mate.

3. You will see the J-Mate camera view on the TRIUMPH-LS screen. You can fine tune the J-Mate view by the navigation buttons to make recognition faster.

You can also manually aim at the center of the J-Target panel and take your shot.

4. Click "Optic" if you want the J-Target panel to be searched and centered automatically.

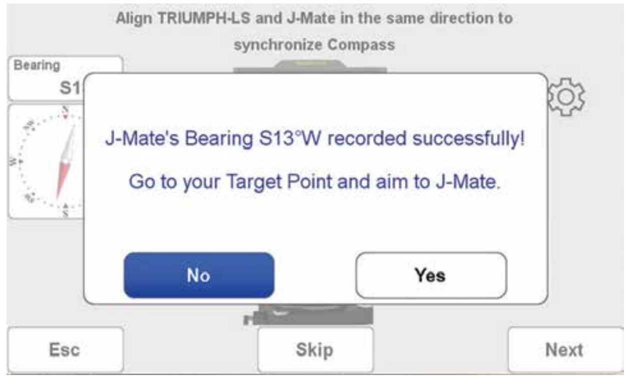
When J-Mate focuses on the center of the J-Target, you can click the "Take" button. You will be asked if you want to record the point.

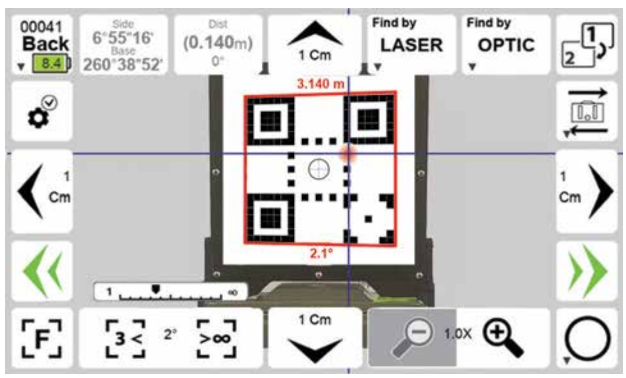
5. If you also want to find the center of the J-Target by Laser scanning, you can click the "Laser". If Laser scan is successful, you can click the "Take" button to replace the previous measurement with the current measurement done by laser scanning.

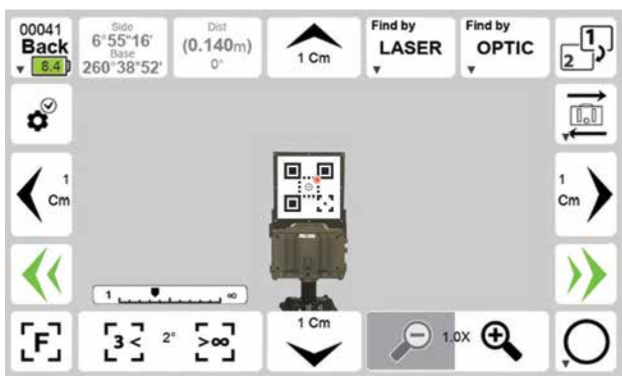
The center of the J-Target is vertically collocated with the GNSS antenna and you don't need to be exactly perpendicular to the J-Mate path.

If light condition is such that camera cannot find the J-Target, chances are better that laser scanner can find it.

Even after the J-Target is found optically, you can continue the laser search with "On J-Mate" option to measure the J-Target and find its center more accurately by laser.



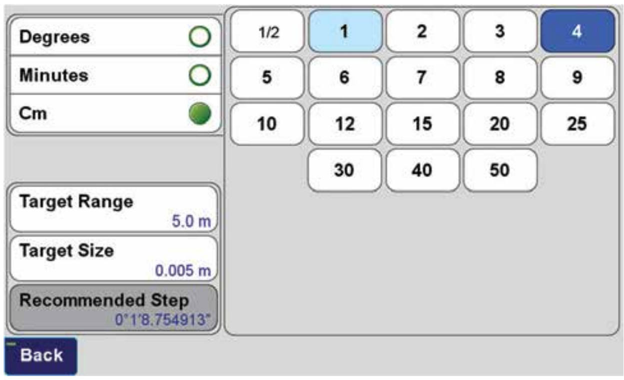




There are five ways that you can manually aim the J-Mate towards your targets:

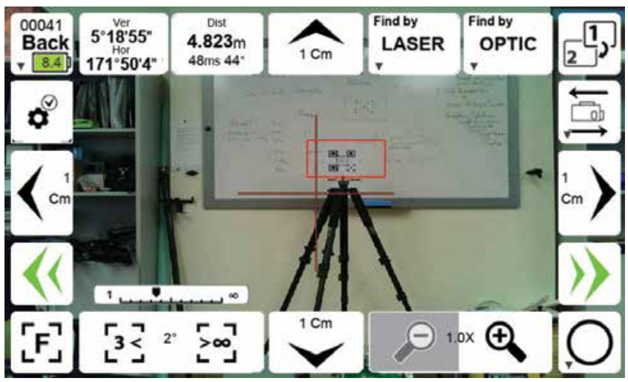
1. Each click of the Left/Right/Up/Down buttons around the screen (**"4"** and **"14"**) moves the J-Mate according to the value that you assign to them in the setup screen (**"15"**), as shown in Figure below (Horizontal and Vertical Motor Step).
2. While holding these buttons **"4"** and **"14"**, J-Mate rotates about 5 degrees per second.
3. Buttons **"9"** are "Fast Motion" buttons. While you hold them the J-Mate rotates about 30 degrees per second.
4. You can point J-Mate towards points by touching points on the screen and by gestures (moving finger on the screen).
5. You can also rotate the J-Mate manually while it is not moving by motors, but limit that to small rotations, not to apply backpressure to motor. Motor manufacturer does not prohibit manual motion, but we think it is better to avoid it as much as possible.

Setup screen



The two cameras

The viewing angle of the TRIUMPH-LS camera is 60 degrees wide, while that of the J-Mate is about 5 degrees. The viewing area of the J-Mate camera is represented on the TRIUMPH-LS camera by a small red rectangle. While TRIUMPH-LS is sitting on top of the J-Mate, you can view your target on the TRIUMPH-LS camera (Click Button **"8"** of Fig. 1), bring it to the rectangle by touching the target or using the navigation buttons, and then switch to the J-Mate camera.



To calibrate the camera of J-Mate with the camera of the TRIUMPH-LS, while TRIUMPH-LS sitting on top of the J-Mate:

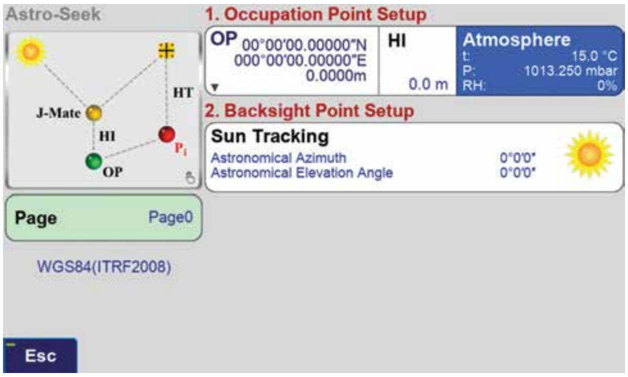
1. Click **"3"** and clear existing Horizontal and Vertical calibration offsets (if non-zero).
2. Aim J-Mate **laser** to the target.
3. Click **"2"** to set the first position of the offset angle.
4. Click **"8"** to switch to the TRIUMPH-LS camera and note the small rectangle that represents the J-Mate camera viewing area.
5. Aim the J-Mate to bring that target to the center of the rectangle.
6. Click **"2"** to finish measuring the offset angles between the laser center and the rectangle.
7. Save them to a location on the scratch pads.
8. Click **"3"** to recall the measured offsets from the scratch pad that you saved in.

Backsight point and the Sun

Similar to using conventional total station, to use the J-Mate you need to first establish its accurate position and calibrate its vertical and horizontal encoders. Then proceed to shoot the unknown points. This is similar to using any total station, but we have improved and automated the process.

With J-Mate you can do these in three different ways as shown in the J-Mate screen of the TRIUMPH-LS. Via the J-Mate-Backsight; J-Mate-Resect and J-Mate-Astro-Seek icons.

If GNSS signals are available at the site, click the J-Mate-Backsight icon.



This screen appears which guides you to determine the accurate positions of the Occupation Point and a Backsight Point to establish an azimuth and calibrate the J-Mate angular encoders.

The tripod is setup at the "Occupation Point" (OP). The J-Mate is secured on top of the tripod.

Next, TRIUMPH-LS is put on top of the J-Mate with its legs registered to the matching features on the J-Mate.

Next Use the RTK Survey feature of the TRIUMPH-LS to quickly determine the accurate location of the Occupation Point. You can use your own base station or any public RTN.

Next, slide the J-Target on top of the TRIUMPH-LS, lift it from the J-Mate and move to the "Backsight Point" (BP). The camera of the J-Mate will search the J-Target. The camera's view is visible from the TRIUMPH-LS screen, which mostly focuses on this J-Target. When at the Backsight Point, its accurate position is determined by the TRIUMPH-LS, and the Azimuth from the Operation Point to the Backsight Point is determined, and the J-Mate is calibrated and ready for use.

After this calibration is complete, if the tripod is disturbed, the red LED on the front of the J-Mate will blink to show that re-calibration is required.

We can now replace the TRIUMPH-LS on top of the J-Mate at the Occupation Point and proceed to shooting as many "Target Points" as the job requires. From now on TRIUMPH-LS is used as a controller and you can hold in your hand too, but it is more convenient to put it on its place to have free hands.

If GNSS signals are not available at the Occupation Point, click the "J-Mate-Resect" icon to shoot two known points to establish its accurate position and calibrate its encoders. Then continue to shoot the unknown points.

Astro-Seek feature: Sun as the Backsight point!

We have added a new innovative feature to the J-Mate that it can automatically calibrate itself via its automatic Sun Seeking feature.

Attach the Sun filter to the camera of the J-Mate, click the "J-Mate-Astro-Seek" icon and click the "Sun" icon in the screen which appears and J-Mate will automatically find the Sun, and use its position to calibrate the angular encoders automatically.

Navigating indoors in 3D geospatial for disaster risk reduction and response

The paper highlights the need assessment and explores the role of 3D geospatial information and modeling regarding the indoor structure and navigational routes as disaster risk reduction and response strategy

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A trend of densely populated high-rise residential, commercial and office buildings are transforming the urban environments in increasingly complex infrastructure development areas (KPMG, 2012). Catastrophic situations as earthquakes, fires or terrorist attacks require quick access to buildings as well as rapid evacuation. This demands pre-planning of access and escape routes (Ronchi, 2015). Devising a good response strategy under different disaster scenarios need to have information about the design of the building, possible escape routes, potential obstacles (such as furniture and dynamic blockades) as well as connecting indoor-outdoor. Scenarios can be generated using 3D spatial information with non-spatial attributes for resource optimization so as to save human and economic losses. The paper assesses the need for 3D geoinformation and explores approaches for 3D indoor modeling, navigation, evacuation and visualization which can be utilized in disaster risk reduction (DRR) and response strategy for a high-rise and complex building structure. For this purpose, several papers have been reviewed.

Rapid evacuation can be accomplished with proper pre-planning in complex infrastructures considering predefined escape plans, escape routes and response of occupants (Ronchi et al., 2013). In case of a fire incident, responders need strategies to evacuate, building access and reaching source of fire using floor plans of indoor structure (OSHA, 2001). A response route is drawn for this purpose. In addition, they need assessment of reaching time to the desired place in the building based on distance, the location of obstacles, type of structure, and other materials expected inside. Locational information of these obstacles, escape routes, storage points, etc. is required in multi-floor large buildings in addition to the floor connecting stairs, inside and outside connecting corridors or lobbies. 3D spatial information is much more effective than traditional 2D mode to understand the indoor structural formation and navigating optimally (Gangraker et al., 2015). Figure 1 illustrates an imaginary use of 3D indoor information in an emergency situation.

Obtaining 3D indoor spatial information has been researched upon in various publications, and many 3D approaches have been devised. However, the 3D models need additional enrichments and links to many other data sets to be able to support disaster risk reduction and response effectively.

Disaster risk reduction and response requires information-based preparation and mitigation strategies to deal with an emergency event. Spatial information enables capturing the emergency situation better, consider various parameters and create a better common operational picture (Diehl et al., 2005). The existing paper or digital based 2D format spatial information has limited interactive capability.

With the advancements in spatial science-based GIS and Remote Sensing technologies, 3D information is getting generated on the much wider scale.

It is primarily used for visualization purpose and as a virtual reality training tool (Berlo et al., 2005). In recent times, it has emerged as analytical tool with realistic views and application simulations such as plume modelling, forest fire simulation or landslides (Wang et al., 2017; Kemeç et al., 2010).

With rapid urbanization, complex three-dimensional structures are developing on a large scale as underground networks, basements and multi-floor high rise buildings.

Based on literature study, the following requirements have been identified:

1. 3D reconstruction of indoor spaces should be done in a quick and feasible manner (Holenstein et al., 2011; Staats et al., 2017).
2. The reconstruction approaches should be able to collect information about obstacles.
3. The 3D models should be semantically enriched containing information about properties of building components and spaces of importance for DRR (Diakité et al., 2016 a).
4. Accurate information on space connectivity and accessibility should be recorded in the models, emphasizing potential openings in case of disaster.
5. The information should be organized in a way that allows flexible derivation of navigation networks, which enables user-tailored navigation, considering their profile as well as tasks
6. Application development should be supported for different platforms using the models.
7. The navigation should consider different situations that might occur during emergencies, e.g. smoke, lack of electricity, water, not using elevators
8. Constraints to wayfinding need to be dealt for route planning (Stoffel et al., 2007).
9. The developed interfaces should be simple and expressive.
10. The developed applications should have a self-contained variant, being able to work with or without internet access.

Therefore, 3D indoor geospatial information is gaining importance for an efficient and quick response. This justifies the need to develop methods which can provide reliable, accurate, context wise semantics-based 3D indoor data for reconstruction and navigation purposes on a mass scale.

The reviewed approaches are analyzed using parameters in the context of indoor risk and disaster management. These parameters are implementation, connection to outdoor, spatial model and network, constraints handling.

Indoor space capturing can be efficiently performed byTerrestrial laser scanners and handheld devices. Mobile Laser Scanner (MLS) devices are more efficient than static terrestrial scanners since they can provide a continuous scan of the environment following a trajectory (Holenstein et al., 2011; Staats et al., 2017). Sensors such as Kinect V2 from Microsoft are popular among the RGB-D cameras (Figure 2). These sensors provide low-cost and accurate depth images after proper calibration and thus can be used for 3D reconstruction (Jiao et al., 2017). Use of micro unmanned aerial vehicles (UAVs) for 3D mapping of the facility have been suggested for quick data collection. Using 3D axis parallel box (APB) approach which in plural sense include maps closed to basic set operations of union, intersection and set difference, etc. (Leth et al., 2017). Another example is Google-Tango Development Kit, which enables indoor reconstruction combining different sensors (Gülch, 2016).

Regarding quick processing of point clouds, Octree data structuring has emerged as a common method. This allows efficient structuring of space, in which case a large empty space can be represented by a large node high in the octree (Rodenberg et al., 2016).

Reconstruction of semantic and geometric components include volume shifting and loop closure, the coarse-to-fine iterative closest point (ICP) algorithm, the SIFT odometry, inertial measurement unit (IMU) odometry combined to robustly and precisely estimate pose and least square adjustment algorithm (Huai et al., 2015, Jamali et al., 2015). Contextual relationships as well as local features based planar patches can be input for the classification algorithms (Xiong et al., 2010).

Artificial or image-based textures can enrich an 3D environment. Stock objects from 3D warehouses (e.g., Google 3D Warehouse) can also be used for this purpose. Further enhancement can be done by importing such models into 3D gaming engines for instance Unity3D (Gangraker et al., 2015). Another way is to use a vocal interface with contextual information about the surrounding environment (Ran et al., 2004). In case of incomplete knowledge of space, further observations can be made from actions performed, using derived knowledge to achieve the goal (Raubal, 1999).

Automatic reconstruction of 3D interiors from raw point clouds as a grammar-based approach enables building modelling with rooms access through hallways on horizontal, continuous floors. Seamless transition from LOD3 to LOD4 building models is possible by embedding such grammar in an iterative automatic learning process. After the initial grammar, higher-level grammar can be applied to predict realistic geometries to building parts where only sparse observation data are available (Becker et al., 2015). Too much reliability on empirical analysis in case of absence of large datasets needs to be tackled with

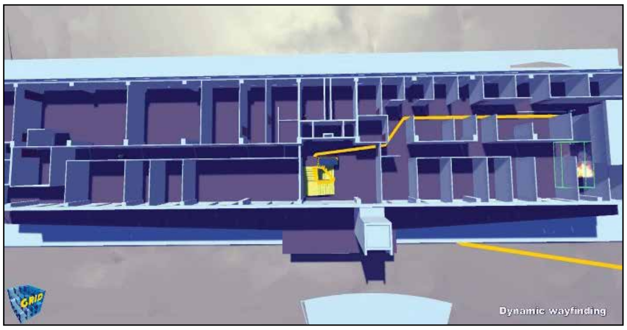

Figure 1: 3D simulation of dynamic wayfinding in case of fire on a staircase, UNSW, Sydney

human interpretation of results based on experience and expert judgement.

Different approaches have been explored for information collection about potential obstacles in indoor environment from existing plans. This can allow the automatic prediction and generation of building floor plans serving as the basis of building a 3D indoor model using architectural regularities and probability distributions for doors location prediction (Dehbi et al., 2017).

Point clouds can also be utilized to detect potential obstacles (Vilariño et al., 2016). Such models could be developed as interactive and context-sensitive by utilizing the sensor on the mobile devices which include built-in accelerometer, compass and camera capabilities (Low et al., 2015).

All such methods differ in one way or another. The, laser scanner sensors use separate technologies and designs for 3D model generation along with different prices, sizes, quality, measurement capabilities and additional requirements of usage.

Besides accuracy and suitability for emergencies, very often access to devices and transporting them to the place to be modeled are points of importance (Sirmacek et al., 2016).

The 3D data collection and reconstruction aspects could be highly useful for DRR and disaster response activities. Enriching the data with semantics attributes, geometric attributes and textures can generate more realistic environment in 3D for DRR and response planning. Detection and prediction of potential obstacles could enhance these disaster management efforts.

In case of indoor navigation, the path of a person is not limited the way it is for a car in case of outdoor navigation (Gotlib et al., 2013). In case of emergencies, two types of navigation can be considered: 1) from outside to indoor for rescuers and responders and 2) from indoor to outdoor to aid people in need. Depending on the type of user the applications differ.

Important building information within the spatial context of the rescuer can be provided on a mobile device for rescuers (Rueppel et al., 2009). In case of response process initiated, indoor and outdoor drones can perform monitoring both inside and outside the building, sending all visual data to the server (Maravall et al., 2017). This visual data can be utilized by rescuers. Indoor navigation for evacuees requires a guidance system which could be based on navigation algorithm devised using information on hazardous areas, emergency spreading, congestion areas (Weeraddana et al., 2013).

Another specific application of indoor navigation research is for routing purposes to fulfil the transportation necessities of each production asset (Scholz et al., 2017). Similarly, a user can be a normal person with no problems with eyesight while another user could be a visually impaired person or a person in an environment with bad visibility (e.g. smoke). Thus, indoor navigation aid has to be developed accordingly taking care of the specific requirements of a user (Ran et al., 2004).

Accessibility for different people should be defined using a hysical 3D environment. For instance, an accessibility map for people with disabilities using wheelchairs and first responders caring specialized equipment can vary compared to ordinary people. Hence, in order to calculate the accessibility map aspects related to max slope that a person can climb along with step height and person's radius and height should be taken into account (Barrera et al., 2015).

Navigation of people and wayfinding in indoor environments is affected from the fact that different navigation areas can be used by a person such as open spaces, corridors, doors, stairs, elevators and escalators (Bukowski et al., 2016). Apart from that other people having the same trajectory can influence the navigation process (Braun et al., 2003). Therefore, considering the impact of the number of people residing a building during a different period of a day should be considered for path calculation (Tashakkori et al., 2016).

Thus, two navigation types are identified: outdoor/indoor navigation for first responders and indoor/outdoor navigation for evacuees. Regarding first responders, real-time information about the current situation and the best route should be provided. When it comes to evacuees, aspects such as people abilities and their performance using different egress components should be taken into account to provide the best navigation for them.

Evacuation is one of the most critical activities during emergencies. People have to be lead outside the building to a specific safe place in an appropriate period. Usually, these estimations are made in advance during the risk preparedness phase and are validated with the help of simulation models.

One of the approaches for simulating an evacuation is Multiple Ant Colony Optimization (MACO) algorithm coupled with heuristic information, two-colony rules and local search for generating

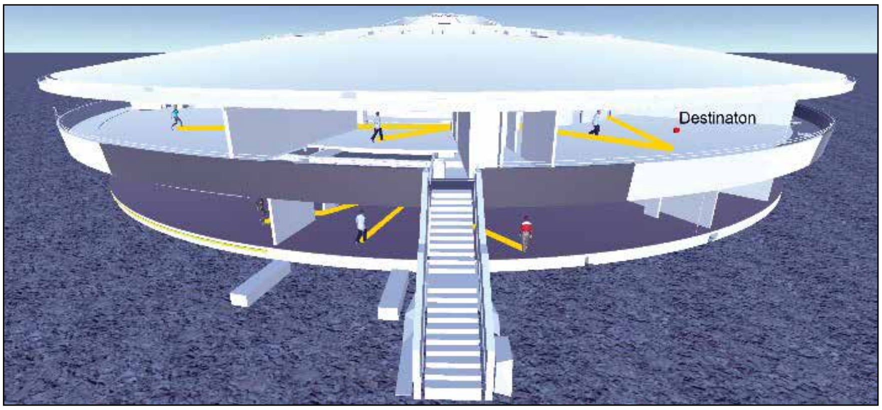

Figure 2: Indoor wayfinding to a specific destination, Round House, UNSW, Sydney

optimal indoor room spatial patterns (Yang et al., 2017). In case of a disaster event, Ant Colony Based algorithm can find the required number of first responders and their potential individual routes to search points of interest in a building which will minimize the overall time spent by all rescuers inside the disaster area (Tashakkori et al., 2016). Based on a swarm algorithm, swarm creatures can search for the requested target and, once found, return to the user whilst creating a path (Yoon et al., 2006).

In order to track evacuees' movements, data from RFID devices and smartphones can be used (Ortakci et al., 2015). Also, surveillance videos can be processed to detect their movements (Zhou et al., 2016). Another approach suggests using the concept of decentralized evacuation targeting single evacuees in a dynamically changing environment with risk-aware guidance on their smartphones. Information depositories, collecting the knowledge acquired by the smartphones of evacuees passing by, at strategic locations convey it to other passing-by evacuees (Zhao et al., 2017). 3D localization approaches can be based on the use of Bluetooth (BT) radio technology and implemented using Java and J2ME (Cruz et al., 2011).

An important aspect of evacuation is guidance. Landmarks fetched in the memory of evacuees or responders can help them to prepare a mental map of the optimal route for escape or evacuation. Algorithms used can calculate path linking the minimal amount of actions to the landmarks (Vaiene et al., 2016). An optimization technique considering time-space-based risk is proposed taking into account the spatial location of evacuees within a building to minimize the risk (Han et al., 2007). One interesting approach used is of navigation graphs with weights, done with affordances based on ontology (Scholz et al., 2017).

Implementation of the constraint models require to take into account visibility and generating route descriptions (Stoffel et al., 2007). 3D engines have some capabilities to handle collision avoidance during route planning. For example, the physics component of the Unity Engine (Gangraker et al., 2015). Mosaics can be used to map local areas to ease user navigation through streets and hallways, by providing a wider field of view (FOV) and the inclusion of more decisive features. Besides, audio support, visual support can be considered as signage, visual-text, and visual-icons for augmenting environments (Molina et al., 2012).

3D information is essential to determine required safe egress time (RSET) performing evacuation simulations to understand evacuees' performance as well as to accurately calculate available safe egress time (ASET) carrying out fire simulations (Bukowski et al., 2016).

Several important aspects have been identified in this section presenting the components that should be considered for effective evacuation and DRR. Thus, different algorithms based on ant colony and swarm optimization can be utilized to find the best option among the available set of solutions integrating various aspects such as risk, dangerous locations and people preferences. Localization and dissemination of information to evacuees is another important aspect which needs careful investigation for DRR. Different methods such as audio support, the use of text and arrow based signage can be utilized to reduce the risk during an evacuation. 3D information can be also used to determine RSET and ASET times to provide safe evacuation for evacuees though a building.

In many cases indoor location is more appropriate to be given as a relative location, such as 'next to', 'at from of', or 'close to', and approach which is not used for outdoor navigation (Sithole et al., 2016). Indoor Navigation models such as IndoorLocationGML can support establishing such locations and linking them to outdoor notations for seamless indoor-outdoor expression of location (Zhu et al., 2016). Using mobile phone base station's signal patterns could be an approach to identify the users' location (Wang et al., 2016).

Many libraries are currently available to develop personalised applications. 3D gaming engines make readily available a number of utilities in a package form as a software development kit (SDK). Thus, various SDKs are compatible with mobile devices providing core components such as rendering engine, media engine, physics engine, scripting functionality, networking capability and even Artificial Intelligence (AI). For emergency situations, the role of renderer component is critical due to its interaction with user and allows having 2D or 3D display of the surrounding environment (Gangraker et al., 2015).

One of the promising gaming engines is Unity3D, which enables development of a Graphic User Interface (GUI) which can reflect specific needs or tasks. Also, objects that are within a visible field of view can be rendered, and thus increase the performance of a graphical processing unit (Lovreglio et al., 2018). Another suitable 3D gaming engines is 3DState (Rahman et al., 2007). Research has been conducted connecting indoor modeling process, route finding and visualization using CityEngine (Kim et al., 2015). A multi-layer system with application, web-service and database can be developed to provide services of localization, navigation and visualization (Xu et al., 2013). However, such internet-based approaches should be used with care in case of emergency response as internet connection might fail.

Navigable areas can be automatically extracted and presented over the physical 3D space enabling a person to intelligently move through an available walkable environment, which option is also available within Unity3D. Visualization of different navigable layers within a building impacting the speed of people as well as the calculation of the shortest path, using A* algorithm considering layers' costs and even dynamic obstacles, can be undertaken at runtime (Barrera et al., 2015).

In case of emergency, instant visualization on a mobile device with proper information of static obstacles and direction could be useful for responders as well as victims. Direction presented in a visual manner can prevent the disoriented victims, blinded due to invisibility, from getting trapped even when they know the building interiors. For this purpose, Mobile applications have been developed for smartphones to provide the user with such visual support (Ortakci et al., 2014). Static obstacle positions can also be pre-defined (Mutlu et al., 2012). Indoor architecture is represented via corner based feature points obtained through a monocular camera (Celik et al., 2008). Smartphones are readily available which have a geomagnetic sensor which can be used for designing a geomagnetic positioning indoor navigation system based on Android platform (Jiaxing et al., 2017).

Research topics have also explored solutions for navigation with a different perspective for evaluating the ease of wayfinding, considering 3D interactions between wayfinding behaviors and signage location, visibility, legibility, noticeability, and continuity to detect 'disorientation spots' such as forks (Maruyama et al., 2017). External information can be used (e.g., signage) as a wayfinding aid (Vilar et al., 2012) during emergency route planning. A digital sign system with designated patterns can be readily detected and identified with a digital camera and machine-vision system (Tjan et al., 2005). These digital signages can flash updated emergency messages for evacuees or responders.

Discussion and recommendations

Disaster management is an integral part of planning and development of urban areas in developed countries. The similar issue face high-rise multi-story complex infrastructure environment in metro cities of fast developing economies like India and China, it is going to be an important component of infrastructure development plans. With densely populated areas having complex structures, there is always a possibility of emergency situations like fires or earthquake or flash floods, endangering human lives and infrastructure. Disaster management for urban environments with complex structures requires to focus on 3D indoor applications development as risk reduction and response strategies.

As part of DRR and response strategy, the most critical aspect for indoor applications is the generation and maintenance of 3D information. Generating three-dimensional spatial data with a reliable method on a mass scale at rapid speed is essential to widespread the awareness to use such data among planners. 3D information serves as the basis of modeling for 3D data structuring, visualization and guidance, 3D indoor construction, seamless indoor-outdoor connection and evacuation. This kind of information requires technical accessories and skills available in the form of software & hardware platforms. Our review has shown that such methods exist, but information is unstructured and can be used only for observation. 3D data collection is becoming quick and cheap, but the 3D reconstruction methods are still at experimental stage.

The study clearly shows that terrestrial and mobile scanners are mostly used to generate semantically rich 3D reconstructions. To fulfill geometric measurements and CAD models with high level semantics in the form of key structural components such as walls, floors and ceilings along with their spatial relationships, much research is needed. Standard representations such as BIM and CityGML LOD4 could be very helpful to facilitate exchange and re-use of 3D models, and they have to be maintained and up-to-date. Such accurate geometric and high level semantic information can allow planners to develop very realistic mitigation measures as part of the DRR efforts. Responders will also get very good virtual environments to train in the preparation phase or to create an accurate common operational picture during the emergency.

Information about accessibility of spaces (based on use of spaces) is of critical importance and should be further investigated (Alattas et al., 2017). With 3D information of indoor space, limitless benefits can be achieved such as modelling and calculation of more accurate network routes, precise identification of navigable spaces for users with different capabilities and preferences, better understanding of daily activities of residents, performing realistic RSET and ASET calculations, risk reduction of evacuees considering spatial location of dangerous locations and rapid distribution of first responders for better coverage within a building. 3D reconstruction approaches should also consider mechanical, electrical and plumbing (MEP) designs more and more as integral part of building structure. This will allow to generate better response measures and to consider alternate routes of evacuations with more knowledge of building structural intricacies.

For the purpose of navigation, standardisation approaches to create Geometric Network Model have been gaining interest. In this respect IndoorGML can be mentioned as one promising concept, allowing to create navigation models on the basis of duality of space and indication about connectivity. This concept is further extended to link different space models, which can be organized in a Multilayered Space-Event Model (MLSEM). This provides a flexible framework supporting all indoor navigation tasks. By dividing indoor environment into subspaces and automatically deriving a network, a more refined navigation paths can be computed that considers the task of the navigated agent (user or robot).

These developments must be further intensified and specialized for DRR considering the storage space and processing power required to subdivide the space of interest and tasks to be executed. In case of response to a disaster event, the urgency of the nature of the event, develops requirement to process the data at high speeds considering the dynamics of changing the environment.

Indoor navigation is not only about defining the space models but also developing routes which should be cost effective in terms of time, distance, safety, security or physical effort. Avoiding obstacles is an integral part of it. Indoor navigation aid has to take into context the specific requirements of a user. For rescuers, mobile devices such as smartphones and drones can play an important role by providing inputs about the building structure and displaying the potential routes and obstacles while on the move. Thus, indoor accessibility and evacuation maps have to be extended, considering the physical criteria such as corridor slope or stairs to be climbed and user context such as disable victims and rescuers carrying specialized equipment, need to be developed as a part of DRR efforts.

Any DRR and response strategy has the safe evacuation of victims trapped inside a structure as the first and foremost target to be achieved. This critical activity requires estimates to be made in advance as part of DRR efforts. Reviewed literature showed that most studied approach is Ant Colony Optimization (MACO) algorithm. Importance of mental maps defining an optimal route for escape or evacuation are mentioned in the reviewed literature. Safe evacuation is directly linked to time as a crucial factor. 3D information of indoor environment can enable accurate calculations of RSET and ASET and facilitate modeling of evacuation process. Audio & visual support as announcements, signage, visual-text, and visual-icons can be considered for augmenting environments.

Another critical issue is seamless outdoor and indoor connection, which are important for both evacuation planning and individual guidance. Current approaches of linking outdoor and outdoor networks via anchor points are trivial but insufficient for DRR. The existing outdoor networks fail to provide accurate paths appropriate for human movements. In this respect, an extension of the indoor approaches for navigation could be an option for outdoor.

Using realistic visuals and appropriate guidance on the basis of 3D rendering engines can enhance the perception and comfort of the user. Visual guidance should be combined with sound interfaces. For example, smoke, engulfing the building, or electricity failure can be a reason for reduced visibility, which will require a vocal interface with contextual information about the surrounding environment.

With readily available mobile technologies, the rapid development of mobile applications is observed, but these applications should be extended to serve emergency situations. In case of disaster scenarios, such mobile applications should allow users to plan the escape routes on their own as well as to connect with responders in a 3D visual way for further guidance.

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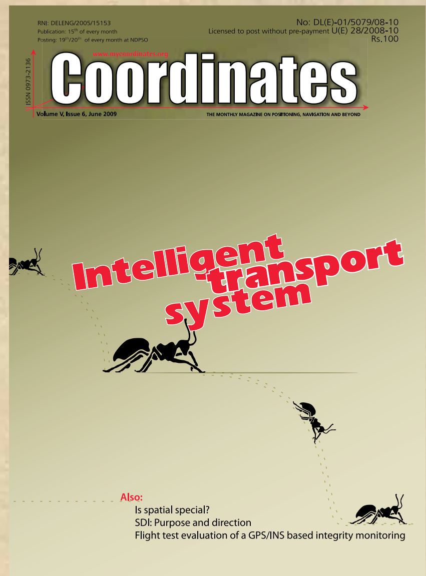

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Intelligent transport system

Renato Filjar, Mićo Dujak, Boris Drilo and Dinko Šarić
Ericsson Nikola Tesla
Croatia

Development of a Traffi c Information System (TIS) providing near-real time traffi c status information is a case study for deployment of utilisation of location-related data embedded in mobile communication networks. The accurate traffi c status estimation requiers a large number of data distributed both spatially and in time accross the area of interest. In a classical approach, dedicated fl oating cars are deployed to act as a mobile traffi c sensors. Those should be equipped with special navigation and communication units, and privacy and security issues should be resolved before the implementation, usually by fi nding a group of mobile users who voluntarily provide their location data in order to yield other benefi ts. For instance, taxi drivers may be interested in providing their whereabouts in exchange for continuous monitoring and assistance in case of being attacked.

Flight test evaluation of a GPS/INS based integrity monitoring

Toshiaki Tsujii, Hiroshi Tomita, Takeshi Fujiwara and Masatoshi Harigae
Aviation Programme Group, Jaxa, Japan

GPS/INS integrated navigation system has been a candidate of integrity monitoring system since an inertial sensor could improve performance of the fault detection and exclusion (FDE) functions. Japan Aerospace Exploration Agency (JAXA) has developed several GPS/ INS systems called GAIA (GPS Aided Inertial navigation Avionics) for over ten years and succeeded in automatic landing of unmanned experimental vehicle in differential mode. Although high accuracy at the level of Category III approach and landing was achieved, GAIA could not be used for civil aviation since its integrity was not ensured. Therefore, JAXA has commenced research on FDE algorithms for GPS/INS navigation system, and a prototype software based on a filter bank method was developed.

SDI: Purpose and direction

Jesús Olvera Ramirez
Direction of the Spatial Data Infrastructure Direction General of Geography and Environment National Institute of Statistics and Geography, Mexico

Since 2004, the National Institute of Statistics and Geography (INEGI: Instituto Nacional de Estadística y Geografía) has formally embedded in its objectives the establishment and building of the Spatial Data Infrastructure of Mexico (IDEMex: Infraestructura de Datos Espaciales de México). So that the IDEMex may achieve a complete development, the strategy of obtaining a government mandate along with the resources for its continuity brings clear advantages. The success of that strategy is closely related to an efficient and timely public service through a transparent access o the public to the government information, where the results of the mandate and the user satisfaction may be appreciated.

ISG transforms 3D model delivery

Global construction services company ISG is using the latest 3D modelling technology to boost its BIM capabilities. By introducing Pointfuse laser scanning software, ISG has speeded workflows with rapid scan-to-BIM modelling whilst maintaining high levels of accuracy. Traditionally this laser data processing could take up to three days to 3D model a single floor, however, using Pointfuse ISG has reduced this to a matter of hours. *http://pointfuse.com*

US Army Geospatial Center select Envitia

Envitia has announced that it was selected by the US Army Geospatial Center (AGC) to develop an innovative capability that will improve interoperability across the Army Geospatial Enterprise and between Coalition partners. Envitia, which specializes in geospatial and data software and services, will rapidly develop and deploy a prototype Portrayal Registry for the AGC that will manage and share standardized mapping elements as a centralized service. *www.envita.com*

Bentley Systems announces OpenSite Designer

Bentley Systems has announced the availability of OpenSite Designer, its integrated application for civil site and land development workflows across conceptual, preliminary, and detailed design phases. It advances BIM through comprehensive 3D site design, spanning reality modeling of site conditions from drone imagery and scans, geotechnical analysis, terrain modeling, site layout and grading optimization, stormwater drainage modeling and analysis, underground utilities modeling, detailed drawing production, and enlivened visualizations. *www.bentley.com*

Cadcorp SIS 9 service release extends support for OS

The first service release to Cadcorp SIS 9 consolidates all updates made since the version's release on 19th November 2018. SIS 9 supported OS Open Zoomstack data in its pre-release format from the outset. In this latest service release, support for OS data released January 2019 onwards has been brought up-to-date. Cadcorp SIS users can open data in OGC GeoPackage and select cartography from the four standard OS styles - 'Light', 'Outdoor', 'Road' and 'Night', and the Cadcorp defined 'Grayscale'. OS Open Zoomstack opened from Mapbox MBTiles is also automatically styled. *www.cadcorp.com*

Topcon announces Advanced Bentley integration

Topcon Positioning Group has announced new cloud-based photogrammetry processing powered by Bentley ContextCapture to its MAGNET Collage Web web-based service for publication, sharing, and analysis of reality capture data. The integration allows MAGNET Collage Web users who share and collaborate with scanning and mesh datasets to now process and add UAV photos directly to the MAGNET Collage 3D environment. *CorpComm@topcon.com*

Qatar Centre for GIS Partners with Esri

Esri has announced that it has contracted with The Centre for Geographic Information Systems (CGIS) - Ministry of Municipality & Environment, Qatar, to update its national data capture and mapping technologies in order to match the region's growth. CGIS turned to Esri to draw on its mapping, surveying, and imagery experience. By partnering with Esri and the aerial survey consulting firm photogrammetry4u, CGIS expects to adopt new technologies and geospatial workflows that will capture location data and turn it into valuable digital 3D products.

New Early Warning Radar System

Hexagon AB has announced IDS GeoRadar RockSpot, a radar system that fills a critical gap in the monitoring of natural and engineered slopes. The system detects, tracks, and analyses the slightest movements from rockfalls, avalanches, and other fast-moving landslide debris flow. RockSpot creates real-time alerts that can be connected to on-site alarms (e.g., sirens, automatic road closures or other alert devices). Georeferenced, recorded event data provides advanced statistics and analytics for risk assessment and vulnerability zone mapping. RockSpot can identify rockfalls up to 2 kilometres from the slope, as well as avalanches and other fast-moving events, like mudflow and debris flow, up to 4 kilometres from the slope. *hexagon.com*

Kochin, India prepares for GIS mapping

Kochin Corporation and Cochin Smart City Mission Ltd (CSML) will conduct GIS based mapping in the Indian port city of Kochin, Kerala that will help the civic bodies to increase the collection of taxes. The municipal administration have to face a lot of problems in accessing the particulars of properties, location, hindrance and the details of property tax. Since, tax collection is the main source for the local administration, the GIS based map will assisting in increasing tax collection. The whole project would be carried out in four-phases with an estimated cost of INR 52 million.

UNOOSA and ESA sign MoU

The United Nations Office for Outer Space Affairs (UNOOSA) and the European Space Agency (ESA) signed a Memorandum of Understanding (MoU) to cooperate on helping all countries identify how space can sustain their efforts to reach the United Nations Sustainable Development Goals (SDGs), with a view to facilitate access to space solutions and with particular attention to developing countries.

Through the MoU, the two organisations will work together on developing a UN Space Solution Compendium ("SSC") containing an overview of how selected space projects, and space technology in general, can help all countries achieve the SDGs. The SSC will document and identify how space applications offered today or being developed by agencies, research institutions and companies are relevant for the SDGs. The SSC will be hosted by UNOOSA.

China launches BeiDou satellite

China launched a new satellite for the BeiDou Navigation Satellite System (BDS) from the Xichang Satellite Launch Center. The satellite was launched on a Long March-3C carrier rocket, and is also the fourth BDS-2 backup satellite and 45th satellite of the BDS satellite family. *www.satellitetoday.com*

$4.6 million to be invested in Russkaya Station in Antarctica

The research station Russkaya, in western Antarctica, on the coast of Marie Byrd Land, mothballed in 1990, will be recommissioned in 2021, for which purpose the Russian Antarctic Expedition will be granted about 300 million rubles ($4.6 million) of budget money, the deputy director of the Arctic and Antarctic Research Institute under the Russian Academy of Sciences, Alexander Klepikov, told TASS. The station was set up in the 1970s. Starting from 1980 it operated as a seasonal field base. Budget constraints forced its suspension in 1990. For a long time the Russian Antarctic Expedition pressed for its reactivation. A group of researchers visited it in 2008 to install distance monitoring equipment. *http://tass.com/economy/1059721*

ESA's NAVISP projects target satellite navigation interference

The European Space Agency's new NAVISP research and development program is prioritizing research into countering jamming and spoofing of satnav signals, with partner companies exploring varied approaches.

ESA's Navigation Innovation and Support Programme (NAVISP) works with European industry to develop innovative navigation technology, with combating jamming and spoofing given high priority, especially as satnav is set to form the basis of new, safety-critical systems such as driverless cars. NAVISP is ESA's program to facilitate the generation of innovative space-based PNT solutions with Member States and their industry. It is designed to provide a valuable support to European industry in the highly competitive and rapidly-evolving global market for PNT, while further supporting Member States in enhancing their national objectives and capabilities in the sector.

Homeland Security Says PNT a "National Critical Function"

The Department of Homeland Security (DHS) has designated positioning, navigation, and timing services (PNT) a "National Critical Function." That is PNT is now officially a capability so vital to the United States that its "disruption, corruption, or dysfunction would have a debilitating effect on security, national economic security, national public health or safety."

The decision reflects a new approach by the agency aimed at improving its understanding of the 55 functions on the new national critical list, DHS said in an explanation. Rather than focusing on a static sector or on assets, "this more holistic approach is better at capturing cross-cutting risks and associated dependencies that may have cascading impact within and across sectors."

This could be a boon for the PNT community. Years ago DHS recognized PNT as a cross dependency among 13 of the 16 critical sectors of the nation's infrastructure—such as the financial and telecommunications networks. Even so the agency did not appear to give PNT the coordinated analysis and scrutiny given early on to the sectors.

Russia to launch nearly 50 satellites for GLONASS System in coming 15 Years

Russia plans to launch 46 satellites for its Global Navigation Satellite System GLONASS by 2034. Roscosmos' materials showed that the space agency planned to launch four Glonass-M satellites, nine Glonass-K satellites and 33 Glonass-K2 vehicles in 2019-2033. Particularly, the launches are planned for 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2029, 2030, 2032 and 2033.

The GLONASS constellation currently comprises a total of 26 satellites, including 24 Glonass-M and two Glonass-K vehicles.

MDA to build search-and-rescue repeaters for GPS 3F satellites

The Canadian government has selected MDA to design, build and deliver 10 search-an- rescue repeaters for its Medium Earth Orbit Search and Rescue system to be hosted on the U.S. Air Force's next-generation GPS satellites.

The Canadian government decided in 2015 to proceed with the MEOSAR project to provide search and rescue repeaters for the USAF's next generation GPS satellites. Once in orbit 22,000 kilometers above the Earth, a MEOSAR repeater will be able to detect signals from emergency beacons and retransmit the signals to receiver stations on the ground. The emergency messages can then be sent to appropriate authorities so that people in danger can be quickly located and rescued. Mike Greenley, MDA's group president, said once qualified as operational, the system will dramatically improve both the speed and location accuracy for detecting beacons, and as a result, greatly enhance the coordination and dispatch of search and rescue teams to help people in distress."

MEOSAR will provide a more capable system to COSPAS-SARSAT (Cosmicheskaya Sistyema Poiska Avariynich Sudov – Search and Rescue Satellite Aided Tracking), according to Canadian military officers. COSPAS-SARSAT is an international satellite-based search and rescue distress alert detection system established by Canada, France, the former Soviet Union, and the U.S. in 1979. It is credited with saving more than 33,000 lives since its inception.

The first GPS 3F satellite is expected to be available for launch in 2026 and will host the first Canadian-made MEOSAR repeaters, Department of National Defence spokeswoman Jessica Lamirande toldSpaceNews. The first repeaters are expected to be fully functional by early 2027, she added. *https://spacenews.com*

CGI, Thales Alenia Space Sign Contract for Galileo Security Software

CGI signed an agreement with Thales Alenia Space to enhance and maintain security software for the Galileo satellite navigation system. Valued at approximately 14 million euros ($15.71 million), the contract will last until the end of 2020. CGI experts are working on this strategic project from Rotterdam and Toulouse. CGI aims to improve the functionality and reliability of Galileo's ground infrastructure, as well as enhance and maintain software for its Public Regulated Service Key Management Facility (PKMF).

According to the release, the Public Regulated Service (PRS) is one of the key features that distinguishes Galileo from other satellite navigation systems. It ensures that only government-authorized entities have access to Galileo's secure PRS signal that meets strict security standards in areas such as defense, law enforcement, customs, etc. *www.satellitetoday.com*

Five Glonass satellites will be launched in 2019

Five more satellites will be added to Russia's Global Navigation Satellite System GLONASS in 2019, according to the Strategy of GLONASS Development until 2030. There are currently 26 satellites in the GLONASS group. *http://tass.com*

Global Installation of GPS OCX Upgraded Monitoring Station

Raytheon Co.'s GPS Next-Generation Operational Control System program finished final qualification testing of the system's modernized monitor station receivers. The receivers are slated to be installed globally beginning in August.

GPS OCX is the enhanced ground control segment of a U.S. Air Force-led effort to refresh America's GPS system. The revamped receivers will measure and monitor legacy military and civilian signals sent by the current GPS satellite constellation as well as the new signals sent by the next-generation GPS III. The receivers will also feed correction models at the master control station.

GTX Corp GPS platform selected by Hill Air Force base in Utah

GTX Corp has announced that it has been awarded a new contract for an initial installation of its versatile and scalable military-grade tagging, tracking & locating (TTL) GPS platform at Hill Air Force Base in Utah (Hill). The Platform was developed for large-scale installations such as military bases. Hill is the second U.S. military base that plans to deploy the Personnel, Equipment Tracking System (P.E.T.S.), a lightweight, mobile, non-cellular, GPS technology platform designed to track personnel and equipment over a large remote area. The initial order is expected to be shipped and scheduled for phase I testing in June. *www.gtxcorp.com*

Kolmostar announces Ultra Low Power GNSS Module JEDI-200

Kolmostar has launched their latest ultra low power GNSS module JEDI-200, which refreshes the industry lowest power consumption record by reducing the energy for one position fix by up to 150x compared to traditional GNSS sensors, providing the ultimate positioning solution for location-based Internet-of-Things applications. www.kolmostar.com

Positioning antenna raises accuracy bar in GNSS bands

Antenova Ltd. is now shipping Raptor, the company's latest positioning antenna. It achieves an extraordinary level of accuracy in the GNSS bands by pinpointing location to within centimeters. The component targets emerging applications in autonomous vehicles, drones, and other mobile devices where its enhanced positioning capability can, for example, indicate which side of the road a vehicle is on. Allegedly, this ability has not generally been possible with previous GNSS devices. Other applications include tracking, surveying, and mapping.

Australian government announces the development of augmentation system

The Australian government has announced the project aimed at developing the Australian Satellite Based Augmentation System (SBAS) and is looking for partners. The initiative is projected to last for four years and was allocated the funding of $160.9 million from the federal budget. The goal of the undertaking is to enhance the positioning of the GNSS, which should have a prominent positive effect on various industries.

Aviation will benefit from the L1 service – a safety critical system which will be approved by the Australian Civil Aviation Safety Authority (CASA). L1 will be supplemented with the Dual-Frequency Multi-Constellation (DFMC) service with its sub-metre accuracy to ensure a full continuity of service.

Other business sectors, such as agriculture and mining, will be able to make use of the capability of the Precise Point Positioning (PPP) service where the decimetre accuracy will become available

GNSS and Iridium antennas for UAV applications

Tallysman Wireless Inc. in Ottawa is introducing three lightweight helical GNSS and Iridium antennas for UAV applications.

The three Tallysman helical antennas are the HC871 (25g) -- a housed, dual band, active GNSS antenna, supporting GPS L1/L2, GLONASS G1/G2, Galileo E1, and BeiDou B1; the HC872 (36g) -- a housed, dual band, active GNSS antenna, supporting GPS L1/L2, GLONASS G1/G2, Galileo E1, BeiDou B1, and L-Band services; and the HC600 (18g) – A housed, passive Iridium antenna. *www.tallysman.com*

Three High Performance Lenses by Phase One Industrial

Phase One Industrial has expanded its RS and RSM lens offering with three new high performance lenses for high-altitude aerial photography and long-range aerial and ground inspection applications. The 300mm AF, 180mm, and 150mm MK II lenses are designed to enhance the performance and flexibility of Phase One Industrial's iXM-RS and iXM aerial camera series. Each offers precision imagery, taking advantage of the cameras' ultra-high resolution backside-illuminated (BSI) CMOS sensors, to maintain a smaller ground sample distance (GSD) while flying at higher altitudes. *https://industrial.phaseone.com*

TCarta teams up with King's College London

TCarta has teamed with King's College London to win funding from the European Space Agency (ESA) to develop an air quality modeling service that leverages commercial satellite imagery. The service will provide organisations with accurate snapshots of existing air quality conditions along with modeling outputs to forecast how modifications in pollutant sources can change concentrations in the air over time.

The TCarta and King's team will match the 1.5 million euros awarded by the ESA ARTES 20 program for a demonstration project that will generate air quality data for a number of major cities worldwide and deliver products through online services, API's and data feeds. TCarta and King's successfully proved the technical and commercial viability of the service in a pilot study also funded by ESA in 2018. *http://air-quality.tcarta.com*

Satellite mapping to monitor illegal construction in UP, India

UP Real Estate Regulatory Authority (RERA) has engaged Remote Sensing Application Centre (RSAC) for inspection of construction sites within 10 km of the Lucknow Development Authority (LDA) limits in Lucknow and adjoining Barabanki districts with the help of satellite data.

In fact, RSAC has already completed 40% of the mandated satellite mapping work, which has been undertaken as a pilot, and the final report is likely to be submitted by June-end 2019. *www.business-standard.com*

Armenia to gain access to Russian remote sensing satellite data

Armenia will be able to get data from Russian remote sensing satellites under an agreement concluded between Russian Space Systems Company and Armenia's Geokosmos.

Under a sub-license agreement, Geokosmos will be able to both obtain the relevant data and disseminate it. The Russian Space Systems press office stressed that this would allow the Armenian company to boost its possibilities for creating geo-information services and "localizing Russian and foreign solutions in this sphere." *http://tass.com*

PrecisionHawk announces aerial mapping platform

PrecisionHawk has announced PrecisionAnalytics Energy, a complete aerial mapping, modeling, and inspection platform that uses the latest generation of artificial intelligence and machine intelligence to automate analysis of their aerial data. Whether inspecting thousands of oil well pads or hundreds of thousands of utility towers, PrecisionAnalytics' customers can reduce costs up to 80% and dramatically improve safety in the field.

Former ISRO chairman A S Kiran Kumar conferred with France's highest civilian award

Former ISRO chairman AS Kiran Kumar was conferred with France's highest civilian award – Chevalier de l'Ordre national de la Legion d'Honneur – for his contribution to India-France space cooperation. According to an official statement, on behalf of the President of France, Ambassador of France to India, Alexandre Ziegler conferred Kumar with the highest civilian honour of France. *www.indiatimes.com*

Government of India to expand Skill India to include AI and IoT

Government of India will soon launch a nation-wide strategy to train the youth in the country to create capable personnel of handling new developments in Artificial Intelligence (AI), internet of things (IoT) and machine learning. The government of India has identified 6 sectors to create a program in the fields of banking, financial services and insurance, manufacturing, e-commerce, healthcare and telecommunications.

Rostec embarks on massive IoT Project

GLONASS-TM, a company related to state-run tech firm Rostec, will build a RUB53bn ($811mn) federal network for Internet of Things (IoT) in a bid to secure a presence in a market that is expected to boom over the next few years. It aims to start building the network in 2020 and complete it in three years, projecting to recoup all the investment in its fifth year of operation. Of the RUB53bn investment figure, construction of base stations will account for about half, or RUB24.6bn. The IoT network will be used for collecting, monitoring and analysing various kinds of data. So far, the company mentioned several areas, in which it expects IoT to be in demand, such as control of water, electricity and natural gas consumption, monitoring engineering and other systems in buildings, access control and collection of data related to numbers and the behaviour of people in public areas. *www.intellinews.com*

Gogo and ForeFlight enabled GPS

Gogo Business Aviation and ForeFlight have partnered to bring new GPS location information and altitude to the ForeFlight Mobile iOS-based application for business aviation. Using an onboard Gogo AVANCE system or an ATG 4000/5000, ForeFlight Mobile can now deliver flight location information throughout the cockpit and cabin using Wi-Fi – it's information typically provided via a separate GPS system that requires additional onboard hardware and antennas. *business.gogoair.com*

SwRI system tests GPS spoofing of autonomous vehicles

Southwest Research Institute in the US, has developed a cyber security system to test for vulnerabilities in automated vehicles and other technologies that use GPS receivers for positioning, navigation and timing.

GPS spoofing is a malicious attack that broadcasts incorrect signals to deceive GPS receivers, while GPS manipulation modifies a real GPS signal. GPS satellites orbiting the Earth pinpoint physical locations of GPS receivers embedded in everything from smartphones to ground vehicles and aircraft. SwRI designed the new tool to meet United States federal regulations. Testing for GPS vulnerabilities in a mobile environment had previously been difficult because federal law prohibits over-the-air re-transmission of GPS signals without prior authorization.

SwRI's spoofing test system places a physical component on or in line with a vehicle's GPS antenna and a ground station that remotely controls the GPS signal. The system receives the actual GPS signal from an on-vehicle antenna, processes it and inserts a spoofed signal, and then broadcasts the spoofed signal to the GPS receiver on the vehicle. This gives the spoofing system full control over a GPS receiver. While testing the system on an automated vehicle on a test track, engineers were able to alter the vehicle's course by 10 meters, effectively causing it to drive off the road. The vehicle could also be forced to turn early or late.

KOITO and Blickfeld explore to integrate Lidar into Headlamps

Koito Manufacturing and Blickfeld have announced that they will explore advanced technologies for the development of LiDAR that can be fully integrated into headlamps.

The collaboration of KOITO's lighting technologies and LiDAR technologies provides high-end automotive component with built in LiDAR for car manufacturers and are expected to function interactively with ADAS (Advanced Driver Assistance System) or autonomous driving technology.

As LiDAR's core technology, Blickfeld's 3D solid-state LiDAR adopts silicon MEMS mirror. As its compactness, the LiDAR can be integrated directly into a vehicle's lighting equipment, enabling real-time 3D mapping and object detection, classification, and tracking without protruding or altering the exterior design of the vehicle. *www.blickfeld.com*

5th Generation Autonomous AI Security Patrol Vehicle

NXT Robotics Corp. has announced the launch of its Generation 5 Autonomous Vehicle and Cognitive Software Platform called "Maverick." Its baseline model includes four high resolution PTX security cameras which can be used to do AI based analysis of a physical environment along with license plate detection and facial and object recognition. It also has the capability to open a two-way audio stream so that robot can communicate with people it encounters along its largely autonomous patrol routes. The audio system can also stream pre-recorded messages and noises in response to particular situations it encounters. *www.nxtrobotics.com*

Monitoring world's water resources through IoT

Myriota, a nanosatellite Internet of Things (IoT) connectivity leader based in South Australia, has teamed up with cloud-based environmental platform Eagle.io with the aim of preserving global water supplies.

The partnership announced recently will provide global software and telemetry solutions for water management issues faced by agricultural players and governments worldwide. The partnership would integrate Eagle.io's cloud-based IoT platform that manages alerts from more than 100,000 environmental sensors with Myriota's secure, low-cost, low-power satellite connectivity. This will allow the agricultural sector to increase the accuracy of its water measurements through regular, automated recordings.

The two companies will work with third party data logger manufacturer MIoT, with Myriota integrating its module into their Captis product line and Eagle.io building a feature that will allow device configuration and management for the Captis from within their application.

NavVis Launches IndoorViewer 2.4

NavVis has announoed that version 2.4 of their IndoorViewer software is now available. This major release includes a number of relevant updates that will increase the possibilities of the 3D visualization solution, such as an option to automatically generate highly detailed floor plans, enhanced routing capabilities, a new way to customize and view content, and enterprise-ready security features.

NavVis IndoorViewer includes a map view to give users a 2D overview of the scanned structure(s) and its surroundings. The default floor plans that appear in the map view are simple outlines of the buildings that have been automatically generated from the scan data. Advanced functions let users replace the simple outlines with custom floor plans that have been created using photo editing or CAD software.

Toyota teams with Carmera on HD maps for autonomous cars

Toyota Research Institute-Advanced Development and Carmera have joined forces to conduct a proof of concept about developing camera-based automation of high-definition (HD) maps for urban and surface roads.

This is the first step towards realizing TRI-AD's open software platform concept known as automated mapping platform (AMP) to support the scalability of highly automated driving, by combining data gathered from vehicles of participating companies to generate HD maps. In this proof of concept, the two companies will place cameras in Toyota test vehicles to collect data over several months from areas of downtown Tokyo. The cameras installed in the test vehicles use Toyota Safety Sense components that Toyota installs on its vehicles globally.

Construction companies benefits of aerial LiDAR surveys

Terra Drone Indonesia has successfully completed two pilot projects that demonstrate how construction companies can benefit from drone surveying and mapping services. Using drones equipped with LiDAR technology, it has carried out survey-grade topographic mapping for two different dam construction projects in West and Central Java.

Topcon announces next generation flight planning software

Topcon Positioning Group has announced the next generation flight planning system for its rotary-wing aerial UAV offering — Intel® Mission Control Software. The new software is designed to facilitate automated flight planning, managing missions, and data handling for the Intel® Falcon™8+ Drone – Topcon® Edition and its available payload options. *topconpositioning.com*

Delair introduces open payload version of long-range UAV

Delair has introduced a new model of its popular long-range UAV, the Delair DT26, which offers an easy-to-integrate architecture for adding user-specified sensors and other payloads to the platform. The new model features a removable container which can hold up to 3 Kg of extra payload and be connected to a power supply of up to 140W. It allows drone users to quickly add specialized sensors for specific imagery needs, such as ultra-high resolution, multispectral and hyperspectral, thermal and oblique imaging capabilities. An optional cargo rack can be used to transport any type of items up-to 3 Kg over the long distance range the UAV supports.

Zing launches public beta for free drone delivery iPhone app

Zing is inviting drone pilots around the globe to beta test their new Zing Drone Delivery iPhone application.

The application allows drone pilots to use any DJI drone to make autonomous deliveries.

To use the Zing Drone Delivery application all you have to do is connect your drone, tap a coordinate on the map, then tap launch. The drone will fly ascend to 200 feet then fly to that location autonomously. After arriving at the location, the drone will descend to about 30 feet before giving the pilot manual control for a safe final descent. Once the delivery has been completed, the pilot taps a button to return to home as usual. The app includes an abort button to resume manual control at any time during the flight.

Cepton launches high scan rate long-range LiDAR for UAVs

Cepton Technologies has unveiled the newest product in its SORA family of scanning LiDAR sensors. It is purpose-built to deliver long-range, high-resolution imaging for drones.

First fully-automated and intelligent drone delivery service

DHL Express have entered into a strategic partnership with EHang to jointly launch a fully automated and intelligent smart drone delivery solution to tackle the last-mile delivery challenges in the urban areas of China.

Using the most advanced Unmanned Aerial Vehicle (UAV) in EHang's newly-launched Falcon series, featuring the highest level of intelligence, automation, safety and reliability, the new intelligent drone delivery solution overcomes the complex road conditions and traffic congestion common to urban areas.

As a fully-automated and intelligent solution, the drones, which can carry up to 5kg of cargo per flight, take off and land atop intelligent cabinets that were specifically developed for the fully autonomous loading and offloading of the shipment. The intelligent cabinets seamlessly connect with automated processes including sorting, scanning and storage of express mail, and will feature high-tech functions such as facial recognition and ID scanning. *www.dpdhl.com*

FAA highlights changes for recreational drones

While recreational flyers may continue to fly below 400 feet in uncontrolled airspace without specific certification or operating authority from the FAA, USA, they are now required to obtain prior authorization from the FAA before flying in controlled airspace around airports. Furthermore, they must comply with all airspace restrictions and prohibitions when flying in controlled and uncontrolled airspace.

The new requirement to obtain an airspace authorization prior to flying a drone in controlled airspace replaces the old requirement to notify the airport operator and the airport air traffic control tower prior to flying within five miles of an airport. Until further notice, air traffic control facilities will no longer accept requests to operate recreational drones in controlled airspace on a case-by-case basis. Instead, to enable operations under the congressionally-mandated exception for limited recreational drone operations, the FAA is granting temporary airspace authorizations to fly in certain "fixed sites" in controlled airspace throughout the country.

Another new provision in the 2018 Act requires recreational flyers to pass an aeronautical knowledge and safety test. They must maintain proof that they passed, and make it available to the FAA or law enforcement upon request. The FAA is currently developing a training module and test in coordination with the drone community. The test will ensure that recreational flyers have the basic aeronautical knowledge needed to fly safely.

Some requirements have not changed significantly. In addition to being able to fly without FAA authorization below 400 feet in uncontrolled airspace, recreational users must still register their drones, fly within visual line-of-sight, avoid other aircraft at all times, and be responsible for complying with all FAA airspace restrictions and prohibitions. *https://www.faa.gov*

ViaLite GNSS/GPS Fiber Extension Kit

Carrying timing signals over optical fiber links to 10+ km, ViaLite's new GNSS/GPS Fiber Extension Kit has been successfully qualified for use with Microsemi's timing and synchronization products. Included in the kit is the ViaLiteHD GPS Link, which is ideal for providing a remote GNSS/ GPS signal or derived timing reference to equipment located where there is no reception, such as inside buildings, tunnels and mines. The kit is suitable for GPS, GALILEO, GLONASS and BeiDou bands, and the links provide a wide dynamic range with negligible signal degradation from noise or interference. *www.vialite.com*

Next-Gen Integrated Smartphone and GIS Data Collector by Trimble

Trimble has introduced the Trimble® TDC600 handheld, an ultra-rugged, all-in-one smartphone and GNSS data collector for GIS and field inspection applications. It boasts an Android™ 8.0 operating system, bright sunlight-readable 6-inch display, powerful 2.2 GHz processor, 4 GB memory and an enhanced capacity all-day battery. The TDC600 handheld is the ideal tool for communicating between the field and office. With Wi-Fi, Bluetooth® 4.1 and 4G LTE cellular connectivity that supports data and voice calls, field workers are able to use the TDC600 as they would any consumer smartphone. *geospatial.trimble.com.*

All-New OEM Positioning by Hemisphere GNSS

Hemisphere GNSS has announced its next-generation digital and RF-ASIC (application-specific integrated circuit) platforms, and the release of three all-new positioning and heading OEM.

Hemisphere's new (Lyra II™) digital ASIC and (Aquila™) wideband RF ASIC designs optimize performance and provide the ability to track and process over 700 channels from all GNSS constellations and signals including GPS, GLONASS, Galileo, BeiDou, QZSS, SBAS, and L-Band Signal support and tracking for AltBOC and BS-ACEBOC, BeiDou Phase 3, L5,

and QZSS/LEX CLAS-D and CLAS-E are also available. This new ASIC technology offers scalable access to every modern GNSS signal available. Also, the Lyra and Aquila ASIC technology provide the foundation for a new GNSS receiver chipset architecture that significantly reduces the number of board components required, thereby reducing complexity, improving reliability, and lowering power consumption. *www.hgnss.com*

Carlson NR3: New compact, lightweight GNSS Receiver

Carlson NR3 network rover by Carlson Software delivers highly reliable GNSS RTK for land surveying, GIS, and other data collection uses. Able to be used as a base or rover, it utilizes all four constellations – GPS, GLONASS, BeiDou, and Galileo – and provides triple-frequency tracking on GPS, GlONASS, and Galileo. Incorporating multipath and ionospheric detection, the NR3 maintains accuracy and continued operation despite shocks, vibration, or other interference. *www.carlsonsw.com*

ASUS Launches the ZenFone 6

ASUS has introduced its new high-end smartphone, the ZenFone 6. The new handset is based on Qualcomm's top-of-the-range Snapdragon 855 SoC, and perhaps most interesting of all, a motorized 180° flip-up camera module. When it comes to connectivity, it supports 4G/LTE, 802.11ac Wi-Fi, Bluetooth 5.0, NFC, Wi-Fi Direct, USB Type-C, GPS, GLONASS, and Galileo. *www.anandtech.com*

Orolia selected for FAA Air Traffic Control System

Orolia has announced that its SecureSync time and synchronization servers have been selected to support enroute radar systems across the U.S. The only Time and Synchronization Device approved by the Defense Information Systems Agency (DISA) for use in U.S. Government networks, SecureSync is designed to provide unparalleled reliability, security and flexibility to synchronize critical aviation operations. FAA employs a variety of radar types for short-, medium- and long-range air traffic control requirements. These diverse radars require different types of timing signals and outputs to suit their operations. SecureSync provides the necessary timing outputs and signals required for these radars.

Harxon GNSS antennas ready for UAVs and UAV base stations

Harxon's newly launched X-Survey antenna offers a 4-in-1 design for multi-constellation GNSS signal reception. It integrates Wi-Fi, Bluetooth and 4G modules for easy integration into real-time kinematic (RTK) systems. It also ensures centimeter accuracy for precision positioning of UAVs, and stability of signal transmission, which provides the navigation and communication performance required by UAV base stations.

CloudStation by YellowScan

YellowScan released of its new software CloudStation, which provides a complete solution to create and manipulate point-cloud data. It allows to extract, process and display data immediately after flight acquisition. The auto-generation of flight lines and the production of LAS files are now done in a few clicks.

GeoSLAM launch ZEB PANO

GeoSlam launched its latest product, ZEB PANO that is set to shake up the property sector by offering property professionals the ability to capture floorplans and hi-res photography simultaneously. It is a handheld SLAM (simultaneous, localization and mapping) scanner and panoramic camera that has been developed for the property sector. SLAM technology is widely known for its use in the automotive industry for self-driving cars, but the technology has applications far beyond that.

Capable of capturing 43,000 data points per second and high-resolution panoramic imagery at the same time, the ZEB PANO stores the exact location of each panoramic image enabling quicker, more accurate, and less intrusive property surveys. Property agents can use this information to create a floorplan and property descriptions in considerably less time. Complementing the ZEB Family range of scanners, the scanner's 'walk-and-scan' method of data collection allows users to quickly and easily survey a property, producing accurate data and high-resolution photography.

First navigation-grade accelerometer by iXblue

iXblue has launched the iXal A5, the company's first navigation-grade accelerometer dedicated to high-performance applications. Based on the Vibrating Beam Accelerometer (VBA) technology and the Vibrating Inertial Accelerometer (VIA) concept developed by the French aerospace lab ONERA, and industrialized by iXblue, the iXal A5 is the first high-performance accelerometer to be launched by the company. It is a rugged sensor that provides high accuracy and repeatability, as well as a high input range (+/-100 g) and an insensitivity to magnetic field.

This offers iXblue's iXal A5 an excellent resistance to challenging environments. The sensor can thus be used in various high-performance civil and defense applications including land, air, surface and underwater navigation, guidance, bridge monitoring and stability, as well as Offshore drilling platform monitoring.

3D Mapping portfolio v19.5

Orbit GT has launched version 19.5 for its full 3D Mapping portfolio, including a significant upgrade for the QGIS plugin. It includes the Introduction of Floors, Street level planar imagery, updates for QGIS, ArcPro plugins, and various updates and fixes.

Kleos to launch first satellites with Rocket Lab

Kleos Space has partnered with New Zealand-based launch services provider Rocket Lab to loft the first of its radio frequency reconnaissance satellites to orbit. It will be the first launch of the firm's Scouting Mission, the first satellites a constellation aimed at providing intelligence on hidden maritime activity. The four satellites have been assembled and tested to fit the launch pod of the Electron rocket, which will be launched from Rocket Labs' Maxwell dispenser.

NavVis Launches IndoorViewer 2.4

NavVis has announed that version 2.4 of their IndoorViewer software is now available. This major release includes a number of relevant updates that will increase the possibilities of the 3D visualization solution, such as an option to automatically generate highly detailed floor plans, enhanced routing capabilities, a new way to customize and view content, and enterprise-ready security features.

NavVis IndoorViewer includes a map view to give users a 2D overview of the scanned structure(s) and its surroundings. The default floor plans that appear in the map view are simple outlines of the buildings that have been automatically generated from the scan data. Advanced functions let users replace the simple outlines with custom floor plans that have been created using photo editing or CAD software.

3D Images service for construction industry by Multivista

Multivista, part of Hexagon, has launched 3D Images as part of its suite of documentation services for the construction industry. The service will be powered by the Leica BLK3D, which is a handheld 3D imager that allows real-time, professional grade, in-picture 3D measurement.

Construction photo documentation captures critical milestones of building sites, so that they can be used as a reference at any point by contractors, developers and owners, architects, and facilities managers. Multivista's precise 3D Images service provides measurement information at critical stages of construction and enables high accuracy planning for completed spaces. This is especially beneficial for complex building and renovation projects during construction, for documenting mechanical, electrical, and plumbing (MEP), pre-slab, and underground utilities such as hydronic heating. Customers can also use 3D Images with finished conditions for space planning or identifying in-wall systems ahead of a renovation or repurpose of space, helping to avoid costly destructive verification methods

Foretellix and Metamoto partnership

Foretellix, an Israel-based start-up with a mission to enable measurable safety of autonomous vehicles (AVs), and Metamoto, a provider of enterprise AV simulation solutions, have announced a partnership to deliver measurable safety of autonomous vehicles.

The solution combines Foretellix's Coverage Driven Methodology for comprehensive scenario variance generation and aggregation of coverage across tests and platforms with Metamoto's highly scalable simulation platform to bring analytics, metrics and confidence to AV testing. *www.foretellix.com.*

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June 2019

United Nations/Fiji Workshop on the applications of GNSS
24 - 28 June 2019
Suva, Fiji
www.unoosa.org

July 2019

Esri User Conference
8 - 12 July
San Diego, California
www.esri.com

August 2019

Nine-month post graduate courses on Global Navigation Satellite Systems (GNSS) and Satellite Communications (SATCOM)
1 August 2019- 30 April 2020
Space Applications Centre (SAC), Ahmedabad, India
www.cssteap.org, www.sac.gov.in.

Smart Geospatial Expo
7 - 9 August
Seoul, Republic of Korea
www.smartgeoexpo.kr

The South-East Asia Survey Congress (SEASC) 2019
15 - 19 August
Darwin, Australia
https://sssi.org.au

Esri India User Conference
User Conference, Hyderabad
August 20, The Park

User Conference, Kolkata
August 22, Hyatt Regency Kolkata

User Conference, Delhi
August 28 - 29, The Leela Ambience Gurugram Hotel
www.esri.in

Hidden Geographies: Slovenia 2019
28-31 August
http://hiddengeographies.geografija.si

September 2019

GI4DM
3 - 6 September
Prague, Czech Republic
www.gi4dm2019.org

Intergeo 2019
17 - 19 September
Stuttgart, Germany
www.intergeo.de

ION GNSS+2019
16 - 20 September
Miami, Florida, USA
www.ion.org

MRSS19 – Munich Remote Sensing Symposium 2019
18 - 20 September
Munich, Germany
www.mrss.tum.de

PIA19 – Photogrammetric Image Analysis 2019
September 18 - 20
Munich, Germany
www.pia.tum.de

ISDE 11
24 - 27 September
Florence, Italy
digitalearth2019.eu

Interdrone
3 - 6 September
Las Vegas, USA
www.interdrone.com

October 2019

The 8th FIG Land Administration Domain Model Workshop (LADM 2019)
4th International Conferenceon Smart Data and Smart Cities (SDSC2019)
Geomatics Geospatial Technology (GGT2019)
1 - 3 October
Kuala Lumpur, Malaysia,
http://isoladm.org
www.geoinfo.utm

40th Asian Conference on Remote Sensing (ACRS)
13 - 18 October
Deajuong City, Korea
www.acrs2019.org

Commercial UAV Expo Americas
28 - 30 October
Las Vegas, USA
www.expouav.com

ISGNSS 2019
29 October - 1 November
Jeju Island, South Korea
www.ipnt.or.kr/isgnss2019

November 2019

GEO Week 2019 and the GEO Ministerial Summit
4-9 November
Canberra, Australia
www.earthobservations.org

International Navigation Conference 2019
18 - 21 November
Edinburgh, Scotland
https://rin.org.uk/events

March 2020

Munich Satellite Navigation Summit
16 - 18 March
Munich, Germany
www.munich-satellite-navigation-summit.org

May 2020

FIG Working Week 2020
10 -14 May
Amsterdam, the Netherlands
www.fig.net

GeoBusiness 2020
20 - 21 May
London, UK
www.geobusinessshow.com