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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

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Inertial Measurement Unit

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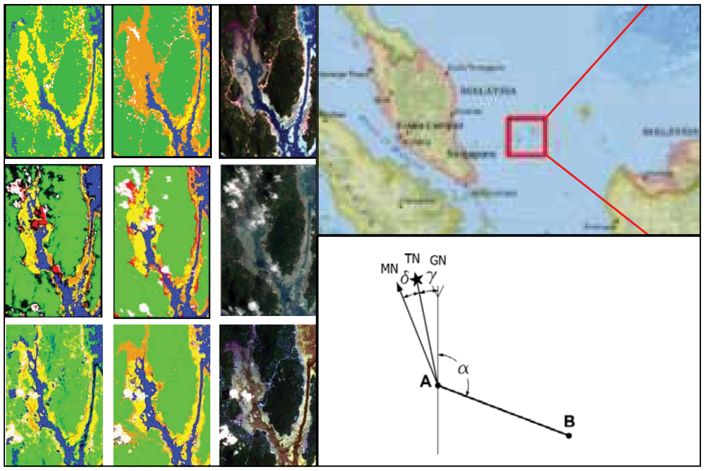

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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

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Is Signal green?

When WhatsApp recently proposed certain changes in their
privacy policy in certain parts of the world,

There was an outrage.

And this further has triggered a rush to the possible alternatives, which are just a few.

What purported as empowering,

Technology has entrenched deep in our lives.

And worse, has enslaved us.

What we do, what we eat, where we go, whom we meet, …

Our actions, our movements are tracked and documented.

Monitored and monetized,

As that was not enough,

It has captivated our brains, our thinking, and our ability to think.

A few techno-oligarch are set to rule the billions.

At times they entice the gullible,

And at times they connive with the tyrants.

Privacy is a privilege - too precious to afford!

Bal Krishna, Editor
bal@mycoordinates.org

The importance of being resilient: Challenges with GNSS in COVID-19 times

We have learned the importance of being resilient – in our societies and in the global economy, by being prepared for disruptions, adapting to changes and taking preventative measures

John Fischer
is a leading industry authority in PNT and GNSS technologies, and serves as the VP of Advanced R&D for Orolia, the world leader in Resilient PN

If we have learned anything from the pandemic of 2020, it is that we can take nothing for granted. Global commerce, social interactions, events both public and private, and our collective health all came into question and were disrupted. Few had mitigation plans for this rare but inevitable event, and even those who did endured hardships in some ways. Each country and community experienced it in its own unique way, but we all experienced it collectively as one world. We have all become more resilient, and similarly, Resilient PNT continues to evolve. At Orolia, we were fortunate that, as a global company, we were already well setup for teleconferencing and working remotely. As a provider of critical infrastructure and defense solutions, our customers still needed our systems, and we were fortunate to be in a position to deliver without interruption.

So, we look back on the year in gratitude, for the measures taken to address the crisis and for the progress made in the PNT industry despite the crisis. This was a year for Science. As we write this, multiple COVID vaccines are being distributed to millions daily, after being formulated and tested in an astounding record time. This represents a major milestone in our understandings of both the human genome and that of all living organisms. History may record this time as one of the pillars upon which the mass extinction of our species was prevented, along with long term solutions to battle climate change, and a fuller understanding of space through exploration.

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Regarding space exploration, we made a quantum leap in the practicality of moving mass beyond the restrictive atmosphere and into orbit. The cost of launching a satellite is less than one tenth of what it was just a few years ago, and the miniaturization of satellites (cubesats or nanosats) allows for launching dozens at a time in a single payload. A record number of satellites were launched with a particular emphasis on Low Earth Orbit (LEO) for communications networks. Most GNSS satellites are in Mid Earth Orbit (MEO), approximately 20,000 km above the earth, where LEO orbits are approximately 1,000 km or less. This closer proximity gives them the advantage of much stronger signals at the earth's surface. Even though these new constellations are primarily for communications, since they are using wideband channels, it is easy to add a precise time feature to them and therefore use them for a PNT purpose too, as an alternative or to augment

Another advancement in the timing world was the proliferation of PTP High Accuracy or what is known as White Rabbit technology. Formerly just a niche technology mostly used in scientific applications like the CERN Hadron Collider, this method of combining synchronous Ethernet with PTP timing is gaining mainstream acceptance to provide nanosecond and even sub-nanosecond accuracy across LANs

GNSS. So why weren't the original GNSS satellites placed in LEO orbit? Because at MEO a single satellite covers the entire earth whereas at LEO it only covers a small patch. So, you need hundreds of LEO satellites to do the same job as a couple of dozen MEO satellites. However, this will no longer be a problem as LEO constellations with several hundreds and even thousands of satellites are being planned. The next few years will see a major augmentation of GNSS with LEO PNT.

This is not to say that GNSS has no future. All the major constellations are nearly fully populated now and are close to full operation. Galileo (European Union) and Beidou (China) are nearing completion of their constellations with the launch of just a few more satellites. India's NavIC regional system is fully populated with seven satellites as is Japan's QZSS with four. Both the USA's GPS and Russia's GLONASS constellations are undergoing a refresh with the launches of their GPS III and GLONASS K CDMA respective satellites. Accuracies continue to improve with meter level precision as the norm and the centimeter level obtained via RTK and PPP. So far, the Galileo constellation is proving to be the most accurate of all, with the precision of the most stable space-based atomic clocks in their satellites. The political strain among various countries over the past year has not been manifested in the GNSS community, as all of these nations continue to cooperate and work towards interoperability. Multi-Frequency, Multi-Constellation (MFMC) receivers are commercially available today because of all these countries worked hard to devise innovative ways for their signals to share spectrum together. We hope this cooperation continues.

Back on earth, PNT progress is also being made. In the USA, an Executive Order was issued in February 2020 for federal agencies to establish guidelines and recommendations for Resilient PNT for all critical infrastructure in the nation. Orolia participated in this initiative, and one of the outcomes was to establish a uniform framework for defining PNT systems and their levels of resiliency. This important definition will avoid confusion and give clarity to both vendors and customers alike. Other nations are making progress establishing national precise timing infrastructures – for example, in both the UK and India the National Physics Laboratories are creating networks to distribute precise time throughout the country, sourced from stable atomic clocks.

2020 also brought us a breakthrough milestone in secure networking time with the release of RFC 8915, Network Time Security. For years, attempts to provide reliable, effective, but practical authentication for time distribution went unfulfilled until this specification established a sound algorithm. We expect this standard to be widely accepted for NTP and work is underway now for adaptations so it can be used for PTP. This release was preceded by two other major precise time networking specifications published in late 2019: IEEE 1588-2019 v3 and RFC 8633 NTP Best Current Practices. With these three specifications, we now have a solid foundation to build ubiquitous precise timing networks for use by all.

Another advancement in the timing world was the proliferation of PTP High Accuracy or what is known as White Rabbit technology. Formerly just a niche technology mostly used in scientific applications like the CERN Hadron Collider, this method of combining synchronous Ethernet with PTP timing is gaining mainstream acceptance to provide nanosecond and even sub-nanosecond accuracy across LANs.

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> Atomic clock technology took a quantum leap forward in 2020 with the next generation Mini Rubidium. Packaged as a standard OCXO component, it consumes much less power than a typical OCXO but with over one hundred times the stability; and over ten times the stability of the first generation of chip scale atomic clocks

Atomic clock technology took a quantum leap forward in 2020 with the next generation Mini Rubidium. Packaged as a standard OCXO component, it consumes much less power than a typical OCXO but with over one hundred times the stability; and over ten times the stability of the first generation of chip scale atomic clocks.

In aviation, the growth of Unmanned Airborne Vehicles (UAVs) continued unabated, increasing demand for accurate and reliable PNT in small Size, Weight and Power (SWAP) packages. The combination of GNSS and other signals of opportunity for navigation, with the continued advances of Inertial Measurement Unit (IMU) technology has brought precise PNT to mission payloads for exceptional performance in Intelligence, Surveillance and Reconnaissance (ISR) applications.

Another milestone this year in aviation was the first successful flight test of a Search and Rescue (SAR) Emergency Locator Transmitter with Distressed Tracking capability (ELT-DT). As a result of the loss of flight MH370 several years ago, the industry has decided to expand the capability of the ELT beacon onboard every aircraft to transmit not only when a crash has occurred, but also when it is in distress so it may be located and rescue actions initiated during the flight. There is no doubt this initiative will save more lives in the future.

Awareness of the vulnerabilities of GNSS' weak signal to easy jamming along with the fact that its open, unencrypted signal standards are susceptible to spoofing has led to increased vulnerability testing of all critical GNSS systems. As the threats become more sophisticated, the defenses must be too. However, before any defensive measure can be devised, one first needs to evaluate the weak points in the system. This is where advanced GNSS simulation test equipment comes in, and advances in the capability and affordability of these simulators, especially software-based ones, were significant in 2020.

On the frontline of defense for Interference Detection and Mitigation (IDM) are CRPA antennas. Controlled Radiation Pattern Antennas will steer the GNSS receiver's antenna beams to track the satellite signals and away from the interference sources. 2020 saw advances in the affordability and practicality of these devices, which previously had only been used in high-end, expensive military applications. New GNSS receivers with narrowband interference cancellers became more common this year, with software features which at least detect and warn of GNSS jamming and spoofing so a user can avoid using a corrupted PVT solution and instead use alternative navigation means.

Another outcome last year from the growing awareness of GNSS vulnerabilities was the recognition that no one solution will be the "magic bullet" to address the challenge. It will take a combination of several alternative techniques, so towards this end, the Open PNT Industry Alliance (www.openpnt.org) was established to strengthen economic and national security by supporting government efforts to accelerate the implementation of backup PNT capabilities for critical infrastructure. This alliance is expected to focus the collective ingenuity of the PNT industry to help create technologically advanced, commercially viable and sustainable long-term solutions for resilient PNT.

One of the many sources for alternative PNT will be the 5G network. Release 16 was finalized in 2020 and it established performance goals for more accurate PNT from its signals, taking the first steps towards accuracy which could rival our current GNSS meter-level performance. Look for further evolutions in the coming years. We can also expect growing resilience in PNT coming from Machine Learning and Artificial Intelligence (ML/AI) techniques. As processing power, memory size and network connectivity bandwidth continue to grow and become cheaper and more ubiquitous, we can expect to see AI in our mobile systems in a few years. One area showing promise is crowd-sourced positioning: a mobile user can infer its position based on incomplete information from many other nodes on its network, many of which know their positions to varying degrees of accuracy. There are still many possibilities for PNT advancement in the near future.

Though most of us are glad 2020 has now passed, we did learn (or re-learn) many important things. We learned that paying attention to boring, mundane essentials like wearing a mask to stay healthy and washing hands to prevent the spread of the virus can make a huge difference in our survival. We learned not to take important things for granted – our family, our friends, our health. We also learned the importance of being resilient – in our societies and in the global economy, by being prepared for disruptions, adapting to changes and taking preventative measures. These were lessons in both life and in the world of PNT.

The COVID-19 pandemic sheds light on our dependence on PNT services

The number of GNSS disruption reports have been increasing rather than decreasing throughout 2020 which is concerning–it's a problem that has not gone away

Guy Buesnel
PNT Security Technologist at Spirent

The polar regions aside, access to highly accurate positioning, navigation and timing (PNT) data opens up enormous potential for economic growth, reduced inequality, and international co-operation. Access to Global Navigation Satellite System (GNSS) has become a fundamental expectation and mainstay of the modern world. The COVID-19 pandemic has not reduced our dependence on GNSS signals – in fact it could be argued that the pandemic has made the task to secure or protect our GNSS signals even more urgent.

GNSS disruption on the increase

The number of GNSS disruption reports have been increasing rather than decreasing throughout 2020 which is concerning–it's a problem that has not gone away. In fact, it is a testament to the seriousness of the potential impact of real-world GNSS threats that even though it has been a struggle, work has continued in several countries to put resilient PNT frameworks and assured PNT strategies in place as soon as possible.

> To a hacker, the RF interface is just another attack vector, which means that increasingly, we are likely to see that the specific GNSS vulnerabilities in the RF domain are dealt with as part of an integrated cybersecurity framework, rather than treated in isolation

Thousands of GNSS disruption incidents were reported in 2020 from locations all around the world, including but not limited to, the Persian Gulf, China, the Eastern and Central Mediterranean and Northern Norway. Most of these instances were GNSS disruption through jamming, but there were some concerning spoofing incidents too.

In October 2020 The US Maritime Administration (MARAD) renewed its advice to the maritime industry to be vigilant for GNSS disruptions worldwide. It notes there have been multiple instances of interference in the Central and Eastern Mediterranean region, as well as the Persian Gulf and some Chinese ports, and encourages crews to report new instances to the US Coast Guard.

Echoing September's MARAD warning, Fortune reports that GPS outages are now standard occurrences on commercial flight routes between the US, Europe and the Middle East. Eurocontrol, the pan-European, civil-military aviation organisation, says it received 3,500 reports of GPS disruption in 2019, an all-time high. Jamming is widespread across the central and Eastern Mediterranean, likely due to electronic warfare between conflicting factions in Syria, Libya and elsewhere in the region.

Many nations' Critical National Infrastructure is dependent on GNSS data to operate and the need to secure Critical National Infrastructure has driven much needed initiatives in several countries to provide assured and resilient PNT services to these user groups

GPS jamming has also been causing problems in the far north of Norway, close to the Russian border. Local police have been reporting jamming incidents since 2017, affecting everything from ambulances to personal safety alarms. Norwegian authorities have identified Russia as the source of the jamming, but the attacks seem to be both unpredictable and unpreventable. Finnmark police chief Ellen Katrine Hætta told the High North News, "There is not much they can do about it. We as a society need to improve our systems." It's a reminder that as civil reliance on GNSS grows, receivers must be protected against the effects of RF interference.

There is evidence too that criminals are becoming aware of how GNSS jamming or spoofing can be used for malicious purposes. In August 2020 a fleet of Chinese fishing vessels were accused of misreporting their location to mask illegal fishing activity. The ships were reporting a location off New Zealand via the Automatic Identification System (AIS), an onboard system that reports a ship's GPS co-ordinates. However, the Ecuadorian government stated that the ships were located near the Galápagos Islands, where illegal fishing has occurred before. This type of AIS 'cloaking' is just one of many ways that criminals use location spoofing of a GPS-dependent system to aid their nefarious activities.

The importance of Precise Time

The incidents I've mentioned above all affected navigation-related applications and we mustn't neglect the fact that accurate navigation only comes about from a precise timing source. While some networks get their time disseminated from groups of atomic clocks maintained by organisations like the National Institute of Standards and Technology (NIST) in the US and the UK's National Physical Laboratory (NPL), which contribute to the generation of global UTC, many networks source time from the accurate and free signals broadcast by GPS and other GNSS.

Precise timing data from GNSS is used in many systems and applications – and these systems and applications are just as vulnerable when GNSS is disrupted by RF interference (jamming or spoofing). In addition to the RF threats to GNSS, timing systems also have other vulnerabilities which are segment dependent – such as the GPS Week Number Rollover, which highlighted a limitation with the way that time is managed in older receivers.

Failure to update master clocks ahead of the 2019 GPS week number rollover, for example, meant that traffic lights operated by the New York City Wireless Network (NYCWiN) malfunctioned for 11 days, and up to 15 flights were grounded when cockpit systems started displaying a date 20 years in the past.

These scenarios are good examples of the risks of not keeping GNSS-reliant timing systems up to date. The organisations in these cases may not have been aware that their network's master clock was sourcing time from GPS, and so didn't realise that a firmware update had to be applied to cope with the week number rollover.

Today's society is dependent on reliable PNT services

All of these issues serve to highlight our dependence on GNSS and the often large and unexpected impact on large numbers of systems when the precise position and timing services we obtain from GNSS are disrupted.

Even though we have seen that the volume of disruption to GNSS services is on the increase, it is still the case that many users are not aware of the specific vulnerabilities that apply to GNSS and have not even considered fully what impacts that loss or disruption to GNSS signals could cause.

The need for resilient, assured PNT

Many nations' Critical National Infrastructure is dependent on GNSS data to operate and the need to secure Critical National Infrastructure has driven much needed initiatives in several countries to provide assured and resilient PNT services to these user groups. Most of this work is driven through systems of systems approach which is based on Dr. Bradford Parkinson's "Protect, Toughen, Augment" framework for GPS. This means employing a layered approach to risk reduction. Recognizing that every system can be exploited in some way, industry is moving away from solely relying on GNSS toward a future that engages other PNT sensors and systems, providing redundancy as well as checks and balances.

The first Resilient PNT guidelines and conformance frameworks have arrived

In September 2020 new guidance from the US Cybersecurity and Infrastructure Security Agency was issued. The document, "Time Guidance for Network Operators, CIOs, and CISOs", provides practical guidance and recommendations for network operators, Chief Information Officers (CIOs), and Chief Information Security Officers (CISOs) on time resilience and security practices in enterprise networks and systems. The guidance attempts to address gaps in available time testing practices, increasing awareness of time-related system issues and the linkage between time and cybersecurity. It is a welcome document which states, "It is important to know the source of your time and to regularly monitor and test your time systems to ensure they are available and operating properly." Real-world failure scenarios are referenced and there is a questionnaire to work through to help timing users evaluate risks to their systems.

Also in 2020, just as this article was being written the US Department of Homeland Security, Science and Technology Directorate released the first issue of their Resilient PNT Conformance Framework. This is likely to be an important document as we move forward – the Conformance Framework concentrates on the property of resilience and is aimed at any user equipment that outputs PNT solutions, including PNT systems of systems, integrated PNT receivers, and PNT source components such as GNSS chipsets. Four levels of PNT resilience are defined in the document (5 if you count level 0 which is defined as being non-resilient).

The test methodology to demonstrate conformance to a particular resilience level in the conformance framework is not stated and this is something that will need to be developed – a suitable test methodology that allows like-for-like comparison of equipment and systems in terms of performance and resilience will be key. The need for quantitative test data as part of any risk assessment process is critical and will help to deliver cost-effective systems that are much more capable and resilient to GNSS threats. There are numerous challenges involved in practically applying the conformance framework to equipment – but it is a very good start.

Also, as more work is done on resilient PNT frameworks around the world, the issues of PNT security will, with a system of systems approach become a part of overall cyber-security frameworks in the commercial domain

This document along with the US Executive Order 13905, Strengthening National Resilience through Responsible Use of Positioning, Navigation, and Timing Services, have served to highlight the importance of a risk-based approach in identifying the areas and applications where PNT services are required and how to use them to minimise impacts of PNT disruption on critical operations and services.

The next year in PNT – some predictions

In 2021 we are likely to see GNSS spoofing attacks on the rise. Since 2015, incidences of GNSS spoofing have been increasing as the availability of readily downloadable software code increases and the cost of suitable hardware (typically software defined radios and transmission equipment) has fallen. Often commercial users become affected incidentally by a spoofing attack, but it has become very important to understand the resistance to spoofing that a user device has, how resilient it is in terms of recovery following a spoofing incident and what the impact of a successful spoofing attack is on the device and any dependent systems. This requires quantitative data – the need for testing in this area is often understated or even disregarded but a little testing and analysis can pay dividends as there are often very simple (and relatively cheap) ways to implement some effective mitigation.

In 2021 we are likely to see GNSS spoofing attacks on the rise. Since 2015, incidences of GNSS spoofing have been increasing as the availability of readily downloadable software code increases and the cost of suitable hardware (typically software defined radios and transmission equipment) has fallen

Also, as more work is done on resilient PNT frameworks around the world, the issues of PNT security will, with a system of systems approach become a part of overall cyber-security frameworks in the commercial domain. Whilst in military circles there will still be a need to evaluate the electronic warfare aspects of GNSS security this is not needed commercially, today users' PNT devices are increasingly one subsystem in a complex device with multiple ports, sensors and connections. To a hacker, the RF interface is just another attack vector, which means that increasingly, we are likely to see that the specific GNSS vulnerabilities in the RF domain are dealt with as part of an integrated cybersecurity framework, rather than treated in isolation.

In 2020 the COVID-19 pandemic has highlighted how dependent our society is on precise positioning and timing data from space-based systems to function safely and efficiently especially in times of crisis. Protecting and securing the integrity of this data as well as improving performance should be a vital goal for all of us involved in the business.

Digital Twin – Industrial navigation Avatars for cooperative multimachine automation

For future automation cooperatively machine missions, working interactively at close ranges, the use of perception technologies to add spatial AI can prove both unreliable and dangerous from a safety perspective.

Graeme Hooper
Managing Director
GPSat Systems, Australia

In the Virtual/ Augmented Reality computing world, a "Digital Twin" (DT)/ "Avatar" is used as a 3D graphical representation of either the user's character/ persona, and movable machines or objects for very visually accurate representation for games and/ or virtual worlds.

The 1999 movie "The Matrix" depicted a dystopian future where humanity is unknowingly trapped inside a simulated "Matrix" reality, the created by future intelligent machines to distract humans, from their real dire situation. While 2009 the movie Avatar, depicted future human scientists using Na'vi avatar hybrids, operated by genetically matched humans for exploring moon Pandora's poisonous biosphere, while mining precious unobtainium.

It was thought these Hollywood imaginary DT concepts would be the inspirational catalyst for future navigation and spatial sciences industry rapid adoption. Real time GNSS /IMU sensor navigation data directly applied to multi-machine DTs, all immersed in 3D synthetic environments. Delivering instantaneous VR / AR for us humans, while concurrently sourcing highspeed 3D digital spatial AI for machine's onboard mission computers. Today, this is still largely a 3D spatial sciences industry pipe dream.

> Most modern automation strategies adopt an "individualistic determination of self", that being, vehicle 3D environmental awareness through fused point-based navigation (GNSS lat/long/height) combined with perception sensor technologies (3D Lidar, Radar, Cameras and Ultrasonics) as they move

Why is Digital Twin important?

For both safety and optimised operational efficiencies, future participating in industrial cooperative automation projects will require very precise inter-machine 3D DT surface updates very quickly.

Many future industrial autonomous machinery projects require multiple machines working both cooperatively, with close proximities. Frequently these machines are complex 3D objects with the ability to change shape and orientations through rotational, jointed, and/ or articulated movable parts. For example, airborne refuelling arms, mining machines or grain harvester discharge chutes, etc. For these types of cooperative machine projects, using the simple machine centroid approach (latitude/longitude/height) is not adequate to meet demanding safety requirements. Instead, real time knowledge and spatial awareness of all DT solid body 3D surface volumes, generated in cooperative distributed 3D navigation systems, will be the essential choice. Delivering high rate and accurate spatial positional knowledge of each machine's solid body volume surfaces in 3D relationships.

Is it possible, DT machine navigation immersed and visualised in a "virtual world"? Yes, interactive technologies via online 3D gaming/ entertainment industries have been cutting edge for years. Using optimised low-cost computational platforms (Xbox™, PlayStation™ and PCs) delivering distributed multiple object and terrain information, immersed in interactive "3D "worlds" at very high user update rates. For equivalent industrial applications, new 3D spatial processors perform the Xbox™ functions, machine mission computers become the "Players", and navigation sensors (GNSS and IMUs) replace the "Joystick Controllers"

Immersion in a multi-machine DT cooperative 3D virtual environment, massive number of precision real time 3D surface interactions can be computed in real time. Rather than for entertainment, determination the complex inter-machine (shape and orientation changes) 3D spatial relationships. These computed 3D spatial inter-surface interaction/ relationships data sets are then mission automation controller ready. Essentially, 3D spatial-AI for those, airborne refuelling arms, UAV landing on moving platforms, (rolling/ pitching ships decks), mining machines or grain harvesters with discharge chutes, etc. applications. Computational power and network communication capabilities then become the only limiting factors for the complex machine the synthetic environments.

Most modern automation strategies adopt an "individualistic determination of self", that being, vehicle 3D environmental awareness through fused point-based navigation (GNSS lat/ long/height) combined with perception sensor technologies (3D Lidar, Radar, Cameras and Ultrasonics) as they move. Continuously scanning and mapping in real time primarily for peripheral object collision avoidance purposes. Typically, the older perception data is quickly discarded. Vehicle 3D spatial volume occupation and precise external surface spatial positioning are not important considerations. For single platform missions, precision navigation and perception sensor fusion this is the popular choice adopted by most companies.

> Is it possible, DT machine navigation immersed and visualised in a "virtual world"? Yes, interactive technologies via online 3D gaming/ entertainment industries have been cutting edge for years

Navigate the surfaces!

Our cities, industrial and rural areas, mines, airports etc. are all being precision 3D scanned to typical resolutions of +/- 2cm creating massive high fidelity surface data sets. To similar accuracies, precision machine 3D surface models are also now commonplace via Laser Scanning (older machines), or, derived from detailed manufacturers 3D CAD designs. Tens of thousands of surfaces precisely defining each machine's external 3D volume extremities, such as, handrails, light poles, etc.

For future automation cooperatively machine missions, working interactively at close ranges, the use of perception technologies to add spatial AI can prove both unreliable and dangerous from a safety perspective. In these missions, the underlying collective DT navigation/ spatial AI are guided by significantly different safety considerations, these being;

- Each machine needs to precisely compute unique external body 3D surface positions (possibly 20K+/ machine) in real time at very high update rates, typically 20/sec.
- Common knowledge of 3D volumes occupied by each machine needs shared/ accessible across all participating platforms quickly via highspeed network communications.
- Based on prior 3D static terrain knowledge, and adjacent machine navigation updates, each machine needs to perform it's own on-board safety spatial AI assessment. Any discrepancies uncertainties, or, impending disasters, then rapidly implement remedial measures.

Todays technologies merged for DT spatial AI future

All the technologies required to deliver the future DT spatial-AI world exist today, they simply need to be merged differently. Precision GNSS and geodesy are long proven reliable navigation technologies. International gaming industry has clearly been delivering 3D high fidelity immersive spatial-AI environments for decades. Field Programmable Gate Arrays FPGA and ASIC electronic are devices that are delivering the high extreme spatial processing used by 3D gaming. Major producers of 3D CAD/CAM software packages with their API interfaces can be easily used for high fidelity simultaneous multi-machine 3D motion scenario generators. While existing affordable GNSS simulation equipment can be used for final mission safety and operational verification work via batch processing.

For the brave, the wonderful world of DT spatial-AI awaits future cooperative machine automation projects. High speed 3D spatial AI for the on-board mission computers. While for the humans-in-the-loop, high fidelity synthetic VR/ AR visualisations delivered anywhere/ anytime across the globe. These benefits include both synthetic 3D Real Time and Recorded Playback, selectable spatial layer visualisation, automatic virtual 3D CCD-TV camera object following and critical event displays, to name a few.

Digital Twin/ Avatar technologies are the future.

C++ programming for cartography and geodesy students

The issues of development and use of a training course on C ++ programming under the conditions of teaching of students in two academic subjects of general geodesy and programming are considered. Recommendations for teaching students on the basis of the introductory course of "C++ programming for cartographers and surveyors" and ways of solving the related tasks using modern information technologies are given

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Introduction

At the Moscow University of Geodesy and Cartography, junior students are taught C++ programming according to a new training course tailored specifically for future cartographers and surveyors. The development of this training course took over 10 years. In the process of developing the training course, specific geodetic and cartographic tasks were selected. Later to solve those tasks already developed algorithms were implemented. The tasks are required to be simple and comprehensible enough so undergraduate students could understand them. We chose real practical tasks, which any cartographer and any surveyor often deal with in the performance of his professional duties.

Based on the selected problems and algorithms to solve them, C++ programs were developed. The sequence of computer programs for study was also specified. The developed sequence of programs as far as possible corresponds to the range of issues studied in the course of general geodesy and cartography. Thus, students start programming classes being acquainted with the geodetic content of programs and having deep understanding of them, due to the fact that they have already studied those issues during the general geodesy course.

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Difficulties could appear in process of linking courses of general geodesy and programming studied at once. As it is known in the course of geodesy, the study of the subject begins with such issues as: the shape and size of the Earth, coordinate systems, orientation of lines, the concepts of a map and a plan. This is followed by the theory of errors in geodetic measurements, and then issues of measuring distances and angles on the ground are considered. After that students start working with measuring instruments (level, theodolite) and performing topographic surveys. Therefore, in the same sequence, students are encouraged to work with training computer programs, and they are to develop their own versions of the programs.

On the other hand, learning C++ programming is also based on a certain order of training content presentation [1, 2]. At the beginning of the course, basic data types are considered and then control instructions (conditionals and loops) are to be studied. This is usually followed by arrays and strings, then

A computer training program to be used as training content in lectures, seminars and for homework has been developed. The program computes the magnetic azimuth of heading using the grid azimuth and the G-M angle. A detailed reference source that explains the purpose of the program instructions used has been developed.

pointers and references. The structured programming section ends with the study of functions. The C++ object-oriented programming part consists of introduction to classes, operator overloading, inheritance, and polymorphism. Currently, a fairly complete set of curricula which covers all the above sections of the C++ programming language has been developed. All computer programs contain geodetic and cartographic content and have been repeatedly tested during the educational process.

We emphasize that the analysis of training computer programs and programming tasks are offered to students after they have become acquainted with the solutions of those problems in the course of geodesy. At the beginning of the training course, students are not offered programs containing issues of usage of the geodetic instruments or features of topographic survey. Programs related to those issues are considered generally at the end of the training course. Of course, there are no hard restrictions, but changing the sequence of programs would require additional efforts from a teacher of the computer science to give students geodetic grounding of the proposed tasks.

The process of teaching students in practical usually involves running the program on a personal computer and then analyzing the instructions of the program. For this purpose, an interactive electronic board is used. Typically, the code of the program is presented on the blackboard. The students should modify the given code, correct syntax or logical errors, and then compile it and run. To check the results of the program performance, a test case is used to quickly determine whether a student has coped with the task or not. At the beginning of the course, rather simple geodetic tasks are used. For example, one needs to calculate the distance between points on the map or the height of a point, or the incline of the slope line, etc. If the obtained and control results match, the student goes to the second stage of the test. To develop C++ programming skills, students perform analysis of the program code in speech. Indeed, at the beginning the programs contain only a few lines, then the number of lines of code increases. Verbal analysis of the code means explaining each instruction in the code and answering questions in regard to the essence and functioning of each line of instruction. For all computer programs, a reference source that explains the purpose of each program instruction was developed.

During the pedagogical experiment, various methods of teaching students and their influence on the retention of training content were investigated. For this purpose, observations of the results of learning process were made. The process was centered on the task to create training programs in "two hands", when two students were put at a personal computer. This organization of programmers' workflow is used in Scrum flexible programming methodology [3]. It is believed that pair programming contributes to concentration, simplifies the search for errors, stimulates brainstorming and helps participants learn all the features of the program code.

However, as experience in the learning process has shown, putting two students at one computer led to conflicting results. Sometimes the effectiveness of the joint work increased and an interest in achieving high results and mutual assistance was observed. Nevertheless, there were also opposite cases, when two students at one computer worked ineffectively and the results turned out to be worse than in case of their individual work. In other cases, loss of the efficiency in pair programming was not observed. Hence, it is to be concluded that we should be leery of implantation of pair programming in the educational process. The task is being completed mostly by the most active student, while his partner is just an observer. In this case, the best option is to fit students to the scheme "one student — one computer". Then, the very fact that it is not possible to take part in programming via observing somebody's work leads to the correct prioritization and, as a rule, ends with the timely completion of the educational task. The student, being alone with the PC, feels that at the end of the lesson he will personally report on the work done. This burden of responsibility keeps students on their toes and as a result the work is done on time.

When developing training computer programs for cartographers and surveyors, the question regarding the method of calculating values was decided. Typically, survey results are double checked. There is even such a special term as "calculation in two hands". In other words, it is control of the performance of calculations. For example, to determine the rectangular coordinates of a point on a topographic map, it is enough to measure two distances, from the desired point to the south line of the coordinate grid and from the same point to the west line coordinate grid and perform calculations. However, for control, the distances from a point to the north and east grid lines are also measured. As a result, two coordinate values X and Y are obtained. Average values are taken for the final coordinates of the desired point.

There are many similar calculation schemes including control in geodetic and cartographic tasks. The use of detailed computational schemes adopted in geodetic manuals when developing programs is a subject to investigation. Geodetic computational schemes including control prevent arithmetic errors in calculations which the computer does not commit anyway. The question is whether it is necessary to include such schemes in the algorithms of training computer programs for processing geodetic and cartographic data. It might be easier to use a reduced algorithm without additional control and then implement this algorithm in a computer program.

The answer to the questions largely depends on the computational scheme used. If the computational scheme is aimed at carrying out additional measurements, then it is likely that such control should be taken into account when algorithmizing the problem and drawing up a program. Control measurement reduces the risk of using fallible data. On the other hand, if the calculation scheme provides only a recalculation of the desired values, and nothing more, then such a check will be unnecessary. A computer, unlike a person, does not make arithmetic errors. Unlike arithmetic errors, errors in input data occur. Therefore, if data input in the program is provided, for example, from the keyboard, it is probably necessary to protect the program from receiving the fallible data. Nevertheless, if data input into the program is not provided (since they are written in the program text as constant values) the use of a double computational check scheme is unjustified.

It could be proven by considering a more detailed algorithm for determination of the rectangular coordinates of a point. This algorithm is used when working with an old and wrinkled topographic map. To simplify the analysis, consider the calculation of only the X coordinate. The algorithm for calculating the increment of the X coordinate is presented below by formulae (1, 2, 3, 4):

$$errorX = (x_1 + x_2) \cdot \frac{M}{1000} - 1000 \quad (1)$$

$$\Delta X_S = \Delta X_1 - \frac{x_1}{(x_1 + x_2)} \cdot errorX \quad (2)$$

$$\Delta X_N = \Delta X_2 - \frac{x_2}{(x_1 + x_2)} \cdot errorX \quad (3)$$

$$\Delta X_N + \Delta X_S = 1000 \quad (4)$$

where $x_1 + x_2$ is the sum of the lengths of perpendiculars to opposite sides of the map grid square (mm), M is the denominator of the map scale; ΔX_1 and ΔX_2 are the increments of coordinates of a point from the south and north sides of the grid square; ΔX_N and ΔX_S are the total increments of coordinates of a point; *errorX* is the abscissa error of the required point.

In the above given algorithm, the error in the graphical determination of the abscissa is first calculated by the formula (1), if this error is acceptable, then the increments of the X coordinate from the north and south sides of the kilometer grid are calculated using formulae (2 and 3). Next, the calculations are monitored using formula (4).

Since arithmetic errors in calculating the increments of coordinates on a computer are not possible, the control of the sum of increments according to formula (4) is clearly unnecessary. Moreover, the control calculation by formula (3) in the program would not increase the accuracy of determining the coordinates of the desired point. Therefore, elimination of this check makes the curriculum simpler and easier to read.

Thus, in those cases when the data entered from the keyboard into the program are to be processed, a computational scheme with control should be used. In other cases, controlled computational schemes are above measure. To simplify the computational algorithms in a number of programs, the data were embedded in the program code. In these cases, abbreviated computational schemes were used without repeating of calculations.

Next, we consider a training computer program designed for students of geodesy and cartography who also study C++. The program demonstrates the use of the *do_while* loop statement. The problem of monitoring the computation results in the developed program is solved by restarting the program and re-entering the initial data. This monitoring method is also widely used in the processing of geodetic measurements and can be applied when working with a computer program. Such a monitoring scheme simplifies the program code and, as a consequence, makes it comprehensible for beginner students of programming. This is the main advantage of the scheme.

Materials and methods

To accomplish the task, the Microsoft Windows 10 operating system was used on a personal computer. The open source programming environment Code::Blocks and the GCC C++ compiler were also in use while performing the work.

Let us dwell on the geodetic formulation of the problem. Let it be required to calculate the magnetic azimuth of the direction for a given grid azimuth of the A – B direction and the magnitude of the *GM* angle. As it is known [4], the following formula is used to calculate the magnetic azimuth of the A – B direction:

$$A_{mag} = \alpha - GM, \quad (5)$$

where A_{mag} and α are magnetic azimuth and grid azimuth, *GM* is correction.

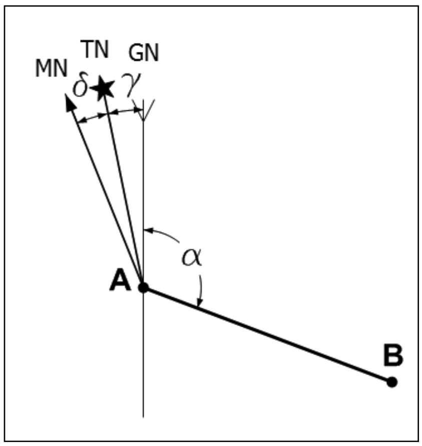

Figure 1. Scheme for computing the magnetic azimuth of line A – B from the grid azimuth and GM angle: GN – grid North, TN – true North, MN – magnetic North

The *GM* angle is found as the difference between the declination of the magnetic needle δ and the magnitude of the convergence of the meridians γ.

$$GM = \delta - \gamma, \quad (6)$$

As a result, we got the formula for calculating the magnetic azimuth of heading in full:

$$A_{mag} = \alpha + \gamma - \delta, \quad (7)$$

In the above given formula, both the declination of the magnetic needle and the convergence of the meridians can have a "+" sign, or a "–" sign. To use the correct signs, diagrams are often used. Please, consider an example in Figure 1. This figure corresponds to an example 1 given in table 1.

Discussion of the results

The program below performs arithmetic operations on angles without converting them to degrees with a fractional part. Therefore, there is no need to convert the values of degrees with a fractional part into degrees and minutes. To perform arithmetic operations on angles, degrees are converted to minutes, and then the program performs the calculations. Let us take a closer look at the code of the program.

This program is intended to illustrate the training content of the 5th lecture "C++ for cartographers and surveyors" [5]. In this lecture, students are introduced to programming concepts such as loops and learn to compose programs using these constructs. The lecture describes how to repeat one or more instructions a certain number of times or until a certain condition is true. The following loops: *for*, *while* and *do-while* are used. The operations performed during the execution of statements of the *for*-loop are analyzed step by step; the schemes of the loop operation with the counter increment and counter decrement are presented. The features of *while* and *do-while* of infinite loops are considered. It must be noted that in some cases usage of such loops should be avoided, however they fit perfectly to solve particular tasks. Using specific examples from geodesy and cartography, the difference between loops are shown. Corresponded types of tasks for each type of loop are described. Making students familiar with loop instructions usually takes place at the initial stage of programming course. Acquirement of skills in usage of the loop instructions is an important milestone in mastering the basics of programming.

Each of the curricula used in the "C++ for Cartographers and Surveyors" course has explanatory text intended for students to learn what a computer program does and how it works. The following is an explanatory reference for the program under study.

In lines 07 – 08, variables are declared. The integer variables *degrees* and *minutes* are used many times, first to define the bearing grid angle, then for the convergence of the meridians, and finally for the declination of the magnetic needle. The main program instructions are in the body of the *do_while* loop in lines 11 – 39. In line 13, the value of the grid azimuth of the A – B direction is input from the keyboard. The received data are converted into arc minutes. Further, in line 17, the value of the convergence of meridians and the value of declination of the magnetic needle in line 21 are also input.

In the program, when it comes to negative angular values, for example, the value of the convergence angle of meridians or the value of declination of the magnetic needle, the "minus" sign is to be entered twice: first for degrees and

```
01:  #include <iostream>
02:  #include <iomanip>
03:  using namespace std;
04:
05:  int main(void)
06:  {
07:   char noneStopCharacter;
08:   int degrees, minutes, gridAzimuth, magneticAzimuth;
09:
10:   cout.fill('0');
11:   do {
12:       cout <<"Enter grid azimuth (degrees, whitespace, minutes): ";
13:       cin >> degrees >> minutes;
14:       gridAzimuth = degrees * 60 + minutes;
15:
16:       cout <<"Enter convergence of the meridians "
16:            <<"(sign, degrees, whitespace, sign, minutes):" << endl;
17:       cin >> degrees >> minutes;
18:       int convergenceAngle = degrees * 60 +  minutes;
19:
20:       cout <<"Enter declination of magnetic needle "
20:            <<"(sign, degrees, whitespace, sign, minutes):" << endl;
21:       cin >> degrees >> minutes;
22:       angle = degrees * 60 +  minutes;
23:       int declinationAngle = degrees * 60 +  minutes;
24:
25:       int G_MAngle =  declinationAngle - convergenceAngle;
26:
27:       magneticAzimuth = gridAzimuth - G_MAngle;
28:
29:       if(magneticAzimuth >= 360 * 60)  magneticAzimuth -= 360 * 60;
30:       if(magneticAzimuth < 0 )    magneticAzimuth +=  360 * 60;
31:
32:        degrees = magneticAzimuth/60;
33:        minutes = magneticAzimuth%60;
34:        cout << "Magnetic azimuth:" << setw (2) << degrees
34:             << char(248) << setw(2) << minutes  <<"\'" << endl;
35:
36:        cout << "Continue? Enter (Y / y) ";
37:        cin >> noneStopCharacter;
38:
39:   }while((noneStopCharacter=='Y')||(noneStopCharacter=='y'));
40:
41:  return 0;
42:  }
```

Fig. 1. Listing of the program for computing the magnetic bearing of heading

then for minutes. If the declination of the magnetic needle is –8° 30′, this value is entered as –8 followed by a space and –30. In line 25, the G-M angle value is calculated according to the formula (6), in line 27, the magnetic bearing of heading according to the formula (5). In the English-language geodetic literature, to define the grid-magnetic angle the G-M angle notation. The magnetic azimuth of the A – B direction is also expressed in arc minutes. After computing the magnetic azimuth of the heading in lines 29 and 30, it is to be checked if the obtained magnetic azimuth lies in the range of 0° to 360° (angular values are in minutes).

Line 29 uses the abbreviated form of the *if*-statement and checks whether the resulting azimuth is greater than 360°. If the expression *magneticAzimuth > = 360 * 60′* is true, then the value of the magnetic azimuth decreases by 360 * 60′. It uses the "compound assignment operator with subtraction": *magneticAzimuth –= 360 * 60′*. Line 30 uses the abbreviated form of the *if*-statement and checks whether the resulting azimuth is less than 0°. If the expression *magneticAzimuth < 0* is true, then the value of the magnetic azimuth increases by 360 * 60′. It uses the "compound assignment operator with addition": *magneticAzimuth + = 360 * 60′*.

In lines 32 – 33, a whole fraction of degrees and minutes are calculated using the value of the magnetic azimuth. The results are displayed on the screen. The screen output of degrees and minutes is performed in the format accepted in geodesy, for example, an angle equal to 45° 6′ will be written as 45° 06′. To do this, line 34 uses the *setw (2)* and *setw (2)* output modifiers, and line 10 uses the *cout.fill ('0')* placeholder. Then the program displays the question "Do you want to proceed?" If the letters "Y" or "y" (short for "Yes") are input, the *do_while loop* keeps working. The user can compute the next magnetic azimuth for the new initial data. If any other letter is input by the user, the *do_while loop* stops its work. This is where the program stops.

Let us make a final remark. Using angular minutes instead of degrees with a fractional part allows performing arithmetic operations (such as division or modulus division) using the "/" or "%" operators and not lose 1′ while performing the computations. If degrees with a fractional part are used, then when converting degrees to minutes in reverse, a minute could be lost. The standard math function *round* was not used deliberately in the program, as it is studied in the Functions section.

Table 1. Program testing results

Grid azimuth	Convergence of meridians	Magnetic Declination	Magnetic azimuth
112°17′	+2°15′	–8°30′	123°02′
127°15′	–2°15′	+6°30′	118°30′
2°15′	–1°30′	+5°15′	355°30′

Testing of the program

Let us test the program. After compiling and running the program, enter the initial values from the first three columns of Table 1. The results of the program calculation are presented in the column "Magnetic bearing".

Conclusions

At the Moscow University of Geodesy and Cartography, a new training course "C++ for cartographers and surveyors" is used to educate students. The issues of the development and use of a training course under the conditions of teaching of students in two academic subjects of general geodesy and programming are considered. Recommendations for teaching students on the basis of the course of "C++ programming for cartographers and surveyors" and ways of solving the related tasks using modern information technologies are given. A computer training program to be used as a training content in lectures, seminars and for homework has been developed. The program computes the magnetic azimuth of heading using the grid azimuth of the direction, the Gaussian convergence of the meridians and the magnetic declination. The program can be used as a training content at a programming course to illustrate loop instructions. An example of reference information for self-study, which describes in detail the program code and explains the purpose of the instructions used, is presented.

References

1. *Podbelskiy V.V. (2003) C++ language.* Finance and Statistics. Moscow, Russia.

2. *Siddhartha Rao (2012) SAMS Teach Yourself C++ in one hour a day.* SAMS, USA.

3. *Stellman A., Greene J. (2017) Head First Agile.* O'Reilly, USA.

4. *Poklad G.G., Gridnev S.P.* (2007) Geodesy: a textbook for universities. Academic Project. Moscow, Russia.

5. *Zablotskii V.R., (2017) Teaching C++ programming language at Moscow State University of Geodesy and Cartography through the geodesic problems and programs*. Proc. 17th Geoconference, SGEM-2017, Bulgaria. https://doi.org/10.5593/sgem2017/21/S07.082.

COVID-19 - Geo-spatial big data analysis

The impact of latitude on population mortality for countries situated at latitudes between 64°N and 35°S

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The outbreak of the Covid-19 emerged from Wuhan, Hubei province of China, spread geo-spatially in more than 210 countries causing more than 25.416 million people of the global population infected and 0.851 million deaths (as on 30 August 2020), which is still exponentially spreading in geo-spatiotemporal way to the new geographical locations. The spread of covid-19 outbreak has seriously attacking societies at their core posing the human crisis, which is more than a global health crisis threatening the human health and life of the people. This unprecedented situation challenges to control the severity of the outbreak by creating a unique health response system to suppress the transmission of the virus to end the pandemic. There are marked variations in the spectrum of daily new cases of covid-19 between different countries that lie below latitudes 64°N, which resulted into six different stages of the spectrum of outbreak such as complete recoverable stage, recoverable stage, safe stage, stabilizing stage, critical stage and beyond the critical stage based on spatial big data analysis. People do not receive sufficient sunlight to retain adequate vitamin D levels during winter in countries situated at the latitude beyond 35°N. Vitamin D is important in preventing the cytokine storm and subsequent acute respiratory distress syndrome that is commonly the cause of mortality, suggesting the need to establish the correlation between vitamin D and the severity of the covid-19 outbreak. The global spreading of covid-19 caused marked variations in population mortality between different countries situated at different latitudes. This stressed the importance of geo-spatial big data analysis for determining the effect of latitude on population mortality from covid-19 and its variability for understanding the severity of the outbreak. In this paper, geo-spatial big data analysis has been carried out for determining the impact of latitude and the role of vitamin-D on population mortality for 52 countries situated between the latitude 64°N and 35°S, based on population mortality data from 15 April to 30 August 2020. This paper explains the variability factor of population mortality from 03 May to 30 August 2020 with respect to population mortality on 15 April 2020 for 52 countries situated between the latitude 64°N and 35°S for determining the severity of the covid-19 outbreak.

This study shows relatively lower population mortality for countries situated between the latitude 38°N and 35°S, whereas, countries that lie beyond 38°N shows relatively very high population mortality, confirming good correlation for different countries due to multiple peaks of population mortality observed. Further, this study shows relatively significant variability factor of population mortality for countries situated between the latitude 38°N and 35°S, whereas, countries situated beyond the latitude 38°N shows non-significant variability factor of population mortality. This paper explains very significant variability factor of population mortality observed for countries such as India, South Africa, Peru, Columbia, Mexico, Brazil, Saudi Arabia, Kuwait, Egypt, Russia and Ukraine from 03 May to 30 August 2020, whereas non-significant variability factor observed for countries such as Argentina, Indonesia, Singapore, Malaysia, Thailand, Philippines, Hong-Kong, Taiwan, Israel, Japan, Iran and South Korea.

Introduction

The outbreak of the 2019 novel coronavirus disease (Covid-19) spread geo-spatially in more than 210 countries of the globe causing more than 25.416 million people of the global population infected and 0.851 million deaths (as on 30 August 2020). The exponential increase in spreading of corona virus spectrum in spatiotemporal way to the new geographical locations has seriously threatened the human health and life of the people as well as posed the challenges for countries to control the severity of the outbreak (BBC,2020; Coronavirus, 2020). This unprecedented situation challenges to control the severity of the outbreak by creating a unique health response system to suppress the transmission of the virus to end the pandemic. The spatial spreading of coronavirus spectrum due to large-scale migration from Hubei province of China caused the outbreak in the southeast Asian region covering the latitude between 38˚N to 6˚S. The first case of coronavirus was reported in Thailand on 13 January 2020, which was followed by South Korea on 20 January 2020, and Vietnam and Taiwan on 22 January 2020 prior to reach Hong Kong and Singapore on 23 January 2020.

Malaysia reported the first coronavirus case on 25 January 2020, which further geo-spatially spread to Philippines on 30 January 2020 prior to reach Indian Sub-continent on 31 January 2020. National lockdowns were imposed by the respective governments of the southeast Asian countries as measures to control the severity of the spectrum of the outbreak. The Hong Kong, Vietnamese and South Korean governments imposed national lockdowns as measures to control the exponential rise of the spectrum of coronavirus from 8, 13 and 20 February 2020 respectively, after 16, 22 and 31 days of the first reported coronavirus case. The governments of Singapore, Malaysia, Philippines, Thailand, Taiwan and India imposed these measures from 6, 13, 15, 20, 24 and 25 March 2020 respectively, whereas, the Indonesian government imposed a national lockdown from 15 March 2020 (BBC,2020).

In Panarese and Shahini (2020), higher population mortality from coronavirus observed in northern latitude exhibiting the population mortality with decreasing north south gradient based on mortality data of 02 April 2020. In Rhodes et al. (2020), population mortality from coronavirus between different countries situated at latitudes below 64˚N showed marked variations with relatively low population mortality at latitudes below 35˚N based on mortality data of 15 April 2020, which supports vitamin D as a factor determining severity of the outbreak. Spatial big data analysis on population mortality carried out for 28 countries including southeast Asian region based on population mortality data from 15 April to 08 June 2020 shows relatively lower population mortality for countries situated at latitudes between 38˚N and 35˚S. Further, the temporal variability factor of population mortality for 28 countries situated at latitude south of 60˚N of the hemisphere supports the significant variability factor as determine factor for the severity of the outbreak (Verma et al., 2020).

In this paper, geo-spatial big data analysis has been carried out for determining the impact of latitude and the role of vitamin-D on population mortality for 52 countries situated between the latitude 64˚N and 35˚S, based on population mortality data from 15 April to 30 August 2020. This paper explains the variability factor of population mortality from 03 May to 30 August 2020 with respect to population mortality on 15 April 2020 for 52 countries situated between the latitude 64˚N and 35˚S for determining the severity of the covid-19 outbreak. This study shows relatively lower population mortality for countries situated between the latitude 38˚N and 35˚S, confirming good correlation for different countries due to multiple peaks of population mortality observed at the same latitude. Further, this study shows relatively significant variability factor of population mortality for countries situated between the latitude 38˚N and 35˚S. This paper explains very significant variability factor of population mortality observed for countries such as India, South Africa, Peru, Columbia, Mexico, Brazil, Saudi Arabia, Kuwait, Egypt, Russia and Ukraine from 03 May to 30 August 2020.

Covid-19 spectrum in southeast Asian region

Figure 1 depicts the variation of the spectrum of 5 days moving average of daily new coronavirus cases from 19 Februaray to 30 August 2020 for 11 countries of the southeast Asian region such as Myanmar, Vietnam, Taiwan, Hong Kong, Thailand, South Korea, Singapore, Phillipines, Indonesia and India. The spectrum of coronavirus outbreak increased expoentially to reach the first peak of the spectrum prior to decesase exponentially to attain the stablity and further increased exponentially to reach the second peak of the outbreak prior to decresase non-liearly to reach complete recoverable stage for Vitenam, Hong Kong, Malaysia, South Korea and Singapore, whereas the spectrum of coronavirus outbreak reached the first peak prior to decrease exponentally to reach complete recoverable stage for Thailand and Taiwan. Further, the spectrum of coronavirus outbreak increased to reach stabilising stage to attain the first peak of the spectrum in August 2020 for Phillipines, Indonesia and India, whereas the spectrum of Myanmar exponentially increased during August 2020 after controlling the outbreak from March 2020 onwards.

Impact of latitude on population mortality

In Panarese and Shahini (2020), higher population mortality from coronavirus observed in northern latitude with highest in Italy and exhibiting the population mortality with decreasing north south gradient based on mortality data of 02 April 2020 for 108 countries. Northern latitudes are associated with vitamin D deficiency for higher population mortality due to low ultraviolet exposure in the northern countries.

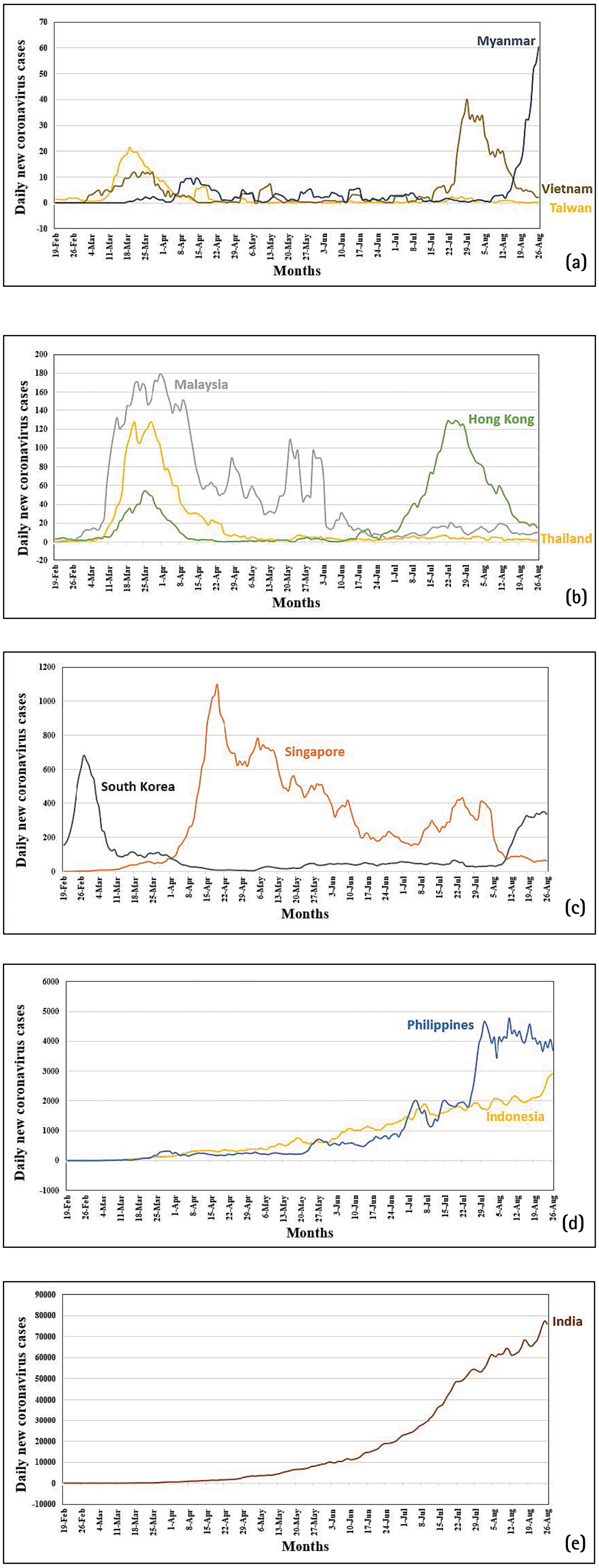

Figure 1: Variability of Covid-19 spectrum from 19 February to 26 August 2020.

When population mortality plotted against the latitude for 130 countries based on mortality data of 15 April 2020 by Rhodes et al. (2020), showed marked variation in mortality between different countries that lie below the latitude of 64°N of the hemisphere. People do not receive adequate sunlight to maintain vitamin D levels during winter in countries situated beyond the latitude of 35°N. All countries that lie below the latitude of 35°N showed relatively low population mortality due to availability of adequate sunlight to maintain vitamin D levels with the correlation coefficient of 0.53 between mortality and latitudes (Rhodes et al., 2020). Further, the potential impact of immune-modulating therapies and importance of nutrition particularly vitamin D is highlighted, which is important in regulating and suppressing the inflammatory cytokine response of respiratory epithelial cells as well as preventing the cytokine storms and subsequent Acute Respiratory Distress Syndrome (ARDS) that is commonly the cause of mortality from coronavirus (Panarese and Shahini, 2020; Rhodes et al., 2020). In Verma et al. (2020), relatively low population mortality from coronavirus is observed for countries situated at latitudes between 38°N and 35°S based on population mortality data for 28 countries from 15 April, 26 April, 3 May, 13 May, 22 May and 08 June 2020.

Higher correlations is observed for the impact of latitudes on population mortality due to continuance of multiple peaks of increased population mortality for countries at the same latitudes, as observed by Panarese and Shahini (2020) and Rhodes et al. (2020). Spatial big data analysis of the variability factor of population mortality from 15 April to 8 June 2020 for 28 countries shows that the variability factor of population mortality depends on the spectrum of daily new cases as well as quality healthcare infrastructure, which acts as determining factor for the severity of the coronavirus outbreak.

Population Mortality for the Southeast Asian Region

Figure 2 (a) depicts the variation of population mortality from Covid-19 for 11 countries of the Southeast Asian region that lie between latitudes 38°N and 6°S based on population mortality data from 15 April to 30 August 2020. There are significant variation in population mortality for India, Hong Kong, Philippines, Indonesia and Singapore, whereas South Korea, Taiwan, Vietnam, Myanmar, Thailand and Malaysia showed non-significant variations in population mortality. Further, Figure 2 (b) shows the variation of variability factor of population mortality from 13 May to 15 August 2020 with respect to population mortality on 15 April 2020. It shows maximum variations of variability factor of population mortality for India in the southeast Asian region, whereas other countries of the southeast Asian region shows non-significant variations in variability factor. The spectrum of daily new covid-19 cases depicted in Figure 2 (c) shows very significant exponential increase for India, causing significant variability of population mortality to determines the maximum severity.

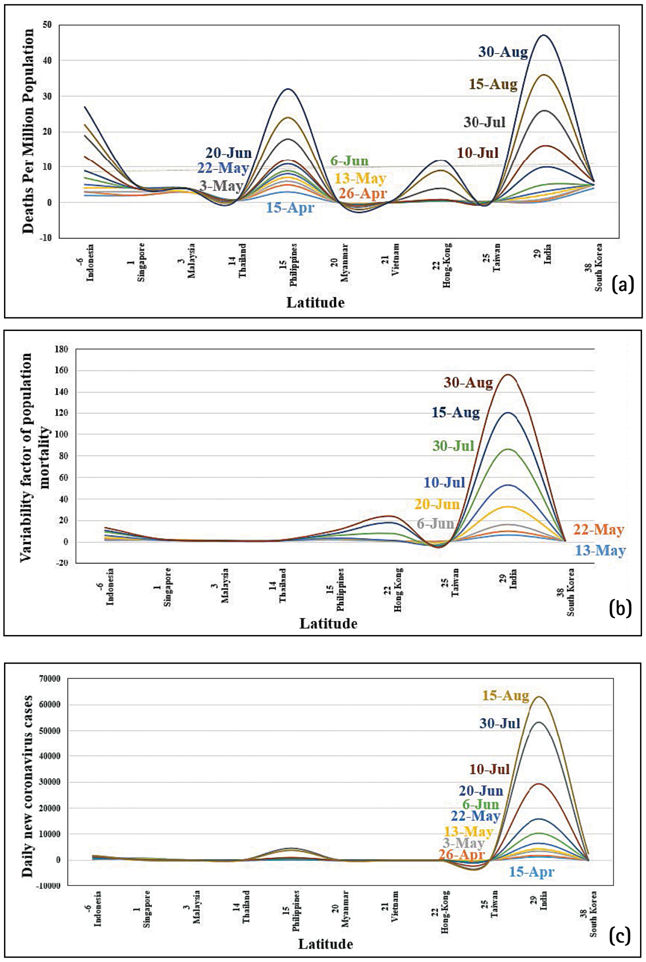

Figure 2: Variation of population mortality for the southeast Asian region.

Population mortality and its temporal variability

Figure 3 depicts the marked variations of population mortality (deaths per million population) for countries that lies south of the latitude below 64˚N based on population mortality data from 15 April to 30 August 2020. It shows relatively low population mortality for countries situated at latitudes between 38˚N and 6˚ S, whereas countries that lies beyond the latitude 38˚N and below the latitude 6˚ S shows relatively higher population mortality, which confirms to the observations of low population mortality between the latitudes 35˚N and 35˚S based on population mortality data of 15 April 2020 (Panarese & Shahini, 2020; Rhodes et al., 2020) and population mortality data from 15 April to 6 June 2020 (Verma et al., 2020). Further, it shows the continuity of the higher peaks of population mortality for countries situated at the same latitudes below 64˚N based on the population mortality of 15 April, 26 April, 3 May, 13 May, 22 May, 6 June, 20 June, 10 July, 30 July, 15 August and 30 August 2020, which shows higher correlation between population mortality and latitudes for countries. Further, the impact of latitudes on population mortality is confirmed to follow relatively higher mortality for countries due to low ultraviolet exposure at northern latitudes beyond 35˚N as well as supports vitamin D as factor for determining the population mortality.

Figure 4(a) depicts the significant increase of temporal variability factor of population mortality from 13 May to 30 August 2020 for countries that lies below the latitude 38˚N with respect to population mortality of 15 April 2020, whereas, non-significant increase of temporal variability factor of population mortality observed during the same period as depicted in Figure

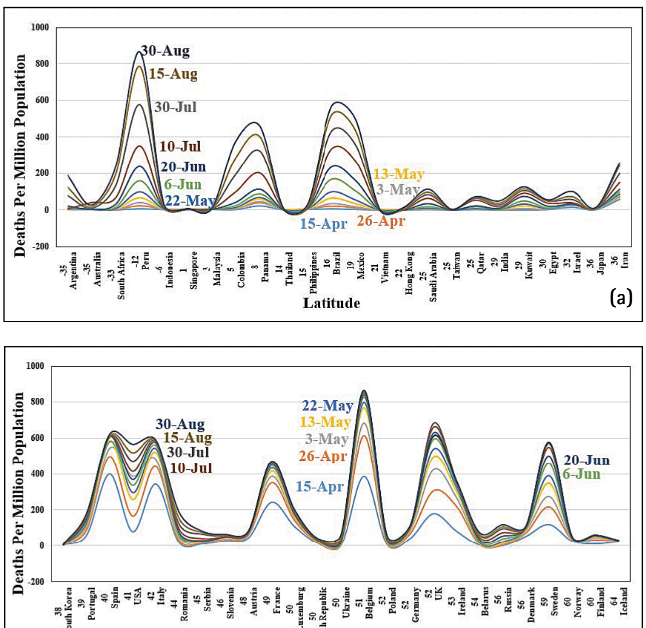

Figure 3: Variation of Population Mortality with Latitude (15 April to 30 August 2020).

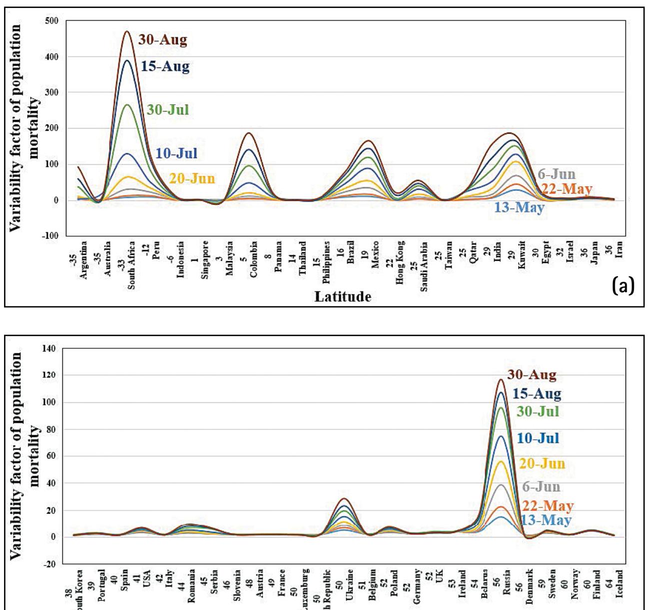

Figure 4: Variability Factor of Population Mortality from 13 May to 30 August 2020.

This study shows that the coronavirus spectrum of daily new cases attained first and second peak of the spectrum for Vietnam, Hong Kong, Malaysia, South Korea and Singapore to reach recoverable stage, whereas Thailand and Taiwan attained complete recoverable stage after attaining the first peak of the spectrum during March 2020. Further

4(b) for most of the countries situated at the latitudes beyond 38˚N, excluding Russia and Ukraine showing significant variability factor of population mortality more than 115 and 30 respectively. Figure 4 (a) shows the significant increase of variability factor more than 100 for many countries situated below the latitude 38˚N such as South Africa, Peru, Columbia, Panama, Brazil, Mexico, India, Kuwait and Egypt, whereas non-significant increase of variability factor observed for countries such as Argentina, Australia, Indonesia, Singapore, Malaysia, Thailand, Philippines, Hong-Kong, Saudi Arabia, Taiwan, Qatar, Israel, Japan, Iran and South Korea. Further, it is observed that most of the countries that lie above the latitude 38˚N shows the non-significant increase of variability factor of population mortality less than 20 from 13 May to 30 August 2020. This justifies that the increase of significant temporal variability factor of population mortality does not depend on latitudes of the countries as relatively lower population mortality observed below the latitude 38˚N, but depends on increase of the spectrum of daily new covid-19 cases and healthcare infrastructure of the country as depicted in Figure 2 for the southeast Asian region. This highlights the importance of variability factor of population mortality as determining factor for the severity or vulnerability of covid-19 outbreak.

Conclusion

This present study of spatial big data analysis of population mortality have been carried out for countries that lie between the latitudes 64˚N and 35˚ S based on population mortality data from 15 April to 30 August 2020, which provides variability factor for determining severity of the outbreak. Further, this study shows that the coronavirus spectrum of daily new cases attained first and second peak of the spectrum for Vietnam, Hong Kong, Malaysia, South Korea and Singapore to reach recoverable stage, whereas Thailand and Taiwan attained complete recoverable stage after attaining the first peak of the spectrum during March 2020. Further, Philippines, Indonesia and India are still stabilising to reach the first peak of the spectrum of the outbreak, whereas the non-linear exponential increase observed for Myanmar. The analysis of the impact of latitude on population mortality from coronavirus from 15 April to 30 August 2020 shows relatively low population mortality in the southeast Asian region and other countries that lie below the latitude 38˚N (Panarese & Shahini, 2020; Rhodes et al., 2020; Verma et al., 2020). The temporal variability factor of population mortality from 13 May to 30 August 2020 for countries situated at different latitudes below 64˚N acts as determining factor for estimating the severity of the coronavirus outbreak for the country, rather than considering only population mortality, such as South Africa, Peru, Columbia, Panama, Brazil, Mexico, India, Kuwait, Egypt, Ukraine and Russia.

The impact of latitude on the variability factor of population mortality is not observed in determining the severity of the outbreak for countries that lie below the latitude 64˚N. The analysis of population mortality and its variability factor from 15 April to 30 August 2020, confirms the highest level of the severity of the outbreak for India, whereas other countries such as South Korea, Hong Kong, Taiwan, Malaysia, Thailand, Vietnam and Singapore, successfully controlled the spectrum to the recoverable stage of the outbreak.

References

BBC, 2020.Coronavirus: The world in lockdown in maps & charts/ Source: Oxford Covid-19 Government Response Tracker /BBC Research. Available online at: https:// www.bbc.com/news/world-52103747 (Last access date: 10 July 2020).

Coronavirus, 2020. Global Covid-19 Data for All Countries. Available online at: https://www. worldmeters.info/coronavirus (Last access date: 10 July 2020).

Jonathan, M.R., Sreedar, S., Eamon, L.& Rose, A.K., 2020. Low population mortality from COVID-19 in countries south of latitude 35 degree north supports vitamin D as a factor determining severity. Aliment. Pharm. Therap. Vol. 51, pp 1438-1439.

Panarese A. & Shahini E., 2020. Covid-19 and vitamin D. Aliment. Pharm. Therap. Vol.51, pp 993-995.

Verma, A.K., Verma, A., Verma A., 2020. Coronavirus Spatial Big Data Predictive Analysis for the Southeast Asian Region. Defence S & T Technical Bulletin, Ministry of Defence, Malaysia. Vol.12 (2), pp 344- 366.

The paper was presented at Asian Conference on Remote Sensing (ACRS) 2020, 9-11 November 2020, Deqing, China

Seagrass mapping with supervised classification method using multispectral satellite imagery

A case study in national marine protected area of Anambas island, Indonesia

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1. Background

The environment for seagrass to grow is in marine ecosystem. Providing habitat for marine biota is the seagrass' primary role. Aside from that, seagrass is also able to absorb and store carbon, thus reducing CO2 in the atmosphere. Seagrass live best in a shallow marine water body and estuary. Seagrass ecosystem are located across the seacoast, with less than 5 meters depth.

Seagrass can be massively found near mangrove ecosystem or coral reef. In Indonesia, there are 13 types of identified seagrass. Anambas, as one of the islands that consist of many islands, is an ideal place for sea grass to grow. entified seagrass. Anambas, as one of the islands that consist of many islands, is an ideal place for sea grass to grow.

The seagrass ecosystem is one of the parts in tropical marine ecology. The role of seagrass ecosystems includes a productivity resource to absorb carbon from the atmosphere with an effectiveness 10 times greater than the forests (Kawaroe et al., 2016).

As a source of productivity, seagrass beds also serve as a place for other organisms to forage, especially dugong *(Dugong dugon)* and endangered turtles (Preen et al., 1992). Seagrass is the home of marine life, including economically valuable biota, including Baronang fish, shellfish, and crabs. The existence of these biota is useful for humans as a source of food. In addition, seagrass acts as a medium for filtration or purification of shallow waters, a place to live for various types of marine biota, which contribute in mitigating and adapting to climate change, controlling ocean currents energy on the coast as well as stabilizing sediments to prevent erosion on the coast. (Kennedy & Björk, 2009; McKenzie, 2008; Dorenbosch et al., 2005; Green & Short, 2003; Nagelkerken et al., 2002).

At present, the condition of seagrass beds in Indonesia is lacking a proper management from the government. Sophisticated technology is required to monitor the development of seagrass in order to maintain the balance of the ecosystem. Thus, various study is critical to contribute to the seagrass protection. The most cost-effective technology to map the seagrass distribution is remote sensing. There are still minimum studies that discuss the function of remote sensing to optimize the result of seagrass mapping. Therefore, this research needs to be carried out continuously to find the most suitable method for mapping seagrass.

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft). (USGS, 2020). Remote sensing helped the process of acquiring the data of a vast area near Anambas. The classification method used in this research is the Spectral Angle Mapper algorithm and Maximum Likelihood. This paper aims to (1) map the distribution of the seagrass and calculate the percentage of seagrass coverage. the usage of multiple satellite imagery to map the sea grass will be discussed. Three type of satellite imagery will be used, which are SPOT-7, Sentinel-2A and Landsat 8 OLI.

2. Methodology

2.1 Study area

The research location is located in *Teluk Sunting*, Anambas Islands, which is one of the National Marine Protected Areas (MPA) under the auspices of the Ministry of Marine Affairs and Fisheries of Indonesia. The total area of the National Marine Protected Areas is 1,262,686.2 ha. The seagrass is located closely to mangrove and coral ecosystems. The three objects are interrelated with its geographic location within the bay. The is having a relatively less strong currents and waves, ideal for the seagrass ecosystem. The research location is within the Marine Protected Area which is spatially included in the Sustainable Fisheries Zone and close to the seagrass monitoring station by the Ministry of Marine Affairs and Fisheries of Indonesia.

2.2 Field survey

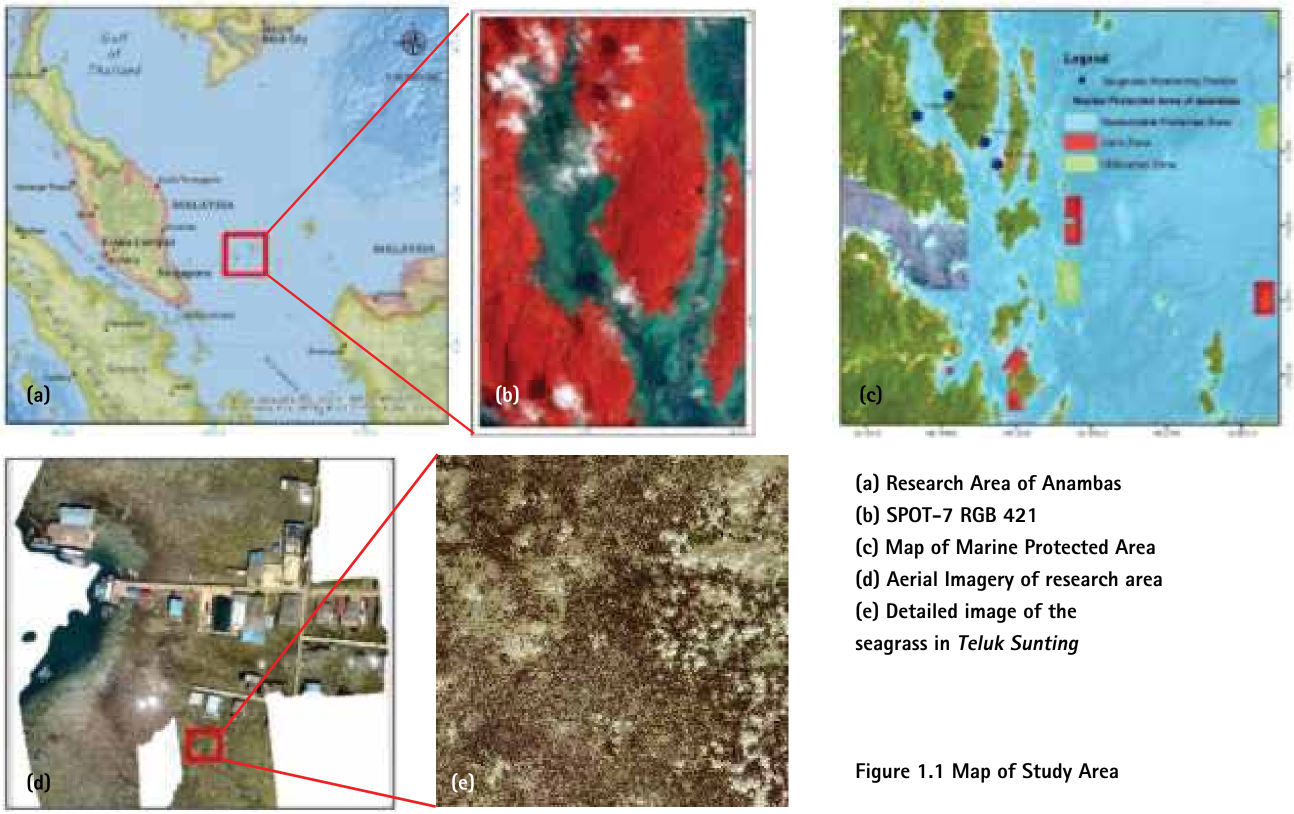
Monitoring of the seagrass ecosystem in the Anambas Archipelago and the surrounding sea is carried out using the Line Intercept Transect (LIT) method. The method is assisted by using a quadratic transect measuring 50 x 50 cm2 (Rahmawati et al, 2017). The LIT points are located along the observation area and determined as far as 100 m. The seagrass observation intervals are 10 m (adjusted to conditions in the field). Transects are drawn perpendicular to the coastline and each transect is placed parallel to one another. Furthermore, at each 10 m point interval on the 100 m line transect, a quadratic transect is stored / placed as an observation area. There are two main parameters, namely the number of species and the total seagrass cover. The tools and materials used in monitoring the conditions of the seagrass beds include transects of 50x50 cm, meter rollers, iron stakes, buoys, pencils, masks, snorkels, booties, newtop paper, and pencils.

The following formula are used to calculate the percentage of seagrass cover.

$$\text{Seagrass cover (\%)} = \frac{\text{Total of seagrass cover}}{4}$$

$$\text{Average of seagrass coverage (\%)} = \frac{\text{Total cover of the transect}}{\text{Total of transect square}}$$

The main parameter data and additional data of seagrass beds monitoring are inserted into a spreadsheet. The average seagrass cover parameters are calculated and the conditions of the seagrass beds are categorized according to the reference book for monitoring the seagrass beds and KepMenLH No. 200 of 2004. After measuring the seagrass cover, it is followed by taking ROI samples which will be used for image processing using GPS. The ROI samples taken were seagrass and sand objects. The total ROI of seagrass extracted is approximately 800 points.



(a) Research Area of Anambas
(b) SPOT-7 RGB 421
(c) Map of Marine Protected Area
(d) Aerial Imagery of research area
(e) Detailed image of the seagrass in *Teluk Sunting*

Figure 1.1 Map of Study Area

2.3 Data analysis

The data used in this study were Landsat 8 OLI, SPOT-7, and Sentinel-2A imagery. These three images were recorded in three different times to ensure the minimum coverage of clouds. The Landsat 8 OLI image consist of 2 sensors, namely the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). There are 9 channels on the OLI sensor with a range between 443nm to 1390nm with a spatial resolution of 30 meters and 15 meters, while on the TIRS sensor there are 2 channels with a spatial resolution of 100 meters. SPOT-7 image has 5 channels consisting of one panchromatic channel with a spatial resolution of 1.5 meters and 4 multispectral channels with a spatial resolution of 6 meters. Sentinel-2A satellite imagery has 13 channels with 4 channels with a spatial resolution of 10 meters, 6 channels with a spatial resolution of 20 meters, and 3 channels with a spatial resolution of 60 meters. The three images that were used in this paper have different temporal resolutions. Landsat 8 OLI has 16 days of revisiting time, SPOT-7 every 26 days, and Sentinel-2A every 10 days. In this study, Landsat 8 OLI imagery was used with the recording time on August 10, 2020, SPOT-7 on February 17, 2018, and Sentinel-2A on March 29, 2019.

Radiometric correction is applied to Landsat 8 OLI and SPOT-7. The correction function to reduce the atmospheric disturbance factor and change the digital number value to a reflectance value. Radiometric correction is not required for Sentinel-2A imagery. The atmospheric value of Level 1-C Sentinel-2A is already corrected and the geometric characteristic is already projected.

The field data used is the result of a seagrass survey in September 2020. This data contained the information of location data with coordinates and type of seagrass. The obtained coordinate data is then taken the spectral value on the image and used to map the distribution of seagrass using the Supervised method, namely Spectral Angle Mapper and Maximum Likelihood. The Spectral Angle Mapper (SAM) method is a method that uses the similarity value of the spectral reflectance of an object by calculating the angle between the two spectra (Kruse et al., 1993). Maximum likelihood classification (MLC) is a method for determining a known class of distributions as the maximum for a given statistic (Nilsson, 1965). The Maximum Likelihood method is a method that considers the maximum similarity of the pixel value of a predetermined object sample, this classification is most often used in digital image processing.

In order to map the distribution of seagrass with these two methods, in addition to the spectral reflectance value of the seagrass object, the spectral reflectance value of other objects is also needed to separate it from the seagrass, such as sand, sea and vegetation objects. Field data taken is only seagrass data, so that the spectral reflectance value of objects other than seagrass is taken visually in the image. The spectral reflectance values taken are different in each image. This is because there are differences in the characteristics of the three images, both spatial and temporal resolution. The results of the distribution of seagrass were analyzed together with the percentage of seagrass cover and the distribution of seagrass species obtained during the field survey and related to the physical and environmental aspects in the waters of the Anambas Islands.

3. Result and discussion

3.1 Coverage and species of seagrass

In the Anambas Islands and the surrounding sea, three seagrass species were found, consisting of *Enhalus acoroides, Thalassia hemprichii and Cymodocea rotundata.* Seagrass cover at the Air Asuk station was 18.07%, Makam Siantan station 23.48%, Tanjung 23.96%, Muntai 10.13% and the overall average seagrass cover was 18.82%. Based on the monitoring of the seagrass ecosystem, the condition of seagrass covers at Air Asuk, Air Nanga, Tanjung and Muntai stations, according to the Minister of Environment and Forestry Decree No. 200 of 2004, seagrass cover in *Teluk Sunting* is categorized as rare and in poor status. Low seagrass cover can be influenced by various factors, such as water currents, substrate, and human influences (settlement, sand suction).

Types of *Enhalus acoroides* spread and found at every observation station, *Thalassia hemprichii* was also found in almost all stations, only one station was not found. Meanwhile, *Cymodocea rotundata* was only found at two observation stations. This is in accordance with the statement of LIPI (2018) that in general, E. acoroides and T. hemprichii are types of seagrass that are often found in Indonesian waters. One of the factors that influence the presence or presence of seagrass species in a location is the texture of the bottom substrate. The Enhalus acoroides and Thalassia hemprichii types of seagrass grew more on substrates with relatively higher silt concentrations, while the texture of coarse sand sediments was overgrown with lemons of the Cymodocea rotundata type. This is consistent with the conditions in the field, which shows that C. rotundata is not found in locations that have mud substrate types and are usually close to mangrove ecosystems.

3.2 Supervised classification result

The images were having radiometric correction to extract the value of reflectance are used to become the basis to determine the Region of Interest (ROI). The ROI is used to sample the vegetation, cloud and deep sea objects, while the ROI sample for seagrass and sand objects is taken from the ROI sample during field surveys. To determine ROI samples other than seagrass and sand, a true color display image can be used as a reference. The true color channel on the Landsat 8 OLI and Sentinel-2A is RGB 432, while on the SPOT-7 RGB 123. True color was used to ease the identification of the objects on the surface. The ROI taken for each image is different due to the different spatial resolution. The Region of Interest obtained by the field survey and image interpretation is used for the Maximum Likelihood and Spectral

Angle Mapper Classification. The two classification methods were carried out on Landsat 8 OLI, Sentinel-2A, and SPOT-7 imagery. The results of the Supervised classification show the ability of different images to classify, but it shows the concentration of the distribution of seagrass in the same location, although with different areas. This can be affected by different image spatial resolutions and different image recording times that affect the ROI sample used. The output from Maximum likelihood and SAM can be seen in the image.

Figure 3.2 is an image showing the distribution of seagrass with the SAM method and Maximum Likelihood. The distribution of seagrass is shown in yellow. Different method shows a visually significant difference in the area of distribution of the object. In the Landsat 8 OLI imagery using the Spectral Angle Mapper method, it can be seen that the distribution area of seagrass is larger than that of the Maximum Likelihood method. When compared with the results of the appearance of the image with the band combination or true color 432 composite, it can be seen that there is inconsistency in the bay. In the appearance of the composite image 432 can be seen in the bay part in the form of sea water objects with a combination of sand and seagrass but the classification results using the SAM method are dominated by vegetation and seagrass, while the results of the Maximum Likelihood classification are seen in the bay part which is dominated by sand and a less seagrass area.

(a) Enhalus acoroides (b) Thalassia hemprichii (c) Cymodocea rotundata

Figure 3.1. Types of seagrass found in Anambas

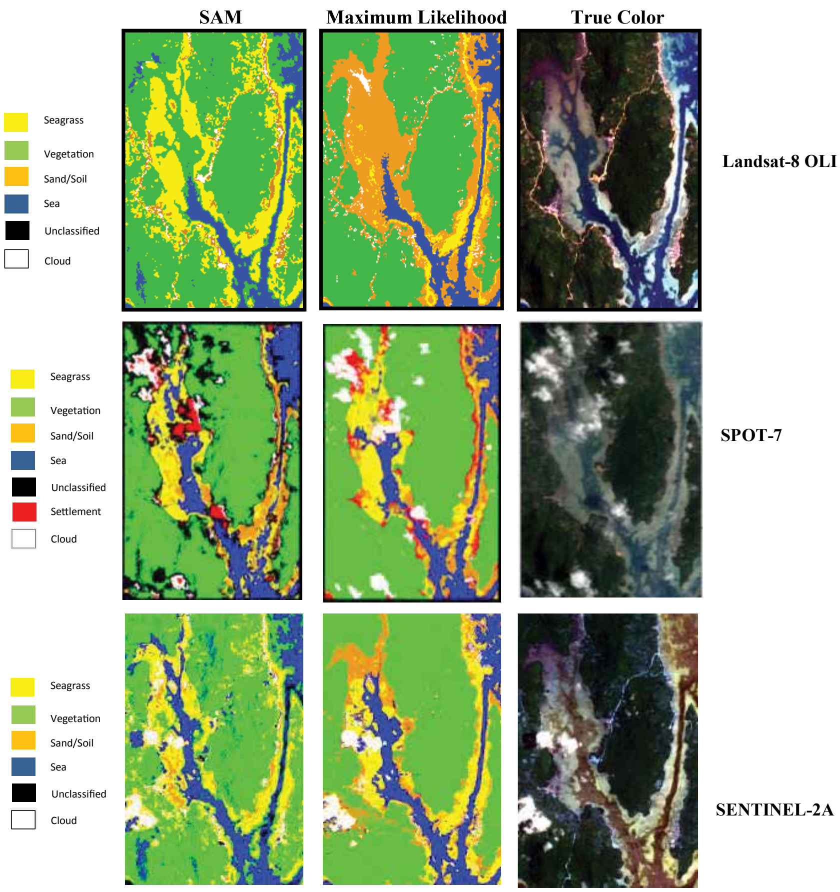


Figure 3.2. Result of SAM and Maximum Likelihood Classification for three different satellite imagery

The true color become the preliminary method to discriminate the objects. True color is easy to be visually interpreted, but there are also some limitations due to the eyes inability to differentiate the pixel value of an image. The Sentinel-2A image classification result of the maximum likelihood has a strong similarity to the true color. The water body is represented very well, the vegetation is also strongly differentiated. The seagrass and the sand also differentiated in a well manner. Different from the maximum likelihood, the SAM method shows a different result with the previous method. SAM shows some area that is unclassified. The sea water has a scattered distribution, shown by the shadow of the cloud is read as the water body. Some vegetation area on the lower part of the image also classified as the water. Sand in SAM is relatively less in comparison to the amount of sand in Maximum likelihood. Further, there are also misinterpretation of the sea grass that is located at the surface vegetation area.

The results of the classification on the SPOT-7 image visually show the differences that are not too far from all objects in the SAM method and Maximum Likelihood. The distribution of seagrass and sand in the two methods is also almost identical, the location of the distribution of seagrass which is quite large is also close to the monitoring point of the seagrass. This can be seen later in the next article, namely the difference in area between methods. It's just that there are differences in interpretation between clouds and settlements, perhaps due to spectral hues that are not much different and equally bright so that there is a misclassification. The high spatial resolution of SPOT-7 makes the number of pixels increase as well for each scene in the study area, so this must be the basis for taking ROI samples which must be more and evenly distributed compared to Sentinel-2A and Landsat 8 OLI.

3.3 Total area of seagrass result

The classification results from the SAM method and Maximum Likelihood can be calculated statistically on the distribution of seagrass, to determine the differences and are shown in table 3.1

Table 3.1 Object Classification Stats

Image	Spetral Angle Mapper		Maximum Likelihood		Difference
Landsat 8 OLI	Class	Area (ha)	Class	Area (ha)	Area (ha)
	Seagrass	896.22	Seagrass	158.4	737.82
	Cloud	37.17	Cloud	63	25.83
	Vegetation	2,080.44	Vegetation	1,858.5	221.94
	Sea	322.02	Sea	341.64	19.62
	Sand/Soil	127.17	Sand/Soil	1,046.34	919.17
	Unclassified	4.86	Unclassified	0	4.86
SPOT-7	Seagrass	410.56	Seagrass	437.16	26.6
	Cloud	122.13	Cloud	296.32	174.19
	Vegetation	1653.12	Vegetation	1900.64	247.52
	Sea	407.98	Sea	389.85	18.13
	Sand/Soil	146.5	Sand/Soil	226.67	80.17
	Settlement	90.21	Settlement	217.06	126.85
	Unclassified	38908.82	Unclassified	38271.6	637.22
Sentinel-2A	Seagrass	767.38	Seagrass	412.05	355.33
	Cloud	178.06	Cloud	152.56	25.5
	Vegetation	1792.47	Vegetation	1822.99	30.52
	Sea	575.44	Sea	482.52	92.92
	Sand/Soil	107.18	Sand/Soil	597.76	490.58
	Unclassified	47.35	Unclassified	0	47.35

The significant difference between seagrass objects in SAM method and Maximum Likelihood on Landsat 8 OLI is due to differences in the spatial resolution. The bay area has a foggy visual characteristic which makes it slightly difficult to be interpreted. There is a possibility that there is a mixture of sea water, sand, vegetation, seagrass and sedimentation objects which affect the spectral reflectance value. The classification results also show some unclassified objects, which are shown in black. This is due to the unequal distribution of the sample objects used for processing using the SAM method and Maximum Likelihood.

Apart from that, the 30 meters spatial resolution of Landsat 8 OLI also affects the classification results of seagrass objects. Seagrass objects in the field are often found with a small area so that in the Landsat 8 OLI Image the spectral reflectance values of some seagrass objects are not purely derived from these objects but are mixed with other objects such as sand and sea water which of course affects the classification results of the two methods. Judging from the spatial resolution of Landsat 8 OLI imagery, the results of the classification and the difference in the area value of seagrass with the SAM method and Maximum Likelihood, mapping the distribution of seagrass is not suitable for the Landsat 8 OLI imagery using this method.

The biggest difference area in Sentinel-2A result were shown in the sand object with total of 490.58 ha. The second one is the seagrass with 355.33 ha. These two objects have so much difference due to the close pixel value of sand and sea grass. Using the true color, it is even harder to differentiate the seagrass with the sand. The color is quite the same. Furthermore, the bigger explanation is the fact that sea grass lives in under the water and near the sand. The very near habitat of sea grass to the sand make it even harder to differentiate. The amount of sedimentation of sand within the water body may be one of the factors that makes it harder to differentiate the sand and the sea grass. The area difference of Sentinel-2A is not as huge as Landsat 8. The higher resolution of Sentinel-2A plays a role to minimize the difference of the area. To increase the precision of the identification, the increasing amount of sand and sea grass is required. The ideal ROI would be from the field survey.

Likewise, the SPOT-7 image requires more and more even ROI samples considering its high spatial resolution, seen from the highest Unclassified area produced in both methods, both SAM and MLH, in contrast to Sentinel-2A and Landsat-8 OLI which do not have value (0 Ha) Unclassified on the Maximum Likelihood results. However, it shows that SPOT-7 is the most capable of mapping seagrass using these methods, this can be seen from the image results and the minimum difference in the area value of seagrass with the SAM and MLH methods, which is only around 26,6 ha. The difference in the area of seagrass using SPOT-7 with the SAM and Maximum Likelihood methods on Sentinel-2A and Landsat 8 OLI images is 355.33 ha and 737.82 ha. The high spatial resolution of SPOT-7 may determine the results of seagrass mapping if it is related to the resolution of Sentinel-2A and Landsat 8 OLI images which are still below the spatial resolution of SPOT-7 images. The same is the case with the inconsistent sand classification results in the Landsat 8 OLI image, seen from the very large difference in sand area between the SAM and MLH methods, which is 919.17 ha, while the difference in the sand area using the SAM and MLH methods in the Sentinel-2A image is 490.58. Ha. The results of theclassification of seagrass and sand in the SPOT-7 image which have a little anomaly value in the SAM and

MLH methods compared to the Sentinel-2A and Landsat 8 OLI images, it can be said that the SPOT-7 image is quite good in mapping the spatial distribution of the seagrass ecosystem. It turns out that spatial resolution plays an important role in mapping the seagrass ecosystem.

The results of the transect method during the field survey showed the percentage of rare seagrass coverage are inversely proportional to the result of image processing that showed a large enough seagrass area. This indicates an influence on the ability of the image's spatial resolution in identifying seagrass and sand. During the field survey, it can be seen that the seagrass is very wide like a seagrass bed but it looks sparse and grows among the sand. Mapping seagrass using drones may reduce the misclassification, but it takes a longer time in comparison of using satellite image. The SPOT-7 image is considered capable of mapping seagrass well.

To produce a more specific classification, further research shall be carried out by not including the vegetation reflectance value into the classification or by masking the vegetation area, and it can also classify seagrass in clear waters and seagrass in turbid waters, such as what happened in *Teluk Sunting*. Different ecosystems and substrate conditions between Muntai station points - Makam Siantan station points and Tanjung station points - Air Asuk station points, where at Muntai and Makam Siantan stations are dominated by muddy sand substrate which can be directly interpreted on the true color image, the color of the western waters is darker than the eastern waters. This substrate is influenced by the surrounding mangrove ecosystem and its geographic condition, which is actually located into the bay compared to the points of Tanjung station and Air Asuk station. The water substrate at Tanjung and Air Asuk stations with clear waters that have more sands and not muddy may be due to its location that does not enter the bay too much so that it has higher currents and waves than inside the bay.

4. Conclusions

In general, 3 species of seagrass were found in Anambas, consisting of Enhalus acoroides, Thalassia hemprichii and Cymodocea rotundata and the average seagrass cover was 18.82%.

Mapping seagrass using the Supervised Classification method on Landsat 8 OLI, Sentinel-2A, and SPOT-7 images results in inconsistent seagrass classifications on Landsat-8 OLI images, is good enough on Sentinel-2A images, and very good on SPOT-7 images. %. The area of seagrass in Teluk Sunting resulted from the SAM and Maximum Likelihood using Landsat 8 OLI image was 896.22 ha and 158.4 ha, in the Sentinel-2A image was 767.38 ha and 412.05 ha, and in the SPOT-7 image were 410.56 ha and 437.16 ha respectively. The smallest difference between the two methods is in the SPOT-7 image, showing that the SPOT-7 image is the most suitable for mapping the distribution of seagrass using Supervised Classification.

5. References

Green, E.P. & F.T. Short. 2003. World Atlas of Seagrasses. University of California Press. USA. 310 pp

J.N. Nilsson. Learning Machines: Foundations of Trainable Pattern-Classifying Systems, McGraw-Hill Series in Systems Science, McGraw-Hill Book Company, New York (1965)

Kawaroe, M. (2016). Seagrass biodiversity at three marine ecoregions of Indonesia: Sunda Shelf, Sulawesi Sea, and Banda Sea. Biodiversitas, Journal of Biological Diversity, 17(2), 585– 591. https://doi.org/10.13057/biodiv/d170228

Kennedy, H. & M. Bjork. 2009. Seagrass Meadows. In: Laffoley, D. D'A & GRIMSDITCH, G. (eds). 2009. The management of natural coastal carbon sinks. IUCN, Gland, Switzerland.53 pp.

Kruse, F.A., 1993. The Effects of AVIRIS Atmosfer Calibration Methodology on Identification and Quantitative Mapping of Surface Mineralogy, Drums Mountains, Utah, in Summaries of the Fourth Airborne Geoscience Workshop, pp.101-104.

Ministerial Decree of Ministry of Environment and Forestry Number 51.2004. Baku Mutu Air Laut.

McKenzie, L. J. 2008. Seagrass Educator Handbook. Seagrass-Watch, Queensland, Australia

Multispectral Resampling of Seagrass Species Spectra: WorldView-2, Quickbird, Sentinel-2A, ASTER VNIR, and Landsat 8 OLI. IOP Conf. Series: Earth and Environmental Science 98 (2017) 012039

Preen, A. R. (1992) Interactions between dugongs and seagrasses in a subtropical environment. PhD thesis, James Cook University.

Rahmawati, S., A. Irawan, I. H. Supriyadi, M. H. Azkab. 2017. Panduan Pemantauan Padang Lamun. COREMAP-CTI Lembaga Ilmu Pengetahuan Indonesia. Jakarta. 35 hal.

Short, F.T., McKenzie, L.J., Coles, R.G., Gaeckle, J.L. 2004. SeagrassNet manual for scientific monitoring of seagrass habitat – worldwide edition. University of New Hampshire, USA. QDPI, Northern Fisheries Centre, Australia. 71 pp.

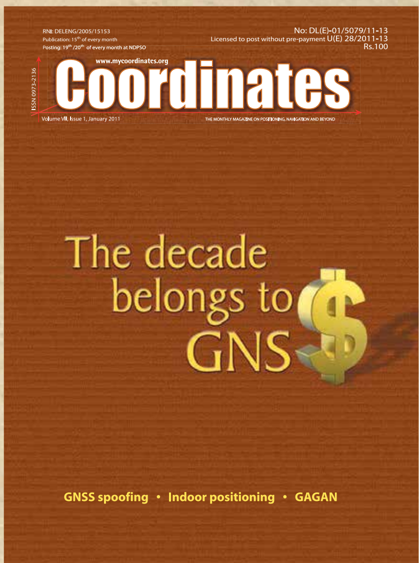
U.S.G.S. (n.d.). What is remote sensing and what is it used for? USGS. Retrieved October 11, 2020, from https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used?qtnews_ science_products=0

KepMenLH No. 200 of 2004, dlhk.kepriprov.go.id. http://dlhk.kepriprov.go.id/wpcontent/ uploads/2018/09/i_kepmenlh_200_2004_baku_kerusakan_dan_pedoman_penentuan_st atus_padang_lamun.pdf, accessed in 01 October 2020.

The paper was presented at Asian Conference on Remote Sensing (ACRS) 2020, 9-11 November 2020, Deqing, China.

In Coordinates

10 years before...



mycoordinates.org/vol-7-issue-1-January-2011

The decade belongs to GNSS

Boris Kennes and Justyna Redelkiewicz Musial
GSA Market Development Department.

According to the 2010 GNSS Market Monitoring report published by The European GNSS Agency (GSA), the global market for GNSS will grow significantly over the next decade, reaching some €244 billion for the enabled GNSS market in 2020. Delivery of GNSS devices will exceed one billion per year by 2020. Mobile location based services (LBS) and Road will be the market sectors with the highest revenue generation.

GNSS spoofing analysis by VIAS

Jyh-Ching JUANG
PhD, Professor, Department of Electrical Engineering,
National Cheng Kung University, Taiwan

The GNSS position deviation effect under spoofing is analyzed. A metric, VIAS, is proposed and used to assess the effectiveness of a spoofer. It is shown that the worst-case position deviation in the presence of spoofing can be expressed as the product of the VIAS and a term relating to range residual or RAIM level. The use of VIAS is of benefit in assessing the use of GNSS navigation in resisting spoofing.

Mass market receiver for static positioning

Marco Piras
Politecnico di Torino DITAG, Turin, Italy
Gianluca Marucco
Istituto superiore Mario Boella,
NAVSAS, Turin, Italy

Alberto Cina,
Associate Professor Politecnico di
Torino, DITAG, Turin, Italy

This research highlights and confirms some interesting aspects about mass market GPS receivers. First, there are differences between GPS receivers that have a important impact on accuracy and performance in static positioning. Carrier phase contribute is fundamental in static positioning in order to obtain the best PVT solution (estimated in real time), but this is true only if the carrier phase measurement quality is good enough.

Status of the GNSS transmitter-based approach for indoor positioning

Anca Fluerasu, Nabil Jardak, Alexandre Vervisch Picois and Nel Samama
Institut TELECOM, Telecom SudParis, Evry, France

This paper has presented the latest updates of the GNSS transmitter-based approach, highlighting its advantages in terms of performances, cost and simplicity of the infrastructure.

$400,000 grant for precision irrigation improvements

Viridix, an Israeli precision irrigation company, has received a $400,000 grant from the Israel Innovation Authority to enhance the remote sensing and AI capabilities of its RooTense® solution. This solution can increase crop yields by 20% while reducing water and fertilizer usage up to 50%. The Authority›s grant funds will also be used to scale production and distribution. Viridix began with a very innovative sensor technology used to measure soil moisture. Through pairing with the latest software to understand the type of plant, age of the plant and soil type it can better respond to crop needs and apply the optimal amount of water. The latest solutions of Viridix are targeted at 70% of the world's freshwater that is used to irrigate agriculture. *www.viridix.com*

African elephants surveyed using AI

A new approach for surveying African elephants using satellite imagery and artificial intelligence (AI) could help in solving some of the present challenges in the conservation of the species. The survey method was developed by an international team of researchers led by University of Oxford. The team detailed their work in a paper titled 'Using very high-resolution satellite imagery and deep learning to detect and count African elephants in heterogeneous landscapes', published in the academic journal Remote Sensing in Ecology and Conservation.

A satellite orbiting in space is capable of capturing more than 5,000 square kilometre of imagery in a single run, within minutes. It not only eliminates the risk of double counting, but also makes it possible to conduct repeat surveys at short intervals, an Oxford release explained. The captured imagery is processed through a deep learning model to detect elephants. The team used a customised dataset of over 1000 elephants in South Africa, to train the model.

"Machines are less prone to error, false negatives and false positives in deep learning algorithms, and are consistent and can be rectified by systematically improving models," the release said. According to the team, elephants can be detected in satellite imagery with accuracy as high as human detection capabilities. In addition, the model was able to spot elephants in places away from the training data location, and also identify calves even though it was only trained on adults. *www.thehindu.com*

ISRO announces free online course on RS

The Indian Space Research Organization announces free online course named "Remote sensing, GIS and GNSS Technology and their Applications". The online course is AICTE-approved, and will be conducted through the Indian Institute of Remote Sensing (IIRS) on the SWAYAM platform. The course can be beneficial especially for undergraduate students willing to receive credit points upon completion.

The course will begin on January 20 till May 5. The module of the course is spread across three sections which will be conducted over 15 weeks and consist of 77.5 hours of learning. The modules consist basics of remote sensing, global navigation satellite system and geographic information system and applications of geospatial technology. The online course will be conducted by Dr. Poonam S Tiwari. Scientist and Teaching Faculty, IIRS, ISRO, Dehradun. *https://onlinecourses.swayam2.ac.in*

World's first wooden satellite

Researchers from Kyoto University are developing a satellite made from wood that would burn up completely at the end of its life to reduce the amount of human-made waste floating in space. Set to launch in 2023, the LignoSat satellite will have a shell made of timber, allowing it to burn up completely as it re-enters the earth's atmosphere. The project is a collaboration with Japanese logging company Sumitomo Forestry and aims to tackle the growing amount of space hardware that is floating in our planet›s orbit despite no longer being functional. *www.dezeen.com*

The Autonomous Saildrone Surveyor Preps for Its Sea Voyage

The 72-foot-long vessel is launched recently into the bay from its dock at a former naval base in Alameda, California. It is designed to spend months at sea mapping the seafloor with powerful sonar devices, while simultaneously scanning the ocean surface for genetic material to identify fish and other marine organisms swimming below.

The carbon-fiber composite and stainless steel-hulled vessel will navigate by itself, following a preprogrammed route to collect and transmit oceanographic data back to Saildrone headquarters via satellite link. The data will then become available to government and academic scientists studying the ocean. In time, its designers say, they hope that solar-powered Surveyor might replace existing oceanographic research ships that are far more expensive to operate and leave a substantial carbon footprint. *www.saildrone.com*

NHPC, India inaugurates RS and GIS lab virtually

A Remote Sensing and GIS Laboratory was inaugurated via video conferencing at the Corporate Office of NHPC (National Hydroelectric Power Corporation), India's premier hydropower company by Shri A.K. Singh, CMD, NHPC on 14 January 2021.

This remote sensing laboratory has been established by the instrument and Diversity Management Division of NHPC. The laboratory has been started with the objective of continuously monitoring the environment of all NHPC projects and who carry out research and development work through this medium. *www.psuconnect.in*

Complete Sonardyne suite for Dive Technologies'

Quincy, Massachusetts, based underwater robotics innovator Dive Technologies has chosen a complete suite of Sonardyne technologies for navigation, tracking and control of its large displacement DIVE-LD autonomous underwater vehicle (AUV) programme.

For underwater positioning and acoustic communications, the DIVE-LD is fitted with Sonardyne's AvTrak 6 – a combined transponder, modem and emergency relocator beacon all in one. *www.sonarydne.com*

GIS mapping resumes in Kollam, India

The Kollam Corporation has resumed GIS mapping and Intelligent Property Management System (IPMS) survey to facilitate technology-based planning. The survey had hit a road block earlier due to resistance from the residents and allegations of data leak, forcing the authorities to stop it temporarily. At present the drone and GPS surveys for documenting geographic and infrastructural details have been completed along with the web portal.

As part of the survey all buildings and other topographic and infrastructural details including landmarks, waterbodies, bridges, wetlands, fallow lands, traffic junctions and parking areas will be mapped and stored using technologies like drone and Differential Global Positioning System (DGPS). According to officials, GIS mapping of the Corporation has been conceived in a way to expedite overall development and ensure that various projects and welfare schemes are reaching the right beneficiaries. "Kollam is the first Corporation implementing such a project and after its completion we are expecting some major changes in project formulation and implementation, town planning, disaster management, and waste treatment."

The Corporation had outsourced the works to ULTS, a subsidiary of the Uralungal Labour Contract Cooperative Society (ULCCS) and in November 2020 the opposition alleged that ULTS has been conducting unauthorised surveys and uploading the data in their private server. They had claimed that the questionnaire included around 200 questions and most of them were health-related following which the Corporation had stopped the survey and ordered a probe. *www.thehindu.com*

SSP Innovations acquires 3-GIS

SSP Innovations, LLC (SSP), the leader in utility GIS products and services, announced the acquisition of 3-GIS, a leading provider of geospatial back-office web and mobile products for the telecom industry. With the 3-GIS acquisition, SSP will acquire telecom software products like 3-GIS Web, 3-GIS Mobile, 3-GIS Prospector and 3-GIS Network Express inclusive of their SaaS offering 3-GIS Live. *https://sspinnovations.com*

A.V. Mapping may put an end to copyright battles

Copyrights are increasingly valued due to the increasing popularity of video content on social media, and time-consuming, licensing conflicts between video creators and music producers are on the rise. Hundreds of thousands of videos around the world are currently involved in copyright infringement suits. A.V. Mapping, which was selected by Taiwan Tech Arena (TTA) as one of the 100 featured Taiwanese startups being showcased at CES 2021, is promoting its patented AI platform as a solution to the problem of copyright infringement in our online media-driven age.

With its unique AI model, the platform analyzes the content, element, and cuts in an uploaded video and then compares the results to the music database for the proper music recommendation for each video. This database currently contains over 6,000 hours of music, covering 120,000 songs in 60 different genres. Continued expansion is expected to increase this database to over 28 million songs in the future.

The AI platform helps filmmakers skip the traditional, time-consuming process of browsing through millions of music studios, testing music out with the film, and music licensing. The entire process can now be as short as 8 seconds, compared to the days or weeks of work required otherwise. *https://avmapping.co*

Version 8.0 of the GeoCalc SDK

Blue Marble Geographics has announced the immediate availability of version 8.0 of the GeoCalc® Software Development Kit (SDK). The new release incorporates many new features including new IOGP data model types for Usage and Scope Objects, Dynamic Datums, and Ensembles. It also offers integration with the new GeoCalc Online service. *bluemarblegeo.com*

MoRTH and DRDO to collaborate for geo-hazard management

Ministry of Road Transport & Highways (MoRTH), India and Defence Research and Development Organisation (DRDO), Ministry of Defence, India recently signed a framework Memorandum of Understanding (MoU) to strengthen collaboration in the field of technical exchange and co-operation on sustainable geo-hazard management.

It has been agreed that MoRTH and DRDO will co-operate in the areas of mutual benefit including, conceptual planning of integrated avalanche/ landslide protection schemes for all weather connectivity in snow bound areas of our country

Defence Geo-Informatics Research Establishment (DGRE), a premier laboratory of DRDO, is leader in the development of critical technologies for enhancing combat effectiveness with a focus on terrain and avalanches. The role and charter of this establishment is mapping, forecasting, monitoring, control and mitigation of landslides and avalanches in Himalayan terrain.

It has been agreed by both the organizations to utilize the expertise of DRDO (through DGRE) in providing sustainable mitigation measures to damages caused by landslides, avalanche and other natural factors on various National Highways in the Country. *https://pib.gov.in*

NASA explores upper limits of Global Navigation Systems for Artemis

The Artemis generation of lunar explorers will establish a sustained human presence on the Moon, prospecting for resources, making revolutionary discoveries, and proving technologies key to future deep space exploration.

To support these ambitions, NASA navigation engineers from the Space Communications and Navigation (SCaN) program are developing a navigation architecture that will provide accurate and robust Position, Navigation, and Timing (PNT) services for the Artemis missions. GNSS signals will be one component of that architecture. GNSS use in high-Earth orbit and in lunar space will improve timing, enable precise and responsive maneuvers, reduce costs, and even allow for autonomous, onboard orbit and trajectory determination.

Expanding the Space Service Volume

Beyond 1,800 miles in altitude, navigation with GNSS becomes more challenging. This expanse of space is called the Space Service Volume, which extends from 1,800 miles up to about 22,000 miles (36,000 km), or geosynchronous orbit. At altitudes beyond the GNSS constellations themselves users must begin to rely on signals received from the opposite side of the Earth.

From the opposite side of the globe, Earth blocks much of the GNSS signals, so spacecraft in the Space Service Volume must instead "listen" for signals that extend out over the Earth. These signals extend out at an angle from GNSS antennas.

Formally, GNSS reception in the Space Service Volume relies on signals received within about 26 degrees from the antennas' strongest signal. However, NASA has had marked success using weaker GNSS side lobe signals — which extend out at an even greater angle from the antennas — for navigation in and beyond the Space Service Volume.

Since the 1990s, NASA engineers have worked to understand the capabilities of these side lobes. In preparation for launch of the first Geostationary Operational Environmental Satellite-R weather satellite in 2016, NASA endeavored to better document side lobes' strength and nature to determine if the satellite could meet its PNT requirements.

Navigation experts at Goddard reverse-engineered the characteristics of the antennas on GPS satellites by observing the signals from space. By studying the signals satellites received from GPS side lobes, engineers pieced together their structure and strength. Using this data, they developed detailed models of the radiation patterns of GPS satellites in an effort called the GPS Antenna Characterization Experiment.

While documenting these characteristics, NASA explored the feasibility of using side lobe signals for navigation well outside what had been considered the Space Service Volume and in lunar space. In recent years, the Magnetospheric Multiscale Mission (MMS) has even successfully determined its position using GPS signals at distances nearly halfway to the Moon.

GNSS at the Moon

To build on the success of MMS, NASA navigation engineers have been simulating GNSS signal availability near the Moon. Their research indicates that these GNSS signals can play a critical role in NASA's ambitious lunar exploration initiatives, providing unprecedented accuracy and precision.

"Our simulations show that GPS can be extended to lunar distances by simply augmenting existing high-altitude GPS navigation systems with higher-gain antennas on user spacecraft," said NASA navigation engineer Ben Ashman. "GPS and GNSS could play an important role in the upcoming Artemis missions from launch through lunar surface operations."

While MMS relied solely on GPS, NASA is working toward an interoperable approach that would allow lunar missions to take advantage of multiple constellations at once. Spacecraft near Earth receive enough signals from a single PNT constellation to calculate their location. However, at lunar distances GNSS signals are less numerous. Simulations show that using signals from multiple constellations would improve missions' ability to calculate their location consistently.

To prove and test this capability at the Moon, NASA is planning the Lunar GNSS Receiver Experiment (LuGRE), developed in partnership with the Italian Space Agency. LuGRE will fly on one of NASA's Commercial Lunar Payload Services missions. These missions rely on U.S. companies to deliver lunar payloads that advance science and exploration technologies.

NASA plans to land LuGRE on the Moon's Mare Crisium basin in 2023. There, LuGRE is expected to obtain the first GNSS fix on the lunar surface. LuGRE will receive signals from both GPS and Galileo, the GNSS operated by the European Union. The data gathered will be used to develop operational lunar GNSS systems for future missions to the Moon.

By Danny Baird
NASA's Space Communications and Navigation program office. www.nasa.gov

White House Issues Space Policy Directive 7 on Space-Based PNT Systems

President Donald J. Trump has issued Space Policy Directive-7 (SPD-7), the United States Space-Based Positioning, Navigation, and Timing Policy. Recognizing that space-based positioning, navigation, and timing (PNT) systems are increasingly critical to the American way of life, SPD-7 directs the pursuit of multiple and varied sources of PNT. SPD-7 directs an increase of cybersecurity for the Global Positioning System (GPS) and GPS-enabled devices, and acknowledges the potential for GPS to contribute to in-space applications. This is the first update to the United States policy on space-based PNT in more than 16 years.

SPD-7 Highlights:

The multi-use PNT services provided by GPS are integral to United States national security, economic growth, transportation safety, and homeland security. These services are essential but largely invisible elements of worldwide economic infrastructures.

The goal of SPD-7 is to maintain United States leadership in the service provision and responsible use of global navigation satellite systems, including GPS and foreign systems.

To achieve this goal, SPD-7 outlines several objectives, including:

- Provide continuous worldwide access to United States space-based GPS services and government-provided augmentations free of direct user fees.
- Operate and maintain the GPS in accordance with United States law to satisfy civil, homeland security, and national security needs.
- Improve the performance of United States space-based PNT services, including developing more robust signals that are more resistant to disruptions and manipulations.
- Improve the cybersecurity of GPS, its augmentations, and United States Government-owned GPS-enabled devices, and foster private sector adoption of cyber-secure GPS-enabled systems.
- Protect the spectrum environment used by GPS and its augmentations.

SPD-7 complements the Executive Order on Strengthening National Resilience through Responsible Use of Positioning, Navigation, and Timing Services, clarifying the pursuit of multiple and varied alternative sources of PNT for critical infrastructure.

On June 30, 2017, President Donald J. Trump issued Executive Order 13803, reviving the National Space Council "in order to provide a coordinated process for developing and monitoring the implementation of national space policy and strategy." In addition to Space Policy Directive-7, the President has signed six previous Space Policy Directives and the National Space Policy to restore American leadership in areas of civil, commercial, and military space. *www.whitehouse.gov*

UK loses Galileo and Egnos but can continue with Copernicus and ESA

The United Kingdom will no longer participate in the European Galileo or Egnos programs but can continue, in principle, with Copernicus and remain member of the European Space Agency (ESA), the British Government said.

On its official www.gov.uk website, the Government lists the Brexit transition: new rules for 2021".

According to the site, the UK will "not use Galileo (including the future Public Regulated Service (PRS)) for defence or critical national infrastructure; have access to the encrypted Galileo Public Regulated Service; be able to play any part in the development of Galileo; be able to play any part in the development of EGNOS; be able to use the EGNOS SoL and EGNOSWorking Agreements (EWAs), which will no longer be recognised by the EU; be able to access or use EDAS".

Furthermore, from 1 January 2021, "the UK will no longer participate in the EU Space Surveillance and Tracking (EUSST) programme. The UK will however continue to have access to EUSSTservices as a non-EU country", the Government says.

However, the UK can continue to participate in Copernicus. "The UK welcomes the agreement in principle to continue to participate in the Copernicus component of the EU Space Programme as a third country for 2021-27," it says. "If the UK confirms in early 2021 to participate in Copernicus, we expect UK-based businesses, academics and researchers will be able to bid for future Copernicus contracts tendered through the EU".

"Similarly, we expect UK users will also be able to access most of the Copernicus data and services as now." "(D) evices that currently use Galileo and EGNOS, such as smart phones, will continue to be able to do so", the Government says.

Also, "the UK's membership of the European Space Agency (ESA) is not affected by leaving the EU as it is not an EU organisation." The UK will thus continue to participate and be able to bid for ESA programs. *https://spacewatch.global/2020/12/uk-loses-galileo-and-egnos-but-can-continue-with-copernicus-and-esa*

Low-cost, flexible and secure Galileo-enabled software receiver

The EU-funded ENSPACE project has made quantum leaps in the development of a software GNSS solution that supports Galileo and is especially aimed at the small satellite market sector, one of the fastest growing in the 'New Space' age. Software-based GNSS receivers enable a new concept for Space. This is an activity that project coordinator Qascom initiated with NASA in 2016.

The experiment was based on the use of a NASA's software-defined radio platform called SCaN, attached to the exterior of the International Space Station (ISS). A first, the SCaN Testbed provided an orbiting laboratory on the space station for the development of software-defined radio technology for improved navigation and communication experimentations. "In ENSPACE, we evolved this concept and invested in a new software GNSS solution that has been installed in commercial off-the-shelf hardware and is also compatible with other system-on-chip components," notes Samuele Fantinato, head of the Advanced Navigation Unit at Qascom.

In Space, GNSS receivers need to operate in quite different environments from those of ground-based receivers. "Precisely determining satellite position in Space is quite easy for those flying in low Earth orbits. In higher altitudes, such as in geostationary orbits or in interplanetary missions, signal variability becomes prominent. Adding new constellations could increase accuracy in these orbits," explains Fantinato. Project members have proposed novel techniques for enhanced navigation, positioning and security in Space. Charged particles and gamma rays are another concern for GNSS receivers. The ENSPACE software GNSS solution integrates techniques and logic redundancy that offer a more robust positioning accuracy in case of radiation events. *https://cordis.europa.eu*

GPS-III Satellite Group Delay, Phase Center and Inter-Signal Bias Data

Lockheed Martin Space has released the GPS-III Satellite phase center and inter-signal bias data for SVN-74 and SVN-75. The information has been posted on the U.S. Coast Guard Navigation Center's website underneath the IIR/IIR-M antenna pattern data files.

The phase center and inter-signal bias data included in this new release provides additional information that supplements the antenna gain pattern data previously available.

The phase center offset data locates the electrical center of the GPS transmit antenna. This data set also includes the inter-signal corrections as measured in the factory. The modernized satellites provide multiple civil signals in addition to the legacy L1 C/A signal, enabling robust dual-frequency or triple-frequency receiver tracking. These techniques can, for example, help eliminate ranging errors due to ionospheric path delays. But proper operation of a multi-frequency receiver requires accommodation of inter-signal biases that arise from differences in the transmit time of each signal type.

Note that the GPS-III SVs also broadcast the Inter-Signal Corrections (ISCs) in the various LNAV/CNAV messages in accordance with all the external IS/ICDs. The value that is being broadcast by the on-orbit constellation is not the factory measured ISCs but the ISCs estimated on-orbit by the Stanford Research Institute (SRI).

GNSS-inertial package for delivery robots and drones

Parker LORD Microstrain Sensing debuted its new all-in-one navigation system this month, which includes onboard RTK and built-in dual antenna GNSS receivers. The advanced inertial navigation system includes: the 3DMGQ7-GNSS/INS, which can achieve centimeter-level position accuracy when paired with the company's 3DMRTK modem and SensorCloud RTK corrections service. *www.microstrain.com*

Spanish elite units receive the first SEEKER RPAS units

A few days ago the Spanish Army and Navy received the first SEEKER Remotely Piloted Aircraft Systems (RPAS). SEEKER is the unmanned aircraft that will boost the intelligence-, surveillance- and reconnaissance-capabilities of the Spanish Army's 6th Paratroopers Brigade and the Marine Infantry Protection Force, two elite forces that enjoy international renown and prestige. *www.gmv.com*

Indian Army signs a $20 million contract with ideaForge

The Indian Army has signed an approximately $20 million contract for undisclosed quantities of a high-altitude variant of ideaForge's SWITCH UAV which will be delivered over a period of 1 year. ideaForge has been awarded this contract after it emerged as the only vendor that qualified the operational requirements in an evaluation done in real-world conditions, for a fast-track procurement. *www.ideaforge.co.in*

Advance autonomous work drone platform

Skyfish has announced the formal launch of their advanced autonomous work drone platform. This includes work drones, Skyfish M4 and Skyfish M6, a long-lasting battery system and a unique ruggedized remote controller. Also, it has a partnership with Sony and supports the Sony Alpha series of A7 cameras including the Sony A7 iv, Sony A7 iii,

Sony A7 ii, the Sony QX series, the Sony R10C, and others. *www.skyfish.ai*

FAA approves American Robotics to run automated drones

American Robotics has became the first company approved by the Federal Aviation Administration (FAA) to operate automated drones without human operators on-site. The company's Scout System™ features advanced acoustic Detect-and-Avoid (DAA) technology that enables its drones to maintain a safe distance from other aircraft at all times. By developing a layered, redundant system of safety that includes proprietary technical and operational risk mitigations, American Robotics has proven that its drone-based aerial intelligence platform operates safely in the National Airspace System (NAS), even when it conducts flights Beyond-Visual-Line-of-Sight (BVLOS) of the operator.

This approval represents a significant inflection point in the commercial drone industry. *www.american-robotics.com*

senseFly launches eBee e-learning platform and operator certification program

senseFly has launched of its new e-learning platform and dedicated Certified senseFly Operator Program, developed to equip UAV operators with the knowledge and skills required to carry out drone missions more accurately, safely and efficiently.

Through the senseFly Academy platform, operators in all verticals – from surveying and GIS to agriculture and construction – can access a wide range of courses and modules as part of a self-paced training program. The platform guides users through the essential steps of drone mapping and usage, in addition to offering more in-depth insights into managing project workflows and in-field and in-flight troubleshooting. *www.senseFly.com*

Indoor mapping goes mainstream with IMDFaaS

IMDFaaS is a full service Indoor Mapping Data Format (IMDF) development platform that delivers precise IMDF archives. Its proprietary technology and development expertise make acquiring high quality IMDF archives fast, simple and affordable for any sized venue or facility.

IMDFaaS's open-format, high quality IMDF archives are guaranteed to comply with Apple validation requirements for the enablement of Apple Indoor Positioning (IPS), streamlining time to value and integration with iOS applications. IPS leverages an IMDF archive to enable accurate indoor location awareness on any iPhone or iPad with no need for additional hardware infrastructure. *www.imdfaas.com*

HERE spearheads private mapping

HERE Technologies has announced the introduction of a unique mapping-as-a-service offering. It is targeted at enterprises wanting to create differentiation and reduce operational costs through building, maintaining, and using unique map datasets for advanced analytics and services. The offering is enabled by advanced platform functionality coupled with industry-leading map creation, processing and delivery capabilities.

Progressively through 2021, the aim is to enable enterprises to bring their own map data onto the HERE location platform and use it in combination with HERE map data and services which will increasingly be available as a self-serve experience. Enterprises will have the option to do this autonomously or can co-develop with the HERE professional services team, who provide a wide portfolio of globally scalable mapping-related services. *http://360.here.com*

XPeng unveils beta version navigation guided pilot function

XPeng Inc., a leading Chinese smart electric vehicle ("Smart EV") company, recently unveiled the beta version of its NGP (Navigation Guided Pilot) highway autonomous driving solution. The Company plans to launch the widely anticipated NGP function, a key part of its XPILOT 3.0 autonomous driving package, to customers in China in the next few weeks.

XPeng's NGP highway navigation function conducts automatic navigation assisted driving from point A to B based on the navigation route set by the driver. Upon its launch, it will be implemented on the Premium version of the XPeng P7 with the XPILOT 3.0 system.

XPeng's NGP solution has been specifically created and tailored for China's complex driving environment. Its full-scenario high-definition positioning capability solves HD-map positioning challenges for China's highly complex road conditions, including areas with no GPS signals. *https://en.xiaopeng.com*

Upgraded capabilities for satellite IoT Tracking

Iridium Communications Inc. has announced commercial availability of the Iridium Edge Solar – a secure, maintenance-free, solar-powered remote asset tracking and management device. With over-the-air configuration capabilities, the Iridium Edge Solar is ideal for Vessel Monitoring Systems (VMS), fisheries management, tracking of freight shipping containers, Supervisory Control and Data Acquisition (SCADA) applications, monitoring of oil and gas pipelines and heavy equipment telematics data reporting.

The Iridium Edge Solar beta trials, which are nearing completion, are thoroughly testing its real-time, two-way communication, over-the-air configuration ability, built-in Bluetooth Low Energy (BLE) connectivity and secure, ruggedized packaging. The addition of BLE technology enables development of customized deployable sensor systems that can be positioned on machinery, vehicles, vessels or across worksites. *www.iridium.com*

AWS announces Amazon Location Service

Amazon Location Service is a fully managed service that helps developers easily add location data to their applications without sacrificing data security and user privacy. The service is now in preview. With Amazon Location, you can build a wide range of location-enabled applications for use cases such as asset tracking, geomarketing, and delivery management.

Amazon Location Service provides cost-effective maps, points of interest, geocoding, geofences, and tracking for applications, using high-quality data from trusted global providers Esri and HERE. At general availability, the service will also provide routing capabilities.

You can get started in the Amazon Location Service console with the visual, interactive design tool to explore geolocation functions. Then, you can start building quickly with the service's SDK and sample code, and combine them with open source libraries such as Mapbox GL. *https://aws.amazon.com*

Cruise and GM team up with Microsoft

Cruise and General Motors have announced that they have entered a long-term strategic relationship with Microsoft to accelerate the commercialization of self-driving vehicles. The companies will bring together their software and hardware engineering excellence, cloud computing capabilities, manufacturing know-how and partner ecosystem to transform transportation to create a safer, cleaner, and more accessible world for everyone.

Cruise will leverage Azure, Microsoft's cloud and edge computing platform, to commercialize its unique autonomous vehicle solutions at scale. Microsoft, as Cruise's preferred cloud provider, will also tap into Cruise's deep industry expertise to enhance its customer-driven product innovation and serve transportation companies across the globe through continued investment in Azure.

2020 – A record year for NovAtel GAJT GPS Anti-Jam Technology

NovAtel has announced that their GPS Anti-Jam Technology (GAJT) product lines achieved a milestone of more than several thousand units shipped worldwide in 2020. Despite COVID-19, 2020 has proven to be one of NovAtel's most successful years in protecting PNT from Cyber Electromagnetic Activities (CEMA) for military and civil organizations.

Jamming and interference are growing threats, from a crowded RF spectrum to malicious jamming attempts. However, the GNSS market is responding with anti-jam technologies. Across the world, on land, in the air and at sea, NovAtel customers use GAJT to protect their GNSS (GPS & Galileo) navigation and precise timing receivers from intentional jamming and unintentional interference. The GAJT portfolio includes commercial off-the-shelf solutions with short order lead times for rapid deployment. *novatel.com*

AVL and R&S announce strategic vehicle-in-the-loop collaboration

Rohde & Schwarz and AVL have intensified their collaboration with the integration of a Rohde & Schwarz radar test system into the AVL DRIVINGCUBE™ toolchain, creating new possibilities for testing radar enabled ADAS features and validating autonomous driving functions with a vehicle-in-the-loop test bed.

The AVL DRIVINGCUBE™ combines both simulation and real vehicles on a chassis dynamometer and powertrain testbed. It provides a new way to speed up the validation and approval process of ADAS and AD systems. The key concept of this solution is operating the real vehicle in a virtual environment, taking into consideration all parts of the "sense, plan, act" chain. *www.pressebox.de*

New Topcon solution for North America

A new point creation software from Topcon Positioning Group to directly benefit construction professionals is now available. Topcon Point Manager, available as a plug-in for Autodesk AutoCAD and Autodesk Revit users in the U.S. and Canada, is designed to automate point creation and easily import and export layout files to and from a robotic total station. The new solution will simplify the BIM-to-field process with a faster, more seamless point creation experience from within the design platform, reducing the time and cost of layout. *www.topconpositioning.com*

SCCS and Senceive partnership

SCCS, part of Hexagon, an authorised distributor and a flagship business for both the rental and sale of Leica Geosystems solutions has formed a partnership with Senceive to distribute the company's wireless remote condition monitoring technology.

UK based Senceive brings unrivalled technical expertise and locally based customer support to enhance the SCCS team. They offer a comprehensive range of geotechnical and structural solutions based on their two wireless communications platforms FlatMesh and GeoWAN. FlatMesh provides intelligent, reliable and rapid responsiveness using mesh technology and GeoWAN offers an alternative longer range LoRaWAN based solution. *www.sccssurvey.co.uk*

GTT adds GNSS to Opticom solutions

Global Traffic Technologies (GTT) has announced that it has added the GNSS to its Opticom™ solutions. This collection of satellites transmits positioning and timing data to GNSS receivers, which use this data to determine location.

Adding GNSS will enable more consistent, reliable priority control in dense urban areas with obstructions such as bridges, tunnels and tall buildings. It will reduce the kind of performance issues that can diminish priority control's effectiveness by helping ensure the correct intersection receives the request for a green light as priority vehicles approach intersections. Better location services will minimize disruptions to traffic, and help fire and emergency personnel, bus drivers and light rail train conductors navigate dense urban areas in safer and faster.

Even with access to more satellites, communication to these satellites can be lost temporarily in areas with tall buildings, tunnels or multi-level roads. To address this, GTT has also added the ability to more effectively determine vehicle position in these areas with software-based "dead reckoning." *www.gtt.com*

ViaLite links used in next generation of space development

ViaLite recently supplied its L-Band links, GPS links, associated outdoor enclosures and indoor system chassis solutions to a major privately funded spaceflight services company. The L-Band link featured the market-leading ViaLite Hyper Wide Dynamic Range (HWDR) solution which provides a spurious free dynamic range of up to 115 dB/Hz. The GPS links were supplied together with the unique ViaLite Multizone Lossless Splitter, for easy distribution of the GPS signals with effectively no signal loss. The products were used to operate the spaceflight company's L- Band communications link and for GPS based network server timing and synchronization. *www.vialite.com*

SailPlan launches to enable intelligent navigation for ships

SailPlan is building an intelligent navigation platform for ships that makes navigation dramatically safer and more efficient in a world with an ever-growing demand for cargo.

Seafaring is the world's deadliest job. In the past ten years, nearly 1,000 ships and thousands of lives have been lost. Most catastrophic incidents result from human error, as navigators rely primarily on their eyes and ears in crowded environments with little room for error.

Founded by Jacob Ruytenbeek, an autonomous systems expert, Sailplan's platform makes ship operations safer and more efficient by identifying collision risks beyond the navigator's line of sight so that ships can safely navigate around them.

Drawing on data around vessel traffic, weather, geographic awareness, and more, SailPlan offers operators unparalleled situational awareness that improves safety and efficiency. Its's routing engine alerts ship navigators to potential collision risks hours, or even days, in advance.

SailPlan's requires no external sensors to provide enhanced navigational capabilities. For increased visibility, it allows operators to integrate almost any external sensor through a standard interface. *Sailplain.ai*

Fugro awarded PETRONAS contract

Fugro in the Caribbean has received a contract award from PETRONAS Suriname E&P for the provision of positioning services for an exploration program in Block 52, off the coast of the capital Paramaribo in the Guyana-Suriname Basin. PETRONAS is a global energy and solutions partner and ranks amongst the largest corporations in Fortune Global 500.

The 2-year contract involves Fugro's Starfix precise positioning solution to help ensure safe and efficient transit, anchoring and drilling activities for the programmer's semi-submersible rig and support vessels.

Eos Positioning Systems announces new Arrow Bundles

Eos Positioning Systems (Eos) has announced the availability of two new Arrow bundles. The Arrow Gold Bundle and Arrow 100 Bundle are immediately available for sale in the United States. These bundles allow customers to combine Esri ArcGIS software licenses with the purchase of Eos Arrow Series® GNSS receivers.

"We are extremely pleased to offer, in partnership with Esri, a hardware and software bundle that has already proven widely effective and popular among our joint customers," said Jean-Yves Lauture, Chief Technology Officer at Eos. "The bundles make it more convenient for organizations to acquire all of their industry-leading field mapping software and hardware." *www.eos-gnss.com*

An Indian startup is mapping potholes

Intents Mobi, a Gurugram-based startup, is making a navigation app that can send pothole alerts, a feature that is non-existent in Google maps. The app called Intents Go is a free, privacy focussed, navigation app, aimed at making drives safer and easier.

The app could update users in real-time on road conditions while driving. It supports voice-guided turn by turn navigation, sends speed breaker alerts and helps find restaurants, toilets and mechanics. The company says it won't collect users' personal data. *www.thehindu.com*

Planet releases ArcGIS Add-In & QGIS Plugin V2.0

Planet announces the release of the new and improved Planet ArcGIS Add-In & Planet QGIS Plugin V2.0. The new integration products are designed to make it easier for GIS users to discover and apply imagery in their preferred mapping and analysis tools, enriching their applications and projects with more frequent satellite imagery.

The ArcGIS Add-In & QGIS Plugin V1.0 were released in December 2019 and enabled customers to search for, preview, and download Planet imagery & Basemaps directly within ArcGIS Pro and QGIS desktop. The update to 2.0 both strengthens these existing features and adds new capabilities to augment users' imagery workflows in their GIS. *www.planet.com*

Trimble introduces 2 new GNSS smart antennas

The AX940 and AX940i are the two GNSS smart antennas introduced by Trimble. They are designed for a broad range of applications including precision agriculture, milling machines in the construction, forestry harvesting equipment, autonomous vehicles, port automation, and mobile mapping, and several others.

The full-featured smart antennas are equipped with 336 channels for multi-constellation support, Trimble RTX and OmniSTAR support, flexible RS232, USB, CAN and Ethernet interfaces, and advanced RF spectrum monitoring. The AX940i also includes WiFi and Bluetooth connectivity for wireless interface and control. *www.trimble.com*

Airbus and Thales win €1.47 bn contracts

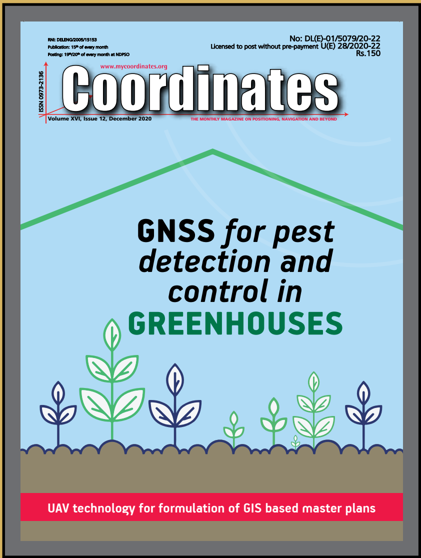
The European Commission has awarded two contracts for 12 Satellites (6 satellites each), for a total of €1.47 billion, to Thales Alenia Space (Italy) and Airbus Defence & Space (Germany) following an open competition.

With this, the Commission is initiating the launch of the 2nd Generation of Galileo, the European satellite positioning system. The aim is to keep Galileo ahead of the technological curve compared to global competition and maintaining it as one of the best performing satellite positioning infrastructures in the world while strengthening it as a key asset for Europe's strategic autonomy. The first satellites of this second generation will be placed in orbit by the end of 2024. *https://ec.europa.eu*

Hexagon and Gold Fields Ghana complete project successfully

Hexagon's Mining division has announced completion of a significant safety installation with Gold Fields Ghana. More than 220 mine vehicles were equipped with Hexagon's MineProtect Collision Avoidance System (CAS) at Gold Fields' Tarkwa Mine in Ghana's Western Region.

MineProtect's Operator Alertness System, Personal Alert and Tracking Radar were also installed with minimal delays, despite pandemic lockdowns. *www.hexagon.com*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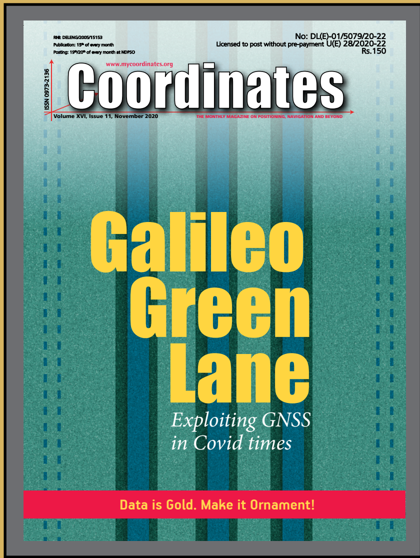
UAV technology for formulation of GIS based master plans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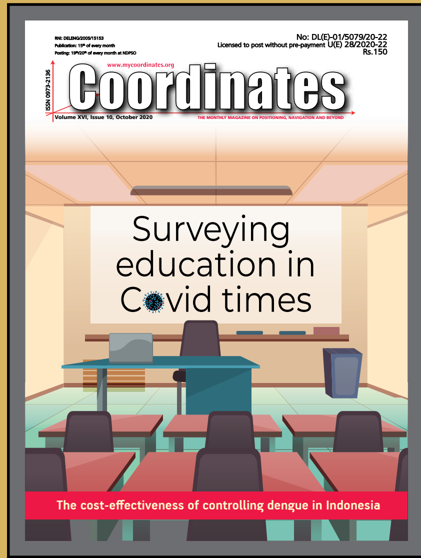
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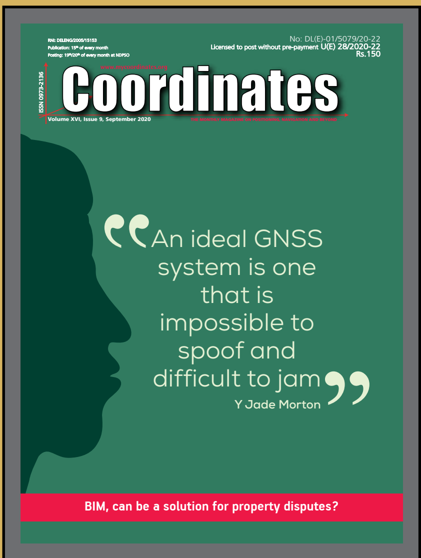
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Y Jade Morton
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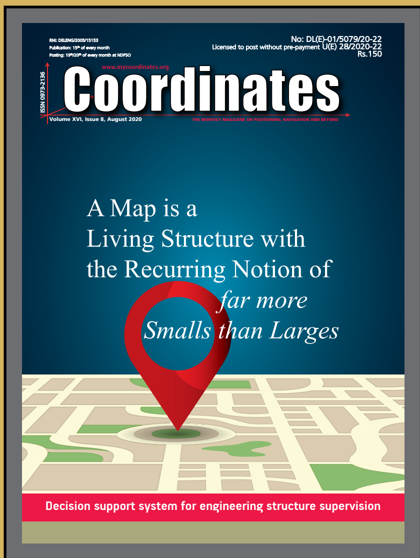
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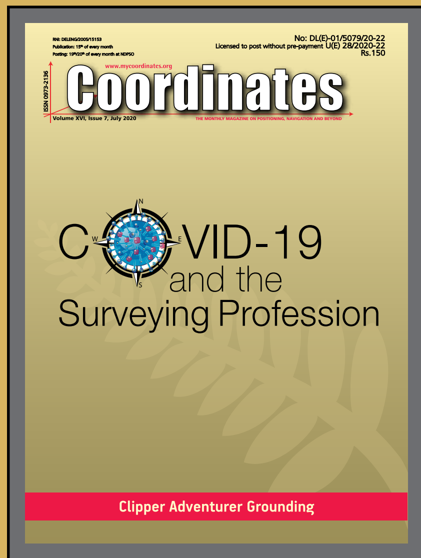
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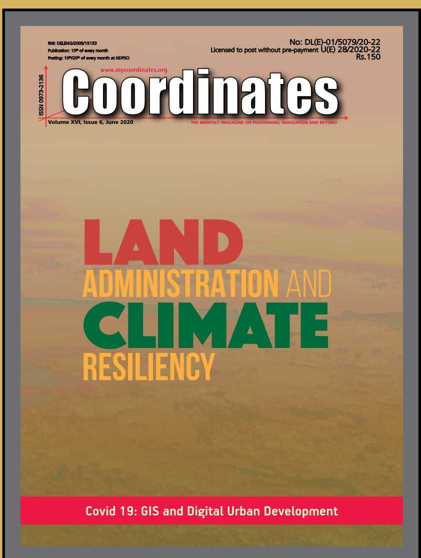
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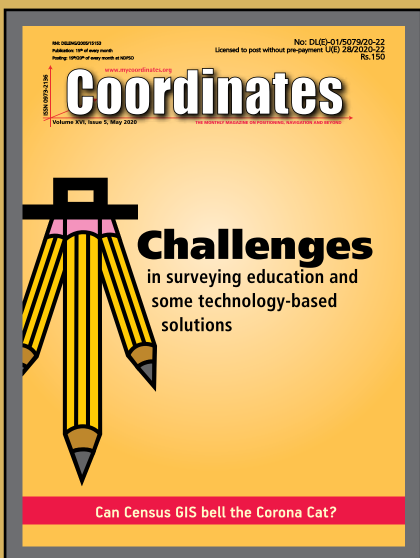
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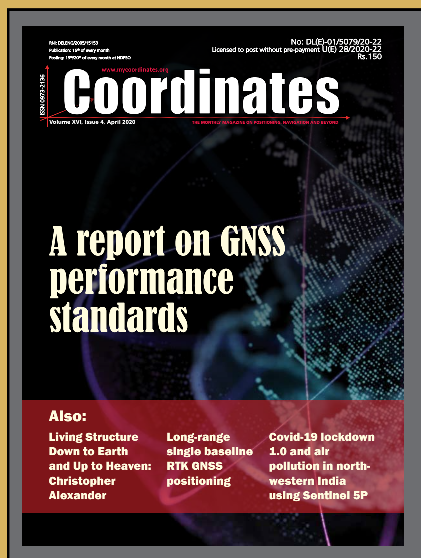
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