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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Earthquake prediction method using artificial intelligence

Road design parameter analysis based on the GNSS data

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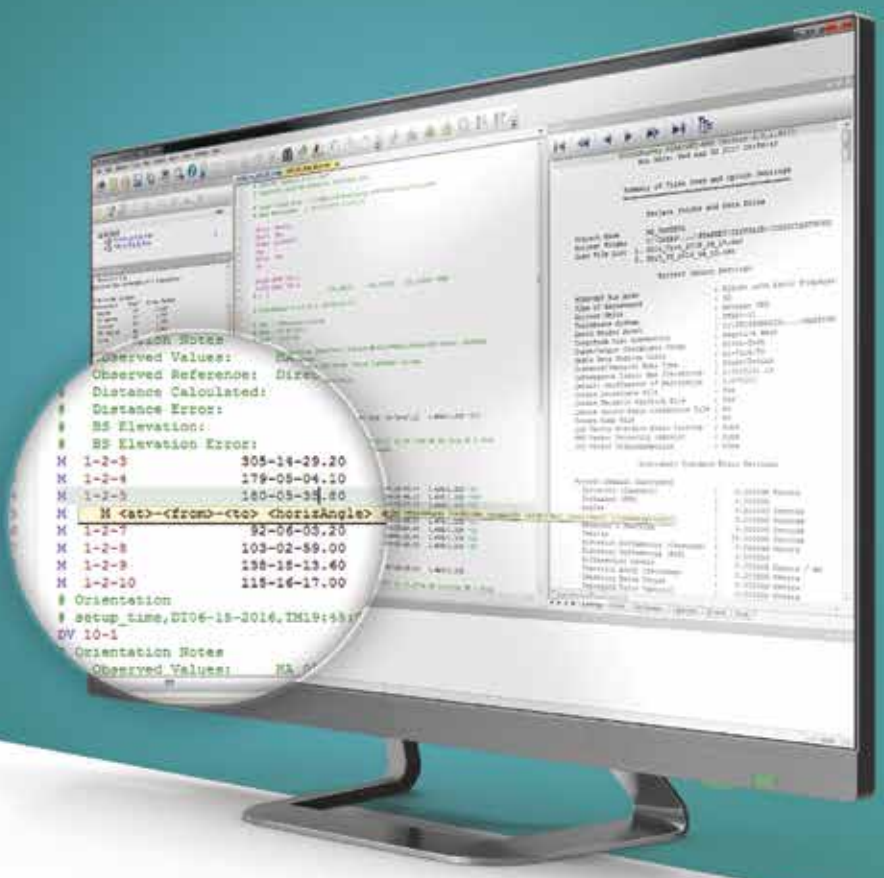

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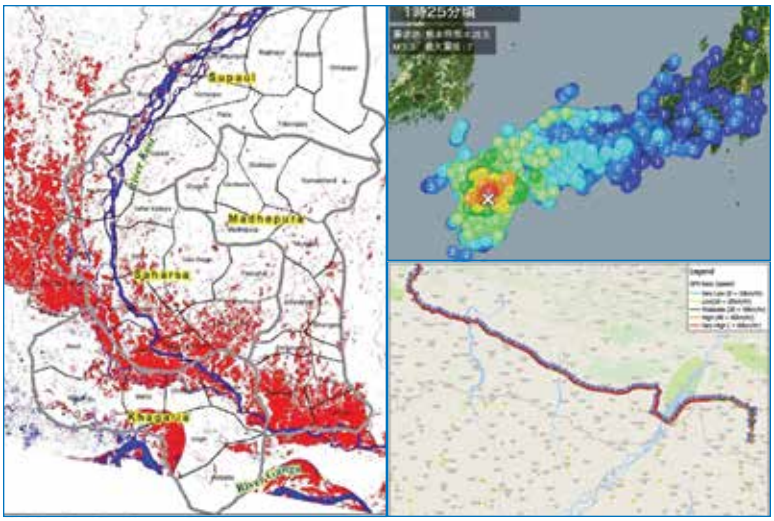

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Columns

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This issue of Coordinates is of 52 pages, including cover.

Pause and re-plan!

A recent study

'Satellite-derived Time and Position: A Study of Critical Dependencies'

by The UK Government Office for Science

Reviews the UK's dependency on GNSS

And recommends measures to improve resilience

Including by adopting potential back-up systems.

More than the findings,

The worth appreciating is the approach.

The approach of 'a pause'

Where stakeholders think of the stakes involved,

And assess the implications and the consequences

Of any possible GNSS disruption.

Existing and prospective GNSS systems

May have lessons to learn.

Bal Krishna, Editor
bal@mycoordinates.org

Development of advanced earthquake prediction method using artificial intelligence

The authors spent two years research on the application of the (Mahalanobis-Taguchi Method) MT method for earthquake prediction which shows interesting result

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President, Angletry Co., Ltd. Sapporo, Japan

JESEA (Japan Earthquake Science Exploration Agency), which celebrated its fifth anniversary since establishment in January 2013, continues to provide mail magazines and web services of "Weekly MEGA Earthquake Prediction" to about 50,000 subscribers in Japan. The prediction method is based on the three-dimensional analysis of daily GNSS data recorded at about 1,300 CORSs which have been constructed by Geospatial Information Authority of Japanese Government as well as 18 CORSs constructed by JESEA (MURAI, S. and ARAKI, H.: 2014, 2015, 2016).

Since the beginning, JESEA has been aiming to predict earthquakes larger than Japanese seismic intensity Level 5. From the commencing date of the business service in February 2013 to the end of 2017, 45 earthquakes larger than Level 5 occurred in Japan. The correctness of the prediction has been 53.3% for 'acceptable' status, 37.8% for 'most likely acceptable' status and 8.9% for 'unpredicted' status. As correctness depends on JESEA's definition of 'acceptable' status, which is within three months of JESEA's public announcement that an earthquake larger than Level 5 might occur in certain areas and when, it should be traceable to published documents or TV broadcasts. Most likely acceptable status is defined as the predicted time of occurrence of the earthquake within 6 months of actual occurrence. To predict exactly when an earthquake may occur is still a big issue for the earthquake prediction.

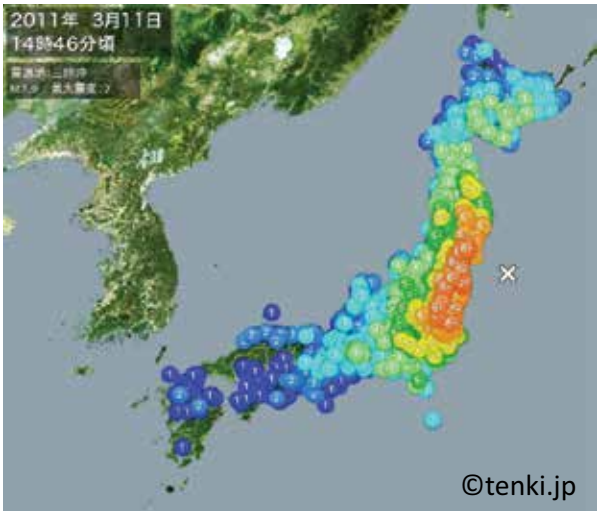

Figure 1 East Japan Great Earthquake (the number shows seismic intensity level)

Recently, in order to improve the prediction correctness, JESEA has developed a new method using Mahalanobis-Taguchi Method (hereinafter called MT Method) which is considered as one of artificial intelligence methods in the field of Quality Engineering of industrial products. The MT method has been developed by the late Dr. Genichi Taguchi who applied Mahalanobis's distance (hereinafter called MD) from the feature space of a certified product group to a product being tested (TAGUCHI, G., CHOWDHURY, S. and WO, Y., 2001). If the MD exceeds the threshold, the product should be classified as an uncertified product. In the case when the MT method is applied to the prediction of earthquakes, the feature space of normal status for earthquakes of less than Level 2 has been generated from big data of daily GNSS data of 1,300 CORSs from May 2005 to the present year. Every week new data should be checked whether or not the MD for normal feature space exceeds the threshold. The authors spent two years research on the application of the MT method for earthquake prediction which shows interesting result as described below.

Introduction

The MT method varies depending on the selection of input parameters such as the number of reference CORSs, the coverage area, the range of normal time space, the features to be derived from XYZ coordinates. The most important aspect is to determine the optimal input parameters to maximize the correlation between the MD and the occurrence earthquakes larger than Level 5. After many validation tests, the authors have developed so called "μDEQ chart", where μD refers to the Malanobis's Distance and EQ refers to earthquake, which shows the risk factor of earthquake occurrence.

According to the validation tests using the daily GNSS data from 1300 CORSs for these 13 years (from 2005 to 2017) and the previous earthquakes larger than Level 5, the results seem feasible as described below.

μDEQ chart in case of East Japan Great Earthquake

As is well known, the East Japan Great Earthquake occurred on the 11th March 2011 with Magnitude 9.0 and maximum seismic Level 7, which killed almost 20,000 people mainly due to Tsunami (see Figure 1). The epicenter was about 130 km offshore from the Miyagi Prefecture in the Pacific Ocean. According to our validation test with three-dimensional analysis of GNSS data, three major precursors were found 6 months, 5 months and 2 months prior to the earthquake as well as just 3 days prior (see MURAI, S and ARAKI, H, 2011, 2012).

The authors attempted to apply the MT method using the 6 GNSS reference CORS stations (Taneishi, Osako, Chokai, Yamagata-shinjo, Kitaibaragi and Nasu) within the range of 250 km from the most seriously damaged area, 95 days in advance of the earthquake, which is considered normal time period for the likelihood of an earthquake, features derived from X, Y, Z coordinates. We changed many different combinations of input parameters to determine the best correlation between the risk factor of the MD and the occurrence of the previously larger earthquakes.

Figure 2 shows the distribution of 6 GNSS reference stations as well as other GNSS CORSs of Geospatial Information Authority, Japanese Government, in Tohoku Area, in addition to the epicenter of East Japan Great Earthquake. The circle shows the coverage of 250 km.

Figure 3 showsμDEQ chart with the time span from the end of May 2005 to the end of August 2011 which includes the East Japan Great Earthquake of March 11, 2011 (called 3.11). The vertical axis shows the risk factor related to the MD with the appropriate threshold. The three thick blue lines in the lower part shows the past three larger earthquakes than Seismic Intensity Level 5 (A: Iwate Inland EQ: 2008.6.14: SI Level 6+, B: Iwate

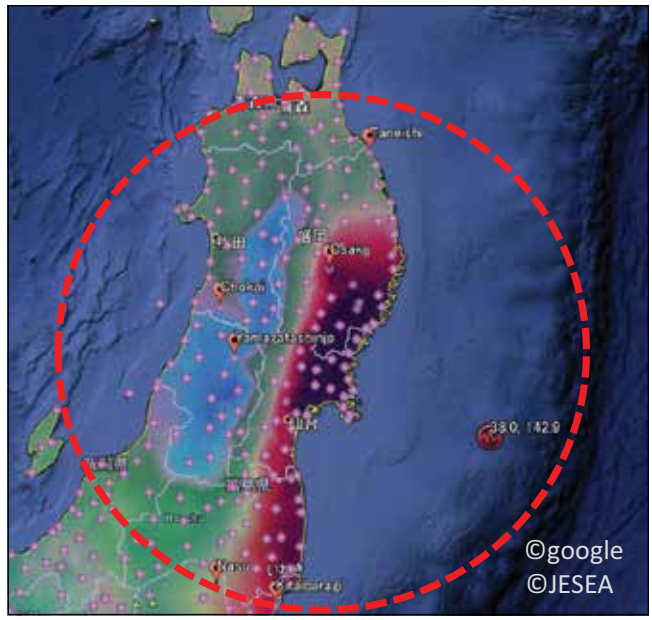

Figure 2 Six GNSS reference stations with the epicenter

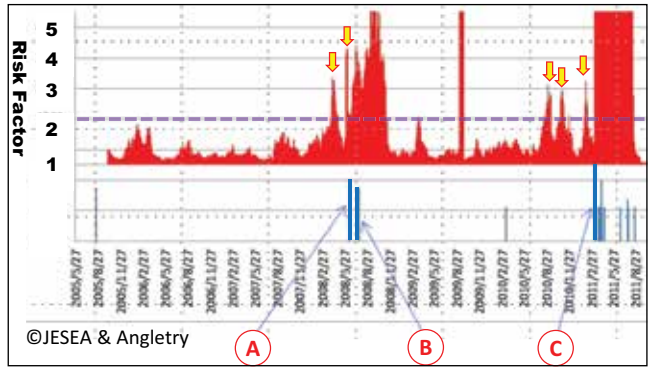

Figure 3 μDEQ chart which showed three EQ cases
A: Iwate Inland EQ: 2008.6.14: SI Level 6+
B: Iwate Offshore EQ: 2008.7.24: SI Level 6-
C: East Japan Great EQ: 2011.3.11: SI Level 7
The arrows show precursors in advance to EQ

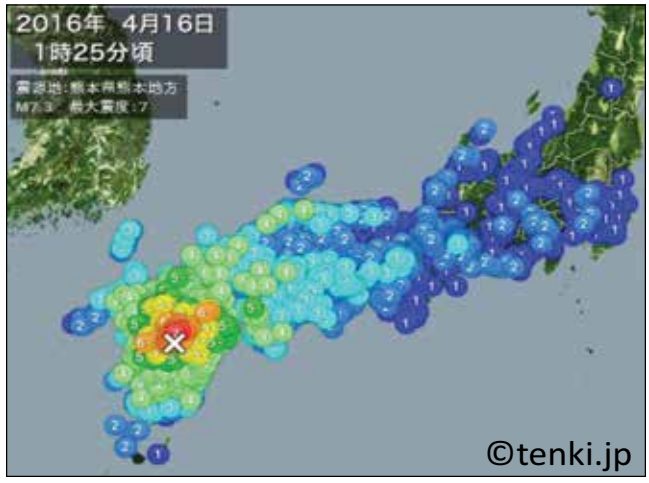

Figure 4 Kumamoto Earthquake (2016.4.16)
(the number shows seismic intensity level)

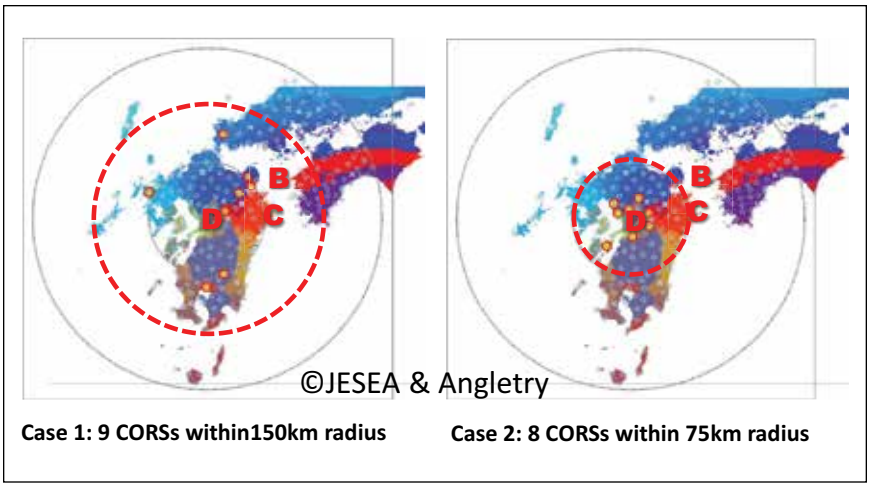

Figure 5 Location of Reference CORSs
A: Epicenter shown in Figure 1 and 2
B: Epicenter of Iyonada EQ
C: South Oita EQ
D: Epicenter of Kumamoto EQ

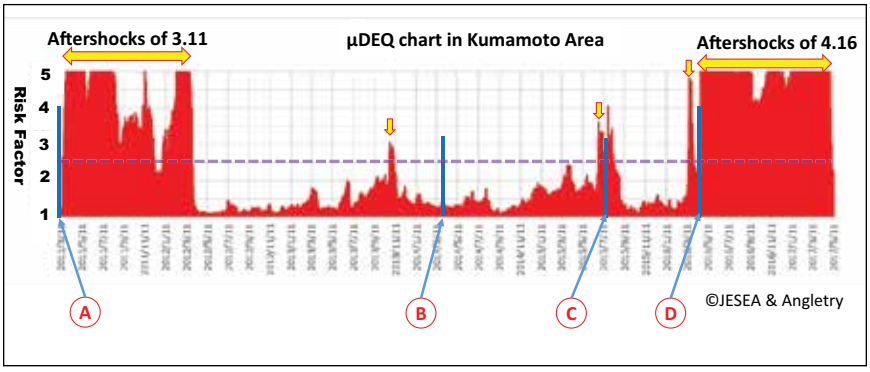

Figure 6 μDEQ chart in Case 1 for Kumamoto EQ
A: East Japan Great EQ: 2011.3.11: SI Level 7
B: Iyonada EQ: 2014.3.14: SI Level 5+
C: South Oita EQ: 2015.7.13: SI Level 5+
D: Kumamoto EQ: 2016.4.16: SI Level 7
The arrows show precursors in advance to EQ

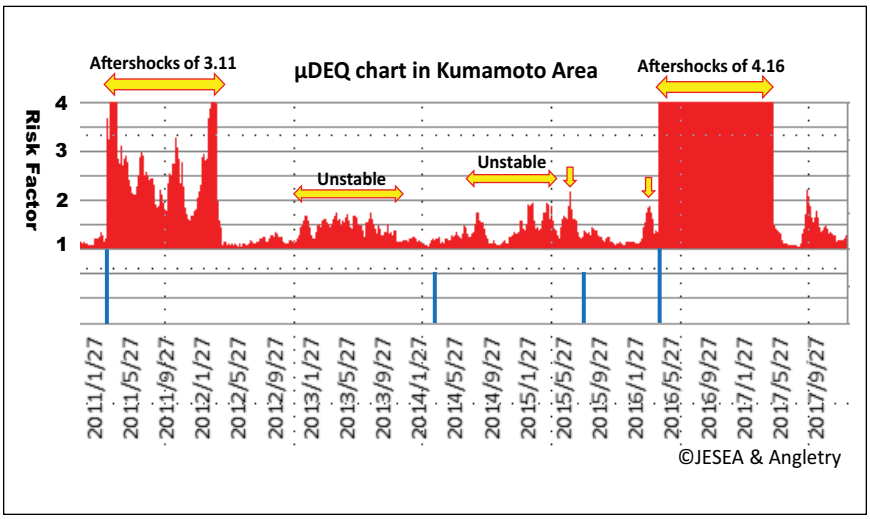

Figure 7 μDEQ chart in Case 2 for Kumamoto EQ The arrows show precursors in advance to EQ

Offshore EQ: 2008.7.24: SI Level 6-, C: East Japan Great EQ: 2011.3.11: SI Level 7). Yellow arrows show the precursors detected in advance of each event. In the case of 3.11, there were three precursors, which coincide with the result of the existing three-dimensional analysis. The size of the aftershocks of 3.11 are identifiable from the large red MD values.

We identified all earthquakes larger than Level 5 within 150 km radius from Sendai City between January 2015 and May 2017 and checked the cross relations as follows;

Case 1: the abnormal risk factor was recognized and an EQ larger than Level 5 occurred within 3 months from the precursor (the prediction was correct).

Case 2: the abnormal risk factor was recognized but an EQ larger than Level 5 did not occur (the prediction was incorrect).

Case 3: the abnormal risk factor was not recognized but an EQ larger than Level 5 occurred within 3 months from the precursor (the prediction was incorrect).

Case 4: the abnormal risk factor for an EQ larger than Level 5 was not recognized and did not occur (the prediction was correct).

Table 1 shows the cross relation of correctness and incorrectness.

	Anomaly recognized	Anomaly not recognized
Larger EQ occurred	11 (Case 1)	1 (Case 2)
Larger EQ not occurred	7(Case 3)	19 (Case 4)

μDEQ chart in case of Kumamoto Earthquake

Kumamoto earthquake took place at 1:25 on the 16th April 2016 with M7.3 and SI Level 7 and the epicenter with the depth of 10 km in Kumamoto City, Kyushu Island, Japan (see Figure 4). However, a foreshock occurred at 21:26 on the 14th April 2016 with M6.4 and SI Level 7, which confused most citizens who imagined that a larger

earthquake would not take place. This misunderstanding caused more fatalities as many people stayed in their houses which collapsed at the time of the earthquake (MURAI, S and ARAKI, H, 2016).

We tried to apply the MT method using different input parameters for validation tests. Out of the validation tests the following three cases are shown below (see Figure 5).

Case 1: 9 reference CORSs within the radius of 150 km.

Case 2: 8 reference CORSs within the radius of 75 km

Case 3: 1 reference CORS at Kumamoto City, close to the epicenter (see Figure 5)

Figure 6 shows μDEQ chart in Case 1 with the relation between abnormal risk factors and the previous larger earthquakes such as the aftershocks of 3.11 East Japan Great Earthquake with the epicenter of aftershocks far from Kyushu Island, Iyonada Earthquake on the 14th March 2014 with M6.2 and SI Level 5+ and South Oita Earthquake on the 13th July 2015 with M5.7 and SI Level 5+. The abnormal precursors in advance of the larger earthquakes can be identified in this figure.

Figure 7 shows μDEQ chart in Case 2 with the precursors in relation of past EQs. Before large EQs, precursors and/or unstable conditions are recognized as shown in the Figure.

The precursor for South Oita EQ and Kumamoto EQ were well recognized in the figure, though Iyonada EQ did not show the precursor clearly because the epicenter of Iyonada EQ is outside of the 75 km radius. However, before the Iyonada EQ, unstable conditions are recognized in the Figure.

Figure 8 shows μDEQ chart in Case 3 with the precursors in relation of the past two Kumamoto EQs which occurred on the 2011.10.5 with M4.4, SI Level 5+ and on the 2016.4.16 (M6.4 and SI Level 7). The first EQ was very local having hit just Kumamoto City Area shown in Figure 9. The precursor of the first local EQ was only recognized clearly in Case 3.

Case studies show that the selection of reference CORSs influences the coverage of the prediction.

Prediction map with risk intensity

After a number of validation tests using the MT method, the authors succeeded to make a prediction map of Japan with risk intensity ranging from 1 to 5 for 30 separate areas with two reference CORSs. Figure 10 shows an example as of January 13 2018. The level 5 shows the highest risk area. The analysis time was around 4 or 5 hours in total depending on the input parameters.

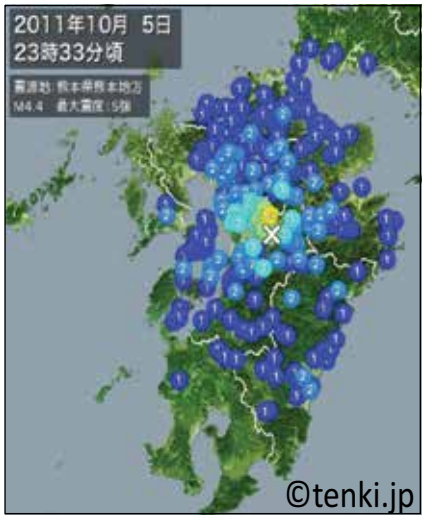

Figure 9 Kumamoto Earthquake (2011.10.15)

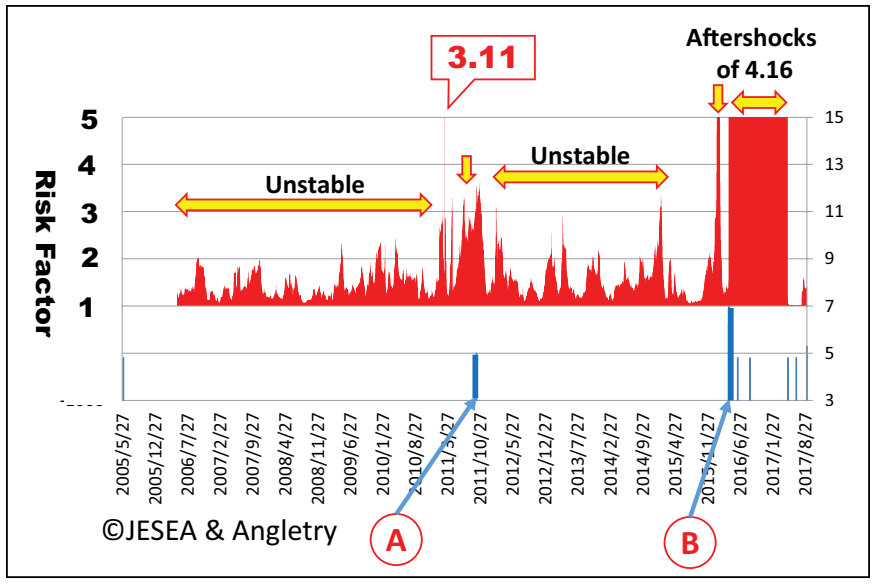

Figure 8 μDEQ chart in Case 3 for Kumamoto EQ
A: Kumamoto EQ: 2011.10.5: SI 5+, B: Kumamoto EQ: 2016.4.16: SI 7

Figure 10 EQ Risk Map as of 2018.01.13

Conclusions

The MT method will be feasible to achieve precise prediction of larger earthquakes if big CORS daily data of more than ten years are provided. However, it is necessary to determine the optimal combination of input parameters to maximize the correlation between the risk factors resulted from the MT method and previous larger earthquakes.

It would be feasible to divide Japan into smaller regions than the large areas used in applying the MT method, because the reference CORSs show similar behavior with high variations, which make the MT method more efficient, as well as reducing computation time.

The establishment of reliable prediction of large earthquakes based on the MT method will take time. Correctness of prediction can be assured by comparisons with the results of the so far successful existing 3D analysis.

Acknowledgment

The authors thank Mr Toshihiro Kitta, President of JESEA for his warm support of the research. The authors appreciate Prof John Trinder for his kind editing the English paper.

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Geomatics and GNSS education in India

Academicians discuss the prospects and challanges

Geodesy education needs special attention

Maj Gen (Dr) B.Nagarajan
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When we talk about Geodesy/ Geomatics education in the country, people normally relate themselves only to remote sensing and GIS with a vague idea of some Surveying practices included. There is hardly any institution in the country where, Geodesy, the mother of all areas in geospatial technology, is covered in a satisfactory manner. Even in several engineering colleges, where geodesy is included in the title of the course, it is essentially principles of surveying which is covered in the garb of geodesy. At PG level, the courses covered are essentially on remote sensing and GIS. It appears that there has been an overselling of the remote sensing and GIS technology, probably because of market forces, absence of any trained faculty pool, and limited understanding of the area geodesy.

There are more than 180 institutions in the country which offer Post Graduate, degree and diploma courses in Geoinformatics today but none of them (except for IIT Kanpur, Anna University, Chennai and one odd other) which offer courses on Geodesy in a satisfactory manner. There is virtually no M Tech level research work in geodesy in last 10 years. Further, not even 5 PhDs have been produced in this area in the last 15 years. The reason may be several fold but important ones are

i. Lack of clarity on understanding the role and significance of geodesy in nation building, study of earth and environment.
ii. Lack of trained/qualified faculty.
iii. Lack of properly equipped labs (equipment being quite expensive).
iv. Overselling of some areas of geospatial technology suggesting that there is hardly any role for geodesy. This situation has produced many mediocre institutions, faculty and students/ manpower who are only familiar using a set of commands in some RS/GIS SW and do not have much depth of the subject in general and geodesy in particular.
v. Lack of standardized curriculum design for Diploma, Bachelors and Masters Courses in all universities, constant training of teachers for upgrading their knowledge, urgent need for infrastructure improvement in these universities etc. as key aspects.

Geodesy education needs special attention from government to bring in the necessary policies, programs, institutional frameworks and networks, career opportunity schemes, etc., so to generate an indigenous pool of expertise in Geodesy. Otherwise, this will become an extinct area devoid of any expertise in the country and virtually no representation at the international fora. MHRD task force identified 6 broad areas for development of geospatial technology (MHRD Report, 2013) But these broad categorization looks apt for the geospatial technology in general, but fails to address teaching, research, capacity building and industry requirements of Geodesy in particular. A careful study of courses and expertise in geodesy from around the world clearly indicates that very strong foundations in mathematics and physics are indeed required for geodesy. Since the field of Geography and Geology without much of Mathematical and computer science background has taken over the subject of Geomatics in the country, the prevailing courses in geospatial technology have probably deliberately ignored this vital basic requirement.

The paucity of geodesy experts in the country has been the key reason for the sorry state of education and research in the field of geodesy the 'mother of all geospatial science'. It has been observed that geospatial technology is at boom in the nation. Many conferences, workshops, high-level meetings are being conducted time-to-time to discuss about various issues and the need for establishing various geospatial policies and devoted geospatial groups. However, it is surprising that the base of all the geospatial science and technology has never been discussed and is generally avoided.

The paucity of geodesy experts in the country has been the key reason for the sorry state of education and research in the field of geodesy the 'mother of all geospatial science'.

Currently, India does not have a well-defined horizontal, vertical and gravity datum. India does not have its precise DEM. The organizations like SOI, NRSC, NGRI, GSI, ONGC, OIL, etc. are collecting their data of interest on a regular basis. However, if there is no National datum defined, then most of these data becomes vague and inappropriate to use and come up with some concrete conclusions. The superstructure fields like geology, remote sensing and GIS have been developed to a great extent in the country without proper consideration to its strong foundation that is, Geodesy.

When we want to discuss the Geodetic Infrastructure in a country we generally dwell on the following:

a. Precise Definition of Horizontal Geodetic Network on which the Country's Surveying and Mapping is based. The accuracy requirements of all scales of mapping (from large scale maps say 1: 10000 and larger to medium scale 1:25000, 1:50000 and small-scale maps say scale 1:250000 and smaller) are to be met. Its definition generally follows the Surveying Principle of 'Whole to Part'.
b. Accurate Definition and Realization of a Vertical Datum over which heights of points of the terrain are measured taking care of water flow criterion and inter-visibility of points in the defined height system.
c. Precise Definition and Realization of a Gravity Datum, meeting the accuracy requirements of various applications for which the gravity measurements are made either from terrestrial, airborne or satellite gradiometric methods.
d. Precise Tidal Datum definition, for various Earth and Ocean system studies.

In the present day scenario, we can see an absolute chaos happening in the country. Due to lack of strong leadership from the National Mapping Organization that is Survey of India, every state in the country talks about setting up their own Geodetic network with so many CORS (Continuously Operating GPS reference Stations), Iconic and secondary control stations for Cadastral Surveying in their states. People who do not understand the accuracy aspects of Horizontal and Vertical networks, boast of providing Centimeter accuracy point positions and contours, to the dismay of various experts in the country. If this situation persists, the country will land up in sorry state of affairs, lagging far behind the rest of the countries in the world.

As regards the Student enthusiasm and involvement in GNSS/Geomatics courses, there is no doubt that it has caught the imagination of large section of the student community, thanks mainly to the contribution of Google and location based services provided by the GNSS systems. With Digital India awareness and high speed internet facilities available, students are feeling that the field of Geospatial Technologies can offer a lot, particularly in their employment opportunities. At least in IIT Kanpur where students join from different engineering background in the department of Geoinformatics, feel that with substantive knowledge offered at IITK in the field of Geodesy, GNSS, Lidar, UAV's, InSAR and Hyper spectral imaging, ample opportunities are there for their employment.

Unlike Western countries like USA, Canada, Germany etc., the educational Institutions in our country do not have any connectivity either with Industry or with Government organizations dealing with Geospatial Data. Government organizations like Survey of India (SOI), National Remote Sensing Centre (NRSC), Geological Survey of India (GSI), Oil and Natural Gas Commission (ONGC), Council of Scientific & Industrial Research (CSIR), National Institute of Oceanography (NIO), Earth System Science Organization (ESSO), Ministry of Earth Sciences (MoES), Ministry of Defence (MoD), Ministry of Science and Technology (MoST) should collaborate with educational institutes (IITs, NITs, etc.) for common projects, student exchange, training of the staff, etc. In that event, a positive environment can be generated to reap the fruits of what Modern Geospatial Technologies can offer to the mankind.

Satellite navigation holds immense promise for the future

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Indian Institute
of Technology,
Kharagpur, India

Satellite-based navigation systems collectively represent all navigation satellite constellations that provide the user with his/her position, velocity and time. Because of their versatility and ease of use, these systems are emerging as a key infrastructure of modern society. Different applications of satellite-based navigation are aircraft approach to landing, marine navigation, land navigation, time keeping in power grids, and financial and telecommunication networks, remote sensing of land, atmosphere, and sea, etc. With the advent of India's Navic (or Indian Regional Navigation Satellite System (IRNSS)), India has a major role to play in this promising area.

However, as with any other new fields, there are challenges to deal with to create awareness among students about the promise this field holds. As an educationist, I notice reservations among students to explore a new field. They are yet to take up this field for further studies.

In my opinion, this could be because of lack of exposure, limited job opportunities, and unavailability of a good number faculty in an institute working in this area. Often, they seek advice of their seniors while selecting a particular field for specialization. Consequently, they show less interest in working in a field that their seniors are not aware of. An additional challenge that I am facing

being in Aerospace is that students are less inclined to work in a field related to signal processing as compared to aerodynamics, aircraft structures, and controls and guidance. Again, this is perhaps because they have the opportunity to attend more courses in those fields. While I offer a GNSS course as an elective, so far, select final year students have registered for the course. That said, I am optimistic that over the years they will learn about the immense potential of the field and eventually show interest.

This would be possible when they will hear about the field from their seniors, who are attending my course and doing their project work. Although currently, there are limited job prospects in this field, I feel more job opportunities will open up for persons with knowledge in GNSS once IRNSS becomes fully operational and is extensively used in numerous civil applications. This may motivate more students to embrace satellite navigation as their field of specialization.

At present, ISRO is the main organization that funds research on satellite navigation systems. They sponsor projects from academic institutes under the RESPOND programme. I have heard that National Atmospheric Research Laboratory in Tirupati is also looking for ways to use IRNSS and other GNSS signals for atmospheric studies and remote sensing.

Major areas that can have industry-academia collaborations would be algorithm development for accurate, robust and reliable positioning, integration of IRNSS with other sensors as well as in smart phones

They also fund select projects through the Respond programme. Among private companies, Accord Software and Systems in Bangalore develops indigenous GNSS receivers and may be interested in engaging in collaborations with academia.

In my opinion, major areas that can have industry-academia collaborations would be algorithm development for accurate, robust and reliable positioning, integration of IRNSS with other sensors as well as in smart phones, novel applications of IRNSS including ones that require high precision, accuracy and reliability, atmospheric studies using multi-GNSS signals, remote sensing, etc.

In conclusion, satellite navigation holds immense promise for the future, but consistent efforts are needed on the part of a GNSS educationist to make students familiarized with its prospects and challenges through course and project work so that they take genuine interest and contribute to this field.

Road design parameter analysis based on the GNSS data

The purpose of current article is to demonstrate the use of such application in analyzing the parameters of road design

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Recently, most of the smart phones come with GNSS device. Owing to this, many GNSS based applications are being developed. Some of the applications, in spite of being free of cost, have full of features. The purpose of current article is to demonstrate the use of such application in analyzing the parameters of road design. For this purpose, an analysis was done to find a relationship between speed and the two other parameters, tortuosity and absolute elevation difference. Basically, speed is dependant on the road condition, the horizontal curvature, vertical curvature and the driver's attitude and skill. In the present study only horizontal and vertical curvature were considered. Tortuosity is a measure of curves and bends in horizontal plane while vertical curvature can be represented by the sum of absolute difference in elevation. For a given section of a road, tortuosity is defined as the ratio of actual length to the straight line length between the end points of the section. In the present study, a road from capital city Kathmandu to one major city in plane area of Nepal was traversed by privately owned passenger micro bus. Samsung J7 Prime was used as Android device to record GNSS data using OSMTracker app. The data recorded by the application was analyzed using QGIS (for GIS) and R (for statistics).

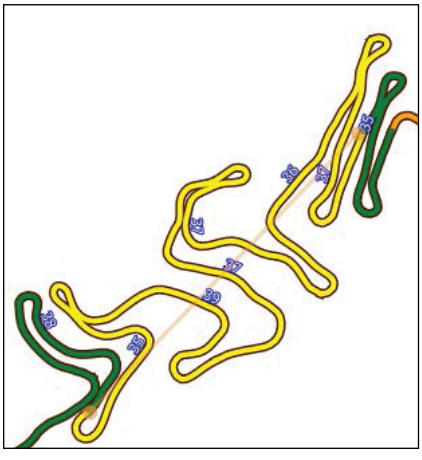

Figure 1. Concept of Tortuosity

Inroduction

Current research attempts to find a statistical correlation between the speed of vehicles and the horizontal and vertical curvatures of road segments. It is possible to use the geometrical design document to find the curvatures, however, in the present study, two parameters were developed to represent horizontal and vertical curvatures respectively so that these parameters can be calculated by the location information. The two parameters introduced in the study are:

1 Bhaduri (1992) had introduced the concept of tortuosity. Tortuosity (of a section of road) is defined as the ratio of length of the road section to the straight distance between the starting point and the end point. Figure 1 illustrates the concept of tortuosity.
2 Sum of absolute elevation difference (Referred to as cumulative elevation difference): This parameter is illustrated in Figure 2.

Above two parameters can be expressed as following two equations.

$$t\ rtuosity = \frac{L}{l} = 3.0/0.6 = 5.0 \quad (1)$$

where L is total length of road segment and l is straight line distance between the end points.

$$\Delta El = \sum|\delta El| = z1 + z2 + z3 + z4 + z5 + z6 \quad (2)$$

where ΔEl is cumulative elevation difference for 500m stretch, and δEl is the elevation difference at each location record.

Research methodology

Current research has following components:

1 Recording the location of vehicle
2 Dividing into equal segments using QGIS and python code
3 Multivariate statistical analysis of the three parameters: a) speed, b) tortuosity and c) cummulative elevation difference

Description of tracked road

Nepal is about 900km long in the east-west direction while the width in north-south direction varies from about 100km to 200km. More than 70% of the area of Nepal lies in the mountainous terrain. Northern part of the country is mountainous and the southern part connected to Indian boarder is flat terrain. In the present analysis, location tracking was done from capital city Kathmandu to Biratnagar in the southern Terai planes of Nepal. Based on the terrain, the track can be divided into two parts: 1) Kathmandu to Bardibas (about 200km in mountainous terrain, includes about 160km of BP highway), 2) Bardibas to Biratnagar (about 200km in plane terrain, includes 170km of East-west highway and 30km of urban road from Inaruwa to Biratnagar). Figure 3 and Figure 4 shows the two portions of the whole track.

Both the portions of Road were in good condition. However, the first section, for major part, is 1.5 lane narrow road while the second section is wide 2 lane road. Final 30km of the road passes through As the number of traffic is low in the first section, the width of road is considered to have no effect on the speed of the vehicle.

Location tracking

Location was tracked using android device with following specification.

Model: Samsung J7 Prime, OS : Android 7.0

There are large number of android apps available for navigation and most of them are freely available. For the present analysis, an offline, open source app called 'OSMTracker' (See: https://wiki.openstreetmap.org/wiki/OSMTracker_(Android)) was used. Its interface is simple. A single button click starts the app and as soon as location fix is available, it starts logging until stopped by using menu. On the way, during location tracking, it is possible to log points of interest which can include textual description, photograph, audio, etc.

Figure 5 shows a portion of road with google street background. It shows that the location tracked by the device is fairly accurate.

Segmentation of the track

Whole tracked road was divided into 500m segments. QGIS was used for GIS based analysis. A python code was developed which can do the followings in a single run:

- Divide the track into equal segments (length of segment can be provided as variable)
- Calculate speed, tortuosity and cumulative elevation difference as shown in Table 1
- Calculate fitted (proposed) speed which is obtained after multivariate analysis

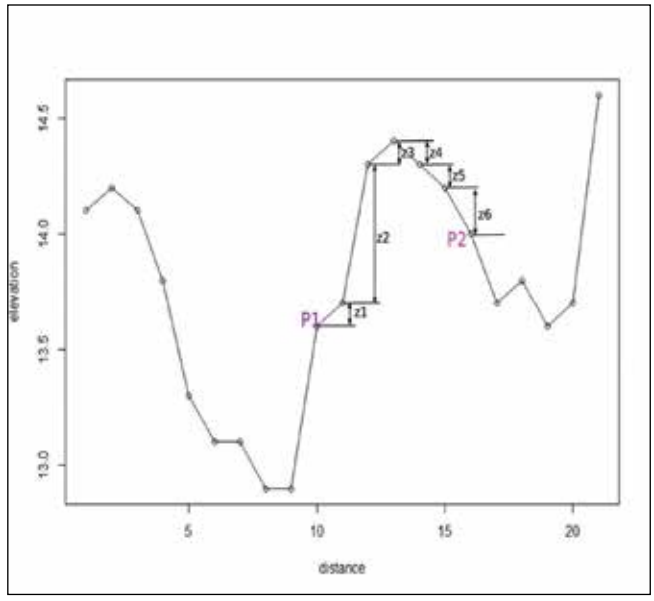

Figure 2. Concept of cumulative elevation difference

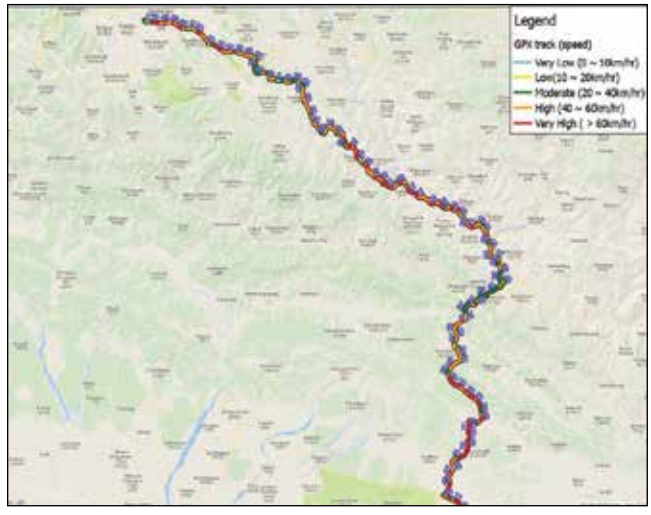

Figure 3. Kathmandu to Bardibas

Table 1. Compiled values of tortuosity and elevation difference

time (seconds)	length	speed (km/hr)	tortuosity	Elevation difference
51	500	36	1.16	17
38	500	48	1.00	14
54	500	33	1.00	19
23	500	78	1.00	9
29	500	63	1.00	1
29	500	63	1.00	6
30	500	59	1.00	8
153	500	12	1.05	18
29	500	63	1.00	9
31	500	57	1.00	13

Table 2. Summary of coefficients and error

parameters	Estimate	Std. Error
Intercept	95.23490	2.57490
tortuosity	-19.46632	2.49961
elevdif	-1.04890	0.07961

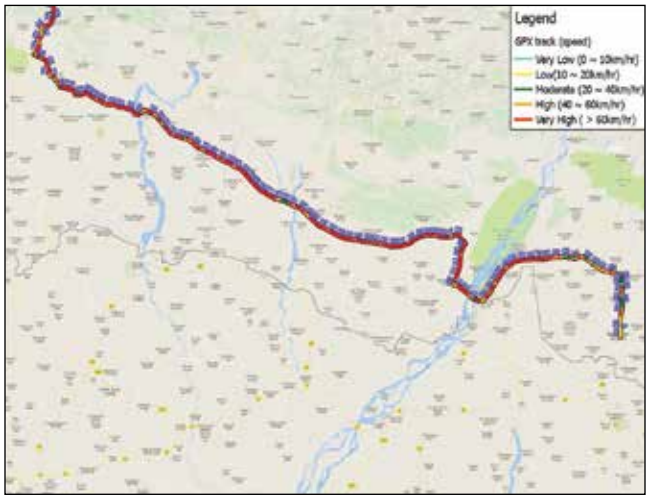

Figure 4. Bardibas to Biratnagar

Figure 5. Location layer above google street map background

Figure 6. Actual vs proposed speed map

Calculation of correlation

Relation between speed of the vehicle was calculate using R programming language. 'rstats' package of R provides many statistical tools for data analysis. In the present analysis, simple function for fitting of linear models was used. Following function gives the coefficients of linear function of fit.

$$lmreg = lm(speed \sim tortuosity + elevdif, data = shape) \quad (3)$$

In the above function, shape data is directly read from ESRI shapefile and the relation *speed~tortuosity+elevdif* is evaluated to produce an equation in the following form.

$$speed = a*(tortuosity) + b*elevdif + c \quad (4)$$

In the above formula *a* and *b* are coefficients and *c* is the intercept of the linear model. The values of these coefficients are stored in the variable *lmreg*, equation. To avoid very high toruosity which reduced the fitted values for higher speed *tortuosity* >3.0 was avoided. Similarly, very low speed which resulted due to stoppage for rest and refueling was filtered out using *speed* <20.

Analysis for whole the road produced following equation:

$$speed = 95.2 - 19.5*turtuosity - 1.05*(\Delta El) \quad (5)$$

Summary of the analysis result is shown in table 2.

Actual vs proposed speed can be shown in map (Figure 6).

Figure 7 shows the actual versus fitted values of speed.

It is evident from the graph that the proposed speed is generally lower than the actual after entering the flat terrain at Bardibas, excluding the final portion which passes through narrow and busy road from Inaruwa to Biratnagar and the urban road in Biratnagar itself.

The same formula obtained from the analysis was used for the vehicle speed from Janakpur (Mid Terai town) to Kathmandu.

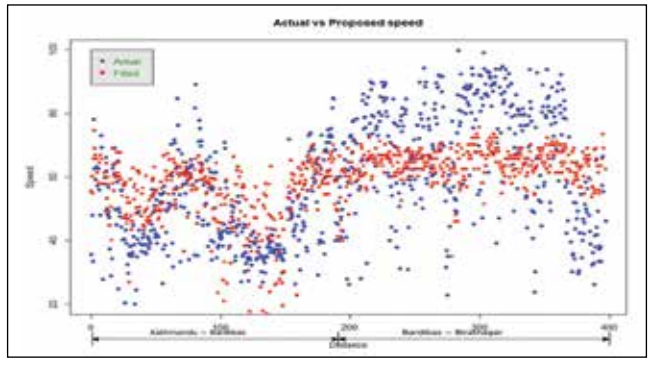

Figure 7. Actual vs proposed speed

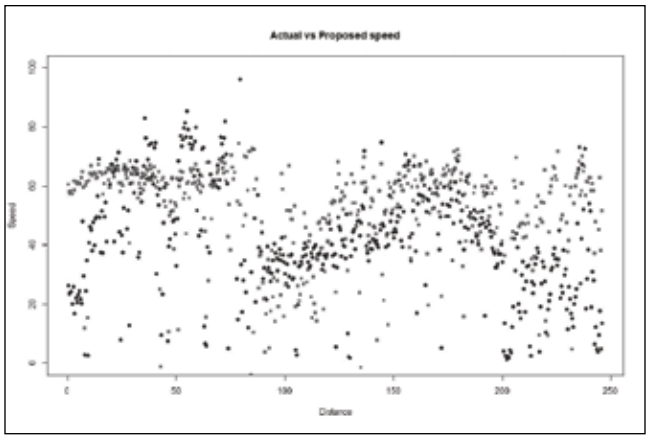

Figure 8. Actual vs proposed speed (Janakpur to Kathmandu)

The road passes through a) Janakpur to Bardibas 32 km (in flat terrain), b) Bardibas to Kathmandu (mountainous terrain).

The graph (Figure 8 Actual vs proposed speed (Janakpur to Kathmandu) clearly shows the correlation between the speed difference (actual vs proposed) and the real condtion as follows:

1 First few kilometers of road lies in the urban area of Janakpur, therefore the actual speed is much lower than proposed speed.
2 For the last 50 kilometers of the road there was heavy traffic jam due to maintenance work. As such, the actual speed is quite low.

Conclusions and discussion

Among the many parameters affecting the vehicle speed, effect of tortuosity and absolute elevation difference was analyzed. Current analysis shows the capability of GNSS based location tracking in the analysis of road parameters. Further analysis is needed to find the proper value of the coefficients for different types of road. The obtained coefficients can be used to study the conditions of road. Low speed compared to the proposed speed (computed using the parameters and coefficients) suggests either road pavement condition is bad or there is traffic jam. Similarly, higher actual speed may reflect the driver's reckless driving.

Acknowledgments

Maps used in the figures are generated with 'Google Maps' background in QGIS using Open Layers plug-in. Use of Google maps is duely acknowledged.

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Simple and effective RAIM technique for multiple outliers

In this paper, the conventional w-test is improved and the forward-backward method is used for multiple outliers. Two observations are flagged as outliers in each iteration by the extended w-test method

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With the development of modern Global Satellite Navigation System (GNSS), the accuracy performance of satellite positioning and navigation is obviously improved, which extends the range of applications greatly for the GNSS receivers. The integrity of GNSS plays a central role in extending the use of receivers. Since it is located at the end of the integrity processing chain, RAIM has the advantage of timely monitoring the receivers' local errors compared with the other ways.

The existing Receiver Autonomous Integrity Monitoring (RAIM) techniques are generally based on a single outlier assumption model. However, with the increasing number of available satellites, the probability of multiple satellites failure increases simultaneously. Meanwhile the GNSS measurements are affected by gross errors in signal-degraded scenarios (e.g., urban canyons and mountain areas).Therefore the RAIM techniques for multiple outliers need more attention and analysis. The new algorithms should be relatively simple in order to minimize the alarm time and not affect the sampling rate of the receiver.

Currently the analysis of RAIM techniques for multiple outliers has focused on the self-consistency of Least Squares (LS) residuals, but there are still some other different approaches. The limitations of the conventional w-test procedure when identifying multiple faults are analyzed in detail in [1]. To maintain algorithmic simplicity, the extended algorithm only deals with the correlation between w-test statistics after obtaining the initial adjustment.

Reference [2] introduces and modifies three kinds of RAIM techniques for multiple blunders used in urban scenarios. They are "Observation Subset Testing", "Forward-Backward Method" and "Danish Method". At the same time, the paper also points out the validity of separability check in avoiding excluding the good measurements. Reference [3] takes advantage of the great redundancy of modern GNSS and the new scheme identifies two outliers in each iteration. However some good measurements are sacrificed. If the number of outliers is known in advance, the parity vector method can be used to identify multiple faults as in [4,5], but it has much matrix operation leading to a large amount of computation. By using measurements collected on different epochs or introducing some constraints, the error of each satellite lost by LS integrity algorithm can be reconstructed as in [6,7]. Reference [8] takes into account the fact that fault detection is simpler than fault exclusion.

The initial fault-free constellation is firstly obtained and the remaining satellites are added into the constellation one by one. The new method only uses the approach of fault detection to implement integrity monitoring.

In this paper, the forward-backward and extended w-test method which identifies two outliers each iteration are combined. Meanwhile the separability check is executed. In the backward process, pseudorange residuals instead of LS estimator are used to determine whether the exclusion is correct. Thereby the amount of computation is reduced.

Conventional W-Test

Due to the non-linearity between the pseudorange and the receiver position, a linearization around an initial estimate must be performed. The measurement model is expressed by:

$$\Delta Y = H\Delta X + \varepsilon \tag{1}$$

where ΔY is the difference between the observed and the predicted pseudoranges; H is the matrix containing the first order derivative of the line of sights with respect to each component of state vector; ΔX is the shift of the state vector; ε is the measurement error vector.

The Weighted Least Squares (WLS) estimated solution of (1) is

$$\Delta X_{LS} = (H^T W H)^{-1} H^T W \Delta Y \tag{2}$$

where $W = (COV(\varepsilon))^{-1}$ is the weighting matrix and is considered the identity matrix in the paper.

The final residuals r can be obtained from (1) and (2).

$$r = \Delta Y - H\Delta X_{LS} = (I - H(H^T H)^{-1} H^T)\varepsilon \tag{3}$$

Denote $S = (I - H(H^T H)^{-1} H^T)$. LS integrity algorithms use the sum of the squares of the residuals as the test statistic, defined by

$$\mathrm{SSE} = r^T r \tag{4}$$

The global test is performed firstly. Assuming Gaussian measurement errors, then SSE should follow a χ^2 distribution (m-n) with degrees of freedom, defined as the difference between the number of measurements m and state dimension n. An inconsistency and outliers in the observations are assumed if the test statistic exceeds the global threshold, which is expressed by

$$\mathrm{T}_G = \chi^2_{1-P_{FA},(m-n)} \tag{5}$$

where P_{FA} is the probability of false alarm which is determined by the specific application requirements.

If the global test does not pass, local test is performed. In this case, the conventional w-test uses the normalized residual of each satellite as the test statistic. The expression is

$$\mathrm{w}_i = \frac{e_i^T r}{\sqrt{e_i^T S e_i}}, \mathrm{i} = 1:\mathrm{m} \tag{6}$$

where, e_i is a unit vector in which the i$^{\mathrm{th}}$ element has a value equal to one. Assuming the variance of the i$^{\mathrm{th}}$ measurement error ε_i is σ^2, then w_i should follow a normal $N(0,\sigma^2)$ distribution . The satellite is considered as an outlier if $|\mathrm{w}_i|$ exceeds the local threshold, which is expressed by

$$\mathrm{T}_L = N_{1-P_{FA}/2}(0,\sigma^2) \tag{7}$$

The conventional w-test method identifies one outlier each iteration, i.e., the measurement corresponding to the $|\mathrm{w}|_{\max}$ is excluded. In order to determine whether there are more outliers in the measurements, LS estimation is continued with the previously identified outlier excluded. Repeat until no more outliers or the number of remaining satellites is insufficient.

Limitations of the conventional W-Test

Because the conventional w-test identifies only one outlier each iteration, it is likely to cause false or missed exclusion when the test statistics are correlated. For example, suppose that there is a strong correlation between the two statistics, and only one of them has a gross error. The other statistic is likely to exceed the threshold and excluded by the RAIM technique. But the real outlier is left. Finally, after several iterations, the solution of the LS estimation is biased and the real outliers cannot be identified, resulting in a large positioning error. The correlation between the statistics is proportional to the number and the magnitude of outliers[1].

Thus, separability check is proposed in order to use w-test method for multiple outliers. The separability check calculates the correlation coefficients for every two satellites, and then those coefficients are considered when fault detection[1,2,9]. The correlation coefficient between two satellites is calculated as follows

$$\rho_{ij} = \frac{e_i^T S e_j}{\sqrt{e_i^T S e_i}\sqrt{e_j^T S e_j}} \tag{8}$$

where, e_j is a unit vector in which the j$^{\mathrm{th}}$ element has a value equal to one.

Extended RAIM technique for multiple outliers

In the current literatures, the RAIM techniques based on w-test method for multiple outliers concentrate on the processing of residual correlation, but still identify only one outlier at a time. Thus, when the residuals are correlated, the first iteration may exclude a good observation and adversely affect the subsequent iterations. For this reason, the conventional w-test method is improved and the forward-backward method is adopted to recover the observations wrongly excluded as much as possible.

If the global test does not pass, the extended w-test method identifies two outliers instead of one at a time when local test is performed. The test statistic corresponding to the i$^{\mathrm{th}}$ and j$^{\mathrm{th}}$ satellite is

$$\mathrm{w}_{ij} = \frac{e_{ij}^T r}{\sqrt{e_{ij}^T S e_{ij}}}, \mathrm{i,j} = 1:\mathrm{m}, \mathrm{i} \neq \mathrm{j} \tag{9}$$

where e_{ij} is a vector in which the i$^{\mathrm{th}}$ and j$^{\mathrm{th}}$ element has a value equal to one.The two satellites corresponding to the $|\mathrm{w}|_{\max}$ are flagged as outliers.

Separability check of the residuals is then executed according to (8). For each satellite that has identified, find the one with the highest correlation among the remaining satellites. If the correlation coefficient exceeds a certain threshold, this satellite is also flagged as an outlier. Therefore, up to four outliers can be identified each iteration. Repeat until no more outliers or the number of remaining satellites is insufficient. The initial outlier-free constellation and initial position information is obtained at the end of the forward process.

In the backward process, each flagged outlier is reintroduced. The LS estimation is no longer carried out and the initial position is used to calculate the pseudorange residual of each flagged outlier to determine whether to recover it. Since the matrix operation is involved in the LS estimation, calculation of residuals can simplify the algorithm. The residual of one satellite is calculated as follows

$$\Delta y = \rho - l + c\delta t_s - \delta t_u - \Delta I - \Delta T \tag{10}$$

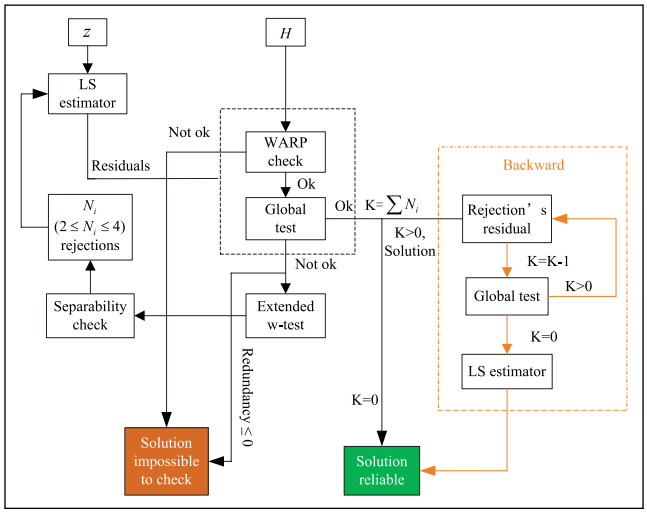

Figure. 1. Scheme of the extended RAIM technique for multiple outliers

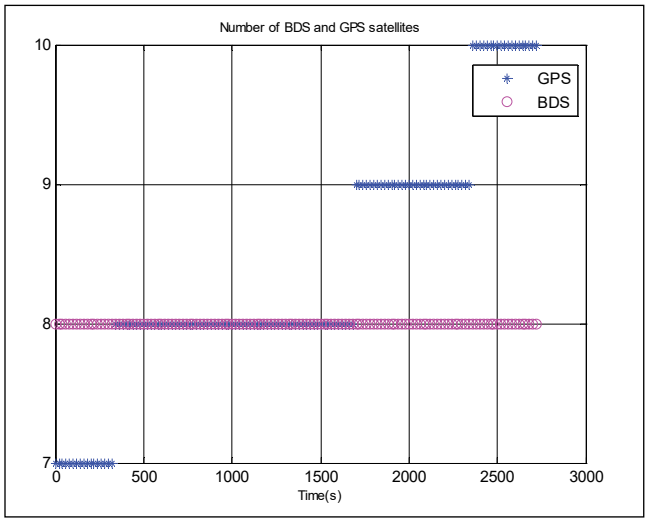

Figure. 2. Number of avaliable satellites

where Δy is the residual; ρ is the observed pseudorange; l is the distance between the initial receiver position and the satellite; δt_s and δt_u are the satellite clock and the receiver clock error respectively; ΔI and ΔT are ionospheric delay and tropospheric delay respectively.

Therefore, the final residual vector is

$$r = \left[\Delta Y_{free}^T \quad \Delta y\right]^T \tag{11}$$

where ΔY_{free} is the residual vector of the initial outlier-free constellation obtained by the forward process. The test statistic is calculated according to (11) and (4) and the global test is performed. If the statistic does not exceed the global threshold, this flagged outlier will be recovered as a good measurement. After all the flagged outliers are confirmed, the final outlier-free constellation is obtained and the LS estimation is performed as the final fixed solution of this epoch. The scheme of the extended technique is shown in Fig. 1.

The extended technique procedure can be outlined as follows:

1) Execute LS estimation using m observations and compute the test statistic according to (9);
2) The two observations corresponding to the maximum statistic are flagged as outliers;
3) Execute separability check according to (8).For each of the two flagged outliers, if the maximum coefficient exceeds the threshold, the corresponding observation is also flagged as an outlier. Assume the number of outliers flagged by this iteration is N_i ($2 \le N_i \le 4$);
4) Exclude the flagged outliers from the current observations;
5) Repeat *1) ~ 4)* until the global test is passed and obtain the initial outlier-free constellation and the initial position information. Denote the total times of iteration as t and the number of initial outlier-free observations as OF, then $OF=m-N_1-N_2-\ldots-N_t$;
6) Compute the residual of each flagged outlier according to (10) and the test statistic according to (11) and (4). If the global test is passed, this outlier is recovered as a good observation. Denote the total number of the recovered observations as RE;
7) Obtain the final outlier-free constellation which has $OF+RE$ observations. LS estimation is performed using these observations as the final fixed solution.

Simulation analysis

A dual-system receiver produced by our institute which can process GPS L1 and BDS B1 signals is used to collect original measurements. A static test of about 45 minutes was carried out. The antenna was located on the roof of our laboratory building. The performance of the conventional and extended technique is compared by post processing. During the test period, the number of visible satellites is shown in Fig. 2.

In order to investigate the adaptability of the RAIM techniques, an error whose value is 60 meters is added to the different

satellites' pseudorange at different time. Certain satellites are assumed to be outliers at the 908sec and 1908sec respectively. The specific scenarios are shown in table I.

In the table, 'B' represents BDS and 'G' represents GPS. 'B' or 'G' is followed by the PRN number of the satellite. When the single outlier and double outliers are investigated, the navigation mode of the receiver is set to BDS. But the navigation mode is set to BDS + GPS when 7 outliers is investigated since single BDS cannot identify so many outliers.

In the scenario of single outlier, the conventional technique can identify the outlier correctly at the first iteration, indicating that the conventional technique works perfectly for single outlier. The detection process of the extended technique is shown in table II. The satellite in parentheses is the outlier flagged by the separability check, and '0' indicates that there is no satellite which has a correlation with the identified outlier.

Table I: Different simulated scenarios

Scenarios	Time & satellites	
	908s	1908s
Single outlier	B4	B7
Double outliers	B4,B5	B1,B7
7 outliers	B4,B5,B6,B9, G18,G20,G21	B1,B2,B7,B10, G12,G15,G24

As can be seen from table II, after the good observation is flagged as the outlier, the real outlier having a strong correlation with it is also flagged by the separability check. Meanwhile the backward process can recover the observation wrongly flagged by the forward process.

Table II: Extended RAIM technique for single outlier

908s		**1908s**	
Forward		*Forward*	
Iteration 1	B2(B4),B7(0)	Iteration 1	B5(0),B7(0)
Backward		*Backward*	
Recover	B2,B7	Recover	B5
Identified outliers		*Identified outliers*	
B4		B7	

Table III: Conventional RAIM technique for double outliers

908s		**1908s**	
Iteration 1	B7	Iteration 1	B5
Iteration 2	B10	Iteration 2	B6

In the scenario of double outliers, the detection process of the conventional technique is shown in table III. As can be seen from table III, because the conventional w-test method only identifies one outlier at a time, the good observation is wrongly excluded at the first iteration. After removing the good observation, the weight of the real outliers is improved, this further causes wrong detection at the subsequent iteration. The navigation solution is finally biased and has a large error.

The detection process of the extended technique is shown in table IV. As can be seen from table IV, since the extended technique identifies two outliers at a time, the real outliers are identified correctly at the first iteration. The good observation having a strong correlation with the real outliers is also flagged by the separability check, but it is recovered in the backward process.

In the scenario of 7 outliers, the detection process of the conventional technique is shown in table V. table V shows that, the conventional technique can only correctly identify BDS outliers at the 908s. Both of BDS and GPS outliers are wrongly indentified at the 1908s.

The detection process of the extended technique is shown in table VI.

Table IV: Extended RAIM technique for double outliers

908s		**1908s**	
Forward		*Forward*	
Iteration 1	B4(B1),B5(0)	Iteration 1	B1(B4),B7(0)
Backward		*Backward*	
Recover	B1	Recover	B4
Identified outliers		*Identified outliers*	
B4,B5		B1,B7	

Table V: Conventional RAIM technique for 7 outliers

908s		**1908s**	
Iteration 1	B5	Iteration 1	B4
Iteration 2	B4	Iteration 2	G20
Iteration 3	G24	Iteration 3	B2
Iteration 4	B9	Iteration 4	G24
Iteration 5	B6	Iteration 5	G21
Iteration 6	G12	Iteration 6	B5
		Iteration 7	B6
		Iteration 8	B9

Table VI: Extended RAIM technique for 7 outliers

908s		**1908s**	
Forward		*Forward*	
Iteration 1	G20(0),G21(0)	Iteration 1	G20(0),B4(0)
Iteration 2	G18(0),G12(0)	Iteration 2	G24(0),B2(0)
Iteration 3	B4(G15), B5(G24)	Iteration 3	B7(0),B10(0)
Iteration 4	B6(0),B9(0)	Iteration 4	G12(G15),B1(0)
Backward		*Backward*	
Recover	G12,G15,G24	Recover	G20,B4
Identified outliers		*Identified outliers*	
B4,B5,B6,B9 G18,G20,G21		B1,B2,B7,B10 G12,G15,G24	

As shown in Fig. 2 and table VI, the extended technique can correctly identify all the 7 outliers when the number of satellites is 16 or 17. Comparing table VI with table V, it indicates that the iteration times of the extended technique is less than that of the conventional technique.

The position errors of the two techniques in the scenario of double outliers and 7outliers are shown in Fig.3 and Fig.4 respectively. In these two scenarios, the conventional technique

excludes the good observations and leaves the real outliers, resulting in a larger positioning error. However the extended technique is able to correctly identify the outliers, making the positioning error relatively small. Since the number of satellites is reduced after the outliers are removed, the positioning error at the test time is slightly larger than that of the other moments.

Conclusion

RAIM is an essential part of the modern GNSS receivers and its performance plays a central role in extending the range of application for receivers. The conventional RAIM techniques which are based on single outlier assumption show failure for multiple outliers.

In the paper, the conventional w-test method is improved to make it adequate for multiple outliers. The extended technique indentifies two outliers at a time and separability check is executed to avoid missed or false detection when the statistics are highly correlated. Since up to four outliers are identified each iteration, the forward process can be accelerated. In the backward process, only the residual of each flagged outlier is calculated without LS estimation, and the amount of computation is further reduced. Simulation results show that the extended technique can effectively identify single outlier and multiple outliers, and the reliability and efficiency of RAIM is improved.

When the navigation solution is badly shifted by the outliers, it will cause good observations to appear as the outliers. Upon removal of these false detections the remaining residuals show better self-consistence. In this case, all RAIM techniques based on residual consistency and global test will fail. Future work will study the mechanism of this problem and how to solve it.

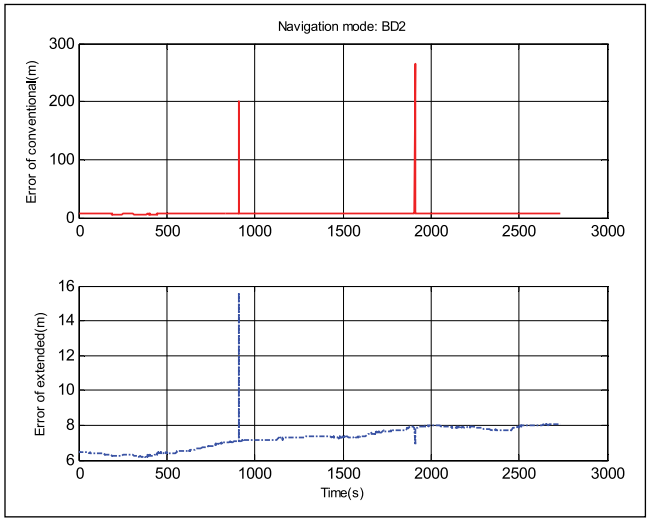

Figure. 3. Position errors when 2 satellites have outliers

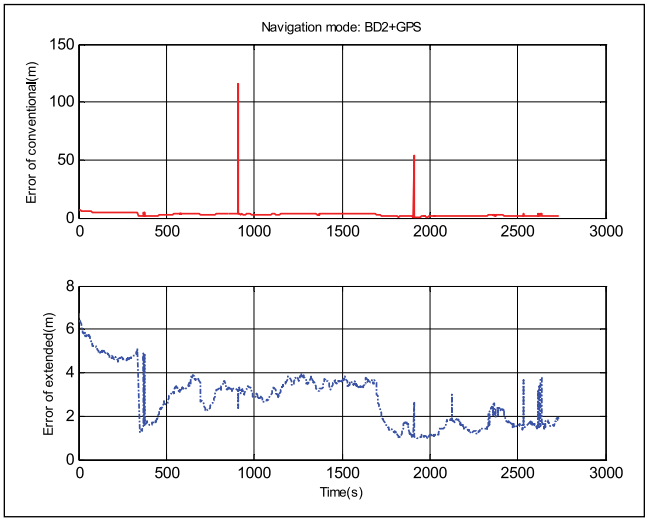

Figure. 4. Position errors when 7 satellites have outliers

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5) L. Zhao, L. Li, J. Cheng and S. Luo, "New RAIM algorithm for identifying simultaneous double-faulty satellites," Journal of Beijing University of Aeronautics and Astronautics, vo1. 36, no. 11, pp. 1261-1265, Nov. 2010.
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8) C. Chen and X. Zhang, "Novel method of multiple-satellite faults exclusion for global navigation satellite system," Journal of Beijing University of Aeronautics and Astronautics, vol. 37, no. 12, pp. 1480-1483, Dec. 2011.
9) A. Innac, M. Z. H. Bhuiyan, S. Soderholm, H. Kuusniemi and S. Gaglione, "Reliability testing for multiple GNSS measurement outlier detection," 2016 European Navigation Conference (ENC), 2016.
10) H. Jin and H. Zhang, "Failure detection using optimal parity vector sensitive to special sensor failure," Conference on Multisensor Fusion and Integration for ntelligent Systems, pp. 55-61, 1996.

Spoofers are completely different from jammers that block GNSS signals. Spoofers create GNSS-like signals that fool receivers to provide false location solutions.

We combat spoofers in two ways:

1. Detect and alarm that spoofer exist. Then distinguish the spoofer signal, ignore it, and use valid satellite signals.
2. Help find the direction that spoofed signals are coming from.

Spoofer detection is available in all of our OEM boards too.

JAVAD

www.javad.com

**“Why Javad?
Because it works where nothing else will and it has abilities and features that nothing else does.”**

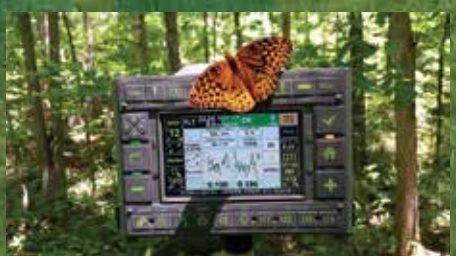
“I got some ridiculous ‘fixes’ today in some horrible situations. Reset receiver, moved around, etc. Tried to get a bad fix but had a hard time doing it.”

“Truly amazing with a 4” grape vine directly overhead and the tree cover.”

“I had 100% confidence this RTK was good. As soon as I stored the shot I inversed to my design point at that location and got 0.06’. No second PPK necessary! Then for the cherry on top, I processed the PPK at the office at it was 0.05’ from the RTK I stored. Just an amazing Surveying machine!”

“This thing is bad ass!”

“Thank you for the most awesome set of equipment I have had the pleasure of running in my 41 years of surveying. I am having the most fun I have ever had!”



The LS has increased our productivity 2:1

FL

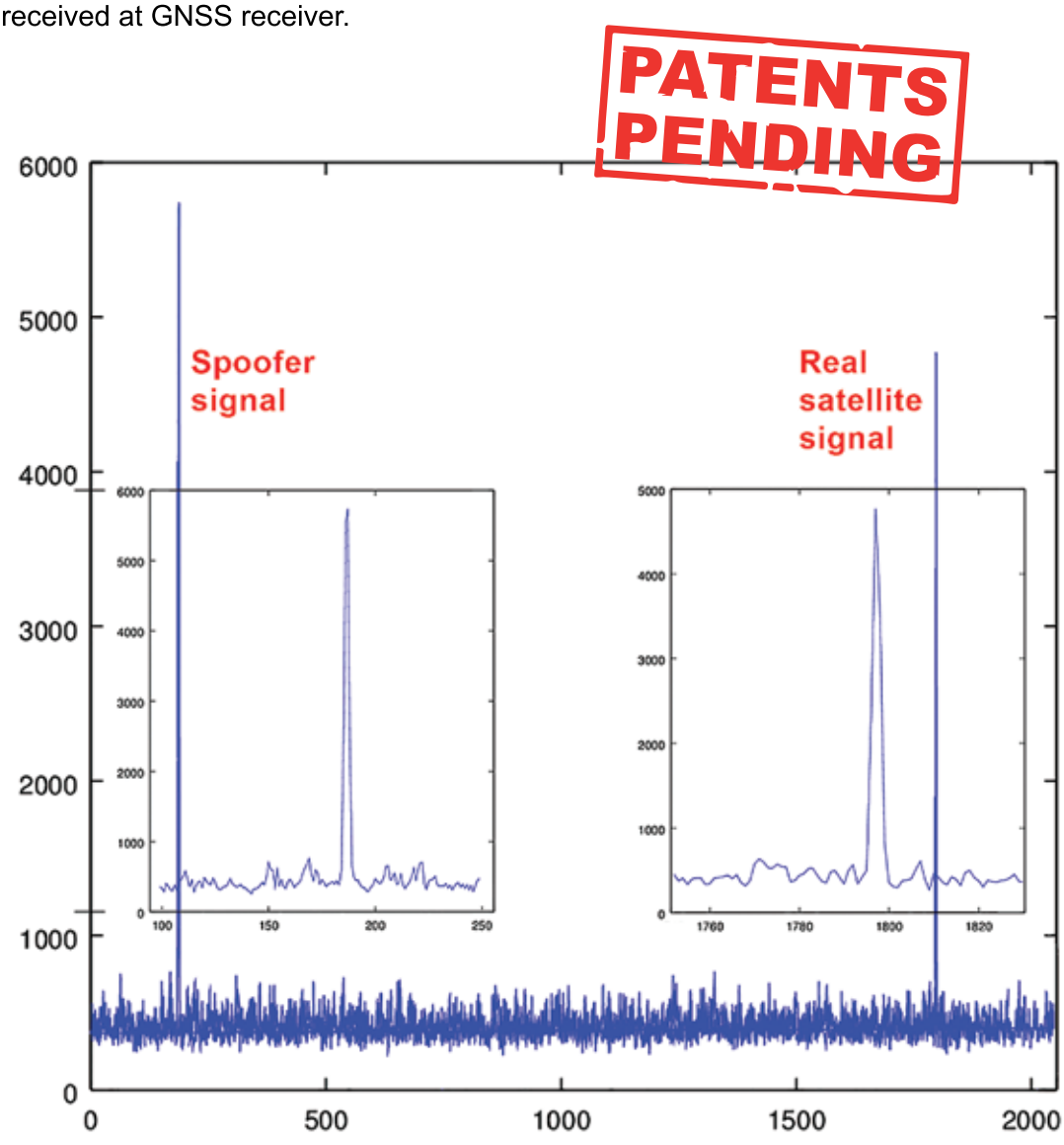
Spoofer Detection

With 864 channels and about 130,000 quick acquisition correlators in our TRIUMPH chip, we have resources to assign more than one channel to each satellite to find ALL signals that are transmitted with that GNSS satellite PRN code.

If we detect more than one reasonable and consistent correlation peak for any PRN code, we know that we are being spoofed and can identify the spoofed signals.

When we detect that spoofing is in effect, we use the position solution provided by all other clean signals (L1, L2, L5, etc... GPS, GLONASS, Galileo, Beidou, etc...) to identify the spoofer signal and use the real satellite measurement. If all GNSS signals are spoofed or jammed, then we alarm you to ignore GNSS and use other sensors in your integrated system.

Figure below shows an example of a spoofer signal and a real satellite signal received at GNSS receiver.



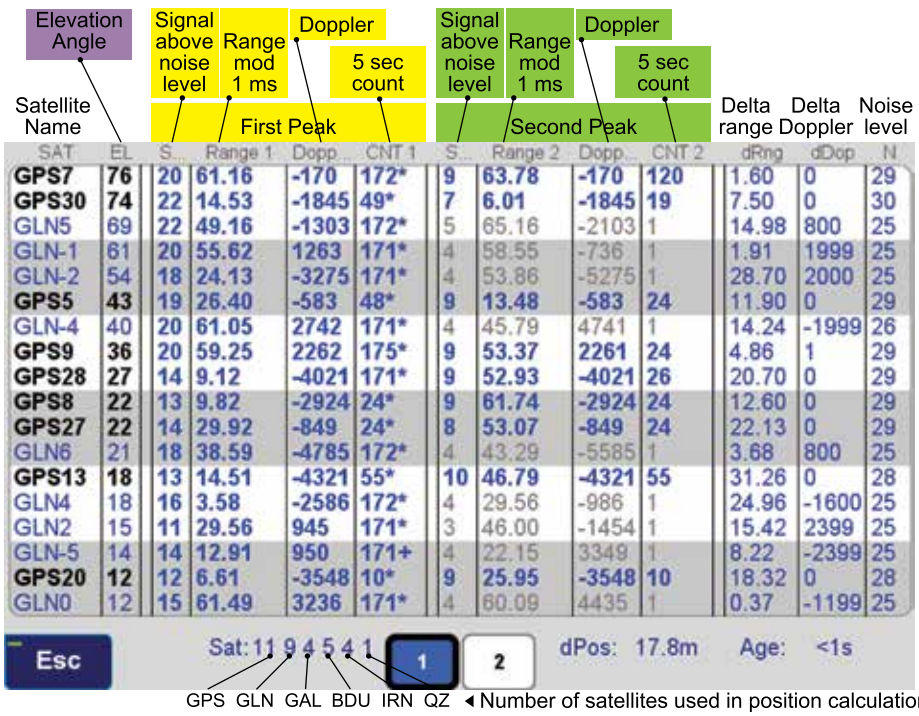
Satellite and Spoofer Peaks

The screenshots below are from a real spoofer in a large city. The bold numbers are for the detected peaks. The gray numbers represent highest noise, not a consistent peak. "*" symbol next to the CNT numbers indicate that signal is used in position calculation. Each CNT count represent about 5 seconds of continuous peak tracking.

SAT	EL	S..	Range 1	Dopp..	CNT 1	S..	Range 2	Dopp..	CNT 2	dRng	dDop	N
GPS5	33	16	61.14	1382	184*	4	25.95	181	1	29.32	1201	29
GPS7	51	21	14.39	1146	184*	4	18.21	-453	1	2.80	1599	29
GPS8	30	18	65.10	-918	184*	4	4.26	-1318	1	3.68	400	29
GPS9	12	14	40.46	2966	184*	4	2.08	3765	1	26.13	-799	29
GPS13	40	16	46.92	-3525	184*	4	8.21	-4325	1	25.80	800	29
GPS15	12	14	12.46	-4336	30*	5	33.00	-1536	1	19.52	-2800	28
GPS20	24	12	13.19	-1707	107*	4	29.32	-3307	1	15.11	1600	29
GPS27	16	11	10.26	1264	184*	4	43.55	63	1	31.22	1201	29
GPS28	53	19	9.41	-2724	184*	4	7.93	-4724	1	0.46	2000	29
GPS30	81	22	13.79	-332	184*	5	34.16	1266	1	19.35	-1598	28
GLN-4	54	20	62.08	1498	1158*	5	21.72	2697	1	24.16	-1199	25
GLN5	46	20	18.04	-2897	524*	4	26.26	-3697	1	7.20	800	25
GLN0	37	18	30.37	2355	1469*	4	38.37	1554	1	6.98	801	25
GLN-1	82	18	34.92	-776	189*	4	12.54	-1576	1	21.35	800	25
GLN-2	26	12	30.96	-4358	229*	4	11.80	-3158	1	18.13	-1200	25
GLN2	21	10	59.73	288	551*	4	47.55	1087	1	11.16	-799	25
GLN4	22	15	30.59	-3361	208*	4	11.74	-5361	1	17.83	2000	25
GLN-5	21	14	20.17	276	187+	3	25.45	2275	1	4.26	-1999	25

Esc Sat: 10 7 6 4 4 0 dPos: 19.0m Age: <1s

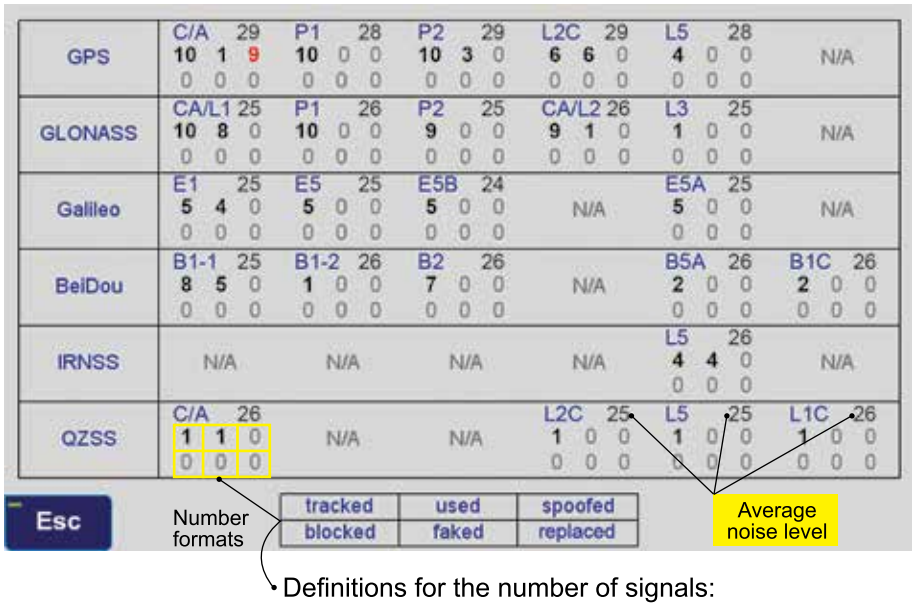
No spoofer. Only one reasonable peak for each satellite.



In the above screenshot all GPS satellites have two peaks and all are spoofed. We were able to distinguish the spoofer signal and use the real satellite signals in correct position calculation as indicated by the "*" next to the CNT numbers.

GNSS Overall View

The screenshot below shows the status of all GNSS signals.
The format and the signal definitions are explained below.



GPS L2C: L+M
GLN L3: I+Q
GAL E1: B+C
GAL E5: alboc
GAL E5B: I+Q
GAL E5A: I+Q
BeiDou B2: B5B
QZSS L2C: L+M
QZSS L1C: I+Q

Definitions for the number of signals:

Tracked: Tracked by the tracking channels and has one valid peak only.

Used: Used in position calculation.

Spoofed: Has two peaks. Good peak is isolated, if existed.

Blocked: Blocked by buildings or by jamming. If jammed, shows higher noise level.

Faked: Satellite should not be visible, or such PRN does not exist.

Replaced: Real signal is jammed and a spoofed signal put on top of it. Because of jammer, it shows higher noise level.

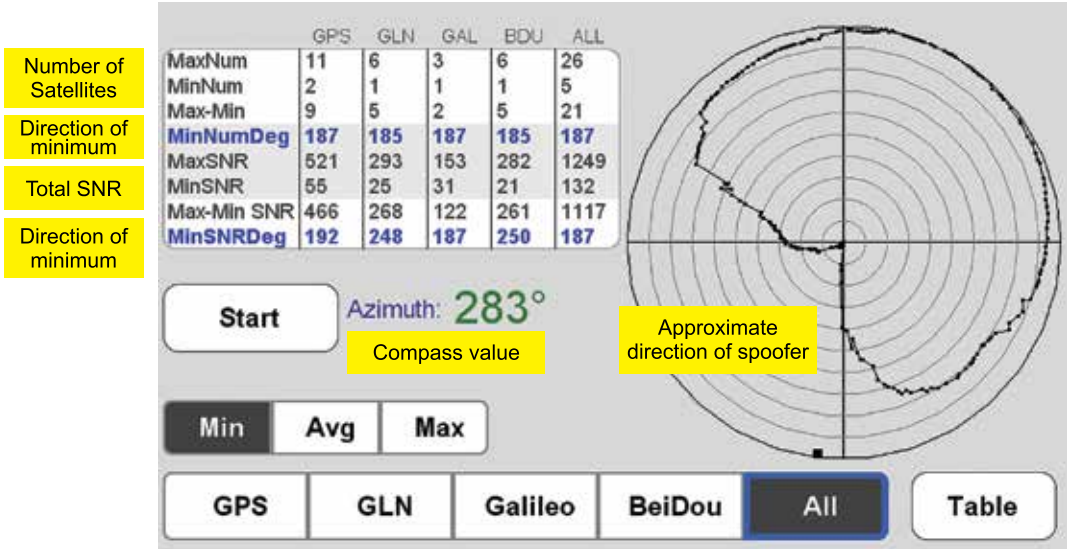
Spoofer detection available in all of our OEM boards too.

See details in GPS World expert opinions section “What is the biggest challenge facing designers of multi-constellation GNSS receivers today?” with Javad Ashjaee and at www.javad.com

Spoofer Orientation

When you detect that spoofers exist, you can also try to find the direction that the spoofing signals are coming from. For this, hold your receiver antenna (e.g. TRIUMPH-LS) horizontally and rotate it slowly (one rotation about 30 seconds) as shown in the picture and find the direction that the satellite energies become minimum. This is the orientation that the spoofer is behind the null point of the antenna reception pattern.

After one or more full rotations observe the resulting graph that shows approximate orientation of the spoofer as shown in figure below.

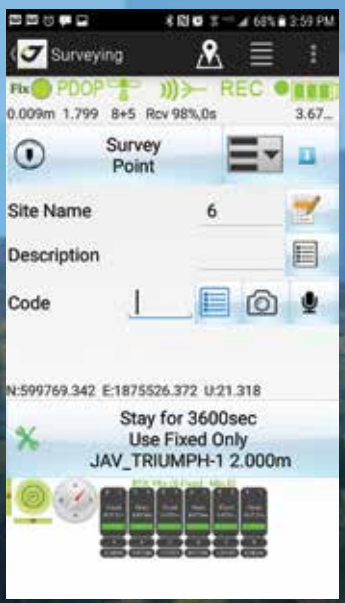


This screenshot is from the experiment within an anechoic chamber. That is why the picture is clean and smooth.

www.javad.com

Javad Mobile Tools (J-Mobile)

I used “Beast Mode” on a small project yesterday and all I can say is WOW!!!! Did Javad and Red Bull team up to enhance RTK or did my system drink hypercaffeinated coffee when I wasn’t looking? Amazing accomplishment/development Javad. I can’t imagine using any other GPS equipment.



Javad Mobile Tools (J-Mobile) is an RTK & static control software app which allows you to connect JAVAD GNSS receivers to Android™ or iPhone/iPad devices. J-Mobile includes a full set of RTK and static survey routines including, data collection (RTK and static), RTK stakeout, CoGo, localization and more.

“I surveyed 20 acres today and never used the total station.”

“Since I got the Javad system, I go places NEVER BEFORE possible, and WITH confidence, because, the quality checks are there.”

“The only bitching now is for the crew that has to take out the Hyper V.”

“Using licensed professionals for development has been a brilliant idea. Tip of the hat to the programmers and designers that put the original box together it appears to me that they knew where they were going with this years ago.”

FR

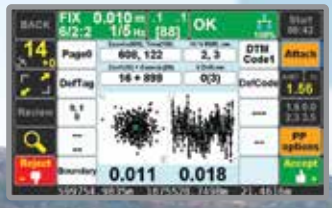
JAVAD

“More than just a ding, an RMS and here’s your answer, trust us. Complete Data Analysis for every shot.”

J-Field Software Features

864 Channels
RTK 6 Pack
BEAST MODE RTK

Only from
JAVAD GNSS



Verification
& Validation
Automatic

Only from
JAVAD GNSS

Customer favorite feature #1

Hybrid RTK
Another check on the work
PPK Solution

Only from
JAVAD GNSS

Customer favorite feature #2

RTK Rovers - On a Budget

TRIUMPH-2
Complete RTK
Network Rover

$5,680
with Budget Smartphone & JMT

$8,255
with Rugged Victor-LS & J-Field

TRIUMPH-2
Complete RTK
UHF Rover

$6,930
with Budget Smartphone & JMT

$8,265
with Rugged Victor-LS & J-Field

Pushing beyond the limits of technology in 2018

Perhaps sooner than we imagine, we will be talking about stitchless laser scans, flying laser scanners and voice-controlled total stations

Dr Burkhard Boeckem
Chief Technology Officer of Hexagon Geosystems

Self-learning total stations. One-button laser scanners. Calibration-free, forget-the-bubble GNSS receivers.

Just a few years ago, these concepts would have been unheard of in our industry. Today, they've not only become accepted, but, dare I say, expected. Technology is on a continual evolution, and at Hexagon, we are developing not just instruments and software to lead this evolution but mindsets to open the space and creativity to push beyond today's limits for future innovations.

Where do we see these opportunities? All around.

Technologies for everyone

To begin with, for technology to continue to evolve, it must be accessible to more people. I've shared before my fear our industry equates innovation with more difficult processes. This simply isn't nor should be the case. If we can't bring everyone along on our innovation journey, and instead raise barriers to entry and leave them behind, are we even really innovating?

We are continually seeing the adoption of the idea of creating technologies for all - making devices more intuitive, creating software to be more immersive, simplifying operations. Moving technology that was exclusive to only a few and developing it to be more inclusive for all, we are seeing real innovation across the board. At the core creation of the Leica BLK360, the world's smallest imaging laser scanner, was the concept of bring technology to a wider audience. Breaking down barriers to entry of technicality and expense, this reality capture solution was made for simple operations, capturing 360-degree HDR spherical imagery and 360,000 points per second laser scan at the single touch of a button. Pulling from the LiDAR technologies created within the Leica Geosystems' portfolio, the BLK360 is the epitome of taking large, exclusive, purpose-specific platforms and transforming them into small, inclusive, all-encompassing devices to provide a fit-for-purpose solution to all.

Moving technology that was exclusive to only a few and developing it to be more inclusive for all, we are seeing real innovation across the board.

Moving from the cloud to the edge

Technology originally evolved statically – it wasn't shared but stayed to one location. Then the power of information sharing was realised, entering the cloud. Several users could access the same information and work together in better collaboration.

An issue with cloud computing, though, is the time it takes for devices to access the central information. When you're out in the field, especially in tough outdoor situations where you have poor connectivity and poor bandwidth, and you need insights quickly to make informed decision, waiting for a central hub to first receive your data, then process it and finally send it back is not ideal. Enter edge computing where data processing is done at the outermost edge of the network, as in on the device.

We recognise the speed at which measurement professionals need to work, and that's why we develop our sensors

with powerful, fit-for-purpose processors on board. Our laser scanning solutions use more and more edge computing to process the millions of points collected for faster, cleaner results. When 3D models can be completed in the field, users not only realise time savings, but they can also make the best-informed decisions on site, making re-visits to sites to collect missed data nearly obsolete.

Going further than IoT

For the Internet of Things (IoT) to truly work, the device-generated data must be meaningful. That data must first be understood and then be connected in an open system. Only after this clarity and integration will the IoT truly be beneficial and purposeful for technology evolution.

In an open system, this meaningful data creates an ecosystem of shared insights. When different service providers enter a shared economy of information, not only do they provide the whole picture, but they also enhance their own offerings. No longer are they operating in a silo providing users a single piece of information, but they give the controls of the complete project to the stakeholders.

Consider a town located at the foot of a mountain, like we have so many of here in Switzerland. With monitoring GNSS receivers, total stations and interferometric radar placed along a potential avalanche route connected to processing software, like Leica GeoMoS or IDS Georadar's Guardian, any movement, any deformation from the norm is immediately communicated. When the local town's emergency services have GeoMoS or Guardian integrated into its operations centre, first responders are immediately alerted.

The benefit doesn't stop there, though. Imagine if this town's transportation department has already captured evacuation routes with laser scanning mobile mapping platforms, such as the Leica Pegasus:Two . These two departments share this data – deformation monitoring and evacuation route details – and they develop a shared economy of information that can create a safe, effective and life-saving early warning system. When we evolve past just the IoT, we find endless possibilities.

Automating for more than just easy operations

According to the Standards & Poor's Report, by 2030 there will be more than $50 trillion in infrastructure construction needs, yet only around $24 trillion will be available for this construction. This gap will not be bridged by operating as normal. Another technology evolution in the form of automation must be implemented to become more productive with what we currently have.

What does automation in construction look like? A machine operator no longer must worry about grading to a specified accuracy – input the measurements and the job can be automated to milimetres. Avoidance digging zones of cables or pipes are no longer a constant threat as they can be automatically detected and alerted to the operator. With personal protection systems, the safety of anyone working on a construction site is substantially increased.

In our business, automation comes in the way of sensors and workflows. Without the time-consuming tasks of diving through the processes and the big data, sensors combined with reliable workflows, like the Leica iCON machine control and IDS GeoRadar detection systems, marry information to action. Together, daily tasks on sites are automated, freeing up experts to concentrate on the bottom-line driven aspects of their jobs of gaining valuable insights to make deliverables better, on time and on budget.

Creating smart cities from digital realities

With a global population expected to reach 9 billion by 2050 and more than half of that already living in urban centres, cities are undergoing their own technology evolutions to become safer and more efficient for citizens. Yet, cities can't fully realise their potential as smart cities until they first become digital cities, and that comes from creating the digital reality.

To create the digital reality of a city, we must first digitalise every aspect – buildings, infrastructure, public transportation routes, surrounding terrain, documentation – everything. Then, we must make it smart. How? By taking that ecosystem of now digital physical features and supporting elements and connecting them to advanced insights. With analytics we garner from machine learnings and artificial intelligence, such as automated 3D object reconstructions, combined with the digital assets, we now can draw insights and make better decisions from the complete picture instead of a fragmented cityscape.

In Shanghai, the city has been captured with our airborne LiDAR sensors to create a complete digital reality of the city. This is the first step, and we are now working with city officials to create a smart digital reality of the city. This moves the city toward becoming a smarter city, connecting services, insights and informed-decision making to best support the more than 25 million people who live there.

Technology never stops evolving

Perhaps sooner than we imagine, we will be talking about stitchless laser scans, flying laser scanners and voice-controlled total stations. If there is one thing I have learned in my position as CTO, it's certainly that technology never ceases to advance and amaze.

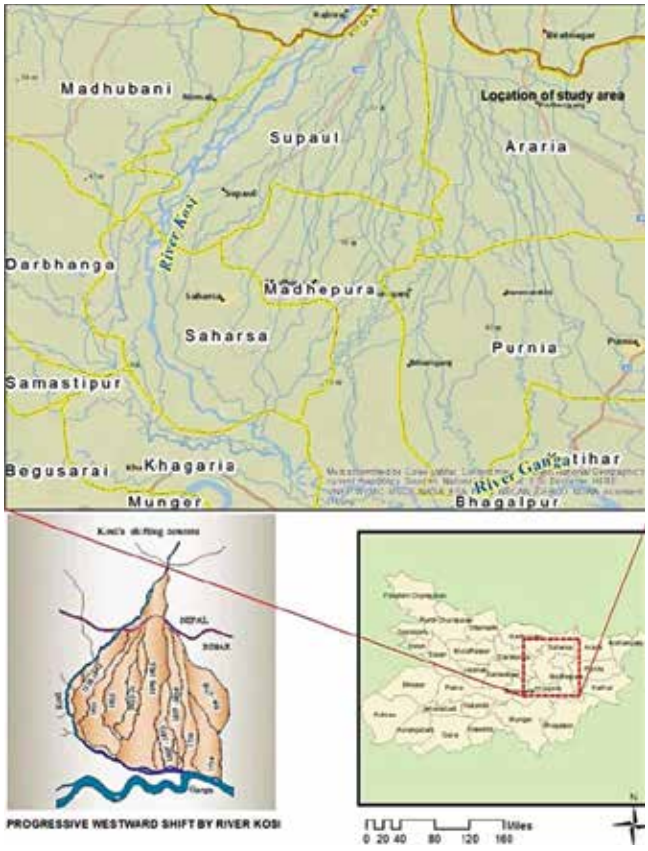
I'm excited to have a front-row seat to this evolution and to work with those leading the charge. My colleagues at Hexagon and our customers are finding and developing opportunities every day to push beyond the limits of technology and witnessing the impossible become possible. I hope you will join us for the journey.

Sentinel-1 SAR data based flood mapping and monitoring of River Kosi, Bihar, India

The study makes an attempt to assess the inundated/flooded areas by comparing two time-series Sentinel-1 SAR dataset of 24th June 2017 i.e. pre-flood areas which depicts the permanent waterbodies (referred as archive image) and the image of 23rd August 2017 which depicts the actual flooded area (referred as crisis image)

Shashi Shekhar
Scientific Officer,
Himachal Pradesh
State Pollution Control
Board, Shimla, Himachal
Pradesh, India

Kosi belt (Alluvial fan) in Bihar has historically been under the constant flooding by River Kosi, the river popularly known as the 'Sorrow of Bihar'. Each year it inundates hundreds of acres of fertile land and invades highly populated area, which incurs tremendous loss to human life and property. Nonetheless, the people live with floods for years and adapted the unpredicted behavior of the river. The latest remote sensing data have come as a boon in flood forecast, relief planning and management. Under the European Union's Copernicus programme, radar based satellite Sentinel-1 (all weather satellite) offers huge capability in improving crisis management and helping response efforts. The high revisit time and rapid data dissemination make the Sentinel-1 radar data the most sought after satellite imagery as on date. The study makes an attempt to assess the inundated/flooded areas by comparing two time-series Sentinel-1 SAR baseline dataset of 24th June 2017 i.e. pre-flood areas which depicts the permanent waterbodies (referred as archive image) and the image of 23rd August 2017, which shows the actual flooded area (referred as crisis image). The study area has been restricted only for four north-eastern districts of Bihar i.e. Saharsa, Khagaria, Madhepura and Supaul in view of voluminous dataset of Sentinel-1.



PROGRESSIVE WESTWARD SHIFT BY RIVER KOSI

Flood in general

Floods and flooding impact more people globally than any other type of natural disaster. Floods have the potential to devastate entire communities and cities, destroy homes, take lives and even spread disease. With global warming having a greater effect on our climate than ever before, an increasing global population and a growing number of people living in flood-prone regions worldwide, vulnerability to flooding is set to increase further in the near future.

Hence, strengthening our capabilities vis-à-vis flood forecast and preparedness thereof is of utmost importance.

Kosi Flood

As per one estimate, Bihar is India's most flood affected States in the country having over 73 percent of its lands under recurring flood. Among all, Kosi does the most of the damages in the State. Floods have defamed the Kosi to be called the "River of Sorrow". Its unstable nature has been attributed to the heavy silt it carries during the monsoon season. The Kosi alluvial fan is one of the largest in the world, and extends from Barāhkṣetra across Nepalese territory, covering northeast Bihar and eastern Mithila to the Ganges, 180 km (110 mi) long and 150 km (93 mi) wide. It shows evidence of lateral channel shifting exceeding 120 km (75 mi) during the past 250 years, via at least twelve major channels. The river, which flowed near Purnea in the 18th century, now flows west of Saharsa (Refer figure-1 & Wikipedia).

Extensive soil erosion & silt load

Owing to extensive soil erosion and landslides in its upper catchment by factors both natural and human, the silt yield of river Kosi is estimated to be about 19 m³/ha/year, one of the highest in the world. The Arun – a trans-boundary river forming upper main part of River Kosi, with its origins in Tibet, brings the greatest amount of coarse silt in proportion to its total sediment load. The river is able to transport its heavy sediment load down the steep gradients and narrow gorges in the mountains and foothills, but on the plains beyond Chatra where slopes are flatter, the sediment load is deposited in an immense alluvial fan that has grown to an area of about 15 000 km². This fan extends some 180 km from its apex where it leaves the foothills, across the international border into Bihar state and on to the Ganges. Instead of a single well-defined channel, the river has numerous interlacing channels that shift laterally over the fan from time to time. Without sufficient channelization, floods spread out very widely. The record flow of 24 200 m³/s is equivalent to water a meter deep and more than 24 kilometers wide, flowing down the slight slope of the alluvial fan at one meter per second (Wikipedia).

Need for effective monitoring and flood management

Detecting and monitoring flood events globally is crucial to our understanding of the processes, how it happened, how it can be prevented, how it can be managed, how can we prepare better in the future and how can we best warn people situated in at risk areas. In the midst of a disaster, information is needed as quickly as possible to provide an overview of the situation, to improve crisis management and to help response efforts.

Satellite data

With an unprecedented amount of satellites monitoring the Earth on a constant basis, there has never been more data available to help us assess, monitor, analyze, model and view floods around the globe as and when they happen. The data and imagery which satellites provide have proved invaluable as countries around the globe seek to identify at risk areas and inform planning to help mitigate the impact of future flooding.

Sentinel 1

SAR's inherent capability to observe during cloud cover and SENTINEL-1's frequent revisits makes it ideal for flood monitoring. The use of synthetic aperture radar (SAR) data is presently well established in operational services for flood management.

Sentinel-1 is an imaging radar mission providing continuous all-weather, day-and-night imagery at C-band. The Sentinel-1 constellation provides high reliability, improved revisit time, geographical coverage and rapid data dissemination to support operational applications in the priority areas of marine monitoring, land monitoring and emergency services.

Sentinel-1 potentially images all global landmasses, coastal zones and shipping routes in European waters in high resolution and covers the global oceans at regular intervals. Having a primary operational mode over land and another over open ocean allows for a pre-programmed conflict-free operation. The main operational mode features a wide swath (250 km) with high geometric (typically 20 m Level-1 product resolution) and radiometric resolutions, suitable for most applications.

Description of the study area

Four districts of Bihar namely Saharsa, Khagaria, Madhipura and Supaul have

Figure 2: Four districts and important settlements falling in the study area along with transport network

been taken as the study area as indicated in Figure-2. Selection of Sentinel-1 to assess the flood is based on two reasons. Firstly, the radar data provided by the satellite is particularly effective and useful in assessing the impact of flood affected areas as unlike other remote sensing satellites, it is able to penetrate rain and cloud cover; issues which generally affect flood hit areas. This also means that a flood can be monitored in real-time as it progresses, with a clear picture of the height and extent of it emerging. Secondly, Sentinel-1 offers regular coverage of the Earth's surface, with a revisit period of only 6 days. This allows us to capture an affected area before a flood to help visualize and identify any changes to the landscape.

- For analysis of the flooding in Saharsa and its surrounding districts, two Sentinel-1 radar images were processed. One captured before the flooding and the other captured at the height of the floods. The first image was captured on 24/06/2017, indicates pre-flooding.
- The second image was captured on 23/08/2017. This shows the same area around the study area after a sustained period of heavy and persistent rainfall. There is a marked difference between the two images. The second image clearly details the extent of the flood with vast swathes of area along the River Kosi clearly under water.

Data used and methodology

It was decided to use SNAP Desktop (version 5.0) as the main geospatial data processing software especially designed for pre-processing and post-processing analysis of Sentinel SAR dataset. The most of the operations were conducted in SNAP Desktop1 *(A common architecture for all Sentinel Toolboxes is being jointly developed by* Brockmann *Consult, Array Systems Computing and C-S called the Sentinel Application Platform (SNAP). The SNAP architecture is ideal for Earth Observation processing and analysis due the following technological innovations: Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management, and a Graph Processing Framework.)* processing software. The first step was to subset the image for the study area comprising of four districts namely Saharsa, Supaul, Khagaria and Madhepura of Bihar, India. Since, the Sentinel SAR data are very voluminous on account of high spectral and spatial resolution, sub-setting the data was an important step. Subsequently, multi-looking processing was applied to reduce speckle and dimension of large image to speed out processing time. If one is interested in high resolution satellite mapping, can have the same factor in the processing parameter. However a multi-looking factor of 3x3 was kept so as to reduce the size of image for speedy processing. This is followed by applying calibration of the images to make them comparable and change them to digital number to sigma0 backscatter (per unit area ground range). In the resultant image, most of the pixels have demonstrated very low backscatter value and very few pixels have high backscatter value. In order to rectify this, it makes sense to convert the pixels from linear scale to non-linear algorithm scale (db). This conversion was applied to make it easier to manipulate histogram of both datasets. This helped in better visualization and made easier to manipulate histogram. After the conversion, the decibel dataset had much better distinction between land and water pixels. One peak represented land while other smaller peak represented water. This was followed by application of terrain correction to project the image on the map-system and make correction in distortion due to terrain. To achieve the same desired map system, Range Doppler Terrain Correction was applied on both the archive and crisis images. Again linear to decibel conversion was applied on both the images for above-stated purpose (Refer Figure-3 &4).

Subsequently both the images were combined, stacked and RGB composite was created in order to distinguish flooded areas and permanent waterbodies. Further, it was also checked through the abstracted metadata information that the satellite passes of the both the images were descending and had the similar instance angle. However during the course of analysis the virtual images were converted to real images in Snap-5 software.

The graph-1 enlists the steps taken in pre & post processing of archive and crisis images. Several contrast stretch of the histogram was also applied for checking the result. All the above stated procedures were applied on the archive and the crisis images. The terrain corrected images are presented as below in figure 3 and 4:

Finally both archive and crisis terrain corrected and decibel images (db) were stacked into one to visualize the flood affected areas. During the stacking product

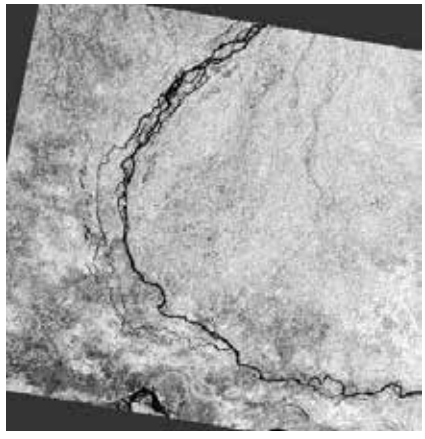


Figure3: Processed Amplitude VH Sentinel radar1 image acquired on 24th June 2017demonstrating black as permanent waterbodies

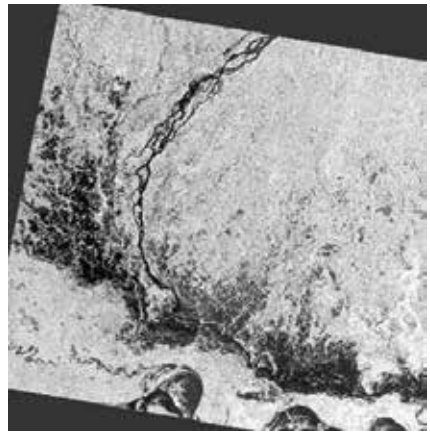


Figure 4: Flooded area in black In the crisis processed Ampltude VH radar image reflecting low backscattered return, which are specular reflection over the smooth water surface

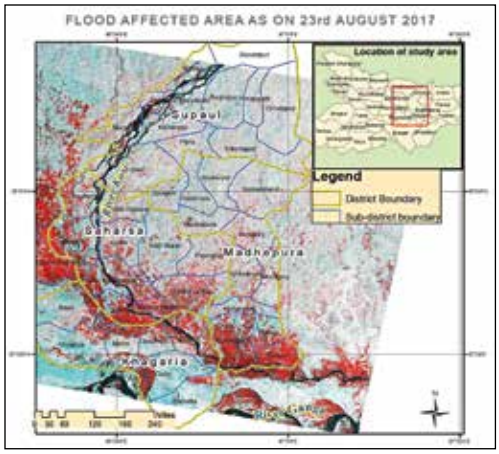


Figure 5: Stacked RGB archive and crisis images

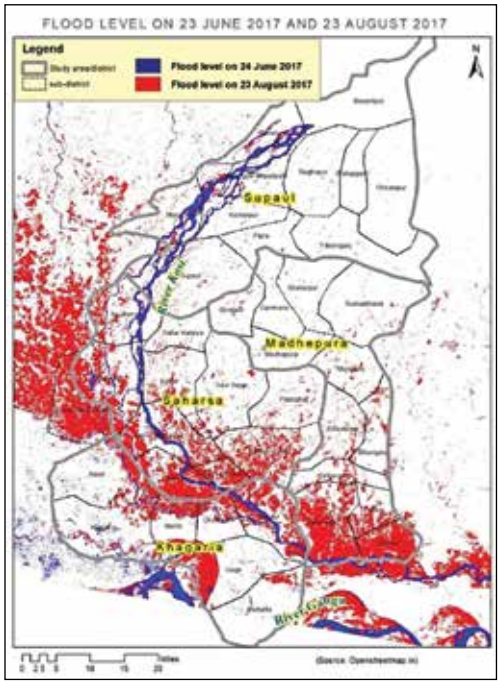


Figure 6: Water mask vector layer of archive image dated 24th June 2017 (shown in blue) and crisis image dated 23rd August 2017 (shown in red) – permanent waterbodies shown in blue and flooded areas in red;

geolocation was utilized in initial offset method. All bands were put to one stack and overlaid both archive and crisis images for visualization.

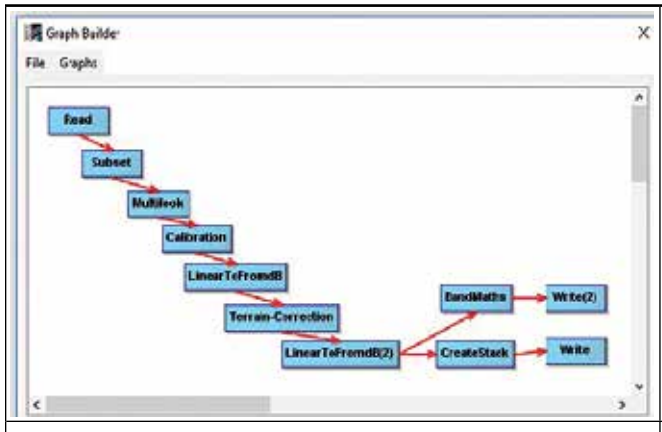
Image RGB composite

In order to distinguish between permanent waterbodies and flooded areas, a RGB composite was created. To accomplish the same, archive image was used as red band and crisis image was used as green and blue band. Selecting archive image as red is due to flooded area having high radar response by virtue of being land in archive image and it is not expected to see them as flooded area. However these lands shall have low backscatter return in crisis image as they are flooded area. Consequently, wherever there is flooded area, they shall appear red. However, wherever there are lands in both images, they shall have more or less similar backscatter return in red, green and blue channels, hence the image shall appear grey. And wherever backscatter return is low in both the images, the area shall depict dark as permanent waterbodies or rivers. Therefore areas shown in the RGB composite as red are clearly the flooded areas. However some areas have high backscatter return in crisis image are also shown in cyan indicating that there are some ground cover change which is not related to flood or may be related to crop characteristics (Refer Figure-5).

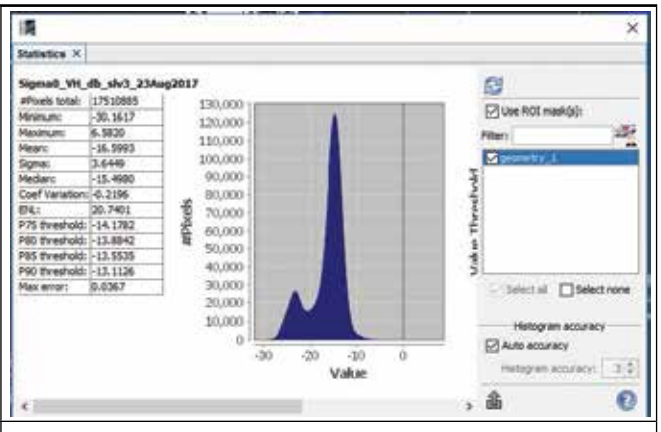
Creating water mask

For quantitative and further spatial analysis of flooding areas, water mask is created in SNAP-5 Desktop. To undertake that, the most effective method is binarization. It is needed to select the value that will separate water from non-water. As is obvious the flooded area has low backscatter return than non-flooded area, taking advantage of this, the processed SAR image was classified after obtaining a threshold value (Graph-2). There are several methodologies to obtain threshold value such as by inspecting the pixel value. The histogram of the image was analyzed. The pixel value of Sigma0 image was analyzed though pixel info in table of content. For this a polygon of water area was created in ArcGIS software and vector layer was added into the Snap 5.0 (Refer Figure -6). Subsequently, statistics was analyzed by selecting the water-logged polygon by using region of interest (ROI) (Refer Graph-2).

Histogram of the image demonstrated statistics falling in water polygon file. By analyzing minimum, maximum and mean value, a threshold value was decided after stretching the histogram in the process. By several stretching water and non-water area were clearly distinguished and a threshold was decided (Refer Graph-2). Through Band Math tool in SNAP by applying threshold and editing Band Math Expression, a new water mask layer created and saved for further analysis. The layer was further exported to a GIS compatible format (.geotiff) for further analysis in ArcGIS software and .kml format for overlaying



Graph-1 Graph-builder and batch-processing steps undertaken for both the images;



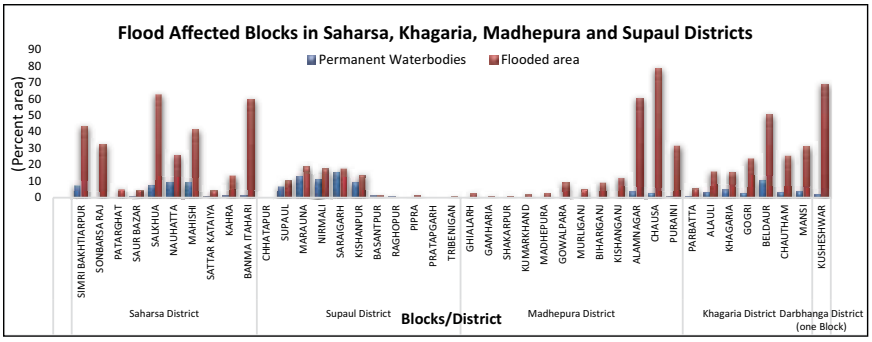
Graph-2 Statistics for obtaining threshold for water mask vector layer creation;

in Google Earth (Refer Figure-7).

The .geotiff water mask table was added as a layer in ArcGIS and further sub-district/block layer was superimposed over water mask layer to visualize which sub-district/block had how much of its area under flood. The Graph-4 indicates that the southern blocks of Saharsa and Madhepura and north of Khagaria are falling under high flood zone. Further quantitative analysis for obtaining flooded area is carried out as below.

Result and discussion

- With the above assessment, it is now much easier to employ spatial analysis for further impact assessment, which may be required by the district administration for damage & compensation assessment. Furthermore, overlay analysis on vector layers such as block, panchayat and village boundary may help in effective and accurate impact assessment and relief distribution. With the coarse resolution data digitized from sources such as Census of India, a broad assessment of block-wise flood area calculation is thus carried out.
- It is observed that most of Blocks of Saharsa and Khagaria districts seem to be under high flood zone, while some southern blocks of Madhepura are also falling in high flood zone as well. In addition, it can also be observed that area under permanent waterbodies occurred in many Blocks of Supaul district. However, such occurrence is insignificant in Madhepura District.
- If the permanent waterbodies are deducted to visualize the net flooded area of each block, the following pattern emerges (Refer Chart-4). Chausa Block of Madhepura district and Banma Itahari and Salkhua of Saharsa Districts are the worst flood affected blocks. Kusheshwar-sthan – the only block considered from neighboring Darbhanga District is one of the most flood affected blocks in the region.



Graph 3: Flood affected blocks (in percent area)

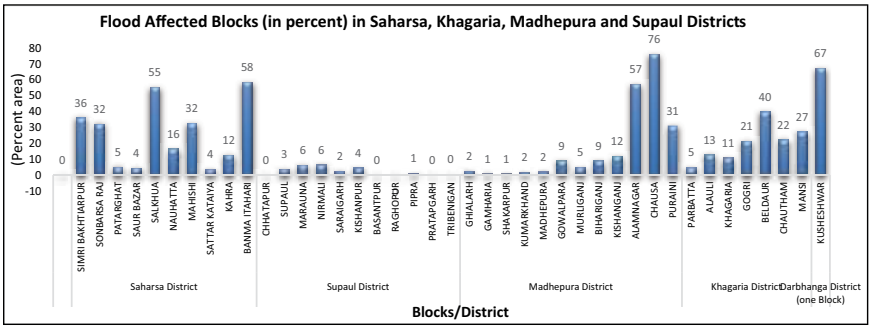


Chart 4: Net area under flood (percent area)

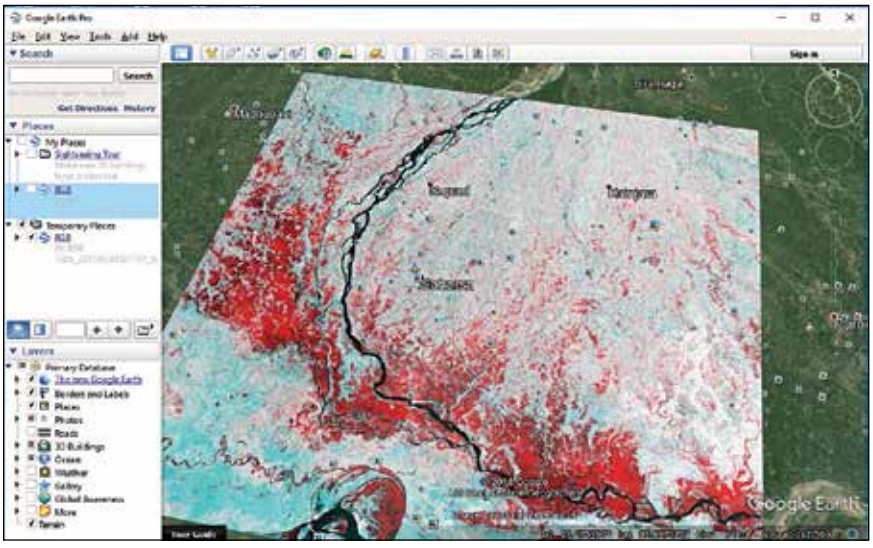


Figure 7: Flood layer exported into Google Earth (GE)

The benefits

The study of flooding in the Saharsa, Supaul, Madhepura and Khagaria districts, using satellite remote sensing SAR data, has highlighted a number of potential benefits for using such techniques, which have emerged as potential tool in effective flood mitigation and planning. Benefits include:

- First responding team such as district administration and National Disaster Relief Force (NDRF) can quickly and easily access data which can help assess the situation, deploy their forces in critical areas and inform any rescue efforts by the district administration;
- Sentinel-1 SAR data is an all-weather satellite, hence incessant rainfall during monsoon period, which is a regular phenomenon, cannot hamper in obtaining necessary information/data;
- Flood-prone and at risk areas are easily identifiable;

The study is simply a demonstration of the application of Sentinel SAR data in flood management and relief planning. There are huge scope for improvisation of the study for effective decision making.

- Such studies can help inform future decisions on flood planning and prevention measures, including important areas to protect, such as densely populated areas;
- There are a range of satellites which provide free and easily accessible data, including the Landsat and Sentinel series of satellites, both information could be combined for better relief and prevention measures;
- Historic analysis can be carried out on particular areas to help identify trends and patterns in flooding;
- Frequent revisit times ensure that there is a rich amount of data available for a wide range of areas;
- Sentinel series of satellites collect a range of different data all of which can be used to help visualize and analyze any particular area of coverage;
- Analyzed data can be overlaid onto various base maps and google-earth for user friendly demonstration and decision making.

Conclusion

The mapping and remote sensing services seen in this case study can be used to provide value to organizations engaged in disaster management across departments/ organizations. Departments which can benefit from these services include:

- Agriculture - to help in the verification or analysis of agricultural land usage to inform drainage and flood planning;
- Insurance - to determine properties at risk from flooding and to inform premium rates;
- Governmental - to identify key areas in need of protection and to help inform measures to prevent or mitigate future floods;
- Transport - to help identify infrastructure which could be at risk of floods or which requires extra protection and prevention measures;

The above study is simply a demonstration of the application of Sentinel SAR data in flood management and relief planning. There are huge scope for improvisation of the study for effective decision making.

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Key role of Bathymetry in aquaculture siting project

British Engineering and Scientific Consultancy Firm, BMT, is using Satellite Derived Bathymetry from TCarta as a critical dataset in the selection of new fish farming sites in the Arabian Gulf. BMT is performing the site selection work on behalf of Environment Agency – Abu Dhabi (EAD).

BMT used the TCarta data sets in its hydrographic modeling software to select ideal fish farming sites based on two key criteria. First, the chosen offshore locations must fall within certain maximum and minimum water depth thresholds to accommodate the large fish cages. And secondly, the cages must be placed in areas such as natural subsurface channels where water currents will continuously flush waste from the enclosures and keep the growing fish healthy. *https://bathymetrics.shop/.*

Uttarakhand signs MoU with ISRO

The state government of Uttarakhand, India, signed a memorandum of understanding (MoU) with the Indian Space Research Organisation (ISRO) in Ahmedabad on February 15. The collaboration will pave the way for better forecasts and instant delivery of post-disaster imagery.

Earlier, The Uttarakhand Disaster Mitigation & Management Centre (DMMC) was receiving forecast alerts from the Indian Meteorological Department (IMD).

IIT-Roorkee professor develops new technology for aerial survey

Professor Kamal Jain with the Indian Institute of Technology, Roorkee, has developed a new technology for carrying out aerial survey, which is more cost-effective and precise than the LiDAR system used at present.

Professor Jain at the civil engineering department of the IIT used a drone for taking videos with an interactive web map to demonstrate the technology that records data, including the place and time on a computer screen. The LiDAR (light detection and ranging) is used in aircraft to map aerial images of an area and is a costly and cumbersome technology . It requires a camera-mounted aircraft mapping images from the air, for which an aircraft needs to fly at a specific height and requires permission from civil aviation authorities, Jain said.

"We use a drone over a particular area to take video images which are tagged with a web map that enables the user to know the accurate geospatial information like latitude or longitude of each point."

Isro plans to launch India's 2nd space observatory

Indian Space Research Organisation (Isro) is planning to launch the country's second AstroSat-2 or space observatory. The mission is meant to further the study of astronomy (the study of celestial bodies) and astrophysics.

Isro made the announcement of opportunity on February 3 to seek proposals from all institutions currently involved in astronomy/astrophysics for the development of scientific instruments for astronomy payload and mission

The advantage of having such a space observatory in outer space is that it helps observe distant planets, galaxies and other astronomical objects more clearly than from the Earth. Space telescopes avoid problems of ground-based observatories, such as light pollution and distortion of electromagnetic radiation. The first AstroSat-1 weighing 1,515kg was launched on September 28, 2015. *https://timesofindia.indiatimes.com*

Russia's remote sensing satellites send first Earth images

Russia's remote sensing satellites Kanopus No. 3 and No. 4 launched and orbited on February 1 have sent their first images of the Earth's surface, the press office of Roscosmos State Space Corporation reported. *http://tass.com/science/989655*

Mapping Agency transforms into Geo-Spatial Information Agency

Ethiopian Mapping Agency is pondering a structural reform following the legislation of a proclamation which also changed its name to Ethiopian Geo-Spatial Information Agency.

In the reformation process, the Agency will add new directorates and departments, according to Tesfamikael Taffesse, communications director of the Agency.

The Agency was re-named due to the high demand to use geospatial information for different commercial, investment, mining, electric and telecom line installation, and an input for policy draft in the country, according to Tesfamikael. *https://addisfortune.net*

Project aimed at mapping ocean floor by 2030

An international project has been launched to fully map the world's ocean floor by 2030 for clues to finding valuable resources.

The Seabed 2030 Project was jointly set up by Japan's Nippon Foundation and the Guiding Committee of the General Bathymetric Chart of the Oceans, or GEBCO. GEBCO members include UNESCO and the International Hydrographic Organization.

Mapping ocean topography is a key to locating resources such as oil, natural gas and rare metals. It also helps predict effects of climate change.

But only about 15 percent of the world's seabed has been mapped in detail, due to shortages of personnel and funding, as well as countries' unwillingness to share data on their exclusive economic zones.

The project involves setting up 4 regional centers and asking governments and shipping companies to provide data. It is also designed to support new research and develop unmanned robot technology for underwater surveys. *www3.nhk.or.jp*

Automated mine monitoring solutions by 3D Laser Mapping

Two unique scanner and software packages, developed by 3D Laser Mapping, are set to boost safety, efficiency and productivity for underground and open pit mining operations. The long standing SITEMONITOR software gets an upgrade with the introduction of SITEMONITOR LIVE. The scalable solution marks a major step forward in mine surveying, asset monitoring and inventory management, providing real-time data and automated reports for improved operational intelligence. *www.3dlasermapping.com*

Pune, India to use GIS mapping to keep track of civic work

The Pune Municipal Corporation (PMC) is planning to conduct GIS mapping of every civic work it undertakes to ensure transparency and avoid wastage of public money. A civic official said the PMC spends most of its funds on construction of roads and footpaths, laying pipelines, managing sewage and storm water drainage systems, developing gardens, erecting street lights, among other infrastructural projects. It also spends a major chunk of its budget on repair and maintenance work, the official added.

The civic body, the official said, has received several complaints alleging wastage of public money in "unnecessary" repair and maintenance works, before the completion of its life-span. "The civic administration would conduct GIS mapping of each development project it undertakes — from construction to maintenance and repair. This would ensure that every detail regarding the civic work can be accessed by the public at the click of a button," the official said. *http://indianexpress.com*

Indo-German MOU on Smart Cities in India

An Indo-German MOU has been signed for an "Implementation Agreement in Sustainable Urban Development and Smart Cities in India". The objective of the programme is to develop and apply concepts for sustainable urban development about the provision of urban basic services and housing in selected cities and Smart Cities in India.

The Agreement was signed between Ministry of Housing & Urban Affairs(MoHUA), Government of India and Deutsche Gesellschaft für Internationale Zusammenarbeit(GIZ) GmbH, India on behalf of the Government of Federal Republic of Germany in the presence of Shri Hardeep Singh Puri, Minister of State (IC) for Housing and Urban Affairs, Government of India and Dr. Martin Ney, the German Ambassador to India.

Speaking after signing of the MOU, Shri Hardeep Puri said that the technical cooperation measure will support approaches for sustainable urban development in the area of integrated planning, provision of affordable housing and basic services with particular focus on water, waste water and solid waste management and mobility. The 'Sustainable Urban Development Programme - Smart Cities in India' project is supported by the German Federal Ministry for Economic Cooperation and Development (BMZ) and jointly implemented by the Ministry of Housing and Urban Affairs, Government of India and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). *http://pib.nic.in*

Aerial mapping of Bengaluru's solar energy potential takes off

Bescom has commissioned the mapping in a bid to meet its target of generation of 1,000 MW of rooftop solar energy by 2022 from Bengaluru alone. The initiative, which is based on a 2016 agreement of Bangalore Electricity Supply Company (Bescom) with the Centre for Study of Science, Technology and Policy (CSTEP) and Karnataka Renewable Energy Development Ltd. (KREDL), finally took flight on at Jakkur aerodrome. Over the fortnight, a helicopter armed with LiDAR system will fly across the city, mapping its potential to generate rooftop solar energy. The aircraft will cover an approximate area of 1,100 sq. km, generating high resolution images of rooftops of buildings in the city. The mapping will be carried out by CSTEP and the data generated will be submitted to the Energy Department.

The LiDAR technology will send pulsed laser light on to the rooftop of a building and translate the reflected light into data points. Based on objects such as trees surrounding the rooftop, shadow-free area available for solar power generation will be calculated and an estimate will be arrived at as to the capacity of solar generation of each building in the city, said officials. *www.thehindu.com*

e-GEOS will be the provider of SAR data for AMSA

e-GEOS, together with its Australian partner Geospatial Intelligence Pty Limited, has recently won an international tender to provide its services to AMSA (Australian Maritime Safety Authority) whose objective is to monitor the marine environmental safety.

AMSA's request was for a service provider capable of supplying an oil spill monitoring and surveillance service, based on SAR (synthetic aperture radar) technology. *www.e-geos.it*

HP launches the large format printers for GIS mapping

HP Inc has introduced HP DesignJet T1700 printers, next-generation 44-inch solutions for CAD and GIS workgroups to produce highly accurate documents and maps with powerful processing and a new level of security.

New added features on the HP DesignJet T1700 make it the most secure large format workgroup printer available today. The improved security is designed to help enterprises print CAD and GIS applications while protecting printers and data from unauthorized or malicious access in infrastructure construction, urban planning as well as utilities industries such as oil, water, gas, and electricity. *http://whattheythink.com*

China adds two more satellites to home-grown navigation network

Two more Chinese Beidou navigation satellites successfully lifted off aboard a Long March 3B rocket on China's seventh space launch in five weeks.

The Long March 3B rocket and a restartable Yuanzheng upper stage deployed the two Beidou navigation satellites — the 28th and 29th to join China's navigation network.

A third stage engine placed the two Beidou satellites and the Yuanzheng upper stage into a preliminary elliptical orbit. The upper stage engine was programmed to place the twin payloads into a circular orbit approximately 13,700 miles (22,000 kilometers) above Earth.

Chinese state media confirmed the launch was a success, and U.S. military tracking data showed the Beidou satellites were orbiting on their planned trajectory inclined 55 degrees to the equator. *https://spaceflightnow.com*

ESA, Airbus sign contract for EGNOS V3 Upgrades

Airbus has been selected as the main contractor to develop EGNOS V3, the next generation of Europe's Satellite Based Augmentation System (SBAS). The company was awarded the contract by the European Space Agency (ESA), which manages EGNOS (European Geostationary Navigation Overlay Service) development under a working arrangement signed with the European GNSS Agency (GSA).

For the next generation of the EGNOS augmentation system, the GSA requested the complete overhaul of the outdated EGNOS ground segment. This modernization program will see the deployment of EGNOS V3 in ground stations at more than 50 sites in Europe, and surrounding countries.

The GSA also requested the development of new EGNOS capabilities to support the augmentation of a second GPS signal (L5) and of the Galileo signals E1-E5. Another requirement is that the system be made more robust, to deal with the increase in user numbers and to reflect their increasing dependence on EGNOS and its ground applications - in some countries (e.g. France) instrument landing systems (ILS) are being decommissioned on several airports because the civil aviation authorities have decided instead to rely on EGNOS.

EGNOS V3 is planned to provide the aviation community with advanced Safety of Life (SoL) services as well as new services to maritime and land users. It will provide augmented operational SoL services over Europe that improve the accuracy and availability of user positioning services from existing Global Navigation Satellite Systems (Galileo and GPS) and provides crucial integrity messages to EGNOS users with alerts within a few seconds in case of system degradation, consolidating EGNOS' position as one of the leading edge GNSS Systems in the future.

Russia hopes to increase ERA-GLONASS system in cars threefold

Vice-Premier of Russia Dmitry Rogozin said that a three times increase in the connection of cars to the ERA-GLONASS system is expected. "Currently, more than 1,500,000 cars are already traveling around the country, connected to this system. By the end of the year, we expect up to 3 500 000 – 4 000 000," said the Chairman of the Board of Directors of JSC Glonass.

The Chairman of the Board of Directors of JSC "Glonass" said that the technology developed in Russia is interested abroad. "In the countries of Europe and not only apply for advice to us. Europeans are still only preparing to launch their analogue of our "ERA-GLONASS" – eCall ", – said Dmitry Rogozin.

Earlier it became known that the terminals of the ERA-GLONASS system will receive an additional button. Commercial services are promised to be connected in 2018. With the help of the new functionality, drivers can call an "emergency commissioner" through the call center, provide technical assistance or order fuel delivery. Buy updated versions of devices can be in any mobile phone.

Air Force to acquire new jam-resistant GPS satellites

The Pentagon plans to spend $2 billion over the next five years on a new constellation of GPS satellites that will be hardened to withstand electronic interference from hostile nations.

In a solicitation for bids posted Feb. 13, the Air Force Space and Missile Systems Center announced it will "conduct a full and open competition" for the production of 22 GPS 3 satellites starting in fiscal year 2019. The Air Force already has ordered 10 GPS 3 satellites from Lockheed Martin Corp. The new program that is now getting underway is to acquire an improved version of the satellite *http://spacenews.com/*

DOD looking for the next GPS

The Defense Department is in the market for a GPS alternative. For the past three decades, starting with Operation Desert Storm, the U.S. military has relied on GPS extensively as its primary mode of what it calls "positioning, navigation and timing" (PNT) — the ability to locate something and its movement at a given time. But the satellite-based GPS system has become "contested" and "vulnerable" and can no longer be relied on as the primary source of PNT for the Pentagon, Brig. Gen. Kevin Kennedy said.

The Pentagon recently issued a solicitation for PNT support in the office of the DOD CIO for "a broad range of programmatic, research and system engineering support, technical analyses, assessments and policy formulation support with respect to the research, development, acquisition, procurement, deployment/fielding, and operation of all DoD GPS, PNT and [navigation warfare] systems including national security, civil, commercial, and international cooperative aspects of the DoD PNT Enterprise." *www.fedscoop.com*

Britain reviewing risks to its satellite-reliant infrastructure

Britain is reviewing its reliance on satellite-based technology for critical infrastructure including the GPS as the threat of jamming attacks and disruptions grows, a government report said.

Emergency services, transport, communications and financial networks are among key sectors which depend on GNSS such as GPS. Such technology needs accurate and reliable position and timing signals. Experts say the problem with GNSS is their weak signals, which are transmitted from 12,500 miles (20,100 km) above the Earth and can be disrupted with cheap jamming devices that are widely available. They are also vulnerable to signal loss from weather effects as well as radio and satellite interference. A previous study commissioned by the British government and published last April estimated that five days of GNSS disruption would cost the UK economy 5.2 billion pounds ($7.35 billion). *www.reuters.com*

GNSS earthquake early-warning tested in Chile

Researchers testing a satellite-based earthquake early warning system developed for the U.S. West Coast found that the system performed well in a "replay" of three large earthquakes that occurred in Chile between 2010 and 2015, reports the Seismological Society of America.

The results, reported in the journal Seismological Research Letters (SRL), suggest that such a system could provide early warnings of ground shaking and tsunamis for Chile's coastal communities in the future.

The early warning module, called G-FAST, uses ground motion data measured by GNSS to estimate the magnitude and epicenter for large earthquakes — those magnitude 8 and greater. These great quakes often take place at subducting tectonic plate boundaries, where one plate thrusts beneath another plate, as is the case off the coast of Chile and the U.S. Pacific Northwest.

Using data collected by Chile's more than 150 GNSS stations, Brendan Crowell of the University of Washington and his colleagues tested G-FAST's performance against three large megathrust earthquakes in the country: the 2010 magnitude 8.8 Maule, the 2014 magnitude 8.2 Iquique, and the 2015 magnitude 8.3 Illapel earthquakes.

NASA will test a key deep space navigation tool this year

The Deep Space Atomic Clock (DSAC) is finally ready for testing, and NASA's JPL has begun preparing it for launch this year after working on it for two decades. Current space vehicles and observatories already use atomic clocks for navigation -- they are, after all, some of the most accurate timekeeping devices ever. However, the way they work isn't ideal for use in vessels going beyond Low-Earth Orbit.

See, the atomic clocks space agencies and companies use today need to be paired with ground-based antennas. The antenna sends signals to a spacecraft, and the vessel sends them back to Earth. Current clocks use the difference in time between sending and receiving a signal to calculate a space vehicle's location, path and velocity. It then relays commands to the spacecraft based on those calculations. While signals travel at the speed of light, that process can still take hours -- the farther the spacecraft is, the longer it has to wait for a signal. Deep Space Atomic Clock solves that issue by being onboard the spacecraft itself, which means it doesn't need to rely on two-way tracking.

It can use the signal sent from Earth to calculate for its host's position and velocity without having to toss that signal back. That means vehicles can move and change course more quickly than current ones can, and they can focus on completing mission objectives rather than spend time readjusting antennas. In addition, DSAC will allow ground-based antennas to keep track of multiple satellites in one area -- say the Martian orbit -- since they don't need to wait for vehicles to respond.

DSAC will launch this year attached to General Atomic's Orbital Test Bed spacecraft, which will blast off aboard the US Air Force Space Technology Program mission. *www.engadget.com*

Beidou's quick positioning platform serves over 200 countries, regions

The quick positioning platform of China's Beidou navigation and positioning system is serving more than 200 countries and regions around the globe, China North Industries Group Corporation Limited (NORINCO) announced Thursday.

The location service platform of Qianxun Spatial Intelligence Inc, a company using Beidou services that was co-founded by NORINCO and Chinese e-commerce giant Alibaba, has more than 90 million customers, the corporation said at its yearly work meeting.

Qianxun's centimeter-level service is expected to cover the whole of the Chinese mainland in 2018, when the high-accuracy positioning of Beidou will become a public service shared by all walks of life.

NORINCO has also won the bidding for the construction project of a base station network for foreign navigation satellites, marking the first step in its bid to push applied Beidou system overseas. *www.ecns.cn/2018/02-08/292086.shtml*

Tekhnoserv to support network monitoring system of Era-Glonass

Russian integrator Tekhnoserv has concluded an annual contract to support of the network monitoring system of Glonass, reports Cnews.ru. Tekhnoserv will support the activity of monitoring and analysis system Spyder from Russian company SevenTest. The system is being used for the monitoring of the the Era-Glonass emergency network. The contract will run until the end of this year. *www.telecompaper.com*

$110K in startup contest for GNSS-denied navigation technologies

The U.S. Department of Defense (DoD) and Israel's Ministry of Defense are joining forces for the third time in setting up a startup competition to tap into new technologies to beat terrorism. More than $200,000 in prizes will be awarded to the most promising startups.

The challenge is is divided into two tracks.

The Urban Navigation Technologies Challenge focuses on navigating without GPS — an increasingly important issue for special forces, law enforcement and other anti-terrorism professionals who need to operate indoors or in environments where GPS is not available.

The General Technologies Challenge includes surveillance, social media analytics, image and video, cybersecurity, drones, robotics, personal protection, biometrics, reconnaissance, and detection of explosives or water contamination. The most promising startups will be invited to present at the Combating Terrorism Technology Conference in Tel Aviv University on June 17.

ISRO to launch another IRNSS satellite in April

Tthe Indian Space Research Organisation (ISRO) is gearing up to launch another IRNSS satellite in April.

"The next launch will be in March end or April, but NavIC is already in full scale as four satellites are sufficient for navigation and we already have six. Adding more satellites, however, will guarantee better accuracy," according to ISRO chairman K. Sivan. Dr. Sivan said preparations were in full swing to ensure the success of the launch. He said the launch of Chandrayan-II would also take place in April subject to satisfactory integrated tests of the rover, lander and orbiter.

"The plan is to land on the moon's south pole during the day and one moon day is 14 earth days. *www.thehindu.com*

AI likely in new industrial policy in India

The Government of India is expected to provide incentives for use of frontier technologies like artificial intelligence and robotics in the new industrial policy that is likely to be unveiled soon. Besides, the industries would also be encouraged to adopt green technologies to promote cleaner environment.

The proposed policy, the draft of which has been released by the Commerce and Industry Ministry for consultation with various stakeholders, will completely revamp the Industrial Policy of 1991. The world is talking about industrial revolution 4.0 that includes artificial intelligence, robotics, deep learning and Internet of Things and incentives and there is a need to promote adoption of these modern technologies, which are capital intensive, according to government sources.

The Department of Industrial Policy and Promotion (DIPP) in August last year floated a draft industrial policy with an aim to create jobs for the next two decades, promote foreign technology transfer and attract USD 100 billion FDI annually.

The department is working to formulate an outcome oriented actionable policy that provides direction and charts a course of action for a globally competitive Indian industry that leverages skill, scale and technology.

The development assumes significance as India is aiming at increasing the contribution of manufacturing sector in the GDP to 25 per cent by 2020, from the current level of about 16-17 per cent. *www.thehindubusinessline.com*

Mumbai to have India's first artificial intelligence centre

In a first in India, the State government of Maharashtra will be setting up an institute for artificial intelligence (AI) in Mumbai.

"We have discussed cooperation in artificial intelligence and other port-led development. Maharashtra has already become the first state to unveil a FinTech Policy," said the Chief Minister, while setting up a joint working group for AI cooperation with the government of Canada.

The meeting between Canadian Minister of International Relations, Christine St-Pierre, and Mr. Fadnavis was held on AI cooperation in the industrial and service sectors. *www.thehindu.com*

Indoor Positioning Analytics Engine with Artificial Intelligence

Inpixon has announced that in connection with its 2018 product enhancement and development strategy, it intends to enhance its Indoor Positioning Analytics (IPA) engine by using artificial intelligence (AI) and machine learning to anonymously capture device identity, build a repository of device profiles and fingerprints, and offer intelligent solutions for enterprise security and marketing customers. Following this enhancement, Inpixon's IPA AI engine will assist in providing predictive, more accurate, bidirectional information to secure the indoors. *inpixon.com*

Collaboration on autonomous indoor mapping technology

NAVER LABS of NAVER Corporation, Korea and HERE Technologies have announced that they have signed a preliminary agreement to collaborate on autonomous indoor mapping technology.

The collaboration aims to combine NAVER LABS' Scalable & Semantic Indoor Mapping (SSIM) technology, autonomous robots, and AI-based image recognition capabilities with the HERE Open Location Platform to create, maintain and publish 3D maps of indoor environments such as airports and train stations. Such maps are useful in various ways, from helping people find their way at complex transit interchanges to supporting last mile guidance and more efficient logistics. The companies are planning initial testing work in Korea, with a view to deploying the technology globally to support the rapid creation of indoor maps.

Intel introduces 'Intel AI

Intel has unveiled "Intel AI: In Production," a new program that makes it easier for developers to bring their artificial intelligence prototypes to market. Since its introduction last July, the Intel® Movidius™ Neural Compute Stick (NCS) has gained a developer base in the tens of thousands.

Once developers have a prototype, the next step is to take it into production, which can be challenging and costly for small companies and entrepreneurs. To make it easier, Intel selected AAEON Technologies*, a leading manufacturer of advanced industrial and embedded computing platforms, as the first Intel AI: In Production partner. Through the program, AAEON provides two streamlined production paths for developers integrating the low-power Intel® Movidius ™ Myriad™ 2 Vision Processing Unit (VPU) into their product designs.

Toyota AI ventures boosts investment in self-driving startups

Toyota AI Ventures is co-leading an $11.5-million seed investment in May Mobility, an Ann Arbor-based startup that is developing self-driving shuttles for college campuses, central business districts and similar low-speed applications. BMW i Ventures is a co-investor. *www.btvi.in*

AI-powered speakers, smartphones, and more

Microsoft and Xiaomi have signed a memorandum of understanding (MoU) to work closely in cloud computing, AI, and hardware.

Microsoft is planning to allow Xiaomi to use its cloud computing products, including Azure, to develop upgraded phones, laptops, and smart devices to bring them to an international market. At the same time, the partnership will also give Microsoft more reach and access to the Chinese market. Xiaomi are also in talks about projects that will use different Microsoft AI technology, including conversational AI and speech, and services like Bing, Edge, and Skype. *www.theverge.com*

Self-driving taxi service test in Japan next month

Nissan Motor and DeNA have announced that field tests of Easy Ride, the self-driving taxi service they developed together, will begin next month in Japan. This means that Nissan and DeNA now rank among Uber, Lyft, GM, Didi Chuxing and other companies pioneering self-driving taxi pilots, with the goal of launching commercially within the next few years. *https://techcrunch.com*

Driverless vehicles now legal in Victoria

The Victorian Parliament has this week passed historic legislation that allows autonomous vehicles to be trialled across the state.

The move follows a similar law established in South Australia in June 2016, and driverless vehicle trials on certain Victorian roads including Melbourne's CityLink and EastLink freeways since last year. The Victoria government says self-driving vehicles will be "a game-changer for Victorian roads", initially by reducing and ultimately eliminating human driver error.Under the new laws, all driverless vehicle trials will require a human supervisor to monitor the vehicle from either inside or outside the vehicle. *www.motoring.com*

South African nautical charts now available from East View Geospatial

East View Geospatial (EVG) has announced that it has expanded its nautical chart offerings via an agreement with the South African Navy Hydrographic Office (SANHO). This agreement makes EVG an official distributor of SANHO's original paper charts – the only paper distributor located within the USA. The South Africa nautical chart series includes 91 charts and covers all of South Africa, as well as the coastlines of select neighboring countries.

PoLTE collaborates with Sequans

PoLTE Corporation has announced a new initiative with Sequans Communications whereby the two companies will prototype a joint solution integrating PoLTE positioning technology into Sequans' Monarch LTE Platform, enabling ultra low-power, highly-accurate indoor and outdoor positioning capability for LTE for IoT devices. This solution is based on off-loading small amounts of modem data to PoLTE's cloud servers where location engines accurately calculate positioning of devices.

TomTom RIDER 550

A new navigation device created for motorbike riders - the TomTom RIDER 550 has several new features to make it faster, smarter and better connected.The new features start with Wi-Fi® updating – no more wires or computers are needed to update the device with the included Lifetime Services (World Maps, Traffic and Speed Cameras). It offers access to TomTom Road Trips – with 150+ exclusive riding routes available to download. *www.tomtom.com*

Honeywell introduces indoor navigation to building occupant app

Honeywell Vector Occupant App give occupants more control over their experiences within a building with the swipe of a screen. Its indoor navigation, which uses GPS-like technology to help users find their way around complex buildings that are difficult to navigate without directions. With the app's location-based technology, users can rate spaces on aspects ranging from room lighting to cleanliness, helping staff pinpoint ways to improve user experience and comfort.

MapmyIndia unveils smart mobility platform

MapmyIndia has unveiled the new, comprehensive MapmyIndia Smart Mobility Platform (MSMP), designed to address the emerging challenges of the Automotive Industry for both personal and commercial customers. MSMP can be easily connected to the vehicle using multiple interfaces like SDL(smart device link).

Real-Time Mapping by DroneDeploy

DroneDeploy released Live Map, calling it a first-of-its-kind feature that allows any drone operator to create real-time maps in the field with their iOS device. Users plan a flight, take off, and see maps render on-screen during flight, without the need for internet or cell connection.

Users no longer need to experience image upload and processing times traditionally required with mapping and photogrammetry software. They get an aerial view of their jobsite, field, or project in seconds, which enables them to make real-time decisions.

Since the original Live Map inception, mobile devices have doubled in computational power, allowing DroneDeploy to improve map quality 400%. *www.dronedeploy.com*

Icaros uses TatukGIS SDK

Aerial geospatial solutions provider Icaros has selected the TatukGIS Developer Kernel (DK) to develop the next-generation geospatial data viewer component of its OneButton software product, which is used to process raw aerial images collected from manned and unmanned aircraft into readily usable GIS-compatible maps. The Icaros OneButton product is used by some of the largest private and government organisations worldwide operating in a range of industries. Icaros collaborated extensively with TatukGIS on the early development and prototyping of the DK based version of the OneButton Viewer application.

Geomni launches new mobile app

Geomni, a Verisk business has launched its new mobile app for ground imagery and UAV or drone, inspections. The app enables users to collect imagery and other data directly with their mobile devices or to conduct complete UAV inspections with compatible DJI drones.

The Geomni mobile app enables iOS smartphones and tablets to act as remote sensing devices that can capture images and other data. This ground-based imagery offers unique views and angles, complementing imagery and data captured from aircraft and satellites. *www.geomni.net*

Company uses drones for surveys in Nepal's rough terrain

DroNepal recently conducted several hydropower mapping projects in remotes areas of rural Nepal to test the potential and feasibility of using drones for surveying.

Nepal is planning to develop hydroelectric dams to help power its economy and export electricity to neighboring countries. Nepal's Department of Electricity Development has issued licenses to nearly 400 private companies for surveys and electrical generation projects. Last year, DroNepal was named the winner of WeRobotics' first Business Incubation Program..

Delair offers advanced UAV

Delair has introduced the next-generation of its high-performance DT26X Lidar UAV. It is a long-range fixed-wing drone that combines highly accurate lidar sensing capabilities with an integrated high-resolution RGB (red, green, blue) camera, dramatically increasing the precision, efficiency and cost effectiveness of surveying and 3D mapping. The Delair DT26X lidar's combined payload of a lightweight sensor and integrated camera allows the acquisition of lidar and photogrammetry data in a single flight, which drastically reduces cost and immediately provides an extremely detailed digital model of the inspected assets.

TEOCO launches UAV service enablement platform for drones

TEOCO has launched AirborneUTM, a Service Enablement Platform for UAVs. Designed to support the next generation of IoT Services delivered via drones, the platform combines Airspace, Radio-Signal-Space (3D radio coverage), environmental data (wind and weather), as well as cost and regulatory information to enable, optimize and operate autonomous flight plans and missions.

Autonomous UAV operation requires 3D radio connectivity for command & control, communication, authentication and tracking. Wireless operators are perfectly positioned to provide these capabilities, as they have been providing them for the past 25 years in 2D environments. Now it is time to expand to 3D. *www.teoco.com*

PrecisionHawk acquires Droners and AirVid

PrecisionHawk has announced a duo of acquisitions as the commercial drone company looks to build the biggest network of commercially licensed drone pilots in the U.S.

The two startups that have been bought by PrecisionHawk are Rhode Island-based Droners, a platform dedicated to helping drone operators hire licensed drone pilots specializing in aerial photography; and Ontario, Canada-based AirVid, which serves as a platform for finding all manner of drone pilots dealing in photo, video, cinematography, surveying, mapping, and more. *https://venturebeat.com*

Wingtra's high-precision drone sets a new benchmark in photogrammetry

Swiss UAV manufacturer Wingtra has set up a new benchmark in large-scale surveying and mapping applications, with the launch of its WingtraOne PPK (Post-Processed Kinematics) drone. The UAV can deliver orthomosaic maps and 3D models with an absolute accuracy down to 1 cm (0.4 in). With the latest upgrade, WingtraOne PPK can offer broad coverage and high resolution at ultra-precise accuracy.

UAVenture and Daedalean partnership

Zürich based Daedalean aims to bring full "level-5" autonomy to the personal electric aircraft of the near future. Daedalean's engineers apply insights from modern

robotics, deep learning and computer vision to build an autonomous guidance system that meets the highest bar (DAL-A) for safety critical aerospace systems (DO-178C, DO-254 and DO-160G). Their product provides visual based guidance and navigation intended to enable both unmanned operations and personal transport certified for Visual Flight Rules (VFR) conditions.www.*uaventure.com*

Cyberhawk completes UAV inspections on 63 platforms for Dubai petroleum

The rationale behind Dubai Petroleum's use of UAVs was to quickly complete detailed inspections of all their risers. Risers are traditionally a difficult area of an offshore platform to inspect; in the under deck and the splash zone, options for access, such as abseiling or scaffolding, are limited, extremely time consuming and very expensive.

Using UAVs as a scanning tool, the high-quality reports produced by the Cyberhawk team allowed the client to plan contact-based inspections or repairs. Additionally, now that a full inspection has been completed on all risers, defects can be tracked over time to understand their long-term degradation. *www.thecyberhawk.com*

Former Google drone engineers develop self-flying AI-enabled drone

A start-up founded by former Google drone engineers, Adam Bry and Abe Bachrach, Skydio has developed a self-flying camera that makes aerial photography a hands-free task, according to a CNBC report. The UAV uses computer vision and other types of artificial intelligence to fly itself, follow and record a subject down below. What's rather interesting about the UAV is that it doesn't require any sort of piloting or camera skills.

The report quotes Bry saying, "This technology is like what's being used in autonomous vehicles, in many ways. But of course, we had to develop this to deal with the general 3D motion of flying, and the lack of structure that goes with road systems." Unlike DJI's market-dominating drones, the Skydio R1 is operated without any controllers. Instead, users launch the Skydio iOS or Android app, and tap the screen on their mobile device to tell the R1 who to follow. *www.cnbc.com*

MIT develops NanoMap

A team from MIT's Computer Science and Artificial Intelligence Laboratory(CSAIL) has developed NanoMap, a system that allows drones to consistently fly 20 miles per hour through dense environments such as forests and warehouses.

One of NanoMap's key insights is a surprisingly simple one: The system considers the drone's position in the world over time to be uncertain, and actually models and accounts for that uncertainty.

Specifically, NanoMap uses a depth-sensing system to stitch together a series of measurements about the drone's immediate surroundings. This allows it to not only make motion plans for its current field of view, but also anticipate how it should move around in the hidden fields of view that it has already seen.

The team's tests demonstrate the impact of uncertainty. For example, if NanoMap wasn't modeling uncertainty and the drone drifted just 5 percent away from where it was expected to be, the drone would crash more than once every four flights. Meanwhile, when it accounted for uncertainty, the crash rate reduced to 2 percent. *http://news.mit.edu*

Lockheed Martin launches unmanned vehicle control software

Lockheed Martin software has been simultaneously flying, on average, at least six unmanned aircraft during every hour of the last 25 years, completing missions as diverse as reconnaisance, inspection, mapping and targeting. Recently, VCSi, a new vehicle control software, as the culmination of more than two decades of experience and 1.5 million hours of operational use was launched.

VCSi is a safe and reliable software platform that can be adapted to any vehicle – from one you can hold in your hand, to a 50,000-pound machine; from a vehicle that flies for a few minutes, to a vehicle that flies for months at a time. The user can integrate as many vehicles as required to complete their missions, including boats, quadcopters, fixed-wing aircraft or even high-altitude pseudo satellites. Across commercial or military missions, VCSi is adaptable to the challenge and further extends the power of the human-machine team. *www.lockheedmartin.com*

Airbus Helicopters' parcel delivery drone completes first flight demonstration

Airbus Helicopters' Skyways unmanned air vehicle has successfully completed its first flight demonstration at the National University of Singapore (NUS). The drone took off from its dedicated maintenance centre and landed on the roof of a specially designed parcel station where a parcel was automatically loaded via a robotic arm. Once successfully loaded with the parcel, the Skyways drone took off again and returned to land, demonstrating its automatic unloading capability.

This inaugural flight demonstration follows the launch of the experimental project with the Civil Aviation Authority of Singapore (CAAS) in February 2016 to develop an urban unmanned air system to address the safety, efficiency, and sustainability of the air delivery business in cities such as Singapore. The collaboration was subsequently extended in April 2017 with Singapore Post (SingPost) becoming the local logistics partner to the project.

Airbus Helicopters is at an advanced stage of the Skyways project. The research and development phase is progressing well, with equipment and facilities installed at the NUS campus. Campus students and staff will be able to make use of Skyways to have small parcels between 2kg and 4kg delivered to designated parcel stations within the campus, which is the size of 150 football fields. *www.airbus.com*

SBG Systems' Ellipse 2 Micro Series Inertial Sensors

The Ellipse 2 Micro Series from SBG Systems is a new product range reducing size and cost of high performance inertial sensors for volume projects. The Ellipse 2 Micro Series is available as an inertial measurement unit (IMU), or as an Attitude & Heading Reference System (AHRS) or inertial navigation system (INS) running an Extended Kalman Filter.

It is designed to provide high accuracy for volume projects with benefits that include:

- Industrial Grade - comes with a 2-year warranty
- Cost-effective - designed for volume projects
- High Quality IMU - calibrated in Dynamics and Temperature
- High Performance - 0.1° Roll and Pitch (AHRS & INS models)
- Lightweight - 10 grams
- 5 centimeter Real-time Heave (AHRS & INS models)
- Connection to external GNSS and Odometer (INS model)

Available in three models to best fit users' project requirements:

- Ellipse 2 Micro IMU is an Inertial Measurement Unit. It embeds 3 gyroscopes, 3 accelerometers, 3 magnetometers and a temperature sensor.
- Ellipse 2 Micro AHRS additionally runs an Extended Kalman Filter to provide Roll, Pitch, Heading, and Heave.
- Ellipse 2 Micro INS additionally connects to a GNSS receiver and an odometer for navigation.

Applications for the Ellipse 2 Micro Series include marine, land and aerospace.

GNSS OEM receiver boards for WingtraOne PPK drone by Septentrio

Septentrio has announced selection by Swiss drone manufacturer Wingtra to supply GNSS OEM receiver boards and PPK processing software for the newly launched WingtraOne PPK drone. The combination of VTOL (vertical take-off and landing) technology and a high-spec PPK (Post-Process Kinematics) brings wide-area coverage at ultra-high precision. *www.septentrio.com*

Helix Technologies wins ESA contract

Helix Technologies Ltd has been awarded a significant contract by the European Space Agency (ESA) to develop its NEXTGEN GNSS antenna –multi-frequency GNSS antenna optimised for the advanced Galileo E1 Alt-BOC and wide-band E5 Alt-BOC waveforms for use in driverless cars.

The antenna, to be developed under the ESA's Navigation Innovation and Support Programme (NAVISP), will provide enhanced performance due to its dielectric, multi-filar construction. It will also be optimised to take maximum advantage of the Galileo E5 Alt-BOC waveform, which enables significantly improved measurement accuracy, precision and multi-path suppression over conventional GNSS signals. *www.esa.int*

Electric Transmission Corridor to be Surveyed with SP60 GNSS Receiver

The Spectra Precision SP60 GNSS receiver has been selected to perform survey work for construction of a new 450-kilometer electric power transmission corridor. Connecting Mauritania's two largest cities, the capital Nouakchott and to the south Nouadhibou, the 225/90Kv transmission line parallels the Atlantic Ocean as it traverses the Sahara Desert. The Mauritanian Electricity Company, SOMELEC, through its contracting company, awarded the sub-contract for surveying the transmission line and infrastructure to ETAFAT, a geospatial data acquisition and processing firm.

Difficult work conditions, including high heat (over 45°C) and the lack of existing control points, were key factors in ETAFAT's selection of the SP60 receiver. Because of the absence of existing benchmarks along the entire corridor, it played a key role to ensure homogeneity in the coordinate reference frame between the two cities. The RTX technology leverages real-time data from a global tracking station network with innovative positioning and compression algorithms to compute and relay satellite orbit, satellite clock, and other system adjustments, transmitted to the SP60 via satellite or IP, to deliver real time high-accuracy corrections, even in remote locations. *www.etafat.ma*

Validate the performance of eCall modules

Approximately one year after ERA-GLONASS became mandatory for Russia and the Eurasian Customs Union, the use of its European counterpart eCall will become obligatory as of April 1, 2018. Before eCall or ERA-GLONASS modules can be integrated into cars, they need to be certified. They have to undergo a series of conformance and performance tests, which must be in line with applicable standards.

The GNSS receiver integrated into the eCall module typically evaluates signals from GPS, Galileo and satellite-based augmentation systems (SBAS) to determine the vehicle position. In an emergency, the module automatically places a call to the nearest emergency call center and transmits vehicle position data and other information via a cellular link.

The R&S SMBV100A in combination with the new R&S SMBV-K361 option and the R&S CMWrun sequencer software is the ideal tool for performing fully automated GNSS performance tests on eCall modules in line with the EU2017/79, Annex VI and UNECE 2016/07 specifications.

The new R&S SMBV-K361 eCall test suite is now available from Rohde & Schwarz. With this new GNSS performance test solution for eCall modules, Rohde & Schwarz offers a complete portfolio of standard-compliant conformance and performance test solutions for both eCall and ERA-GLONASS based on the R&S CMW500 and R&S SMBV100A. *www.rohde-schwarz.com*

Galileo update

French Space Agency claims 100 million users for Galileo navigation system

The Galileo satellite navigation system has about 100 million users after its first year of operation, as per the French Space Agency CNES. The system, which is highly crucial to Europe, went operational in December 2016. It took 17 long years to be ready for launch. Initially the services it provided relayed a weak signal, and some of the timekeepers on the satellites did not function as two satellites were arrayed in the wrong orbit.

But, since then, additional satellites have been added, and by 2020 Galileo is supposed to offer enhanced accuracy than GPS, focusing on a location to within a meter, instead of several meters earlier.

European industry has its say on Galileo's post-2020 future

With Europe's Galileo satellite navigation system is only one launch away from full global coverage, representatives of European industry gathered at ESA's centre in the Netherlands to discuss the transition towards the future Galileo Second Generation.

Galileo Initial Services began on 15 December 2016, while the constellation in orbit has grown to 22 satellites. An Ariane 5 launch later this year of another quartet will bring the constellation to the point of completion with 24 satellites, plus two orbital spares.

Looking further ahead, with the aim of keeping Galileo services as a permanent part of the European and global landscape, a replacement set of Galileo satellites will be required post-2020, serving as transition to a future generation.

The Galileo Second Generation is foreseen to offer improved performance and added features. This is why the European Commission has decided on a Transition Programme, with ESA is in charge of its technical definition and implementation.

Together with the European Commission and the European Global Navigation Satellite System Agency, the Agency invited leading European space companies to its technical centre in Noordwijk to discuss Galileo's future and present short-term plans in relation to this transition programme.Having started with the ESA European Global Navigation Satellite System Evolutions Programme (EGEP), the system and technology development of Galileo Second Generation is being supported through the EU's GNSS and Horizon 2020 HSNAV Programmes, with ESA being delegated its technical definition and management of its related implementation.

Eleven Phase-B contracts were signed at the meeting for the Design Phase for both the Galileo Second Generation and the Transition Programme, complementing the more than 50 technology contracts signed in 2017 to prepare for Galileo's future.

In recent years, innovations have been analysed and predevelopments performed in various technology fields (system, ground, space, receiver technologies) in order to assess their suitability for future Galileo activities, while ensuring backward compatibility and continuity of Galileo Services.

Hexagon Mining introduces personal alert

Hexagon Mining has introduced HxGN Mine Personal Alert, an accident-avoidance device worn by field personnel that ensures 360-degree visibility around heavy equipment. It's the latest integration with the company's Collision Avoidance System, (CAS) which is used in more than 25,000 mine vehicles worldwide. It offers an additional layer of safety to operators and pedestrians who every day must deal with the dangers of blind spots, noise, heavy traffic and poor visibility. *hexagonmining.com*

Hexagon launches next generation Leica Rugby lasers

Hexagon has launched the Leica Rugby CLH and Leica Rugby CLA lasers. It offers the unique capability to adapt to user application needs through software upgrades – an industry first. With a focus on application flexibility, simplicity and durability, it increase productivity and allow for maximum performance as construction projects evolve.These new lasers provide users access to upgrades that extend functionality and adapt to application needs. This ensures users have the right laser for any leveling, aligning and squaring tasks on site.

Leica Geosystems launches linear-mode LiDAR system

Lecia TerrainMapper is its next-generation linear-mode Lidar system. As part of the Real Terrain airborne Lidar mapping solution, the new sensor builds on Leica Geosystems' sensor technology and is supported by the HxMap unified multi-sensor post-processing workflow.

TerrainMapper enables users to increase point accuracy and deliver even point density across the swath and accommodates more efficient flight planning in complex terrains such as those encountered in urban spaces and mountainous areas. The newest sensor increases both acquisition speed and processing productivity, providing efficiency and precision for any project.

NavVis sets new standard in SLAM precision

NavVis has announced new mapping software that significantly improves the accuracy of simultaneous localization and mapping (SLAM) technology in indoor environments, such as long corridors. The software update will be available for users of the NavVis M3 Trolley and will significantly improve the accuracy of the resulting maps and point clouds.

CHC APACHE 5

APACHE 5 is integrated with intelligent water navigation robot technology, topographic survey technology, providing a smart, unmanned, integrated, motorized and networked measurement solution. Key Features include, triple-hulled vessel, Light shipbody, less than 10 kg, internal high sensitivity inertial navigation system, adjustable speed, up to 5 m/s, counter rotating dual propellers technology, high flexibility to carry different sensors, equipped with high definition web video camera.

APACHE 5 is widely used for geomorphological survey and mapping, channel survey, underwater geological exploration, etc. The system can reduce personal security risks and improve the flexibility and efficiency of underwater monitoring as well as hydrographic surveying. *www.chcnav.com*

Software-Based GPS receiver from GSN now available

Cadence Design Systems and Galileo Satellite Navigation, Ltd. (GSN), a developer of multi-system GNSS products, announced that the software-based GNSS GPS receiver from Galileo Satellite Navigation is now available for the Cadence Tensilica Fusion F1 DSP.

The software-based GNSS receiver allows customers to easily add full GPS functionality with design flexibility and long-term upgradeability at a minimal cost, low power, and no physical size to today's cost-sensitive internet of things (IoT) applications.

Tersus BX306Z GNSS RTK Board

Tersus' BX306Z GNSS RTK board features powerful flexibility and compatibility to meet or exceed the needs of OEMs and system integrators. As a new member of the BX-series GNSS OEM boards, BX306Z is a cost-efficient GNSS RTK board for positioning and raw measurement output. This board is a compact, multi-GNSS (GPS L1/L2, GLONAS G1/G2, BeiDou B1/B2) RTK module with centimeter-level accurate positioning capability. www.Tersus-GNSS.com/products/bx306z

Averna Introduces 500 MHz Wideband RF Record

Averna has announced a wideband RF Record and Playback platform. The RP-6500 records and plays back up to 500MHz of RF spectrum—from 9 kHz to 6 GHz—making it ideal for multi-constellation GNSS applications. The system can also capture other signals such as Wifi, GNSS, V2x, spectrum sharing, and cellular applications. *www.averna.com*

Bentley's reality modeling solution

Bentley Systems has announced the general access of its reality modeling cloud services, ContextCapture Cloud Processing Service, and ProjectWise ContextShare. UAV companies and surveying and engineering firms that leverage reality modeling in-house can utilize ContextCapture Cloud Processing Service to upload photos and generate 3D engineering-ready reality meshes, orthophotos, digital surface models, and point clouds dramatically faster than ever before. It automates the production of 3D models of virtually any size without the need for high-end hardware or specialized IT support.*www.bentley.com*

Croatia signs cooperation agreement

The Republic of Croatia signed a Cooperation Agreement with ESA on 19 February 2018. It will allow Croatia and ESA to create the framework for a more intensive and concrete cooperation related to ESA programmes and activities. *www.esa.int*

Next Generation GNSS Reference Receiver

Trimble has introduced its next generation Global Navigation Satellite System (GNSS) reference receiver for real-time network (RTN) applications—the Trimble® Alloy™ GNSS reference receiver. Setting a new industry standard with 672 channels, the Continuously Operating Reference Station (CORS) receiver provides users and operators with access to multiple constellations and signals, supplying robust and reliable reference data.

Trimble RTX technology

General Motors' is using Trimble RTX (Real-Time eXtended) technology as the GNSS/GPS correction source to deliver absolute positioning to vehicles equipped with GM's Super Cruise hands-free highway driving system, now available on the 2018 Cadillac CT6.

Trimble is now enabling semi-autonomous operations for passenger vehicles with Trimble RTX technology, delivering high-accuracy GNSS corrections via a global network to support absolute vehicle positioning in combination with other sensors and inertial dead-reckoning. The technology provides real-time, multi-constellation GNSS positioning capable of achieving better than 1.5 inches accuracy, claims the company, whereas standard GPS signals can drift up to 25 feet, which could cause incorrect lane identification.

MX9 Mobile Mapping System

The Trimble MX9 combines a vehicle-mounted mobile lidar system, multi-camera imaging and field software for efficient, precise and high-volume data capture for a broad range of mobile mapping applications such as road surveys, topographic mapping, 3D-modeling and asset management.

It captures dense point cloud data along with 360 degree immersive georeferenced imagery using an industry-leading spherical camera, GNSS/INS technology and dual-head laser scanning sensors. *www.trimble.com*

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The 7th Digital Earth Summit 2018
17-19 April
El Jadida, Morocco
http://www.desummit2018.org/

9th IGRSM 2018
24-25 April 2018
Kuala Lumpur, Malaysia
https://igrsmconf18.wixsite.com/igrsm2018

International Navigation Forum
Navitech 2018
24-27 April
Moscow, Russia
www.glonass-forum.ru

May 2018

Geoscience-2018
2-4 May
Rome, Italy
http://geoscience.madridge.com/index.php

12th Annual Baška GNSS Conference
6 - 9 May
Baška, Croatia
www.rin.org.uk

FIG Congress 2018
6 - 11 May
Istanbul, Turkey
www.fig.net/fig2018/

The European Navigation Conference 2018
14 - 17 May
Gothenburg, Sweden
www.enc2018.eu

GEO Business 2018
22 - 23 May
London, UK
http://geobusinessshow.com

June 2018

HxGN LIVE 2018
12-15 June
as Vegas, USA
http://hxgnlive.com

7th International Conference on Cartography & GIS
18-23 June
Sozopol, Bulgaria
www.iccgis2018.cartography-gis.com

2018 BGC Geomatics
18-23 June
Olsztyn, Poland
http://bgc2018.systemcoffee.pl/index.php?id=1

July 2018

GI Forum 2018
3 - 6 July
Salzburg, Austria
www.gi-forum.org

Esri International User Conference 2018
9 - 13 July
San Diego, USA
www.esri.com/events

September 2018

Inter Drone 2018
5 - 7 September
Las Vegas, USA
www.interdrone.com

ION GNSS+ 2018
24 - 28 September
Miami, USA
www.ion.org

October 2018

Joint Geo Delft Conference
The 6th International FIG 3D Cadastre Workshop

The 3D GeoInfo Conference
1- 5 October
Delft, the Netherlands
www.tudelft.nl/geodelft2018

Intergeo 2018
17 - 18 October
Frankfurt, Germany
www.intergeo.de

November 2018

Trimble Dimensions 2018
05 - 07 November
Las Vegas, USA
www.trimbledimensions.com

December 2018

The 16th IAIN World Congress 2018
28 November - 1 December
Chiba, Japan
https://iain2018.org

FORM IV

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I, Sanjay Malaviya, hereby declare that the particulars given above are true to the best of my knowledge and belief.

March 1, 2018 Signature of publisher

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- Galileo: E1 / E1a / E5a / E5b / E6
- SBAS: WAAS, EGNOS , GAGAN, MSAS, SDCM
- IRNSS

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