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Coordinates

Volume XIII, Issue 05, May 2017

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

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Robust Signal Processing for GNSS

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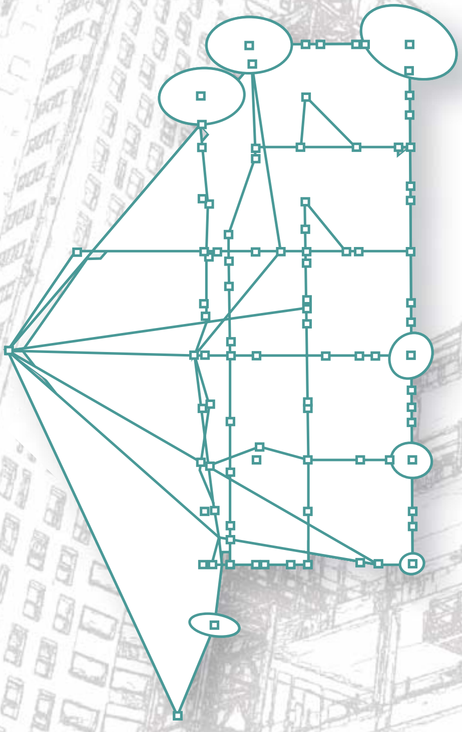

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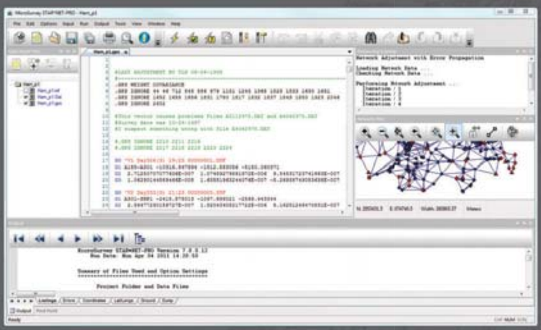

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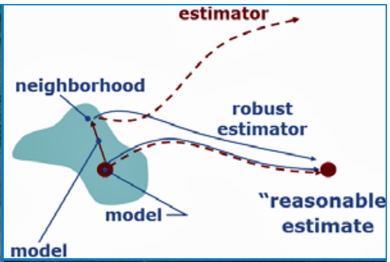

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Columns

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


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UAV: Flying and flying

A few years ago

It was euphoria.

A technology not only handy

But also as effective and cost-effective.

However, UAVs could not fly

As ‘high’ as anticipated

Given the difficult policy terrains.

Now, with the wider recognition and acceptance

And emerging range of applications,

It appears to be on realistic footing,

With eager and enthusiastic users

Willing to fly it, ‘higher’.

Bal Krishna, Editor
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Robust Signal Processing for GNSS

Robust statistical approaches can significantly improve the performance of GNSS receivers in the presence of jamming and interference. The paper reviews recent developments on the subject

Daniele Borio
European Commission, Joint Research Centre (JRC), Directorate for Space, Security and Migration, Italy

Digital signal processing plays a fundamental role in any Global Navigation Satellite System (GNSS) receiver: the presence of GNSS signals is detected and the signal parameters are estimated by the acquisition and tracking blocks, the main signal processing stages of a GNSS receiver. Standard acquisition and tracking algorithms are designed under the hypothesis that the noise affecting the input samples provided by the receiver front-end is Gaussian. This assumption leads to a non-linear Least Squares (LS) problem where GNSS signal parameters are estimated by minimizing a quadratic cost function.

GNSS signal reception can however be affected by several impairments such as multipath and interference. Under such circumstances, the Gaussian assumption may fail. Jamming is a special type of interference where powerful signals are broadcast in the GNSS frequency bands with the ultimate goal of preventing GNSS signal reception. A common approach to mitigate the impact of interference is to apply the Interference Cancellation (IC) principle: the interfering signal is at first estimated and then removed from the received samples. However, a model for the interfering signal is required and imprecise a-priori information can significantly degrade the performance of IC mitigation approaches.

During the last decades, significant interest has been devoted to robust statistical approaches and robust signal processing schemes. In this context, a technique is considered robust if it is able to effectively deal with model uncertainties and model mismatches.

Several approaches exist to design robust processing schemes where the assumption of Gaussian input noise is relaxed and the LS principle is replaced by less sensitive criteria, such as the minmax approach where the worst-case scenario is considered.

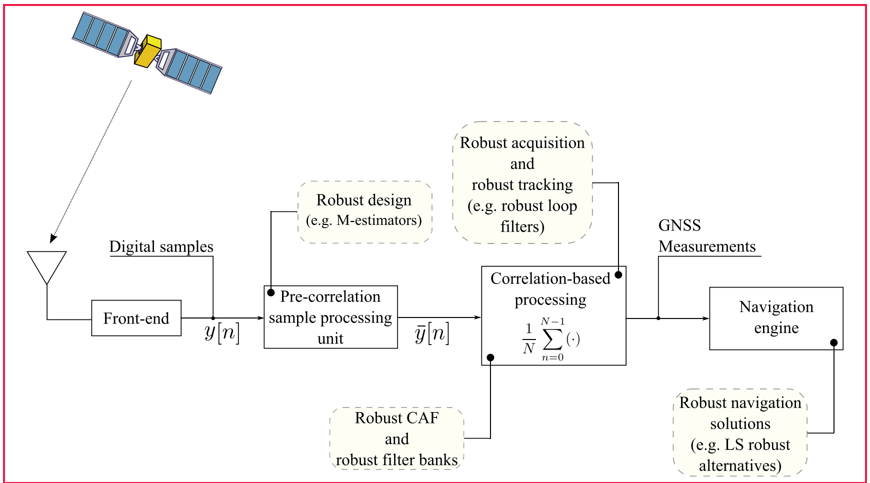

Figure 1: Design of a robust GNSS receiver: functional blocks where robust techniques can be applied (from [2]).

Robust signal processing techniques have the potential to significantly improve the performance of GNSS receivers in the presence of non-Gaussian phenomena and can be implemented at almost every stage of a GNSS receiver. This fact is illustrated in Figure 1 that briefly reviews the different receiver stages that can benefit from robust approaches. Despite their wide applicability to GNSS receiver design, the usage of robust approaches has been quite limited. Robust techniques have been recently considered for the computation of the user position from raw GNSS observables [1]. These approaches [1] provide significant performance improvements in the presence of multipath errors and outliers in the pseudo-range measurements.

Robust signal processing at the sample level can provide significant resilience to interference and improve receiver performance. We review and discuss two general approaches recently proposed for the design of robust acquisition and tracking schemes [2]. We show that robust techniques can provide an effective alternative to traditional IC approaches without requiring a good knowledge of the interfering term. The validity of the approaches proposed is demonstrated using the data collected during the Slovenian experiment described in a previous issue of Coordinates [3].

Classical GNSS signal processing

Standard GNSS signal processing is based on the assumption that the samples provided by the receiver front-end are affected by Additive White Gaussian Noise (AWGN). The Gaussian (or Normal) hypothesis naturally leads to a LS problem. In particular, one of the main goals of acquisition and tracking is to estimate the signal parameters, τ_0, f_0 and φ_0, i.e. the signal code delay, Doppler shift and carrier phase. Standard GNSS signal processing approaches estimate these parameters by minimizing the cost function

$$J(\tau, f_d, \varphi) = \sum_{n}^{N-1} \left| y[n] - Ac(nT_s - \tau)e^{j2\pi f_d nT_s + j\varphi} \right|^2 \quad (1)$$

where $y[n]$ are the input samples provided by the receiver front-end. $Ac(nT_s - \tau)e^{j2\pi f_d nT_s + j\varphi}$ is a locally generated replica of the input GNSS signal. In particular, the receiver tries to reconstruct the GNSS signal exploiting the knowledge of the Pseudo-Random Noise (PRN) code, $c(nT_s - \tau)$, and of the complex carrier represented by the exponential term in (1). A is the signal amplitude, which also needs to be estimated, and τ, f_d and φ are the arguments of cost function (1). The values of τ, f_d and φ that minimize $J(\tau, f_d, \varphi)$ are the estimates of the signal parameters. The differences between input samples and local signal replicas are generally called residuals and classical GNSS signal processing minimizes the sum of the squared residuals. N is the number of samples used in the computation of the cost function and T_s is the sampling interval.

Standard signal acquisition and tracking are optimal estimators in the LS (Gaussian) sense: $J(\tau, f_d, \varphi)$ is minimized in a two steps process. Acquisition employs a brute-force search to provide initial estimates of τ and f_d whereas tracking refines the parameter estimates using a gradient ascent/descent approach and determines φ.

The minimization of (1) is equivalent to (see [4] for the mathematical details)

$$\left\{\hat{\tau}, \hat{f}_0\right\} = \arg\max_{\tau, f_d} \left| C(\tau, f_d) \right| \quad (2)$$

$$\hat{\varphi} = \angle C\left(\hat{\tau}, \hat{f}_d\right)$$

where

$$C(\tau, f_d) = \frac{1}{N} \sum_{n=0}^{N-1} y[n] c(nT_s - \tau) e^{-j2\pi f_d nT_s} \quad (3)$$

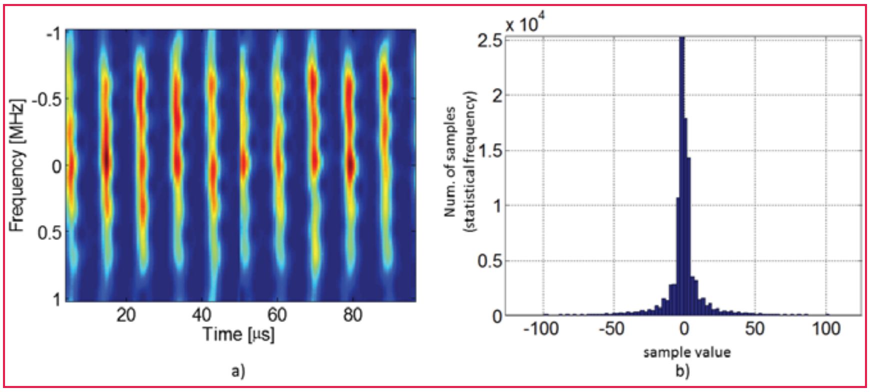

Figure 2: a) Time-Frequency distribution of GNSS samples collected in the presence of jamming. b) Histogram of the collected samples

is the Cross-Ambiguity Function (CAF), which is usually evaluated using a bank of correlators. Note that (2) does not depend on the signal amplitude, A, which will be independently estimated, for example, for the evaluation of the Carrier-to-Noise spectral density power ratio (C/N_0), one of the main GNSS signal quality indicators.

The processing described here is optimal when the model assumptions are fulfilled, i.e., when the input samples are affected by Gaussian noise. This type of processing, however, fails in the presence of model mismatches as those described in Figure 2. The figure provides the Time-Frequency distribution and the histogram of the GNSS samples collected during the Slovenian test campaign described in [3]. The input samples are corrupted by a jamming signal that periodically enters and exits the receiver input bandwidth. The presence of pulsed jamming alters the distribution of the input samples and the Gaussian assumption is no longer valid: under these circumstances, standard receivers are unable to operate.

Robust statistics and GNSS

Robust statistical methods have been developed to deal with situations where deviations from the design model may occur and render classical approaches ineffective [5-6].

The main idea behind robust statistical methods is illustrated in Figure 3: a robust estimator shall be able to provide reasonable estimates even in the presence of model deviations.

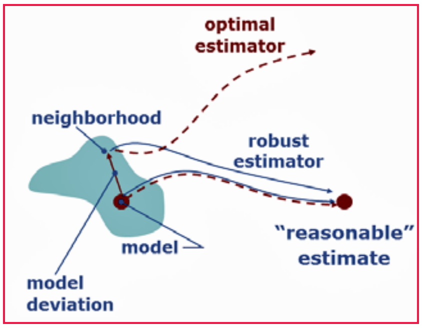

Figure 3: Intuitive description of robust approaches

Several approaches exist for the design of robust techniques [6], which are less sensitive to model mismatches than the optimal approaches based on the Gaussian hypothesis. These approaches are generally obtained by considering heavy-tailed noise processes whose distributions better describe situations like the one depicted in Figure 2.

Two approaches are considered here and are both based on the M-estimator framework [6]. The main idea of the M-estimator paradigm proposed by Huber [6] is that LS problem (1) can be generalized as

$$J_\rho(\tau, f_d, \varphi) = \sum_{n=0}^{N-1} \rho\left(y[n] - Ac(nT_s - \tau)e^{j2\pi f_d n T_s + j\varphi}\right) \quad (4)$$

where the squares have been replaced by $\rho(\cdot)$, a less rapidly increasing function of the residuals. In this case, $\rho(\cdot)$ is a positive function of complex argument that is zero only if its argument is zero. The idea is that $\rho(\cdot)$ will de-weight the impact of residuals with a too large magnitude. A possible way to design $\rho(\cdot)$ is to consider heavy-tailed random processes and set

$$\rho(z) = -\log f(z) \quad (5)$$

where $f(z)$ is the probability density function (pdf) of the input noise. The reader can readily verify that the original LS problem is obtained when $f(z)$ is the Gaussian pdf.

Distributions with tails heavier than the Gaussian pdf are the Laplace and Cauchy pdfs defined as

$$f_L(z) = \frac{1}{2\pi\lambda^2} K_0\left(\frac{1}{\lambda}|z|\right) \quad (6)$$

and

$$f_C(z) = \frac{\sqrt{K}}{2\pi\left(K + |z|^2\right)^{3/2}} \quad (7).$$

In (6), $K_0(\cdot)$ is the modified Bessel function of the second kind and of order zero and λ is a scale parameters. In (7), K is the so called linearity parameter and controls the decay of the tails of the Cauchy distribution. It is noted that the input GNSS samples, $y[n]$, are assumed to be complex valued and thus (6) and (7) should be interpreted as bi-variate joint distributions where z is a complex variable.

The generalization of the LS problem considered in (4) leads, in general, to complex minimization problems. A possible solution is to assume that the GNSS signal amplitude, A, is small and to approximate (4) with its Taylor series expansion. In this way, a robust equivalent of (2) and (3) is obtained (see [2] for mathematical details):

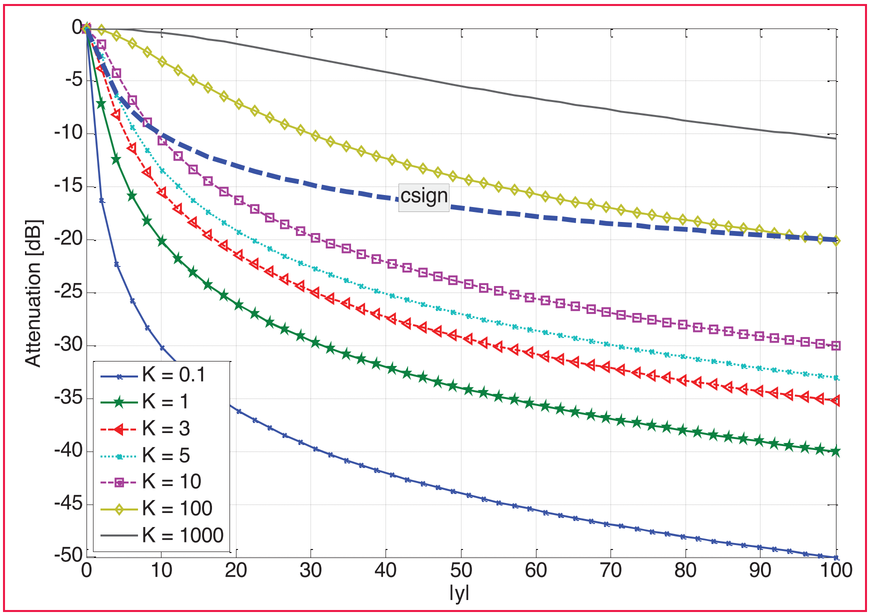

Figure 4: Attenuation profile of the complex sign and myriad non-linearities for different values of *K*

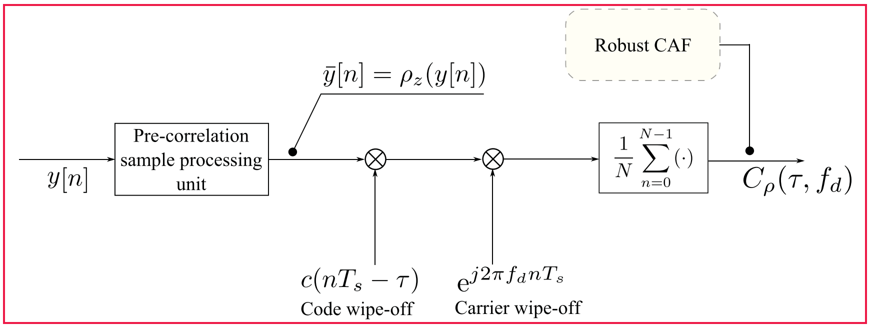

Figure 5: Robust CAF obtained using a pre-correlation sample processing block (from [2])

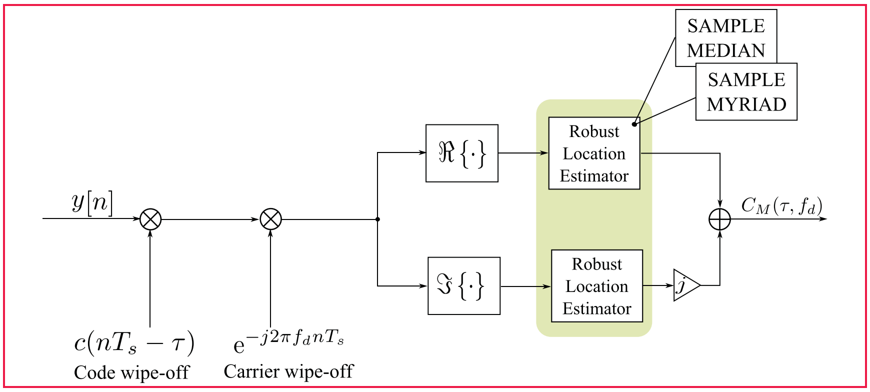

Figure 6: Robust CAF obtained using the filter bank approach (from [2])

$$\{\hat{\tau}, \hat{f}_0\} = \arg\max_{\tau, f_d} |C_\rho(\tau, f_d)|$$
$$\hat{\varphi} = \angle C_\rho(\hat{\tau}, \hat{f}_d) \quad (8)$$

where

$$C_\rho(\tau, f_d) = \frac{1}{N}\sum_{n=0}^{N-1}\rho_z(y[n])c(nT_s - \tau)e^{-j2\pi f_d nT_s} \quad (9)$$

is a robust version of the CAF. $\rho_z(\cdot)$ is a non-linear memory-less function used to pre-process the input samples and it is defined as

$$\rho_z(z) = \rho_I(z) + j\rho_Q(z) = \frac{\partial\rho(z)}{\partial z_I} + j\frac{\partial\rho(z)}{\partial z_Q} \quad (10).$$

Robust estimators are obtained when $\rho_z(\cdot)$ is bounded. In the Gaussian case, $\rho_z(\cdot)$ is equal to the identity and thus it is not bounded. In the Laplace case considered in (6), $\rho_z(\cdot)$ is approximately given by the complex sign non-linearity:

$$\rho_z(z) = \text{csign}(z) = \begin{cases} 0 & \text{if } z = 0 \\ \frac{z}{|z|} & \text{if } z \neq 0 \end{cases} \quad (11)$$

The myriad non-linearity is obtained when a Cauchy distribution is assumed [4]:

$$\rho_z(z) = \frac{Kz}{K + |z|^2} \quad (12).$$

Eq. (12) has been obtained by normalizing the derivative defined in (10) in order to make $\rho_z(\cdot)$ converge to the identity for large values of K.

It is important to note that the non-linearities considered here are always proportional to the input variable, z, and that only the amplitude of the input samples is affected. The phase of the samples is preserved and only the signal amplitude is attenuated.

The attenuation profile for the complex sign and myriad non-linearities are provided in Figure 4. In general, the attenuation increases with the amplitude of the input samples: the larger the amplitude of the input sample, the higher the attenuation provided by the non-linearity.

Pulse Blanking (PB), a technique widely used for interference mitigation [7] can also be inscribed in the paradigm described here where $\rho_z(\cdot)$ does not derive from a pdf and it is given by

$$\rho_z(z) = z\cdot\mathbf{1}(|z| < T_h) = \begin{cases} z & \text{if } |z| < T_h \\ 0 & \text{if } |z| \geq T_h \end{cases} \quad (13).$$

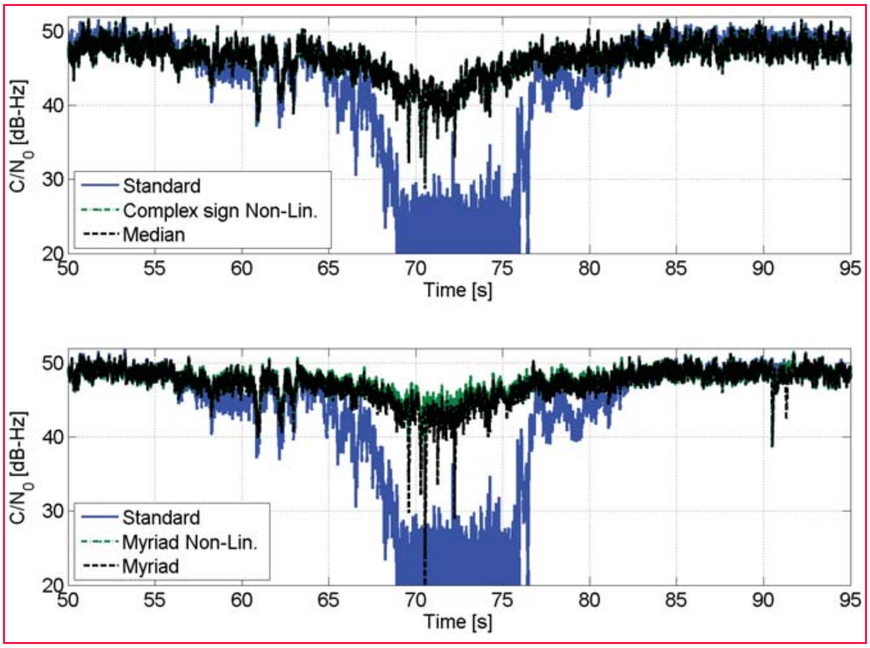

Figure 7: Comparison between C/N_0 values estimated using the standard approach and robust techniques. Upper part: robust techniques designed using the Laplace noise model. Bottom part: robust techniques designed using the Cauchy assumption

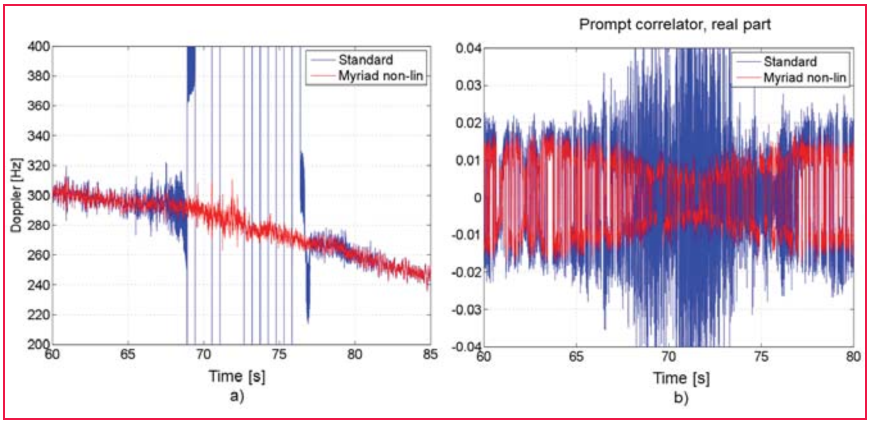

Figure 8: Comparison between standard processing and myriad non-linearity during the most critical part of the car experiment. a) Estimates of the estimated Doppler frequency. b) Real part of the prompt correlator

$\mathbf{1}(\cdot)$ denotes the indicator function which is equal to 1 only if its argument is true and it is zero otherwise. $T_{h,}$ is the blanking threshold.

The results exposed above lead to the processing scheme depicted in Figure 5. Finally, the robust CAF can be interpreted as a form of Locally Optimum (LO) detector/generalized correlator [8], which is obtained by tackling the problem from a detection perspective.

A second approach to introduce robustness to the standard signal processing blocks of a GNSS receiver is to act directly on the filter bank (correlator) structure of acquisition and tracking. In particular, the mean performed in (3) can be replaced by robust alternatives such as the sample median and the sample myriad operators [9]. The myriad is a location estimator that is obtained when a Cauchy distribution is considered. As for the myriad non-linearity defined in (12), it depends on the linearity parameter, *K*. In the next section, *K* will be fixed to the value determined in [4]. Using these considerations, the processing scheme depicted in Figure 6 is obtained.

Experimental results

In order to illustrate the potential of robust signal processing techniques for the acquisition and tracking of GNSS signals, the data collected during the Slovenian experiment [3] are considered here. As described in [3], a car, equipped with a u-blox reference receiver and a Realtek RTL2832u device used as a Software Defined Radio (SDR) front-end, was periodically passing in front of a jammer placed on the side of the road. Although the data collected with the RTL2832u device were mainly intended for the design of jammer detectors, they can also be used to empirically evaluate the potential of the robust techniques discussed above.

In the close proximity of the jammer, i.e. for a distance of about 5 metres, the interfering power was so strong that the u-blox receiver was not able to operate. The standard approaches discussed in Section 2, are also unable to detect and track useful GNSS signals from the data collected with the RTL2832u device. This fact is illustrated in Figure 7 that provides the C/N_0 values estimated using different approaches. In the [60 - 80] s interval, the car is sufficiently close to the jammer to suffer performance degradations. In the middle of such interval, the jamming power is so strong that the standard approach is unable to track and re-acquire the signal. This fact is reflected by the C/N_0 values shown in Figure 7.

Robust approaches enable receiver operations even in the close proximity of the jammer and signal tracking is maintained during the whole duration of the experiment. The upper part of Figure 7 considers the case where robust tracking is implemented considering a Laplace noise. The complex sign and the median filter bank lead to the same C/N_0 values.

Robust techniques obtained under the Cauchy assumption are considered in the bottom part of Figure 7. Among all the techniques considered, the myriad non-linearity provides the best performance. The computation of the myriad correlation requires an iterative, computationally demanding procedure and the loss of performance with respect to the myriad non-linearity may be due to an incomplete convergence of the algorithm. In general, the filter bank approach is more computationally demanding and pre-processing the input samples using a memory-less non-linearity seems a preferable solution.

Since the myriad non-linearity provides the best performance, it is further analysed in Figure 8. During the most critical part of the experiment, i.e. in the close proximity of the jammer, the myriad non-linearity allows the receiver to maintain frequency and phase lock. The estimated Doppler frequency is shown in Figure 8 a): when the myriad non-linearity is used, the receiver is able to provide reasonable Doppler estimates during the whole duration of the experiment. The right part of Figure 8 shows the real part of the prompt correlator which is used to estimate the navigation bits. Also in this case, the myriad non-linearity allows proper receiver operations and the bits can be effectively estimated from the prompt correlator.

These results show the advantages and the potential of robust signal processing for GNSS.

Conclusions

Robust signal processing techniques have the potential of significantly improving the receiver performance in the presence of model mismatches. Two approaches, based on the M-estimators framework, have been analysed in the paper: both techniques allow the receiver to operate in the presence of jamming. The first approach considered uses a non-linearity to de-weight the impact of samples with abnormally large amplitudes. These samples are, in practice, considered outliers and thus their amplitude is significantly reduced by the non-linearity. This approach has a complexity that scales linearly with the number of input samples. The second approach operates at the correlation level: robust operators, such as the sample median and the sample myriad, replace the sample mean performed by standard techniques. Although, also in this case, a significant performance improvement is observed, this second approach is more computationally demanding. The experimental results presented show the benefits of robust techniques whose usage should be considered also for the design of other receiver stages such as the filters of the tracking loops.

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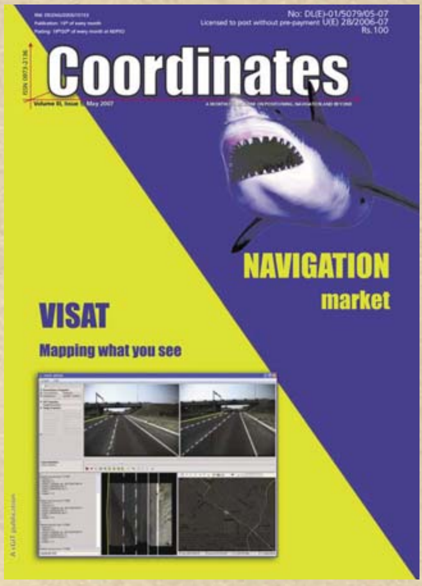

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POLICY

GPS enabled mobiles reclassified

The circular presented here is the reclassification of higher technology featured mobile phones by Central Board of Excise and Customs, Government of India. It is also supplimented by news that appeared recently in Economic times. If GPS as a secondary feature on a mobile phone attracts lower customs duty, could we hope for the same for stand alone GPS receivers?

NAVIGATION

Navigating the navigation market

The market will move away from pure navigation to also-navigation

ALDEN LEE

Conclusion

Besides a few big players medium-sized hardware companies will only survive in niche markets. In a first wave mobile phone companies will control the low-end market, while notebook companies will control the high-end market. In a second wave automotive companies will gain more and more market share.

Current software companies may retain their current business but there is enough room in the market for new software companies that can offer detailed map attributes and/or attractive new applications.

The market will move away from pure navigation to also-navigation, offering life-style features like restaurant recommendations and safety features like cameras or eCall.

Big companies will only survive when they stay price competitive, while small and medium-sized companies can only survive when they anticipate market trends on time and are amongst the first to supply new demand.

DISASTER MANAGEMENT

Early warning system for Tsunami in the Indian Ocean

The entire national Early Warning System is targeted to be made operational by September 2007

SHAILESH NAYAK

GNSS

Understanding Galileo

Galileo will make civil users of satellite navigation in Europe and all over the world independent of the American GPS

HENDRIK THIELEMANN

Even more, especially in connection with civilian use, Galileo will outperform GPS and thereby open the gate for new applications and markets for satellite supported navigation. Especially in the combination with navigation, mobile telecommunication and information services, there is an immense utilisation and market potential.

Navigation in ancient walls

The 14th edition of the Munich Satellite Navigation Summit was held on March 14 - 16, 2017 at the Munich Residenz, again organized by the Institute of Space Technology and Space Applications (ISTA) of the Universitaet der Bundeswehr Muenchen. About 420 participants from 23 nations made their way to Munich to discuss the latest news on Positioning, Navigation, and Timing as well as the necessity for backup solutions.

Looking at the bright side of satellite navigation

The official program of the three-day conference was kicked off on March 14 in the ancient walls of the Court Church of All Saints. Prof. Dr. Bernd Eissfeller, chairman of the conference, and Prof. Dr. Merith Niehuss, president of the Universitaet der Bundeswehr Muenchen, welcomed the participants. The Deputy Bavarian Minister-President and Bavarian State Minister for Economic Affairs and the Media, Energy and Technology, Ilse Aigner, emphasized via video message that satellite navigation plays an important role for the economy, especially with the latest declaration of the Galileo Initial Services. The panel discussion of the first conference evening was dedicated to the topic “Satellite Navigation in a changing political and technical environment”. High-level representatives from European ministries and entities as well as from the USA and China took the questions from the moderator Claus Kruesken.

After the outage of clocks on board of several Galileo satellites was much debated in the weeks before the conference, the European representatives made clear that this failure is not a fundamental issue and that the general function of the satellites is not affected. In principle, Pierre Delsaux, Deputy Director General, DG Internal Market, Industry, Entrepreneurship and SMEs at the European Commission, underlined that it is important to look on the bright side of life. Given the complex technology of satellites, Europe should be proud of what it has already achieved with 18 fully functional satellites in orbit. According to Pierre Delsaux it is still the aim, to provide the fully operational system by 2020.

GNSS – Is it time for backup?

The program of the following two conference days offered a variety of up-to-date topics. Besides the traditional presentations on the global, regional and augmentation satellite navigation systems, the morning of the second conference day was dedicated to the overall theme “GNSS - Is it time for backup?”. The correspondent session pointed out how GNSS services could be complemented by terrestrial PNT systems and was chaired by Dana Goward, president of the Resilient Navigation & Timing Foundation. He explained that backup is not about single systems, but rather about building up a complementary and resilient architecture. Dominic Hayes from the European Commission underlined that Europe wants to include several backup options instead of focusing only on one specific navigation solution.

The program also entailed the second generation of the Galileo system. Prof. Vidal Ashkenazi, CEO of Nottingham Scientific Ltd, debated amongst others with representatives of the European Space Agency (ESA), the European Commission and the OHB System AG, how stability, precision and integrity can be ensured for the new generation. The third and last conference day was dedicated to panel discussions on the Galileo Public Regulated Service (PRS), the Civil GPS Service Interface Committee (CGSIC), the BeiDou system as well as the Interoperable GNSS Space Service Volume (SSV).

Opening speakers from left to right: Prof. Dr. Bernd Eissfeller, Pierre Delsaux, Prof. Dr. Merith Niehuss, Prof. Dr. Johann-Dietrich Woerner, David Comby, Harold Martin, Dr. Xiaochun Lu, Carlo des Dorides, Prof. Dr. Hansjoerg Dittus

Besides the technical program the participants had the chance to visit exhibition booths of several companies and institutions like Airbus Defence and Space, the European Commission, NavCert GmbH and Telespazio.

Munich Satellite Navigation Summit 2018

The Munich Satellite Navigation Summit 2018 will take place on March 5 - 7, 2018.

Kristina Kudlich, www.munich-satellite-navigation-summit.org

Galileo update

EU working to 'push' Britain out of the space race by cancelling Galileo contracts

The European Commission is working to "push" British companies out of contracts for the latest phase of work on the EU's Galileo satellite navigation system, according to reports.

The body is understood to be calling for the right to cancel existing contracts if a supplier is no longer based in an European Union member state.

The total cost of the latest project is €10 billion (£8.5 billion) and managed by the European Space Agency.

The Financial Times reports that the Commission is demanding that any company kicked out of the programme should be asked to finance the cost of finding a replacement supplier.

An UK government official said: "It feels like the UK is being targeted.

"We have been fighting to stay involved in Galileo whereas some European partners are working to push us out."

The majority of Galileo's existing satellites have been provided by the UK's Surrey Satellite Technology, majority owned by France-based Airbus.

British companies with interests in the project include Qinetiq, CGI, Airbus and Scisys. *www.telegraph.co.uk*

Galileo search-and-rescue service officially launched

The Galileo Search And Rescue (SAR) service, made possible by the Galileo satellite constellation, is now active.

Galileo SAR is Europe's contribution to the COSPAS-SARSAT network, a distress alert detection and information distribution system best known for detecting and locating emergency beacons activated by aircraft, ships and hikers.

By providing COSPAS-SARSAT with the coverage capacity of the Galileo constellation equipped with SAR transponders, Europe is helping to reduce the detection delay of a distress signal from up to several hours to 10 minutes.

A return link, a signal informing the person in distress that the signal has been received and localized, will be added to the system by the end of 2018.

With Galileo, the time to identify the location of a beacon signal is reduced from several hours to a few minutes. At sea, this makes SAR rescue operations easier thanks to a narrowed "search box," since the vessel in distress has less time to drift.

On land, the quick acquisition of a precise position enables rescue teams to more quickly reach the operation zone and assist the victims.

RuggON announces the VX-601

RuggON Corporation has launched a new rugged in-vehicle terminal, the VX-601, which provides superb visibility from a large, bright, sunlight-readable touchscreen display; great durability; seamless connectivity and communications; as well as smart power management. The VX-601 is suitable for challenging environments and diverse applications such as intralogistics, cold chain logistics, waste management, mining, harbor freight handling, agriculture and construction.

TravelTab selects HERE Mobile SDK

TravelTab has selected HERE as the mapping and navigation provider for its new travel companion devices available to car rental customers in the United States, Canada and Mexico.

MapMyIndia launches digital twin of real world

MapMyIndia has announced alliances with Indian Space Research Organisation (ISRO), Idea Cellular , Visit Health, Aatapaha Smart Lighting, Reverie Language Technologies and Udacity India, to develop India-specific solutions. It offers India's best maps and location technologies to ISRO, including ISRO's satellite mapping portal, Bhuvan. ISRO has recently launched NAVIC, India's indigenous satellite navigation system. MapMyIndia also announced the acquisition of VidTeq, a pioneer in VideoMaps. *http://www.newseleven.in*

Low-power LNA for GNSS radio receiver applications

Skyworks Solutions of Woburn, Massachusetts, USA, has launched the SKY65623-682LF low-noise amplifier (LNA) for applications including wearables, asset trackers, navigation devices, and action cameras. The SKY65623-682LF is a Microwave Monolithic Integrated Circuit (MMIC) front-end LNA designed for GNSS radio receiver applications. The device is designed to provide low current consumption (1mA @ 1.8V supply), optimal gain, and a superior noise figure (NF). Output matching components are embedded inside the device. Only one external input matching inductor is required.

Smart Counting – Oil Palm tree inventory with UAV

This article demonstrates an efficient way of taking stock of oil palm tree stands at the comfort of the owner without the usual several days of hard labour

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Unmanned Aerial Vehicle (UAV) System has gained popularity in the field of photogrammetry, remote sensing and geospatial engineering for civilian applications. Its impact on society and the speed of project delivery has undeniably presents users with varieties of choice and producers with very attractive competitiveness. Business leaders and geospatial users are increasingly faced with the challenge of how to incorporate various UAV technology preferences in their projects. Currently, UAV is the fastest means of collecting high quality image and generating DEM of sizeable project area. Satellite remote sensing has been widely used for collecting data over large areas for vegetation and agricultural applications, particularly for plantation monitoring [1]. But for small to medium scale enterprises, the use of space and airborne platforms are not economical due to budget constraint.

In recent times, UAVs are being deployed for many remote sensing applications. Depending on the type and mission of the UAV, it can be flown at different altitudes and at any time. This flexibility allows for optimization of the operations according to weather conditions over a given area and the user requirements. High spatial resolution and speed of delivery makes application of data acquired with UAV becoming popular in environmental remote sensing such as cadastral mapping [2], post-flood analysis [3], [4], vegetation cover assessment [5], crop monitoring [6], forest fire [7], traffic monitoring [8]–[15] etc.

In Malaysia, Oil palm is one of the main economic crop and the larger percentage of the plantations are owned by private individuals categorised as small scale farmers. One of the common activities is taking stock of the number of palm trees within the plantation. This information is vital for estimating yield and productivity. Conventionally, inventorying is achieved by either manually counting oil palm tree crowns on imageries or ground surveying using GPS to gather their locations information. Obviously, it is impossible to obtain accurate inventorying with these methods in large oil palm plantation. Besides, the traditional process of counting is prone to erroneous estimation, expensive and time consuming.

UAV-based palm tree inventory

High spatial resolution images captured with UAV offers a reliable prospect to detect palm trees with a characteristic crown formation. Template matching algorithms is a popular technique for detecting object from image using the object's boundary as a criteria [16]. In some cases, however, the use of boundary could be misleading due to image distortion or occlusion [17]. Furthermore, template matching can be affected by the geometry and scale of the object in the image. To overcome these limitations, object-based analysis was applied where the boundary of objects are defined through segmentation. Selection of segmentation parameters that are suitable for varying geometry and scale of trees can result to accurate detection. For these reason, template matching and object-based image analysis were integrated into a single processing workflow (Figure 1) to improve the counting accuracy and the result was

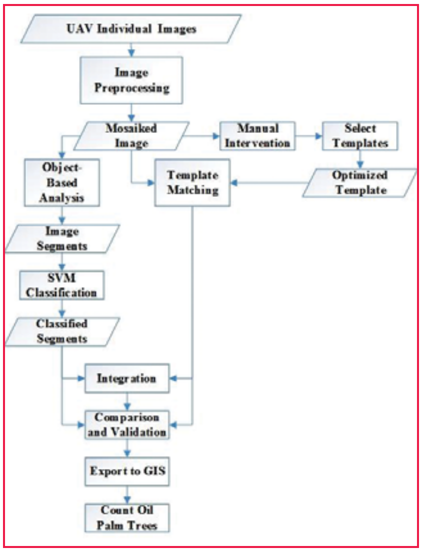

Figure 1: General data processing and analysis workflow

compared with another experiment produced with template matching only.

With Canon S100 (12-mega pixels) mounted, a fixed-wing J-HAWK UAV (Figure 2) was flown over the Melaka Pindah oil palm plantation, Peninsula Malaysia, for data collection. Following data collection, individual UAV image was visually evaluated and only the high quality images with minimum noise and blurring were retained. Subsequently, the images were matched in Agisoft Photoscan [18] using ground control points acquired with GPS for the registration process. The registered images were mosaicked to generate panoramic image from which the study area was subset for this study.

Theoretical bases

Template matching has been used in computer vision for object recognition [19]. The algorithm searches the image to find an area within a larger image that matches a specific and smaller template image (i.e. a sub-image of that larger image). Basically, it is a measure of the similarity between the image and the feature [20]. One way to perform template matching is to calculate the cross correlation between the template and the images, compared using the squared Euclidean distance (Equation 1 – 3). The algorithm compares a template that contains the shape we attempt to find (i.e. oil palm tree crown (Figure 3)) to an image.

$$d^2_{f,t}(u,v) = \sum_{x,y}[f(x,y) - t(x-u,y-v)]^2 \quad (1)$$

where d is the sum is over x, y under the window containing the feature positions at u, v). In the expansion of d^2

$$d^2_{f,t}(u,v) = \sum_{x,y}[f^2(x,y) - 2f(x,y)\, t(x-u,y-v) + t^2(x-u,y-v)]^2 \quad (2)$$

The term $\sum_{x,y} t^2(x-u,y-v)$ is fixed. If the term $\sum_{x,y} f^2(x,y)$ is nearly constant then the remaining cross correlation term

$$c(u,v) = \sum_{x,y} f(x,y)t(x-u,y-v) \quad (3)$$

Object-based image analysis (OBIA) is the tool of the era among remote sensing professionals for extracting useful information from an image. Compared to the pixel-based methods, OBIA considers spectral information from a set of similar pixels believed to belong to the same object. The basic element of OBIA is segmentation which partitions an image into unclassified segments or image objects based on a measure of spectral properties that include colour, size, texture, shape and contextual information [21]. Specifically, the quality of segmentations and the resulting object primitives are based on colour, shape, size and pixel neighbourhood influenced by parameters set by the user. As a rule, a user needs to define the scale and colour/shape parameters. The value of the scale parameter determines the size of the image object. Large scale value allows high variability within each object which ultimately results in relatively large segments being created [21]–[23]. On the contrary, small scale value permits less variability and, therefore, creates smaller segments. Like the scale criteria, colour and shape parameters also affect how segments are created. Higher value for colour/shape criteria optimizes spectral and spatial homogeneity. Within the shape criterion, the degree of smoothness of object border and compactness of the segments are two important parameters that must be defined along with scale parameter.

Experimental result

First, the UAV subset image was visually examined and several templates were selected. The templates were tested to predict possible presence of other trees and thereafter the optimized template was selected. Once this was done, the optimized template was passed through template matching process to generate correlation image. Each pixel in the generated image demonstrates the correlation factor between the template and the image. Further processing was carried out to generate a thematic layer representing the palm tree crown where centroid point was produce to represent each tree stand in the image. Note that the points were generated by using a correlation threshold. For example, if a threshold of (0.7) is selected, then all pixels in the correlation image are converted into points while those not

Figure 2: The Fixed-wing J-HAWK UAV used for image acquisition

Figure 3: Samples of some of the randomly selected templates

meeting the threshold are regarded not to be palm trees. To appropriately select this threshold, a sensitivity analysis is required; so, several thresholds were examined and the best threshold based on the prediction capability was selected. In addition, the image was further analyzed to create image objects using multi-resolution segmentation, an object-based image analysis technique (explained earlier). Using the spectral and spatial attributes of the segmented image objects, two classes, oil palm trees and background, were defined. Subsequently, the oil palm trees class was integrated with the result of the template matching which produced improved result. Finally, the results were exported into GIS to automatically count the number of oil palm trees in the image. Thereafter, the performance of the two approaches (template matching and integrated template matching-object-based) was evaluated using manually selected samples.

Several templates were identified in the original image and stored in a database. These templates were classified into three classes, oil palm tree, error, undefined based on visual investigation. In order to select the vtemplate with the best image quality, the templates were analysed and the accuracy of counting determined for each template using the correlation coefficient (R^2). The template with the highest R^2 was selected as the best.

Based on the optimum template, the correlation image was constructed. Each pixel value in the correlation image represents the correlation coefficient between the template image and the original image. Correlation image is represented in shade of grey scale where high correlation is represented as bright (white colour) whereas the dark pixels represent low correlation values. From Figure 4, it can be seen that the oil palm trees are shown as bright colour in the corresponding correlation image (Figure 4b). This indicates that the template matching algorithm detected the location of oil palm trees. For the purpose of counting, correlation value greater than the threshold (T) were converted into points

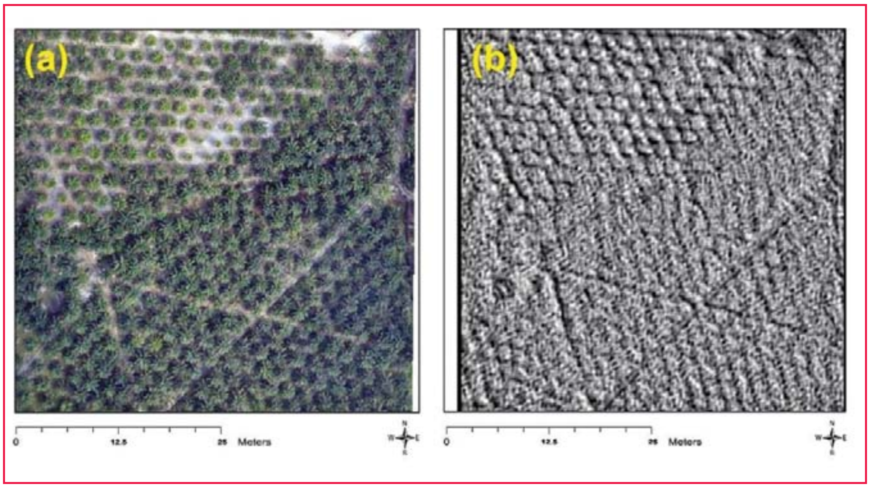

Figure 4: (a) Subset image and (b) the corresponding correlation image

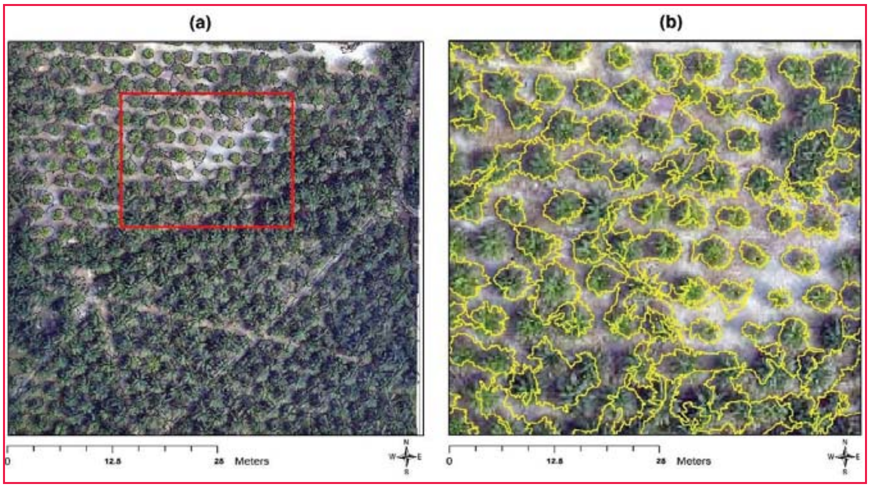

Figure 5: (a) Subset image segmented and (b) synoptic view of segmentation result for the part highlighted in the rectangular box in the left plate

(vector format). The threshold (T) of 0.65 was selected using trial and error approach to generate the point representation of the oil palm trees in the image.

Object-based analysis generated image objects, a non-overlapping homogeneous regions from the subset image (Figure 5a) based on the defined segmentation parameters values 85, 0.4, and 0.5, for the scale, shape and compactness respectively (Figure 5b). From the image objects, 20 training samples comprising of 10 oil palm trees and 10 background samples were randomly selected for the classification using Support Vector Machine (SVM) classifier. SVM was selected because of its relative simplicity and the well-published quality of classification performance in literature [24]. Even though the quality of image segmentation is good, the challenges identified include two or more image objects merging into one segment (over-segmentation) while at times individual trees crowns are represented by two or more segments (under-segmentation). Again, due to the viewing angle relative to the sun position, shadow areas are considered as tree crowns and segmented as such too. These issues degraded the quality of object-based method making it difficult to solely rely on it for counting. This makes integrating the two methods a feasible solution.

The outcome of the two approaches are represented in point form for ease of counting (Figure 6). It can be seen that most of the trees were detected accurately, however, the main challenge is that some trees were counted twice or more especially, in dense areas (6a). In areas where palm trees are separated, the template matching algorithm works well. But in the denser part, error occurred such as those highlighted in the north part of the study area. A clearer perspective of this phenomenon is amplified in the north part of the study area in the image at the bottom.

On the other hand, the result obtained by combing the two methods yielded better detection. It significantly reduced the error observed in the template matching method as presented in the bottom plate of Figure 6b. Where a single palm tree crown is represented by more than a point in the template matching method, the second technique corrects the error by identifying it with single dot. However, where two or more tree crowns are knitted, the integrated approach have some limitations in deciding how many they are, and therefore leave it blank. Nonetheless, the integrated approach performs better than the template matching, and this is further elaborated in the quantitative evaluation.

Comparison with the ground truth data offers quantitative metric to evaluate the performance metrics using precision, recall and the F-measure [1], [25], [26] expressed in Equation 4 - 6.

$$\text{Precision} = \frac{TP}{TP + FP} \quad (4)$$

$$\text{Recall} = \frac{TP}{TP + FN} \quad (5)$$

Table 1: Accuracy evaluation of the template matching and combined methods

Method	Number of Detected Oil Palm Tree	Ground Truth	FP	FN	Precision	Recall	F-Measure
TM	790	509	281	21	0.63	0.95	0.711
TM+ OBA	582	509	73	45	0.86	0.91	0.87

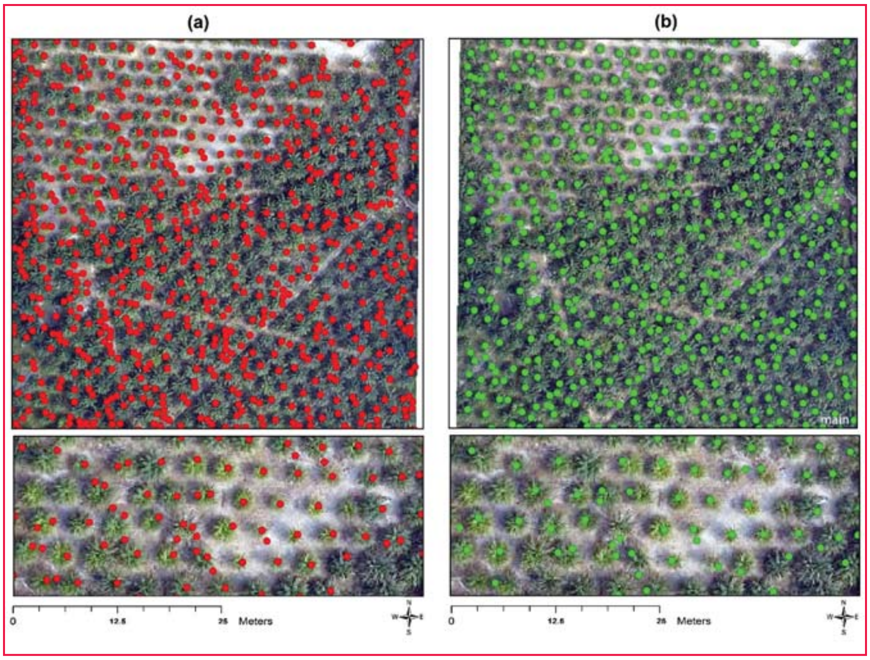

Figure 6: Oil palm detection (a) template matching (b) integration of template matching and object-based analysis

$$F - \text{measure} = \frac{(1+\alpha) \times \text{Precision} \times \text{Recall}}{\alpha \times \text{Precision} + \text{Recall}} \quad (6)$$

where a True Positive (TP) is the number of correctly detected oil palm. A False Negative (FN) is an oil palm tree that is not detected. A False Positive (FP) shows a pixel that is recognized as an oil palm tree but it is something else. α is a non-negative scalar. In this study, is set to 0.5 as suggested in [25]. In this context, precision can be interpreted as the probability that a detected oil palm tree is valid and recall is the probability that the correct oil palm tree (ground truth) is detected. The F-measure defines the (weighted) harmonic mean between precision and recall, where the precision and recall are combined into a single performance measure. As a consequence, it measures the overall performance metric with 87% accuracy compared to 71% in template matching (Table 1). The detection precision follows similar trend.

Summary

Advances in space science and computing have largely improved farming methods, productivity and yield. This article demonstrates an efficient way of taking stock of oil palm tree stands at the comfort of the owner without the usual several days of hard labour. The approach employed significantly minimizes error in counting compared to using the widely employed template matching (a meticulous manual counting check confirmed this). Reduction in error of estimation from of 790 tree stands 582 (i.e. about 27%) is a great improvement to effective decision making process, allocation of resources and quantitative yield estimation. Automation of this process into a computer-based program simplified for non-technical users will be a vital tool not only to the farmers but policy makers and relevant government agencies in making informed decision.

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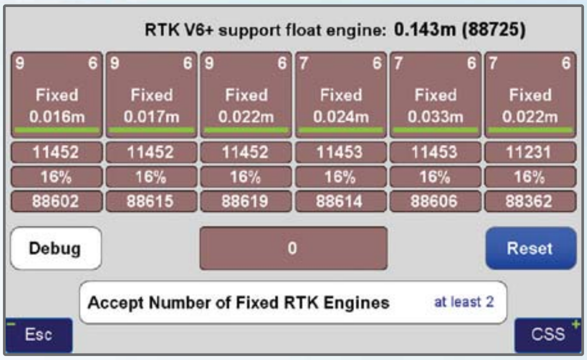
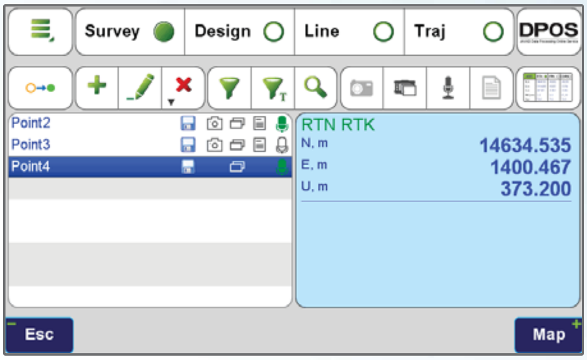
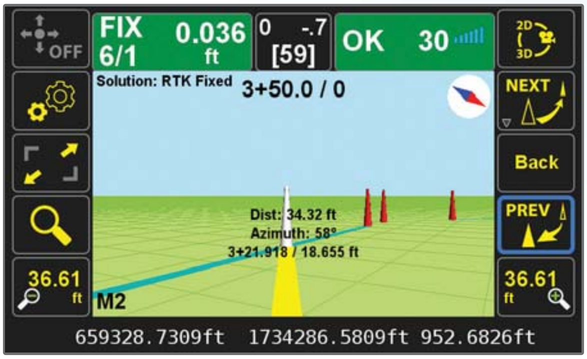
TRIUMPH-LS and J-Field

Hands free operation







J-Field is the embedded application program of TRIUMPH-LS. It has the following unique features for each point surveyed:

- Six parallel RTK engines to maximize solution availability.
- Automatic Engines Resets, verification and validation strategy.
- Several graphical and numerical confidence reports and documentation.
- Voice-to-text conversion for hands free operation and documentation.
- Lift & Tilt and automatic shots for hands free operation
- Visual Stakeout (Virtual Reality)
- “DPOS it” or “Reverse Shift it” features. The most advanced RTK verification.
- Photogrammetry and angle measurements with embedded cameras.
- Automatic or manual photo documentation.
- Automatic screen shots documentation.
- Audio files for documentation.
- Automatic tilt correction.
- Comprehensive HTML and PDF reports
- Comprehensive codes, tags and drawing tools.
- Over 3,000 Coordinate Systems.
- Automatic and free software update via Internet.

J-Tip

J-Pod

J-Pack

J-Shield

Works Where Others Can't Goes Where Others Won't

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.

The LS has increased our productivity 2:1

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.

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

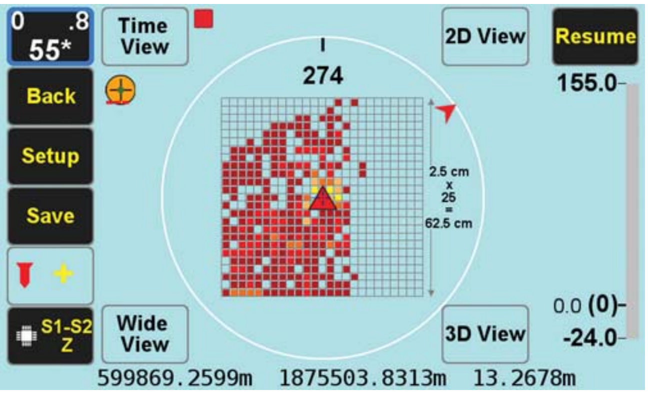
FL

J-Tip

Integrated Magnetic Locator

$850

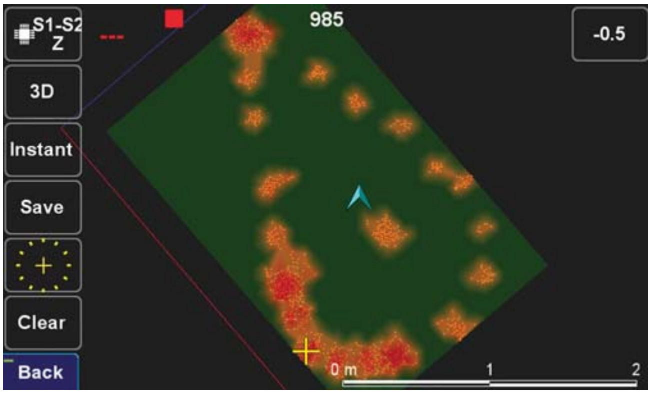
TRIUMPH-LS tags coordinates with magnetic values, It also guides you to top of the item to survey it.

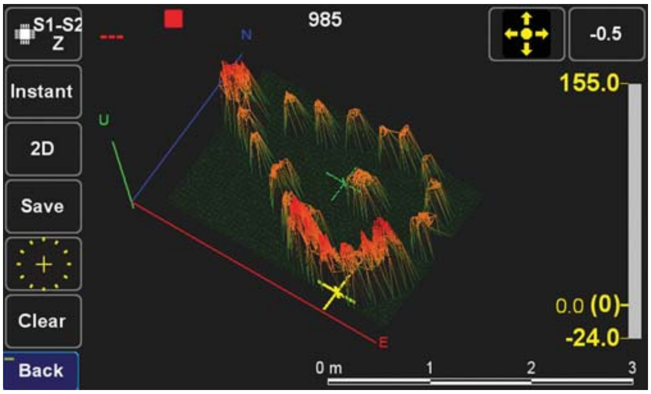


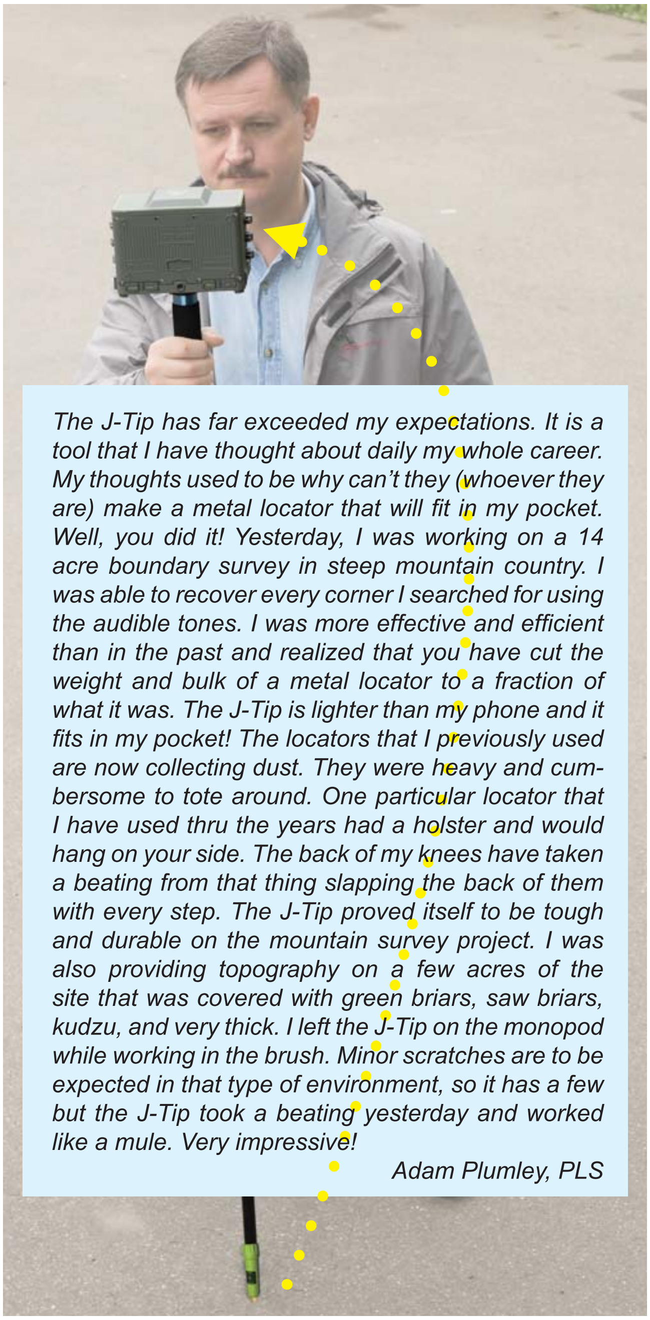
The Mag View focuses only on the mag object with the highest mag value.

The audio and graphical bar on the right side show the magnitude of the magnetic object.

In “Setup” you can select the cell size and the size of the field you want to scan.







The J-Tip has far exceeded my expectations. It is a tool that I have thought about daily my whole career. My thoughts used to be why can’t they (whoever they are) make a metal locator that will fit in my pocket. Well, you did it! Yesterday, I was working on a 14 acre boundary survey in steep mountain country. I was able to recover every corner I searched for using the audible tones. I was more effective and efficient than in the past and realized that you have cut the weight and bulk of a metal locator to a fraction of what it was. The J-Tip is lighter than my phone and it fits in my pocket! The locators that I previously used are now collecting dust. They were heavy and cumbersome to tote around. One particular locator that I have used thru the years had a holster and would hang on your side. The back of my knees have taken a beating from that thing slapping the back of them with every step. The J-Tip proved itself to be tough and durable on the mountain survey project. I was also providing topography on a few acres of the site that was covered with green briars, saw briars, kudzu, and very thick. I left the J-Tip on the monopod while working in the brush. Minor scratches are to be expected in that type of environment, so it has a few but the J-Tip took a beating yesterday and worked like a mule. Very impressive!

Adam Plumley, PLS

2D and 3D views of the field show the magnetic objects that have been scanned.

Zooming the 2D and 3D screens can show the shape of the magnetic objects under the ground.

For many sophisticated features of the J-Tip see its Users Manual in www.javad.com

J-Pod

A rugged Transformer-Pod

$850

Monopod, 8 and 40 sec
level vials, compass,
Accessory hooks.

Connect legs on demand
to make bipod or tripod.

+ Bipod.

+Tripod.

Monopod >>> to + Bipod >>> to + Tripod... On demand.

Rugged, Light, Compact,
Easy to level.

* Detachable landing and resting pads.
* Mace grips (concrete, asphalt, bricks, soil)

Travel mode.

Inside bag.

The most stable tripod.
It will never collapse,
even on wet glass.

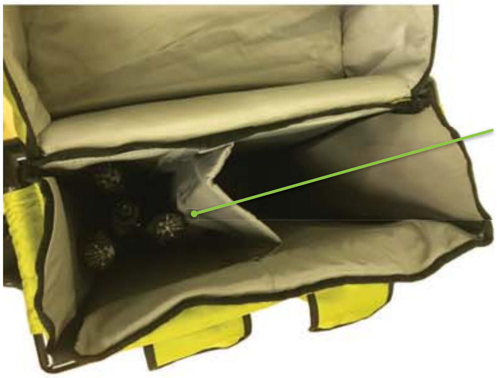
Think of it as a rugged
Transformer-Pod,
We call it **J-Pod.**

J-Pack

Nice and convenient survey bag

$290

It was not our job... You asked for it - we did it!



Javad......Bravo!!!!

The J-Pack is nicest bag I have ever seen for surveying. I especially like the pocket in the back and all of the places to tie down equipment and stuff.

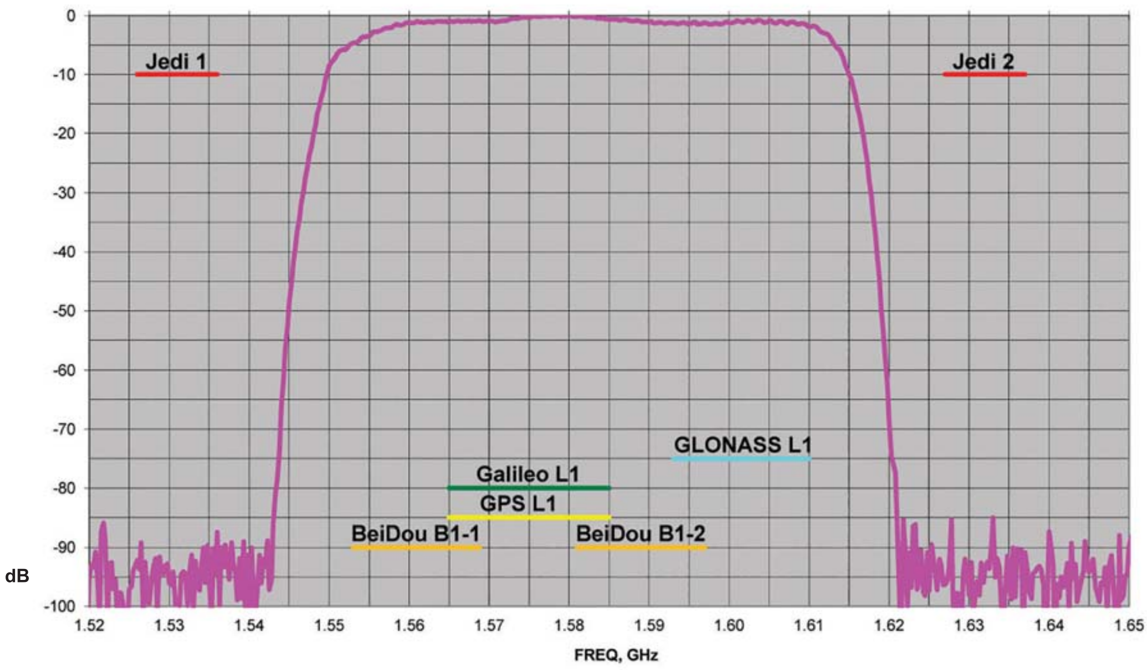
Adam Plumley, PLS

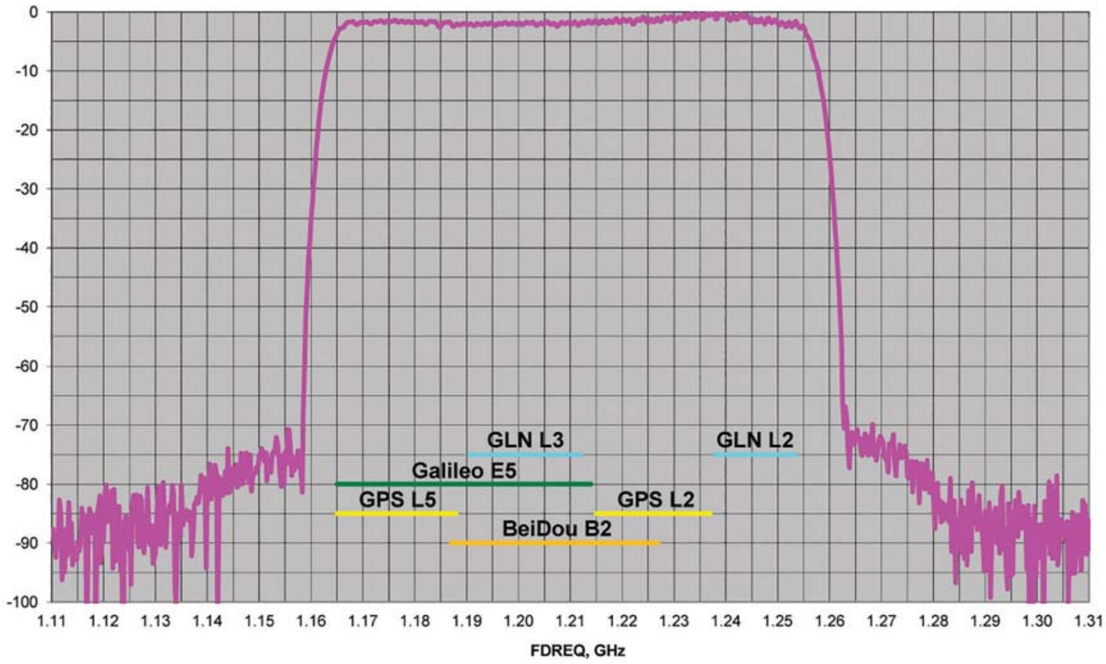
Ship date - January 2017
See full video “J-Pack & J-Tip in Use” www.javad.com

J-Shield

In case the **Jedi** returns

$450





J-Shield of TRIUMPH-LS
protecting all GNSS Bands.

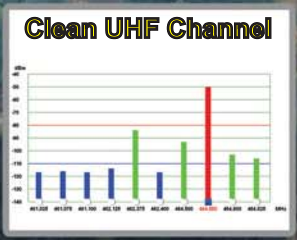
J-Field
Software Features

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.

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

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

DPOSit
Data Processing Online Service



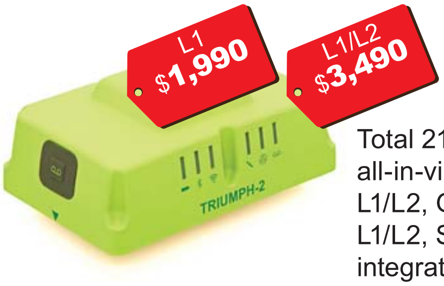
REVERSE SHIFT<<it

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!

TRIUMPH-1M

864 channel chip, equipped with the internal 4G/LTE/3G card, easy accessible microSD and microSIM cards, includes “Lift & Tilt” technology.

TRIUMPH-2



Total 216 channels: all-in-view (GPS L1/L2, GLONASS L1/L2, SBAS L1) integrated receiver.

The one and the only Digital Radio Transceiver in the world!

Unique adaptive digital signal processing, which has benefits: the full UHF frequency range and all channel bandwidths worldwide • the best sensitivity, dynamic range, and the highest radio link data throughput • embedded interference scanner and analyzer • compatibility with another protocols.
Cable free Bluetooth connectivity with GNSS receivers and Internet RTN/VRS access via embedded LAN, Wi-Fi, and 3.5G

And all this with competitive prices!

HPT435BT/HPT135BT/HPT225BT*

$2,710

35 W UHF/VHF Transceiver

HPT404BT/HPT104BT/HPT204BT*

$1,640

4 W UHF/VHF Transceiver

HPT401BT/HPT101BT/HPT201BT*

$2,040

1 W UHF/VHF with internal battery

L-Band/Beacon*

$1,550

Receivers for multiple applications

JLink 3G LTE BAT*

$2,735

Web-interface Wi-Fi, Ethernet, 3.5 G, UHF/VHF/FH915, internal battery

OEM Solutions

$840

902-928, 360-470, 225-255, 138-174 MHz

*Power, data cables and antenna are included.

Back

MTCAS: An e-Navigation Assistance System for Cooperative Collision Avoidance at Sea

MTCAS is the abbreviation for Maritime Traffic Alert and Collision Avoidance System, which implies the basic idea of adopting the Airborne Collision Avoidance System (ACAS) implementation TCAS. This paper informs about the activities in the MTCAS project.

Christian Denker
OFFIS - Institute for Information Technology, Germany

Axel Hahn
University of Oldenburg, Germany

The history has shown a continuous increase in year to year accidents at sea. In the near future, higher traffic density is estimated, which contributes to this increase. Within the 3-year Project MTCAS, 5 German partners from industry and academia contribute to accident reduction by developing an e-Navigation Assistance System for pro-active, predictive and cooperative collision avoidance.

MTCAS is the abbreviation for Maritime Traffic Alert and Collision Avoidance System, which implies the basic idea of adopting the Airborne Collision Avoidance System (ACAS) implementation TCAS. However, MTCAS broadens its bounds by assisting the ships' crew in conflict detection and conflict resolution under consideration of a ships holistic environment. Concrete examples include regularities, bathometry, non-equipped vessels and VTS, which are elaborated in this paper. Dissident from TCAS, MTCAS does not automatically intervene in terms of issuing steering commands, but supports seafarers in cooperatively finding safe and efficient trajectories, whose on-board implementation avoids collisions.

This paper informs about the activities in the MTCAS project. We welcome constructive thought and feedback to foster synergies amongst our domain.

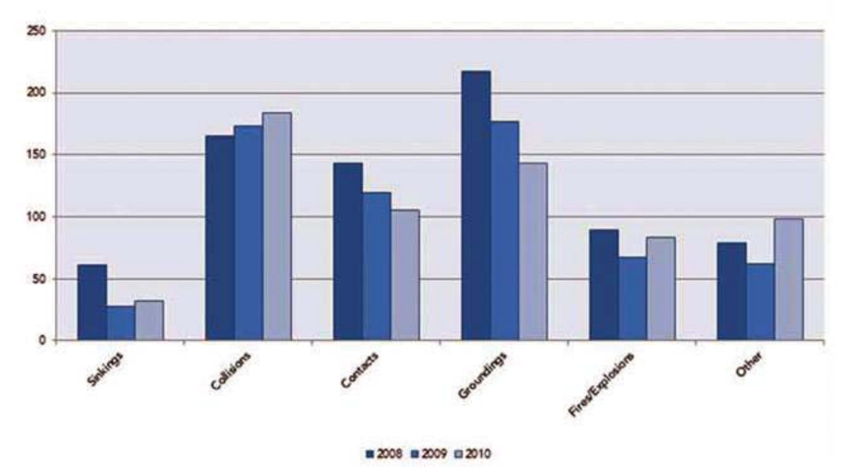


Figure 1: Comparison of accident classes 2008-2010. Source: EMSA

Introduction

Continuous increasing accident risk drives the need for a Maritime Traffic Alert and Collision Avoidance System (MTCAS). As broadly known, "around 90% of world trading is carried out by the shipping industry" (Chauvin, Lardjane, Morel, Clostermann, & Langard, 2013)the shipping industry has implemented a number of measures aimed at improving its safety level (such as new regulations or new forms of team training and thus shipping can tip the scales of our world's economy. The ongoing trend towards an increasing size of new builds, in terms of capacities for cargo and passengers seems to contribute to the magnitude of accident risk: A correlation to an increase in maritime accidents can be perceived from current accident statistics (see Figure 1). Whereas collisions is solely one of six categories in the EMSA accident statistic, at least samples from the categories contacts and groundings, such as beaching, can be accounted to accident preventive actions.

Nowadays Collision Avoidance Means

Collision avoidance is a major process on a ship bridge and in Vessel Traffic Services (VTS), where officers, pilots and operators strive towards efficiency and safety of maritime transport. Therefore classical navigational means are used, which are briefly introduced in this section.

Automatic Radar Plotting Aid (ARPA)

ARPA is a plotting aid, whose functionality includes detection and tracking of foreign vessels. On modern INS bridges it may be integrated into ECDIS. For collision avoidance it provides restricted **movement predictions**, which are based solely on CPA/TCPA, which imply a constant velocity approach.

Automatic Identification System (AIS)

AIS is a radio system for exchanging navigational and ship data in-between ships and as a means for shore-side surveillance via a VTS-System. Since enactment of SOLAS continuously commercial fleets have been equipped with this technology, to continuously interchange static and dynamic passage data. Non-obtrusive shortcomings of AIS are potential **misuse through users**' key errors and **lag of security**, such that the integrity, confidentiality and availability of data is not given.

Maritime Mobile Service (MMS)

MMS is according to ITU a "mobile service between coast stations and ship stations, or between ship stations, or between associated on-board communication stations; survival craft stations and emergency position-indicating radio beacon stations …" (ITU, 2012). The inter-stations communication via voice bears the risk of **imprecise situation forwarding** amongst participants, since English is the second language for many and language barriers may displayable conveying crucial information.

Related Work

MTCAS incorporates technologies, which are part of the current state of the art in ship dynamics modelling, trajectory planning, VTS technologies and modern positioning, navigation and timing (PNT).

Ship Dynamics Modelling

Physical characteristics of a ship limit its manoeuvrability. Ship characteristics, such as hull form, size, and propeller/engine, effect with environment conditions, such as water/waves and air/wind. Both, ship characteristics and environment conditions are part of modern mathematic models for dynamic manoeuvrability calculation. Model results can be facilitated in trajectory planning. (Benedict, Kirchhoff, Gluch, Fischer, & Baldauf, 2009)

Trajectory Planning

On a strategic level waypoint planning is part of every voyage plan, which is typically settled pre-departure. On an operational level ships' crew executes manoeuvers by adjusting the helm or autopilot, to start a turn. On the tactical level, decisions are made, that implement the strategy on the operational level. This is where manoeuvrability and environment can have leverage on operational performance on safety and efficiency. With evolutionary algorithms, behavioural leaning approaches and/or neural networks trajectories can be found, which consider ship and environment. With these techniques, single ship optimal solutions can be found. To find a global optimum n-trajectory negotiation approaches have recently been developed (Hornauer & Hahn, 2013).

VTS Technologies

Detection of deviations from anticipated behaviour is implemented in modern VTS-Systems. The project EfficienSea, and its successors, advance in the area of centralized concepts for sea traffic management. Times of VTS's sole availability via MMS will soon be surpassed. With ongoing activities such as the project COSINUS, VTS-Systems are integrated into automated route exchange amongst ships via a data link.

Resilient Positioning, Navigation and Timing (PNT)

To exchange trajectories for proficient collision avoidance, instead of routes, precise data is required. This is not given in nowadays systems, where GPS may induce standard deviation error in positioning and GNSS may negatively influence common timing through interferences. Resilient PNT encounters these disadvantages with sensor data fusion, which has been demonstrated in project ACCSEAS and MonaLisa.

Whenever collision avoidance as a safety of life critical application should be based on absolute positioning, then the question arises, how resilient provision of PNT data can be achieved onboard a vessel. Due to the vulnerability of GNSS with respect to ionospheric disturbances, jamming and spoofing the joint usage of other systems (terrestrial backup systems) and other onboard sensors is considered. Vulnerability encountering backup systems like e-LORAN, R-Mode or absolute RADAR positioning have been evaluated and proposed (Ziebold et al., 2010), (IMO, 2012). Onboard a vessel a sensor fusion algorithm is responsible for the PNT data provision. All available Position, Velocity and Timing (PVT) and Navigation data, from onboard sensors in order to provide optimal PNT output data, is integrated. Asides optimal estimations of the PNT output data, also integrity information is provided, based on accuracy estimations.

THE MTCAS Approach

MTCAS assists in collision avoidance by warning the crew before critical situations develop and recommends evasive manoeuvres for conflicting ships. Dissident from TCAS, MTCAS does not automatically intervene in terms of issuing steering commands, such that it can be seamlessly integrated into nowadays (legally regulated) operations on-board of a ship. Meanwhile, MTCAS supports seafarers in cooperatively finding safe and efficient trajectories, whose on-board implementation (solely by seafarers) avoids collisions.

MTCAS will be developed on the basis of required equipment and advanced sensor technologies. Further, within the project, organizational processes around MTCAS are developed and tested, considering responsibilities and interaction of people on board and in VTS. The development of MTCAS is based on four core concepts:

Improved Situational Awareness

An essential contribution of MTCAS is enhancing safety and efficiency, by increasing situational awareness about critical traffic situations. A starting point for MTCAS is the route exchange technology, which has been developed in the COSINUS project, enhancing harmonized situational awareness aboard and ashore. MTCAS integrates this technology for conflict detection and evasion. To gain required operational precision the technology will be extended with improved integrity monitoring and exchange of ship dynamics. Additionally, MTCAS is collecting information about the environment from heterogeneous data sources. The more information is available, the better is the situation assessment. When the situation is evaluated, MTCAS will provide the result to the captain and ask for a confirmation. That happens on all related ships. MTCAS will submit the confirmation of the captain to all off the other ships. Therefore, all captains are aware of the situation and know that the others are as well. MTCAS ensures all captains have the same information about the situation and prevents misunderstandings.

Context-sensitive Prediction

Depending on the current traffic situation and under consideration of ship dynamics as well as information on the route and past motions of the own ship MTCAS predicts ship movements and short term traffic progression. This incorporates for instance intention prediction, topology of water ways, bathymetry, ships' destination, rules and regulations and VTS information. This prediction leads to an enhanced alarm management. Due to the prediction false alarms are suppressed or corrected. This decentralized calculation of traffic and manoeuvre predictions (on each ship) is exchanged (Ship2Ship2Shore) and commonly coordinated/adjusted. Thus a local overview of the situation is enriched to a complete traffic situation overview over time.

Decentralized automatic negotiation of evasive manoeuvres

MTCAS aims at on-board and ashore working decentralized conflict detection and at safe and efficient conflict resolution in critical situations. Ships' masters agree jointly on a set of evasive trajectories. A set of evasive trajectories is therefore always suggested to all ships' masters, which has to be accepted of declined. MTCAS will guarantee that evasive trajectories are found within real-time and that the crew can always be aware of and integrated in the conflict resolution process. Within the project MTCAS' safety will be proven with qualitative and quantitative means, to secure a gain towards maritime safety.

The two mayor benefits from this project are improved predictive situation awareness and to reduce misunderstandings my supporting the seafarer in consistent situation assessment and evasive manoeuvre planning.

Acknowledgement

The ongoing research is conducted within the "MTCAS - electronic maritime collision avoidance" project funded by the Federal Ministry for Economic Affairs and Energy (Germany). A detailed version of this paper has been presented at the European Navigation Conference 2016 in Helsinki (Denker et al., 2016).

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Design and integration of a lightweight multirotor UAV for remote sensing applications

This paper reports an assessment on design and integration of a multirotor Unmanned Aerial Vehicle (UAV) for selected remote sensing applications

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Balloons can be regarded as the oldest platform for aerial observations. As early as in 1858, Tournachon aboard a hot-air balloon to capture aerial photographs of Paris. In 1882 E.D Archibald, an English meteorologist, used kites for aerial photography. One of the most exciting experiments was the use of a pigeons' breast to mount a small camera from the Bavarian Pigeon corps, as proposed by J. Neubronner (Colomina, et al., 2014). Etienne Oehmichen experimented with rotorcraft designs in the 1920s. Among the six designs he tried, his helicopter No.2 had four rotors and eight propellers, all forced by a single locomotive. An aircraft, with six bladed rotors at the end of an X-shaped structure was developed by Dr. George de Bothezat and Ivan Jerome. The Curtiss-Wright company designed the Curtiss-Wright VZ-7, which was a VTOL aircraft, for the United States Army. The VZ-7 was controlled by changing the thrust of each of the four propellers (Rumerman, 2003). In the past 10 years, many small quad copters have entered the markets that include the DJI Phantom and Parrot AR Drone. This new breed of quad copters is cheap, lightweight. In the 20th Century, military research precipitated many widely used technological innovations. Surveillance satellites enabled the Global positioning system (GPS), and defense researchers developed the information swapping protocols that are fundamental to the Internet. Drone/UAV falls into a similar class. Designed initially for reconnaissance purposes, their para-military and commercial development was often out of sight of the public. Seen in such sense, drones came into first use after World War II (year 1939-1945) when unmanned jets, such as the Ryan Firebee (a documentary about the Firebee and the role of early drones of the Vietnam War), started field operation. Since then, the number of drones in military exercise has increased substantially enough that the New York Time decided to refer to it as a novel paradigm for warfare (Dixit, et al., 2016). A far-reaching array of markets and civil applications are likely to surface over the next few years for UAVs presenting a massive business opportunity for the companies involved (Higgons, 2014).

Unmanned aerial vehicles are designed and assembled based on the requirements and can be classified into two categories- fixed-wing and rotorcraft or multirotor or rotary wing UAVs. Fixed-wing UAVs have limitations in terms of complex designs, difficult stabilizing mechanism, requirement of a long runway and difficult to operate in hilly terrain. Nevertheless, they have advantages in terms of long endurance and large payload capabilities. On the other hand, multirotor UAVs use vertical takeoff and landing and has been found more appropriate in hilly and complex terrain. However, unlike most fixed wing models of UAVs, the rotary wing models generally have a much shorter flight time. This is because the specific energy of chemical based energy source such as gasoline is way higher than an electric/electrochemical based energy source such as a Lithium-Ion battery or an alkaline battery (Elert, 2016).

Remote Sensing Applications using UAV

Application of Unmanned aerial vehicle (UAV) is now creating a new vista in geospatial technology. Recently, UAV has been effectively employed for real time mapping, survey and monitoring activities with high spatial and spectral resolution data. UAV data can be applied in combination with satellite data to produce better results e.g. Getting high-resolution images of interested area, getting localized images of satellite shadow zones and it can be utilized to produce real time images of a calamity-affected country, whereas, other aerial views (i.e. using a Helicopter or Airplane) are found very expensive when study requires a number of periodic surveys. The potential of UAV product in the form of very very high-resolution (VVHR) images has enabled to gather detailed spatial information in studying unplanned settlements (Pannel et al., 2011). UAVs can perform an efficient Survey for disaster prone or physically inaccessible areas, quick damage assessment of landslides, floods and earthquakes for enabling relief measures. A number of case studies (Singh et al. 2016) have been taken up to demonstrate the effectiveness of UAV in remote sensing applications.

Objectives

The UAV is expected to be light, small, portable and reliable and should be capable to access regions and areas which would otherwise not be approachable on foot or any other manner of shipping other than flying. The following objectives demonstrate in this paper:

a) Design and integration of a light weight multirotor UAV with a payload capacity up to 2 kgs and a flight endurance up to 30 mins having a range up to 2 kilometers.
b) To deploy UAV for crop damage assessment, large-scale land use, land cover mapping and mapping of landslide-affected region. The case studies have been conducted in three test sites- i) an agro farm in Morigaon district of Assam, ii) Nonghpoh town of Meghalaya and and iii) a landslide affected area on the National Highway 40 connecting Shillong and Guwahati near Nongpoh.

Design & Integration

The various design challenges in terms of payload, frame, communication, autonomous flying etc., has to be address before design of a copter. The most usual and popular configuration of a multicopter for practical applications is quad copter and hex copter (Figure 1 & 2). A hex copter has two extra motors than a quad copter, hence, it is more stable and can carry heavier payloads than a quad copter at the expense of extra components. Copters come in various forms e.g. X configuration, + configuration, Y configuration etc. The X configuration provides more thrust and has a higher speed than a + configuration. This is because in case of The + configuration, only one rear motor is present to provide thrust in a particular direction while in case of the X configuration, two motors are present. In case of the + configuration, a FPV (First Person View) or any camera for that matter are generally obstructed by the propellers while in case of the X configuration, the region between the two propellers provide a clear view.

Design requirements

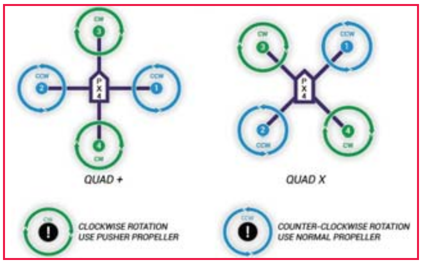

Figure 1: Quad copter Configuration[2]

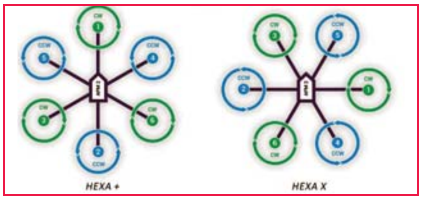

Figure 2: Hex copter Configurations[3]

Following design requirements were taken before choosing the shape of the copter:

a. The copter is supposed to deliver a payload capability of 2.5-3.5 kgs for accommodating different kind of application specific sensors (e.g. RGB camera, Multispectral camera, Hyperspectral camera, Thermal camera etc.).
b. It should hold a flight endurance of approximately 20-30 minutes.
c. It should be capable of manual flying, GPS aided flying and autonomous flying.
d. It should possess a radio control range of 2 Kms radius.
e. The plan should be uncomplicated and cost effective.

After studying the above essentials, it was determined that a Hex copter with X shape (Figure 2) is best fitted for the requirements considering the diverse range of applications.

Here, we consider making a Hex copter of certain **AUW (All Up Weight)** suitable for different remote sensing applications. AUW includes battery and payload along with the weight of the aircraft. Basic equation (eq. 1) to define the total weight of multirotor should be half of the total thrust generated by the motors for hover condition at 50% of throttle.

Total Thrust = 2 x AUW (1)[1]

In short, to lift 1000 grams Hex copter we need 2000 gram thrust.

Selection of components

A Hex copter/multirotor can be divided into seven main sections, the frame, the propulsion, the power, the radio control, the flight control system, the ground station and on-screen display unit and an additional section which is not required for flight, but for a mission in general, the payload. Each of these sections is dependent on one another to achieve a fully functional and efficient multirotor system. Broadly speaking, the frame provides the structural platform to place all our systems onto. The frame of the multirotor system provides a platform to place the components of the multirotor and also protects them from FOD (Foreign Object Debris). The propulsion system is what lifts the multirotor system off the ground. The propulsion system generally consists of the propellers, the motors and the necessary driving electronics. The flight control system is the nub of the moderator and it controls the multirotor making it fly accurately and in a stable manner. The flight controller generally consists of a microcontroller, sensors and a receiver to gather data from the ground station. The ground station is where information is set from to the multirotor. It can be in the form of a simple remote controller to an elaborate setup of computers and other data acquisition devices. Finally, the payload is what drives a multirotor system to be built or multirotor designs are based around the payload.

Frame: The one we selected is a symmetric X configuration (Figure 3) frame

It has a metal central plate and side arms are made of carbon fiber material. The weight of the assembled frame is about 3.5 kgs and the diagonal distance is about 80 cms.

Figure 3: Hex copter frame assembled at NESAC

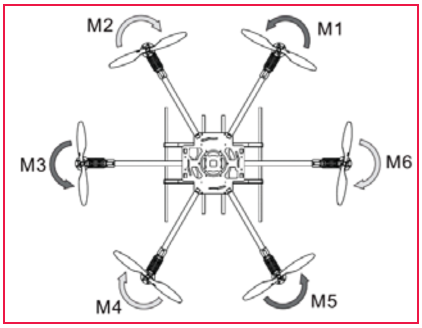

Figure 4: Counter rotating propellers[4]

Figure 5: An ESC[5]

Propulsion

The propulsion system of a multirotor is responsible for providing the required thrust for the multirotor system. The components and parts required to move a multirotor system include the propellers, brushless motors and ESCs (Electronic Speed Controller). One must choose the appropriate combination of these factors to generate the needed thrust.

The propellers are divided based on the diameter. A larger diameter propeller will generate more lift than a propeller at the same angular speed as it encompasses a larger area per revolution. Nevertheless, due to the larger size, more torque will be needed to run the propeller at the same angular speed. Likewise, a larger propeller cannot change its angular velocity quickly because it delivers a larger inertia compared to a smaller propeller due to its larger mass (Henderson, 2016). The propellers are always Counter-rotating (Figure 4). The reason for that would be that the counter rotation motion cancels out the torque on the multicopter due to each propeller.

The motors which are employed for this purpose are brushless DC motors. In a traditional brushed motor the outer permanent magnet is fixed while the coils move (Titus, 2012). These brushless motors provide larger torque, better efficiency, longer life and lower noise due to the lack of connecting parts which would have otherwise lead to wear and tear of the material. The brushless motors available in the market are divided primarily based on their Kv rating. The Kv rating of a brushless motor determines the RPM (Rotations per Minute) of the motor per volt applied when there is no load attached. For example, an 1100Kv motor will rotate at 1100 RPM when 1 Volt is applied. A lower Kv rating will provide a motor with larger torque with lower RPM while a higher Kv rating will provide a motor with lower torque but with larger RPM. It is to be noted that most datasheets provide the thrust provided by common propellers at different voltages/ power. The motor used in this project is DJI E800 with Kv rating of 350 Kv along with 13 inches propellers. The combination provides a maximum thrust of 2100 g/motor and a recommended takeoff weight 800 g/rotor. Since Hex copter has 6 such motors a total of 5.4 kgs of total uplift weight is recommended. The weight of fully assembled aircraft is about 3.5 kgs hence the aircraft provides a payload capability of about 1.9 kgs.

An Electronic Speed Controller (**ESC)** is an electronic circuit (Figure 5) with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor. Electronic Speed Controllers (ESC) are an essential component of multirotor that offer high power, high frequency, high resolution 3-phase AC power to the motors in an extremely compact miniature package. The one used in this project is a 20 Amps ESC.

Radio control

Radio controls are used to transmit the live video feed and the telemetry data from the aircraft to the Ground Station and control inputs from ground to aircraft. It is important to choose the right frequency for intended use and flying environment. Drones are used in different radio frequencies, so one need to make sure that those frequencies are allowed in the country of usage. The **ISM band** was born for such a reason. The industrial, scientific, and medical radio band (ISM band) refers to a group of radio bands or parts of the radio spectrum that are internationally reserved for the use of radio frequency (RF) energy intended for scientific, medical and industrial requirements rather than for communications. The commonly used radio frequencies for UAVs are as mentioned below in the Table 1. The frequencies which we have chosen are 433 MHz for command transmitter, 2.4 GHz for ground station and 5.8 GHz for live video transmission of onboard camera.

Power

The battery is the source of all power in a multirotor. The most popular battery in the RC (radio Controlled) Flight community is the LiPo (Lithium Polymer) battery. LiPo batteries come in many shapes and sizes and are very light, have a very large specific energy (compared to other electrochemical energy sources) and have a very high discharge rate, and to top it off, it is rechargeable (Linden, et al., 2002). These features make it very popular in the RC Flight community. However, a LiPo battery cannot be charged conventionally. A special LiPo battery charger is required. This LiPo battery charger will evenly charge all cells in the battery. The even charging of the cells in the battery will ensure the battery can be used for a larger number of charge cycles. Figure 6 shows a typical LiPo battery used

Table 1: List of frequencies used for different purposes in UAV

Sl. No.	Purpose	Frequencies used
1.	Video Streaming	1.2-1.3 GHz, 2.4 GHz, 5.8 GHz
2.	RC Control	433 MHz, 2.4 GHz
3.	Telemetry	433 MHz, 915 MHz, 2.4 GHz

Figure 6: Tattu LiPo Battery 6S 10,000mAh

in RC Aircraft application while Figure 7 shows a commonly used LiPo battery charger which can evenly distribute the voltage across the cells as the batter is

Figure 7: IMAX B6 Balance LiPo Battery Charger

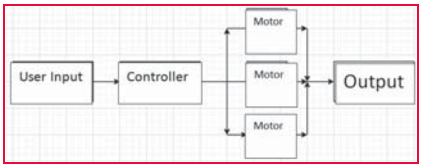

Figure 8: Flight Controller Block Diagram

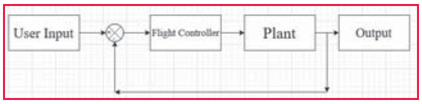

Figure 9: Block diagram of a Feedback Control Mechanism

being charged. The one which we used in this project is 6 Cell LiPo battery of 10,000 mAh capacity (Figure 6).

Flight control system

The flight control system of a multirotor system is the heart and the brain of the multirotor. A multirotor is a very complex system with multiple variables and outputs. The flight controller (FC) gathers the input from the user and converts it into signals which will then be distributed to the motors which will in turn provide the desired output. A simple block diagram of the flight controller is given in Figure 8. We can observe in Figure 8 that the controller distributes the commands from the User to the motors to provide the desired output. An example of the controller coming into play is when the user wants to turn the multirotor about its yaw axis. To achieve such an output, the controller commands certain motors to turn faster while slowing down the others to create the necessary output.

However, the multirotor does not always respond the way it is expected to due to external interferences. This interference or noise will create an unstable and

Figure 10: Naza MV2 FC[6]

Figure 11: Ground station system using laptop as display

unsteady flight of the multirotor. To counter these interferences and noise, a feedback control mechanism is implemented in almost all multirotors. A feedback control mechanism (Figure 9) uses the error between the input and the output to provide extra input commands to the motors to correct the error. Here we have used NAZA FC V2 (Figure 10) for our Hex Copter (Mulcahy, 2013).

Ground station

The ground station combines the video receiver(s), display, RC transmitter. Ground stations vary in shapes and sizes from simple screen and receiver mounted atop of the RC transmitter, to a tripod mounted screen with multiple video receivers (diversity box then chooses the best signal to send to the display) and directional antennas. It also gives the ability to do autonomous missions to the rotorcraft. The 2.4 GHz transmitter coupled with its receiver is the most commonly used ground station for a simple multirotor system. Figure 11 shows a ground station system using a laptop as a display device. It gives user the option to do flight planning offline and the upload the mission when the aircraft is connected and do

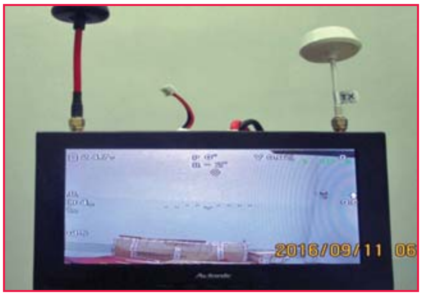

Figure 12: An on-screen display of FPV camera

the autonomous flying. User can also give waypoints so that the aircraft follows the same and complete the mission autonomously. We have used a laptop as display in our project for ground station tool, along with a 2.4 GHz communication system.

On-screen display unit

OSD is usually plugged in between the camera and video transmitter. It adds vital flight telemetry data to the image and allows it to be displayed on the operator's screen. This data can include battery voltage, current, mAh consumed (fuel gauge), altitude, GPS location, home point distance, pitch and roll angles, RC signal strength indicator, and artificial horizon. Some work in conjunction with ground station and can superimpose the aircraft's location and flight path over digital map. We have used an avionics ODS unit (Figure 12) working on 5.8 GHz link to transmit live video from the onboard camera in this project.

Payload

The payload is the driving factor being the construction of a UAV. This payload can come in various forms such as a FPV (First Person View) camera for hobbyists, a high quality video camera for professional aerial photography and videography, multispectral and hyperspectral cameras for remote sensing, goods for the newly proposed AMAZON drone delivery system and LIDAR (Light Detection And Ranging) for surveillance and 3-D mapping. Payloads define the requirements and the requirements define the parameters of a UAV. However, payloads are not necessary for the construction of a UAV. A multirotor UAV can be constructed

Figure 13: YI action camera as a payload

Figure 14: YI action camera

Figure 15: Assembled Hex copter

Figure 16: Hex copter with dummy payload of 1.5 kgs.

simply to understand the physics and the working of a multirotor system and the theory behind how it works. Figure 13 and Figure 14 shows a hex copter assembled at NESAC with a YI action camera as a payload. The payload used in this project is a GoPro camera, a YI action camera and a dummy payload of 1.5 kgs weight.

Final assembly

The Table 2 shows the list of major components used in the Hex copter assembled at NESAC. Figure 15 shows the assembled hex copter. Figure 16 shows Hex copter with 1.5 kgs of dummy payload, which has given a satisfactory performance for a flight time of 15 mins at a height of 60 m.

Test flight results

Following Table 3 summarizes the design requirements and achieved performance of the hex copter assembled at NESAC.

Case studies using UAV

The multi rotor based UAV at the Centre has been flown in the areas of North Eastern states of India for specific remote sensing applications, after obtaining necessary permission from the concerned authority. The data has been processed to get valuable products such as orthomosaics, digital elevation/surface models and 3D point clouds. Soft wares used are Agisoft, Pix4D and ArcGIS. The final products are then shared to the Line Departments for their use in the planning. At NESAC, we are trying to utilize the UAVs for various remote sensing and disaster management applications. Three such case studies are presented in the subsequent sections.

Agriculture

Naramari village of Morigaon District, Assam, India had been reported severe infestation of Boro Paddy by Brown Plant Hopper (BPH) insect (Prasannakumar et al., 2012). As per the request from officials from State Government of Assam, UAV flight was conducted in the affected area and a total area of 0.55 sq. km was covered with a 15 minutes flight. The elevation of the UAV was maintained at approximately 240 m. At this height, ground resolution obtained was about 12cm and the infested areas could clearly be distinguished. Multiple images were obtained with a camera shutter speed of 5 seconds per picture (Figure 17).

Figure 18 shows categorization of BPH infested rice fields. Rice plots having more than 60% infestation, categorized as severely affected, less than 60% is categorized as moderately affected. It was found that out of total area of 0.58 sq. km, 0.015 sq. km was severely affected and 0.04 sq. km was moderately affected. It has been mentioned that there will be hardly any output from the games categorized as severely affected; whereas with immediate intervention measures, part of the crop area could be saved.

Table 2: Specifications of components used for Hex copter assembly

Sl. No.	Name of the Component	Specification of the component used
1.	Frame	X configuration six arms symmetric carbon fiber frame with metal center plate
2.	Propulsion	Motor: Kv350, Propeller: 13x4.5 inches, ESC: 20A
3.	Power	6 cell LiPo battery with 10,000 mAh capacity
4.	Flight controller	DJI NAZA V2
5.	Ground Station	DJI Ground Station software along with a laptop
6.	Frequencies used	433 MHz for command transmitter, 2.4 GHz for ground station and 5.8 GHz for live video transmission of onboard camera.
7.	Payload	GoPro Hero3, YI action camera, a dummy payload of 1.5 kgs.

Large scale land use mapping

Nonghpoh town is the District Headquarter of the Ri Bhoi district of Meghalaya. National Highway-40 (NH-40) is the life line of Meghalaya State connected from Guwahati, Assam passes across the Nongpoh town. Large scale mapping survey was carried out at the request of the Office of the Deputy Commissioner to support subsequent town planning activities. Flight was taken at 120 m height over the Nongpoh town along the NH-40 for a period of 12 minutes with area coverage of 0.84 Sq. Km. The image was acquired

Figure 17: Infested fields in Naramari Village, Morigaon District, Assam

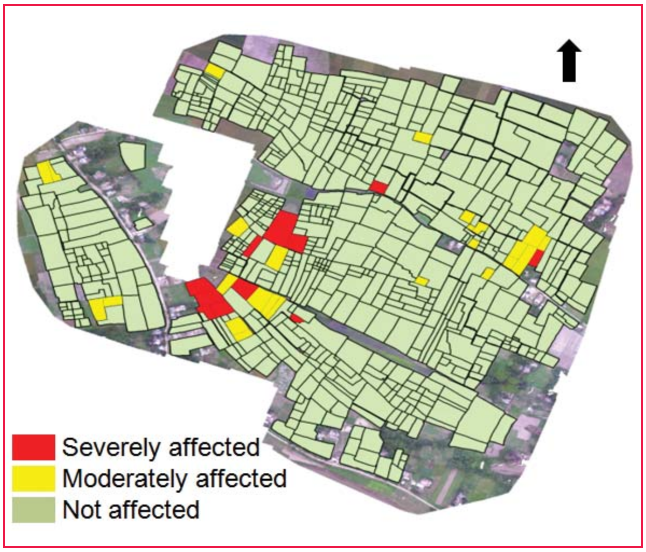

Figure 18: Categorization of BPH infested rice fields (Naramari village)

with a ground pixel resolution of 5 cms. The land use information extracted out form the image of part of Nongpoh town (Figure 19) is presented in the Figure 20. Existing land use of the town is comprised of 27+ land use classes including the minor single land features. The quality of the image was further enhanced and necessary GIS tools were used to identify the features. All the land features were correctly identified and mapped in GIS domain. Even, building structure, road types, lay-overs, open space, even single trees, petrol tanks, etc. could be mapped properly (Figure 20). This type of information will form the basis and accurate information for planning in general and designing technical interventions in particular.

Mapping of landslide affected area

The NH-40 connecting Guwahati to Shillong city is considered to be the life line of Meghalaya State. Some part of the areas along the both sides of the road near Nongpoh is prone to sever landslides. A number of landslides had been occurred already during which caused loss of life and properties. This happens every year during rainy season. Mapping of landslide affected area was taken at the request of District Disaster Management Authority of Nongpoh. UAV was deployed over a landslide area along the road to capture 2D and 3D view of the affected area. UAV flight was carried for about 6 mins and flight height was maintained at 100 m elevation from ground level. Image captured with a ground pixel resolution of 4.64 cms and further processed in GIS domain to estimate the area and volume of the affected sites.

The approximate 3D area (considering the slope) and volume comes out to be 4533.96 sq. m and 7445.26 cubic m (Figure 22) respectively. Terrain 3D length was calculated to be 303.90 m and projected 2D length was calculated to be 277.99 m. These area and volume details can be used for various decision support systems and disaster mitigation tools e.g. an estimate of constructing a retaining wall along the road can be made using the above information so as to minimize the damage for the next time.

Table 3: Comparison of test flight results with design requirements

Sl. No.	Design parameter	Design criterion	Test flight results
1.	Payload capacity	Up to 3.5 kgs	A maximum of 1.5 kgs was tested
2.	Flight endurance	Up to 30 mins	15 mins for 1.5 kgs payload and 25 mins for GoPro/ YI action camera (weight less than 100 gms)
3.	Flying options	Manual, GPS aided, Autonomous	All tested satisfactorily
4.	Flying height	Up to 2 Kms	Tested up to 500 m which was good enough for required applications
5.	Flying range	Up to 2 Kms	Tested up to 1.8 Kms with clear line of sight

Conclusion

This paper has focused more on the rotary wing UAVs (case study: Hex copter) discussing in detail the design and selection of different components based on the requirements and the final assembly. The paper also gives the glimpse of selected remote sensing applications where UAVs can be used. It has been observed that the uses of a rotor based UAV is very specific and limited due to the constraints of the flight time and payload capacity. However, when working within these constraints and limitations, a rotary wing UAV is very efficient in what it does. It has also been observed that the flight controller is a very important component in achieving an efficient and controlled flight of a multirotor. It helps to correct the unstable nature of multirotor-based flight due to the various counteractive aerodynamic and non-aerodynamic forces acting on the aircraft.

Figure 19: Part of Nongpoh Town as viewed from UAV Image, 2016

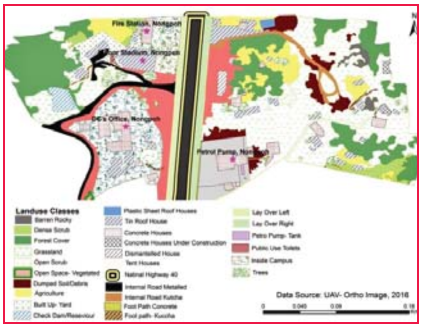

Figure 20: Land Use of part of Nongpoh Town as classified from UAV Image, 2016

Figure 21: 2 D view of Landslide Scar

Figure 22: 3D View of Landslide Scar

The overall performance of the system was found satisfactory as per the required applications. However, selection and integration of an appropriate sensor for a specific application is a challenging job. In future, multispectral, hyperspectral and LIDAR sensors can be integrated in the UAV for detailed study of different test sites. However, the weight of sensor remains a critical parameter, as the payload capability of the multirotor UAV is limited. The UAV can also be integrated with onboard image processing capabilities so as to generate 3D maps onboard for indoor mapping applications.

Acknowledgement

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Air Force says goodbye to 25-year-old GPS satellite

At 25-years old, GPS Vehicle Number 27 completed its time in orbit before the 2nd Space Operations Squadron said goodbye via final command and disposal on April 18. SVN 27 was launched in 1992, meaning it performed more than triple its design life of 7.5 years. Since GPS satellites do not carry the amount of fuel required for de-orbit maneuvers, they are instead pushed to a higher orbit, roughly 1,000 kilometers above the operational GPS orbit.

During the final contact with the vehicle, the satellite is commanded into the safest, lowest energy state possible. This means all fuel has been depleted from the fuel tanks, the batteries are unable to hold a charge and the vehicle is in a spin-stabilized configuration.

CARIS hydrographic production database for Swedish Maritime Admin

Teledyne CARIS has announced the successful implementation of Hydrographic Production Database™ (HPD) as the Swedish Maritime Administration (SMA) production system. This replaces the previously used legacy software employed by SMA for the management of spatial data. HPD supports the creation of paper and electronic charts, special publications and data services, and has been customized to meet SMA's special requirements and workflow needs.

The project, known as 'CHAMPS', included system customization and development, existing data and product migration, training of SMA's project team and end users. The project was completed and approved on time early February this year.

ISRO inaugurates advanced GNSS research lab

The Indian Space Research Organisation (ISRO) has launched the Advanced GNSS Research Laboratory (AGRL) in the Department of Electronics and Communication Engineering at the Osmania University College of Engineering in Hyderabad.

ISRO Chairman A. S. Kiran Kumar inaugurated the facility on April 27. He discussed various technical aspects related to NavIC Satellite Navigation System of India.

He also advised students and faculty to carry out research work on differential corrections, development of various modules using IRNSS, atmospheric effects, work related to mutli-constellation, kinematic applications, fisheries applications and innovative applications for the public.

CNES offers new Android apps for GNSS

French space agency CNES has made available two applications on the Google Play store for Android apps. Both are compatible with Android N (Nougat).

RTCM Converter: This app aims to convert the smartphone GNSS raw measurements to Radio Technical Commission for Maritime Services (RTCM message type 1077) and send them to a caster, for use by third-party software.

PPP WizzLite: This app is a port of the CNES PPP client (code and Doppler only, light version) on Android. Accuracies of 1-2 meters can be reached in kinematic mode, and sub-meter in static mode (using external SBAS data). To do so, users need to pull external RTCM streams for orbits/clocks corrections and broadcasts, such as ones available from the International GNSS Service Real-Time Service (IGS RTS).

Both apps have been validated on a Nexus 5X device with no phase support.

New GLONASS satellites will be transmitting encoded signal

New GLONASS satellites will be transmitting a new encoded signal, according to the deputy CEO of Russia's Roscosmos corporation, Mikhail Khailov"At the moment the manufacturer keeps seven space satellites GLONASS-M in stock. Six will be transmitting the encoded navigation signal in L3," he said.

Currently one GLONASS-M satellite and two new generation GLONASS-K satellites transmit the CDMA signal. *http://tass.com/science/943074*

Roscosmos, ISRO to jointly collect satellite data

Russia's Roscosmos state corporation and the Indian Space Research Organisation (ISRO) have agreed to jointly collect data using the Glonass system and India'a regional satellite system - IRNSS.

Sergey Savelyev, deputy director general for international cooperation at Roscosmos, told the news agency that the organisations have signed a memorandum of understanding (MoU) on mutual deployment of ground stations of the two countries' national satellite navigation systems. *https://in.rbth.com*

Japan's Second Michibiki satellite will boost QZSS

Officials at the Tsukuba Space Center of the Japan Aerospace Exploration Agency (JAXA) announced that the second satellite in the Japanese Quasi-Zenith Satellite System (QZSS) is scheduled for launch in June.

Designed to boost the accuracy and reception of the existing GPS system for Japan, a new version of a satellite that will orbit directly over the Japanese archipelago was unveiled recently. It will improve the existing GPS and provide a better positioning reading for the people in Japan.

A first in Germany as aircraft lands using only satellite navigation

Bremen Airport, in the north of Germany, was the setting for a German first as plane lands using only sat nav.

It was the first time that a passenger aircraft landed in Germany using a new satellite-based precision approach procedure without the aid of the conventional ground-based navigation infrastructure. This was made possible by EGNOS (European Geostationary Navigation Overlay Service), a satellite-based augmentation system (SBAS) that supplements GPS and other satellite navigation systems. It improves the position accuracy of GPS from 10-20 metres to 1-3 meters. Bremen is the first airport in Germany to have implemented a precision approach procedure using SBAS.

SBAS provides an innovative alternative to the conventional instrument landing system (ILS) and can also be used in poor weather conditions. DFS has thus provided airspace users in Bremen with a workable alternative to the old system. This is not the first time that Bremen Airport was on the cutting edge of air navigation technology. In 2012, the world's first approach using a ground-based augmentation system (GBAS) for satellite navigation was employed. The International Civil Aviation Organisation (ICAO) approved the satellite-based SBAS precision approach procedure, giving it the name "LPV 200". The procedure can be implemented in poor visibility for category I (CAT I) weather conditions, one of three levels of all-weather operations. The pilot is guided down to a height of 200 feet above ground, that is about 60 metres, using satellite-based technology that guides the aeroplane horizontally and vertically. When the pilot has the runway in sight, it is safe to land. *www.internationalairportreview.com*

ClearEdge3D Releases Verity™ Construction Verification Software

Verity 1.0 software by ClearEdge3D verifies the accuracy of new construction against design/fabrication models, giving general contractors unprecedented insight into their construction projects. The software analyzes laser scan point cloud data of the as-built construction against the design/fabrication models, identifying variances, missing elements or other potentially costly construction errors. The variance data and corrected model can be exported to Navisworks for as-built clash detection and further analysis. *www.clearedge3d.com.*

SuperGIS Server 10

After releasing the next-gen desktop GIS - SuperGIS Desktop 10 as well as mobile GIS- SuperSurv 10 and SuperPad 10, Supergeo will spare no effort to propel the development of SuperGIS Server 10! It will introduce a practical tool called Web Mapper in SuperGIS Server 10.

With Web Mapper, there will be more templates for users to apply immediately when establishing web applications. Meanwhile, users are able to manage the tools more flexibly as well as to preview the layout of web application on different devices. *http://sgs.supergeo.com.tw*

Demonstration app for Arctic Spatial Data Pilot Project

Esri Canada has announced the completion of the Policy Workbench, a comprehensive demonstration app that can help policy makers better understand Pan-Arctic issues. The web mapping app was created for the Open Geospatial Consortium Arctic Spatial Data Pilot Project (Arctic SDP), an initiative by the United States Geological Survey (USGS) and Natural Resources Canada (NRCan) designed to demonstrate the value of enhanced spatial data sharing among organizations.

The (Arctic SDP) project will ensure that the facts collected in their data formats are interoperable and can be shared from local to global partners in a seamless way.

Built using Esri Story Maps, the Policy Workbench app enables analysis of Arctic food security issues, including how environmental changes are threatening traditional food sources like caribou. It has maps showing different aspects of store-bought and country (or traditional) food. *press@esri.ca*

India to announce next set of 40 smart cities by June end

The Urban Development Ministry will announce by June-end the next set of 40 cities for central funding under the Smart City Mission. Launched on June 25, 2015, the mission aims to develop 100 smart cities across the country in a five-year period. The government has earmarked Rs 48,000 crore for the development of these cities.

Under the programme, each selected city will be given Rs 500 crore over a period of five years by the Centre with the respective states expected to make the matching contribution.

So far, 60 cities have been selected for the scheme and the remaining 40 cities would be announced by June end. The ministry is also preparing a report card on its Smart City Mission as the scheme is set to complete two years of its launch this June. The ministry is compiling data under various heads like the number of projects completed and those being implemented. *www.business-standard.com*

Belarus, Sweden to share experience in GIS development Society

Belarus and Sweden will exchange experience in GIS development - a delegation of specialists of the Swedish mapping, cadastral and land registration authority Lantmateriet will be on a visit to the National Cadastral Agency of the State Property Committee of Belarus.

The Swedish specialists will come to Belarus to share experience in GIS development according to the project on modifying the system of urban development and territorial resource management in Belarus. The parties will also discuss the matters related to the application of GIS in the projects and activities of the National Cadastral Agency.

The Belarusian side is going to present a multilevel distributive regional GIS to monitor the state of territories and objects, phenomena and processes on the basis of complex data of remote Earth sounding (MRR-GIS) developed by the agency's specialists. The visit is another step forward in long-term cooperation between the National Cadastral Agency of the State Property Committee of Belarus and Lantmateriet (Sweden).

Thomas & Hutton Announces New Certified UAV Remote Pilots

Thomas & Hutton (T&H) has announced its new Certified Remote UAV Pilots. Survey Party Chief, Brad Lariscy; Staff Surveyor, Cliff Wilson; and GIS Analyst, Preston Evans, both recently earned this certification. The Remote Pilot Certification is a requirement in order to fly drones legally and requires applicants to pass an FAA aeronautical knowledge exam. *www.thomasandhutton.com*

SITECH® South offers Microdrones® UAV Mapping Systems

Microdrones has announced they are partnering with SITECH South, a leading provider of construction equipment and services in Georgia, Alabama, and Florida - USA. It will now offer Microdrones mdMapper solutions – complete UAV packages with everything needed for surveying and mapping.

Construction companies use drones for many purposes, including volumetric analysis of stockpiles, site overviews, and monitoring progress. *www.sitechsouth.com.*

Drone laws: New German rules aim to stop eye-in-the-sky snooping

According to the new regulations in Germany, if a drone weighs more than 2kg (4.4lb), its operator is supposed to demonstrate knowledge of how to fly it safely, by presenting either a pilot's license or a certificate from an air sports association, or by taking an examination.

If the drone weighs more than 5kg (11lb), operators will have to get special permission from the federal aviation authorities before they can use it.

However, any drone weighing 250g (0.56lb) or more will from October 1 have to carry a badge or aluminum sticker bearing the owner's name and address.

Drones cannot be flown above a height of 100m without permission. If they weigh over 250g, they cannot be flown over residential areas. And whatever the weight, if it can broadcast or record video or audio, flying it over houses that aren't your own is verboten.

The same goes for flying drones over police and rescue operations, main roads, gatherings of people, and airports' flight paths.

As is the case with the UK's drone code and other similar regulations, there's a general rule that operators have to keep their drones in sight at all times.

The German government amended its air-traffic regulations at the start of the year, but the changes only became effective recently. The new regulation will act as a bridge to future laws that are being drawn up at European level, with implementation probably a few years away. *http://www.zdnet.com*

FAA rolls out no drone zones

The Federal Aviation Administration of USA has rolled out its first restricted flight rules aimed at unmanned aerial systems, marking off areas around airports, military bases and possibly critical infrastructure and intelligence facilities.

The FAA said on April 11 that it is poised to release its first set of map data that the mushrooming flock of private UAS operators can use to safely navigate their aircraft around commercial airports.

The announcement comes only a few days after the agency pushed out map data restricting drones over military bases across the country and only a couple of months after the agency reported that the number of close calls between commercial aircraft and unmanned aircraft almost doubled in the last six months compared to the same period last year.

In the April 11, the FAA said it will release the first in a series of "facility maps" that show areas and altitudes near airports where the small aircraft can operate safely. The maps, it said, will also help operators comply with the agency's Part 107 airspace authorization rules, which are now nearly a year old.

Under the new military base restrictions, UAS can't be operated within 400 feet of the boundaries of the military facilities. The restrictions take effect April 14.

The FAA and the Department of Transportation are also setting up a process to accept petitions to restrict or prohibit drones from operating over critical infrastructure facilities. *http://gpsunder500.info*

First approval to fly fully-automated, commercial drones without a pilot

Airobotics has announced that it is the first company worldwide granted with the authorization to fly fully automated drones without a pilot. The certification, that was presented by the Civil Aviation Authority of Israel (CAAI), is solidifying Airobotics' status as a world-leader in the field of automated drones, allowing for the most innovative Beyond Visual Line of Sight (BVLOS) commercial drone operations.

This milestone proves that decisions and actions that were once taken by a human drone pilot, can now be taken by Airobotics' computer software and artificial intelligence. Essentially, an authorized pilot is now replaced by an authorized computer. This concept, of a system operating on its own, was designed and developed for the first time by Airobotics, solving some of the biggest problems for the drone market, such as high costs of labor, increased logistics around drone operations, expensive and lengthy training of aircrew as well as enabling customers that are not drone experts to perform highly complex drone missions. *www.airobotics.co.il an*

Bengaluru Municipal Body to track property tax defaulters via drones

Further ramping up its measures to monitor the non-payment of property tax in Bengaluru, the Bruhat Bengaluru Mahanagara Palike (BBMP) in India is now considering deploying drones to survey and 3-D map buildings to check if property owners are paying their dues. The BBMP has reportedly included the drone plan in its proposal for smart city planning and will submit it to the Union government soon.

Earlier, the BBMP had set up a Geospatial Enabled Property Tax Information System (GEPTIS) link under the citizen services tab on its website. The GEPTIS had been set up in association with the Indian Space Research Organisation (ISRO) and will soon be open for public use. It helped BBMP to track property tax collection across the city, through the Bhuvan Karnataka platform, created by the National Remote Sensing Centre (NRSC), Hyderabad, a wing of ISRO. *https://in.news.yahoo.com/*

DJI has built the ultimate aerial photography drone

DJI has teamed up with camera giant Hasselblad to create a brand new aerial photography platform for drones. The Chinese drone giant has built what it claims is the "world's first" 100-megapixel integrated aerial photography platform, paving the way for incredibly high-resolution bird's-eye imaging. The system is built using a number of different components. *www.trustedreviews.com*

Drones e-tailer launches Cat Drone

Cat lovers can now add a touch of technology to playtime with their cherished animals, following the launch of a new Cat Drone.

Pampered pets big and small can play with the state of the art toy which includes three soft toy attachments, including; mouse, fish and feather dangler toys.

This drone will play 'cat and mouse' for hours, with cutting-edge collision avoidance system technology and altitude hold technology - the flying pet drone will skillfully navigate and track your pooch, keeping toys at paws.

FARO introduces PointSense 18.0 Suite

FARO has announced the availability of the FARO® PointSense 18.0 software suite. This robust software platform evolution delivers seamless integration into the latest 2018 AutoCAD® and Revit® design tools, a better user experience, improved software handling, and enhanced efficiency in processing software data.

The one stop bundle and compatibility across the broad range of Autodesk architecture, engineering, construction and surveying products makes this the most cost effective solution of its kind currently available. *www.faro.com/india*

Distribution of WorldView-4 satellite imagery in Europe begins

European Space Imaging starts commercial distribution of WorldView-4 satellite imagery in Europe - A new ground station and a unique 30 cm satellite constellation enable unprecedented capabilities

European Space Imaging announced that the company has started operations of its new ground station with access to the entire satellite fleet of its WorldView Global Alliance partner DigitalGlobe.

PCI Geomatics releases Geomatica 2017

PCI Geomatics has released Geomatica 2017 - the latest version of the company's complete and integrated desktop, geo-image processing software featuring tools for remote sensing, digital photogrammetry, geospatial analysis, mosaicking and more.

This release greatly expands Geomatica capabilities by adding two new packages, as well as improving core technology and satellite sensor support. "The common theme behind all the advances in Geomatica 2017 is making complex technologies easier to use, for both experts and non-experts" said David Piekny, Product Marketing Manager at PCI Geomatics.

Smartphone-based Hyperspectral Remote Sensing for Agri-science Applications

Galileo Group, Inc. has launched ARMADA™ smartphone-based hyperspectral system for agri-science applications and research, opening the way for generational improvement capabilities in phenotyping, disease detection and experimental plant characterization and modeling.

A new technology with far-reaching capabilities, ARMADA™ is in launch readiness to provide real-time status analyses regarding crop health to include possible nutrient adjustments, weed identifications, herbicide applications and more from the palm of your hand. The data collected can be sent remotely to an office, lab or home computer from the field for immediate scrutiny, so the user may consider an appropriate and timely response for overall crop robustness.

Russia to establish new Earth's remote sensing center in Antarctica

The second center of the Earth's remote sensing will be set up at Russia's Progress research station in Antarctica. "The first Arctic Center of the Earth's remote sensing has already been deployed in Murmansk. A similar center will be established at the Progress station in Antarctica," according to the Russian president, Vladimir Putin. *http://tass.com*

DroneDeploy announces Fieldscanner

DroneDeploy has announced the beta release of its new Fieldscanner product offering real-time drone mapping, just in time for the spring growing season. With Fieldscanner, available as part of DroneDeploy's iOS app, farmers can use any DJI drone to create a map of their fields as the drone flies so that they can view insights before it lands. Fieldscanner can capture a field map in minutes so that growers can make crop management decisions on the spot or use the Fieldscan as a guide for more targeted boots-on-the-ground inspection. *www.suasnews.com*

Orolia partnership with Talen-X

Orolia, has taken the next integration steps with its Spectracom line of Resilient PNT products, which will enable clients to take full advantage of Talen-X's BroadShield Interference and Spoofing Detection technology. Orolia's Spectracom and Talen-X have aligned hardware and software development efforts to jointly develop, market and sell the most advanced PNT solution. The goal is to combine the strengths of leading Spectracom Resilient PNT products with Talen-X's interference and spoofing detection suite (BroadShield). *www.spectracom.orolia.com*

Juniper Systems releases the Mesa 2 Rugged Tablet with Android OS

Juniper Systems, provider of ultra-rugged field data collection solutions, recently released its latest product, the Mesa 2™ Rugged Tablet running Android 5.1. Built with the same IP68 waterproof and dustproof rating, long-lasting battery life, and 7-inch display as the Mesa 2 running Windows 10, this solution offers access to a variety of applications.

"We developed the Mesa 2 with Android to provide an alternate operating system option for customers seeking the reliability the Mesa 2 provides, with the added versatility and familiarity of Android," said VP of Sales and Marketing Nate Holman. "We've been excited about releasing this product for quite some time now, I'm looking forward to seeing the variety of business applications it will be used for."

Teledyne CARIS™ announces the release of HIPS™ Essential

Teledyne CARIS™ has released HIPS™ Essential, the newest edition to the flagship HIPS and SIPS™ suite of products. It has been designed keeping the needs of Ports and Waterways, small survey companies and small hydrographic offices in mind. HIPS Essential is a lightweight subset of the powerful HIPS and SIPS application. It is ideally suited for organizations or individuals wanting a streamlined software package for bathymetry processing. HIPS Essential includes the tools necessary to support both singlebeam and multibeam sonar data including the necessary calibration routines required to deliver accurate data. *www.teledynecaris.com.*

SBG Systems unveils Qinertia

SBG Systems takes a major step in the surveying industry by unveiling Qinertia, its in-house post-processing software. After the survey, this full-feature software gives access to offline RTK corrections, and process inertial and GNSS raw data to further enhance accuracy and secure the survey. For more than 10 years, SBG Systems has been designing inertial navigation systems from the internal Inertial Measurement Unit to the filtering with GNSS data. Expert in real-time data fusion, the company takes another step in the surveying industry by unveiling Qinertia, a fully in-house Post-Processing Kinematic (PPK) software. Whether the survey is made from a car, a UAV, a plane or a vessel, Qinertia will secure and enhance your acquisition.

Trimble News

Millimeter accuracy by new total station

Trimble® S5 Ti-M total station was specifically designed as a powerful, yet cost-effective solution scalable for monitoring projects of any size, from short-term jobs to multi-year construction operations. Its performance and capability is ideal for the monitoring of buildings above tunnel construction and close to excavation sites. It is also well suited for monitoring the subsidence of road surfaces and embankments. It provides millimeter-level accuracy and 3D position information for buildings and other structures. When integrated with Trimble's 4D Control software, it is an even more powerful optical tool capable of handling the most complex monitoring applications. *www.trimble.com/Infrastructure/Total-Stations*

Compact, High-Performance OEM GNSS Sensor

The ABX-Two OEM GNSS sensor delivers precise heading, pitch, roll and 3D positioning information. With two internal MB-Two modules, the ABX-Two offers a third antenna option that provides a drift-free, absolute attitude solution. It is an ideal solution for a wide variety of applications such as agriculture, automotive, aviation, construction and marine systems. *www.InTech.trimble.com*

Smart Water Management Software

Trimble® Unity 3.8 is a cloud-based, GIS-centric Software-as-a-Service (SaaS) solution that offers a suite of applications and tools for the water, wastewater, storm water and environmental water industry. It enables customers to monitor real-time operations, deploy smart meters, assess the condition of assets, reduce leakage and non-revenue water (NRW), and locate and map critical infrastructure using Trimble high-accuracy GNSS mapping technologies. *www.trimble.com*

After the mission, Qinertia gives access to offline RTK corrections from more than 7,000 base stations located in 164 countries. By creating a virtual base station near your project, the software delivers the highest level of accuracy without having to set up a base station. *www.sbg-systems.com*

Pointfuse Point Cloud software transforms design of construction

Swanton Consulting has transformed the design of temporary works – such as façade and basement retention – using a software innovation that creates instant 3D models from laser scanner data. Processing of the millions of individual 3D laser scan measurements, known collectively as point clouds, used to take Swanton up to two weeks. However, since introducing Pointfuse V2 point cloud processing software, Swanton can now produce highly accurate vector models, suitable for immediate use by design engineers, in less than a day. *http://pointfuse.com/*

Blue Marble Releases Geographic Calculator 2017

Blue Marble Geographics has released Geographic Calculator 2017. This major version release introduces a new job for performing quality control on seismic survey data; it includes updates to the geodetic datasource, which forms the core of the application; and it adds the Ordnance Survey OSTN15 geoid model for improved vertical coordinate transformations in the UK. *www.bluemarblegeo.com*

Barcode scanner solution for gas utility pipeline mapping

CartoPac International Inc. has introduced a fully integrated barcode scanning solution for gas utility companies. The solution integrates with the CartoPac Software Suite and enables utilities to quickly and accurately comply with regulations related to the traceability of their as-built natural gas distribution assets. It developed an interface application for the Code barcode reader to stream the captured codex information into the CartoPac Software Suite running on Windows and Windows Mobile GPS-enabled data collection devices, including the Trimble Geo series. Code's barcode reader transmits barcoded data via Bluetooth connection to the CartoPac software where the 18 data points describing the PVC pipe are stored seamlessly as attributes along with other field data collected for inclusion in the enterprise GIS. *www.cartopac.com*

Topcon introduces new GNSS receiver boards

Topcon Positioning Group has announced two new full constellation GNSS receivers for the OEM market. The new B111 and B125 boards are designed for use with a broad range of positioning applications. The boards utilize the GPS, GLONASS, BeiDou and Galileo constellations with the B111 tracking signals in the L1 and L2 frequency band, while the B125 adds signals in the L5 band. *www.topconpositioning.com*

1Spatial Technology makes German Mapping Authorities 40% faster

1Spatial automated map generalisation resulting in a 40 percent improvement in production time, from five to three years, for the participating members of AdV, the committee that coordinates surveying and mapping in Germany. AdV had previously worked to a five year production cycle for all of its high quality map products. However, this was no longer meeting the demands of customers who required information to be updated more regularly, and in shorter periods. Twelve of the 16 AdV members states decided to develop an automatic process to speed up production and reduce manual effort, and founded the IP-ATKIS-Gen project group. 1Spatial was selected as the IP-ATKIS-Gen partner for one of the largest generalisation projects in Europe. Together the two organisations developed an automated, "context-aware" solution using 1Spatial's experience and software tools. *https://1spatial.com/*

Vencore wins prime position

Vencore, Inc. was awarded a prime position on the National Geospatial-Intelligence Agency (NGA) Multi-Intelligence Analytical and Collection Support Services

(MACSS) program. The multiple award, indefinite delivery/indefinite quantity (ID/IQ) contract is valued at $980 million with a performance period of five years. NGA is both a combat support and an intelligence agency of the United States government, with the primary mission of collecting, analyzing, and distributing geospatial intelligence (GEOINT) in support of national security. *www.vencore.com*

Swift Navigation and PolySync announce technology partnership

Swift Navigation has teamed up with PolySync, a leader that is building the tools and software infrastructure at the center of autonomous vehicle development. As a result of this technology-focused alliance, PolySync has built a driver for Swift Navigation's flagship product, Piksi™ Multi. The driver is available now. *https://finance.yahoo.com*

Raytheon says GPS control system OCX on track to hit revised milestones

Raytheon's long-embattled ground control system for GPS is back on track following a government contract breach last year that prompted the U.S. Air Force to work with the company to revise the program's budget and schedule, the program manager said.

"What we've seen through the execution of the program in the 2016 time frame up to now, through the first quarter of 2017, is that the milestones we established at the beginning of 2016, we hit every milestone," said Bill Sullivan, Raytheon's OCX vice president and program manager.

Vectron adds Furuno GNSS Timing Products to Portfolio

Vectron International has entered into an agreement with Furuno to provide Furuno's GNSS receivers and timing modules in North America. Furuno's Opus timing receivers are capable of providing timing accuracy better than 15 ns Root-Mean-Square (RMS) compared to Coordinated Universal Time (UTC) and only need to track one satellite in position hold mode to provide accurate timing. Built-in Time-Receiver Autonomous Integrity Monitoring (TRAIM), anti-jamming, and multipath mitigation ensure signal reception in challenging environments. *www.satellitetoday.com/*

Tersus GNSS launches Precis-BX306 RTK board

Tersus GNSS Inc., a GNSS real-time kinematic (RTK) manufacturing company, has launched its new GNSS RTK board, the Precis-BX306. It aims at facilitating the applications that need centimeter positioning accuracy and dynamic operation mode, enforcing effective observation data logging and management, and popularizing the adoption of high precision in aerial mapping and drone-related integration.

KVH Receives $3.5 million order for TACNAV Tactical Navigation Systems

KVH Industries, Inc., has received a $3.5 million order for its TACNAV® tactical navigation systems for use by an international military customer. TACNAV military vehicle navigation systems provide unjammable precision navigation, heading, and pointing data for vehicle drivers, crews, and commanders. It also serves as a heading and position source for situational awareness.

GNSS Correction Service for Marine Applications by NovAtel

NovAtel has unveiled its Oceanix Nearshore correction service. It is a subscription-based GNSS correction service for Precise Point Positioning (PPP), provides exceptionally reliable sub-decimeter positioning for marine applications such as dredging, hydrographic survey, mapping and coastal patrolling, according to NovAtel. With a robust infrastructure, Oceanix precise corrections data is generated utilizing a network of more than 80 strategically located GNSS reference stations globally.

Its high rate corrections are designed to ensure the full accuracy of carrier phase is gained for enhanced solution accuracy. Oceanix corrections are delivered via geostationary satellites over L-B and directly to the end-user, providing reliable high accuracy positioning worldwide, according to the company.

Leica News

Leica iCON now integrated in Liebherr LIPOS®

Leica Geosystems has announced its Leica iCON rig solution has been integrated into LIPOS® (Liebherr Positioning System) by Liebherr, one of the world's largest manufacturers of construction machinery. The Leica iCON rig solution for drilling and piling machines will be directly implemented into LIPOS® factory-mounted add-on kit, which includes a fixture for the easy and quick installation of hardware without the need to change the machine structure.

Zeno GG04 smart antenna

New Leica Zeno GG04 smart antenna enables a flexible solution to improve mobile devices' GNSS accuracy with Real-Time Kinematic (RTK) and Precise Point Positioning (PPP). Paired with the Zeno GG04, any Zeno or third party mobile device with Android or Windows OS can now collect highly-precise positioning data with Leica Geosystems' GNSS technology and industry-leading 555-channel tracking performance. *leica-geosystems.com*

KDDI and Terra Drone have announced completion of inventing "4G LTE control system"

KDDI and Terra Drone have announced completion of inventing "4G LTE control system", the system allows operators to control drones via LTE network. This system also helps drone businesses by managing the information on each drone and operator and providing detailed flight logs of each flight. Flight plans will be created via the system by setting altitude of each optional flight point and flight forms between the points on an online map. During the flight, control instructions based on the flight plan are transmitted to a drone through LTE network. Automatic flights following set flight plans are not the only things this system can do. This system allows operators to watch real-time flights images through "Live View Area" in order to control drones remotely by sight.

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May 2017

GeoBusiness 2017
23 - 24 May
London, UK
http://geobusinessshow.com

FIG Working Week 2017
29 May - 2 June
Helsinki, Finland
www.fig.net

June 2017

10th International ESA Conference on Guidance, Navigation & Control Systems (GNC)
29 May - 2 June
Salzburg, Austria
http://esaconferencebureau.com

HxGN Live
13 - 16 June
Las Vegas, USA
http://hxgnlive.com/2017

TransNav 2017
21 - 23 June
Gdynia, Poland
www.transnav.eu

2017 Baltic Geodetic Congress (Geomatics)
22 - 25 June
Gdansk, Poland
http://www.bgc.geomatyka.eu/2017/

37th EARSeL Symposium
27-30 June
Prague, Czech Republic
http://symposium.earsel.org/37th-symposium-Prague/

July 2017

IGS 2017: International GNSS Service Workshop
3 - 7 July
Paris, France
www.igs.org

IEEE Frequency Control Symposium and European Frequency and Time Forum
9 - 13 July
Besançon, France
www.eftf-ifcs2017.org

Esri User Conference
10 – 14 July
San Diego, USA
http://www.esri.com/events/user-conference/papers

Geo4Africa Summit 2017 Conference
11 - 14 July
Kampala, Uganda
http://geo4africa.com

United Nations/United States of America Workshop on the International Space Weather Initiative
31 July - 4 August
Boston College, Massachusetts, USA
www.unoosa.org

August 2017

SEASC 2017
15-17 August
Brunei Darussalam
www.seasc2017.org/

September 2017

INSPIRE 2017
4 - 5 September, Kehl Germany
6 - 8 September, Strasbourg France
http://inspire.ec.europa.eu/events/inspire-conference-2017

Interdrone 2017
6 - 8 September
Las Vegas, USA
www.interdrone.com

ESA-JRC Summer School on GNSS 2017
4 - 15 September
Svalbard-Spitsbergen, Norway
www.esa-jrc-summerschool.org

56th Photogrammetric Week '17
11-15 September
Stuttgart, Germany
www.ifp.uni-stuttgart.de/phowo

ION GNSS+ 2017
25 - 29 September
Portland, USA
www.ion.org

Intergeo 2017
26 - 28 September
Berlin, Germany
www.intergeo.de

October 2017

Year in Infrastructure Conference
10 -12 October
Singapore
https://www.bentley.com/en/yii/home

ACRS 2017
23 - 27 October
New Delhi, India
www.acrs2017.org

3D Australia Conference 2017
26 - 27 October
Melbourne, Australia
http://3dgeoinfo2017.com

November 2017

Commercial UAV Show and GeoConnect Show 2017
15 - 16 November
London, UK
http://www.terrapinn.com/template/live/add2diary.aspx?e=9214

December 2017

International Symposium on GNSS (ISGNSS 2017)
10-13 December
Hong Kong
www.lsgi.polyu.edu.hk

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