MINE DETECTION SYMPOSIUM 2017

Program, Sessions and Speakers list

22. + 23. NOVEMBER 2017

University of Basel

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GICHD

Geneva International Centre for Humanitarian Demining

URS ENDRESS foundation.

Speakers:

22. November, 10 am to 5 pm

M. Bold, U. Endress	GICHD, UE Stiftung	Welcome Message and Introduction of GICHD and Urs Endress Foundation	10:00 - 10:30
C. Waldschmidt	Ulm University, Institute of Microwave Engineering	The FindMine Project & Overview of the Program	10:30 - 10:40
R. Bähnemann, R. Siegwart	ETH Zurich, Department of Mechanical and Process Engineering, Institute of Robotics and Intelligent Systems, Autonomous Systems Lab	Autonomous Mobile Robots for more detailed, repeatable and safe Environment Perception	10:40 - 11:05
M. Höpflinger	Federal Department of Defence, Civil Protection and Sport DDPS, armasuisse Science and Technology	Research within DDPS about Robotic Capabilities for Hazardous Environments	11:05 - 11:30
T. Paul	ESG Elektroniksystem- and Logistik GmbH	Performing unmanned flight test - exemplified on an Operational Example	11:30 - 11:55
U. Uschkerat, F. Rial	Fraunhofer Institute für High Frequency Physics and Radar Techniques FHR	Downlooking GPR activities at FHR 1999-2016	11:55 - 12:20

– Lunch Break –

J. Bongartz	Fraunhofer Institute für High Frequency Physics and Radar Techniques FHR	Monitoring Plant-Stress to detect Soil Contamination by Buried Explosives	13:20 - 13:45
I. Makki	Lebanese University	Hyperspectral Imaging for Landmine Detection	13:45 - 14:10
W. Schade	Fraunhofer Institute for Telecommunications, Heinrich Hertz Insitute, HHI	Fiber optical sensor for explosives Detection	14:10 - 14:35

– Coffee Break & Demo –

C. Baer, J. Sachs, R. Bustamante, F.Vega, I.Rolfes, T. Musch	Ruhr-Universität Bochum	MEDICI – Humanitarian Microwave Detection of Improvised Explosive Devices in Colombia	15:15 - 15:40
J. Jebramcik, J. Barowski, D. Pohle, C. Baer, I. Rolfes	Ruhr-University Bochum	An FDFD-based Simulation Concept for Stochastic Investigations on Improvised Explosive Devices in Colombia	15:40 - 16:05
F. Rial, U. Uschkerat	Fraunhofer Institute für High Frequency Physics and Radar Techniques FHR	IED & Mine Detection through the Eyes of a GPR Sensor	16:05 - 16:30
A. Heinzel, E. Schreiber, M. Peichl, S. Dill	German Aerospace Center	Detection of landmines, UXO, and IEDs using advanced synthetic aperture radar technology	16:30 - 16:55

– Dinner & Come Together – 19:00 - open end

Speakers:

23. November, 8:30 am to 1 pm

R. Burr, W. Mayer, T. Walter, C. Waldschmidt	Ulm University of Applied Science, Endress+Hauser, Ulm University	FindMine I: Bistatic FMCW based Ground Penetrating Radar for UAV Application	08:30 - 08:55
N. Docci, L. Ostgen, B. Ruch, H. Eichin	FHNW Brugg-Windisch, University of Applied Sciences and Arts, Institute of Automation	Findmine II: UAV with Sensor Plattform for Mine Detection	08:55 - 09:20
M. Schartel, W. Mayer, C. Waldschmidt	Ulm University, Endress+Hauser	Findmine III: UAV-Based Synthetic Aperture Ground Penetrating Radar	09:20 - 09:45
M. Schütz, M. Vossiek	Institute of Microwaves and Photonics (LHFT), University of Erlangen-Nuremberg (FAU)	A Concept for light weight UAV-Based Radar Remote Sensing assisted by Wireless Local Positioning	09:45 - 10:10
N.T. Nguyen, C. Migiaccio, G. Clement, N. Fortino, J-Y. Dauvignac, J. Willebois, C. Chekroun	Université Cote d'Azur	128 elements switched wideband antenna for Land-mine detection radar	10:10 - 10:35

– Short Break –

A. Blarer	armasuisse Science + Technology	Swarm Intelligence in Mine Detection	11:00 - 11:25
K. Buse, R. Sowade, C. Bolwien, J. Wöllenstein	Fraunhofer Institute for Physical Measurement Techniques IPM	Raman Sensors for Stand-off-Detection and Analysis of Explosives: Fundamental Aspects, State-of-the-art, and Perspectives	11:25 - 11:50
J. Lerch	Ihmati	« AUBE » Paramotor Drone	11:50 - 12:15
M. Bold and U. Endress	GICHD, UE Stiftung	Closing: Summary and Outlook	

– Lunch Break / End –

Monitoring Plant-Stress to Detect Soil Contamination by Buried Explosives:

Jens Bongartz, Caspar Kneer, Alexander Jenal, Immanuel Weber

Anwendungszentrum für multimodale und luftgestuetzte Sensorik (AMLS)
Hochschule Koblenz & Fraunhofer FHR

After a lengthy period of time buried in the ground the explosive compounds of undetonated landmines could leak into the environment, ultimately contaminating the soil. Because plants are rooted in the soil they can be considered indicators of the local environment. The explosives are taken up by plants which will affect the physiology and functioning of the plants. Especially the vital process of photosynthesis will be influcenced, which can be detected by means of optical methods. In the talk an overview of different hyper- and multispectral remote sensing techniques will be given. In particular the spatial distribution of sensor data over larger areas can help to distinguish between natural environmental stress and local environmental contaminations.

Hyperspectral Imaging for Landmine Detection:

Ihab Makki, Rafic Younes, Clovis Francis, Tiziano Bianchi, Massimo Zucchetti

Lebanese University

Since a long time, many countries around the world are suffering from a danger that menaces the citizens: mines and unexploded ordnances. Beyond the immediate dangers to life and limb, the mine problem is imposing a heavy economic burden to the affected communities. Unfortunately, the techniques that are used in the demining process such as metal detectors, specially trained dogs, and mechanical clearance using armored vehicles fitted with flails are generally slow, expensive and dangerous. Because of this and knowing that new technologies may provide effective alternatives, we are working on the use of hyperspectral imaging in landmines detection. Hyperspectral imaging is a trending technique in the field of remote sensing used in different applications like agriculture, mapping, target detection and food quality monitoring. This technique gives the ability to identify remotely the components of the image by acquiring the spectral response at each pixel in a series of narrow bands in the visible and infrared ranges. By this, we obtain a reflectance spectrum that will be used as a fingerprint to identify the presence of landmines.

The process will be as follow: a preconfigured drone (hexarotor or octorotor) will carry the hyperspectral camera. This programmed drone is responsible of flying over the contaminated area in order to take images from a safe distance. Various image processing technique will be used to treat the image in order to isolate the landmine from the surrounding. Once the presence of a mine or explosives is suspected, an alarm signal is sent to the base station giving information about the type of the mine, its location and the clear path that could be taken by the mine removal team in order to disarm the mine.

This technology has advantages over the actually used techniques:

- It is safer because it limits the need of humans in the searching process and gives the opportunity to the demining team to detect the mines while they are in a safe region.
- It is faster. A larger area could be cleared in a single day by comparison with demining techniques
- This technique can be used to detect at the same time objects other than mines such oil or minerals.

In our presentation, we would like to give an overview of different projects that worked on the detection of landmines using hyperspectral imaging. We will show the main results achieved in this field and future work to be done in order to make this technology effective.

In addition, we worked on different target detection algorithms in order to achieve high probability of detection with low false alarm rate. We tested different statistical and linear unmixing based methods. In addition, we introduced the use of radial basis function neural network in order to detect landmines at subpixel level. A comparative study between different detection methods will be shown during the presentation.

A field experiment has been has been done in order to study how the spectral signature of landmine will change depending on the environment in which the mine is planted. For this, we acquired the spectral signature of 6 types of landmines in different conditions: in Lab where specific source of light is used; in field where mines are covered by grass; and when mines are buried in soil. The results of this test will be shown also in the presentation.

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Prof. Rafic Younes; Lebanese University; Beirut Lebanon; ryounes@ul.edu.lb

Prof. Clovis Francis; Lebanese University; Beirut Lebanon; cfrancis@ul.edu.lb

Dr. Tiziano Bianchi; Politecnico di Torino; Turin Italy; Tiziano.bianchi@polito.it

Prof. Massimo Zucchetti; Politecnico di Torino; Turin Italy; massimo.zucchetti@polito.it

Fiber Optical Sensor for Explosives Detection:

L. Eisner, G. Flachenecker, W. Schade

Fraunhofer Heinrich Hertz Institute, Am Stollen 19H, 38640 Goslar, Germany
www.hhi.fraunhofer.de

Optical sensors based on evanescent field interaction of light guided within a waveguide and surrounded by a medium to be analyzed, are well-known for their high sensitivity, their miniaturized design, high mechanical stability, cost efficiency and scalability to sensor networks. Such optical sniffer noses are strongly enhanced in sensitivity by introduction of optical resonant waveguide structures like micro ring resonators, Bragg gratings or plasmonic surface effects, enabling trace gas detection. Currently Fraunhofer HHI concentrates on the development of highly sensitive evanescent field structures in glass fibres for detection of explosives. These sensors provide specific detection selectivity by deposition of receptor coatings acting as key-lock system for adsorption of TNT or other explosives. Additionally, minimization of side effects can be realized by analysing a set of sensors with different receptors by software routines for pattern recognition of sensor signals.

Swarm Intelligence in Mine Detection:

Albert Blarer

armasuisse Science + Technology

Mine detection is an extremely complex process. These days, more than 2'000 construction types of landmines exist around the world. They appear in different sizes, designs and material compositions. A similar diversity exists for the areas where landmines are hidden away and form a major threat to the population. Nowadays, regions from all climate zones are mine-infested, showing large topographical varieties, different soil types and vegetation zones. The diversity of landmines and the diversity of environmental factors makes it extremely difficult to define simple and general mine detection features.

Modern mine detection makes use of many distinct sensor systems, technical and non-technical ones. However, each sensor type also has its limitations. Animals, such as dogs, rats or even bees which are trained to detect landmines by olfaction, fatigue very soon. A metal detector of course will fail to detect mines constructed without any metal parts. It further may have problems to distinguish the metallic mine parts from the metal clutter found in many grounds. Microwave sensors, such as ground penetrating radars (GPR), may work well in moist or wet soils, but become more insusceptible in dry and sandy desert grounds. The list of uncertain or ambiguous sensor signals could be continued arbitrarily. However, using different sensor modalities concurrently, the chances for true positive detections obviously will increase.

First key message: A multi-sensory approach increases the success of mine detection under heterogeneous environmental conditions.

Considering a system of distinct sensors working simultaneously, rises the question of how individual sensor informations could be compiled and fused to get a more conclusive overall result. Here the concept of swarm intelligence comes into play, with many paradigms found in nature.

Swarming honey bees, for instance, are forced to find very rapidly a new nest site. A group of specialised scout bees is assigned to this task. After finding a nest site - for example a hollow trunk that matches all necessary conditions - individual scout bees return to the swarm. There, they inform other scout bees on the swarm surface about the quality of the potential nest site they have found and its location. Reporting good nest site qualities attracts the attention of much more scout bees and causes them to visit the reported nest site by themselves. Essentially, this positive feedback mechanism in the bee swarm guarantees the optimal nest site decision. High quality nest sites attract more scout bees which in turn attract even more scout bees after reporting their positive impressions, whereas nest sites of inferior quality will not be visited that much. The decision for a particular nest site is taken if a minimal number of scout bees accommodates simultaneously in that nest site place. This sort of decision finding works optimally in natural swarms of bees.

If we transfer the swarm scenario to our mine detection system, it is straightforward to imagine, that an individual sensor, say a metal detector, reports to all other sensors its findings. Other sensors with different sensory modalities, like GPR, infrared, gas sensor, etc. are attracted and enforced to investigate the reported location depending on the initial information. We can imagine an unmanned aerial system composed of drones with distinct sensor types. Such a drone swarm would offer many opportunities to implement different search strategies and for fine tuning the rules of collective, intelligent behaviours. The positive feedback loop, as described above in the bee swarm example, would also represent the basic ingredient of the drone swarm, and the fusion of sensory data would provide reliable decisions in the mine detection task.

Second key message: Swarm intelligence offers concepts for more reliable decision criteria in the mine detection process.

Unaffected by the impressive technical progress in recent years, mine detection is challenged by a fundamental but non-technical problem: trust or confidence. Whenever the UN is preparing a mine clearing project, they start to train in the first place local people for the mine sweeping actions. This is not coincidence, since only local domiciled experts can supply the confidence for the mine detection outcomes. Even a technologically ideal solution with 100% clearance rate would not guarantee the necessary confidence that concerned people need to re-access or re-cultivate a reportedly demined area. If we consider the swarm approach described above as an agent-based model, it would be easy to integrate the human capabilities as additional agents into the swarm system. All sensors, purely technical ones, animals or persons, would then act as agents in the swarm network, exchanging their findings and reacting to inputs from other agents.

Agent-based models are currently considered as a promising approach in order to understand and manage complex systems. Different from the current hype in (deep) machine learning, agent-based models offer a much better explainability of the decision criteria, since the working rules and constraints of individual agents are much better traceable.

Third key message: Integrating human capabilities into the mine detection process is fundamental to gain confidence in the results of demining processes. The swarm approach, viewed as an agent-based model, offers easy integration of technical and non-technical sensors, e.g. human agents, to facilitate these confidence-building measures.

Detection of landmines, UXO, and IEDs using advanced synthetic aperture radar technology:

Andreas Heinzel, Eric Schreiber, Markus Peichl, Stephan Dill

German Aerospace Center

The detection of landmines, UXO (UneXploded Ordnance), and IEDs (Improvised Explosive Devices) is still a challenging task. The requirement of efficient and reliable detection of these objects in a reasonable time demands for fast sensors investigating large areas with sufficient resolution and sensitivity. Ground penetrating radar (GPR) is a suitable tool, typically operating in a very close distance to the ground and a rather time consuming punctual method of operation. In contrast to this methodology, standoff synthetic aperture radar (SAR) is able to scan large areas in a rather short time resulting in an increased throughput compared to classical GPRs.

TIRAMI-SAR is a multi-static polarimetric imaging radar at lower microwave frequencies (typ. 500 MHz to 3 GHz) for fast close-in detection of buried and unburied objects on a large area from a save standoff distance. The SAR principle is applied using multiple transmitters and receivers and a side-looking geometry, allowing high spatial resolution in three dimensions. In order to achieve this high resolution also for buried objects, advanced SAR processing is used for proper focusing even within the ground. In the past, the main problem using SAR for buried object detection was to discriminate the object from the background clutter. Now, the setup of the TIRAMI-SAR system demonstrates how to solve this problem by using a multi-static fully-polarimetric approach, consisting of two transmit and four receive antennas operated simultaneously during one scan, and the application of different polarization setups for the identical scene in time multiplex. The superposition of all multi-static images ensures significantly enhanced clutter suppression resulting in fairly improved target detection. Furthermore, typical targets have different shapes and are located under various viewing angles with respect to the radar sensor. Therefore the use of different polarization combinations is indicated to improve the detection of all targets.

In order to illustrate previously mentioned effects, results with various unburied and buried objects are shown. As a special case, an experiment for the detection of thin wires is discussed. Thin wires are often components of IEDs connecting pressure plate structures with the activator of the explosive device. The wires have typically a diameter less than 1 mm, making detection by radar difficult.

An FDFD-based Simulation Concept for Stochastic Investigations on Improvised Explosive Devices in Colombia:

Jochen Jebramcik, Jan Barowski, Christoph Baer, Ilonas Rolfes

Ruhr-University Bochum

The detection and neutralization of anti-personnel landmines and explosive devices is a major challenge in many countries worldwide, Colombia for instance. In contrast to conventional landmines, Improvised Explosive Devices (IEDs), the most frequently used mine-type in Colombia, are constructed and installed in varying manner. Furthermore, most IEDs contain only a small portion of metal parts, namely the detonator and battery pack, making it difficult to trace them reliably and to distinguish them from other buried objects.

Ground Penetrating Radar (GPR) is a recognized method for the detection of buried objects, which has been used with great success in many cases as an alternative to other methods, like metal-detectors for example.

Frequently used methods to counter the weak signal strength of mines are migration algorithms, also known as synthetic aperture radar (SAR) algorithms, compensating the range migration of the ground echoes and therefore focusing the image. An enhanced approach concerning object identification is the utilization of certain resonance behavior of the IEDs. This includes the resonances of metallic parts, like the detonator or the battery pack, as well as internal resonances caused by the reflected bouncing waves inside the dielectric bodies.

Nonetheless, the measurement data strongly depends not only on the configuration of the IEDs itself, but also on different parameters of the surrounding soil structure, like its moisture content, homogeneity and the surface roughness. To analyze this diversity of influences on the results under realistic conditions, a fast and accurate simulator for stochastic investigations is needed.

Simulating a complex environment, including the antenna, ground environment and the IED itself, using an entire three-dimensional simulation, leads to long simulation times, making it impractical for this purpose. In this contribution we present a simulator based on a twodimensional finite-difference method in the frequency-domain (FDFD), which is capable to handle this parameter-diversity.

Even though not as popular as the finite-difference time-domain method (FDTD), the FDFD has considerable advantages for this application, since the lossy and dispersive behavior of the soil structure can be treated more easily in the frequency-domain. Furthermore, the resonances of certain components within the IED may cause long simulation times in timedomain implementations. At the same time the FDFD is a stable and rigorous numerical technique leading to accurate results, which is the reason why it is used with success for simulating photonic crystals and periodic structures, for instance.

Ground clutter is a major problem for the detection of shallow buried objects. In this context we present simulation results concerning the influence of the surface roughness on GPR measurements.

In order to improve the results in terms of signal-to-noise ratio and resolution, we applied a backprojection algorithm on the obtained dataset. This algorithm is based on the successive summation of the phase-corrected and interpolated data at each point in the pixelmap, allowing a pulse-by-pulse image generation. Because of these properties the algorithm is very promising in real-time signal processing of GPR measurements.

Humanitarian Microwave Detection of Improvised Explosive Devices in Colombia – Project “MEDICI”

Christoph Baer, Jochen Jebramcik, Jan Barowski, Thomas Musch, Ilonas Rolfes, S. Gutierrez, J. Sachs, Felix Vega

Ruhr-University Bochum

Colombia has been the last country in Latin America, where anti personal landmines have been planted until 2016. The statistics are horrifying: over 10,000 people have been injured or killed by landmines in the last 15 years.

According to the International Landmine Monitor 2016, this puts Colombia in sixth place in the casualty statistics, and with up to 99 square kilometers of the country being mined, it is still classified as “heavily mine-contaminated”. The forecast in the ten-year plan drawn up in 2011, that the country would be completely cleared of mines by 2021, is considered as “not on track”.

The reason for this sober prognosis has to do with both, the type of mines used and the relatively inefficient detection technology employed so far. Unlike purely military conflicts, in which industrially manufactured mines are used, Colombia’s landmines are improvised from everyday objects.

These Improvised Explosive Devices (IEDs) vary drastically in their construction and ignition mechanisms so that established detection methods work very poorly or are even not effective at all. In addition, the terrain in Colombia’s interior is sometimes extremely difficult to traverse, preventing the use of conventional, large-scale clearing technologies. Mine clearance remains a time-consuming manual job.

To help find a solution to this enormous challenge, researchers from Ruhr-Universität Bochum and Technische Universität Ilmenau in Germany as well as Universidad Nacional de Colombia, and Universidad de los Andes in Bogotá joined forces in the German-Colombian Collaborative

Research Initiative in Electrical Engineering (GeCoCo) set up by the DFG. The resulting joint research project, “Humanitarian Microwave Detection of Improvised Explosive Devices in Colombia – MEDICI” was designed to provide new Ground Penetrating Radar (GPR) based approaches to improve the search for IEDs and accelerate mine clearance. This talk gives an overview on the research results achieved within the last years, including: Low-Ringing UWB Antennas, Ground-Penetrating Synthetic Aperture Radar, and Inertial Navigation Systems for handheld devices as well as characterization of IEDs and surrogate materials for non-hazardous test measurements. Moreover, common international activities which foster the sustainable landmine related research in Colombia are discussed and future research activities will be presented.

IED & Mine Detection through the Eyes of a GPR Sensor

Fernando Rial, Udo Uschkerat

Fraunhofer Institute for High Frequency Physics and Radar Techniques (FHR), Fraunhoferstr. 20, 53343 Wachtberg, Germany

The (Ultrawideband) UWB-Team is a part of the Cognitive Radar Department at the Fraunhofer Institute of High Frequency and Physics (FHR) in Germany. The UWB Team has a long experience in mine and IED detection using Ground Penetrating Radar (GPR) systems. The general idea of this work is to share some key points of our experience developing GPR systems gathered during the last 15 years and to show what our current topics of interest in this field are.

The work starts briefly introducing the UWB-Team at the FHR and our area of expertise. We mention some of the main projects we have been working on during the last years and we introduce some of the GPR systems that the team has developed.

The work continues introducing some key concepts regarding the GPR technology. This includes frequency band, interference, clutter and acquisition geometry (and their implications in the detection and classification) which are particularized for down-looking, forward/side-looking and airborne systems.

In the next section, the resolution and imaging process related with GPR systems is introduced. A vehicle-mounted forward-looking GPR system developed at the FHR is used as example to explain the resolution limits and the main constraints for imaging.

Finally we go though some ideas to implement cognitive sub-functions in a radar system towards a cognitive radar architecture. The concepts of spectrum sensing, match illumination or trajectory planning will be briefly introduced. These ideas are being implemented and tested in a light SDR Unit that will be mounted in a UAV.

128 Elements Switched Wideband Antenna for Land-Mine Detection Radar

N.T. Nguyen, C. Migliaccio, G. Clementi, N. Fortino, J-Y. Dauvignac, J. Willebois, C. Chekroun

Université Côte d'Azur, CNRS, LEAT,

We have designed, made and measured a 7 m linear antenna operating between 2 and 4 GHz for land-mine detection radar application.

In 20013, Chile and France signed a cooperation agreement for the promotion and development of systems that help to get rid of the mines in the desert of North-Chile. The Electromagnetic (EM) Non-Destructive Evaluation (NDE) systems, like radars, have been intensively investigated for this application because they enable to scan the area without touching the land mines. Radars localize and identify the mines, and therefore enable a safe removal, but the problem remains challenging because in-flight radar have to compromise between the transporter carriage capacity and the high resolution requirements linked to the small size of the land mines. Therefore we have settled the design requirements to (7*7*7cm) resolution with a scan area of 4km2 per day for a carrier flying 10m below the ground. High resolution is implemented with SAR postprocessing.

We take advantage of the transporter's displacement for getting the resolution along the flight path, resolution in the other dimension being obtained with the large 1D antenna.

We go through design, fabrication and evaluation steps of the antenna. It consists of 128-switched elements of loaded Vivaldi type arranged in 16 sub-arrays. The feed of the antenna consists of a switching network that operates in three stages: 16*8 SP8T on the first one, 2*SP8T on the second, and 1*SP2T at the input. The switching network is embedded in a metallic rail placed below the radiating elements. The rail is designed onpurpose for avoiding unwanted coupling and backward radiation between the radiating elements and the coupling network. Antenna is coated with a Teflon radome that also acts as air-tightness structure. We have first conducted the overall checking of the antenna.

Then, we have successfully detected a dielectric block placed on a metallic plate (assumed as severe environment). For this, we use a sub-array of 8 elements driven by the radar front-end that will be further used on board. We use a neutralization technique for the front-end calibration.

A Concept for Lightweight UAV-based Radar Remote Sensing assisted by Wireless Local Positioning.

Martin Schütz, Martin Vossiek

Ruhr-University Bochum

In this talk, we will introduce a custom-built UAV-based sensor platform for radar remote sensing. It is controlled by a redundantly implemented, customized flight control system and equipped with a comprehensive embedded system for radar baseband processing. Both systems are synchronized by a common reference clock with low phase noise, which is temperature-stable and allows for the coherent acquisition and continuous recording of sensor data. A commercial differential GPS receiver is used for satellite-based positioning. The platform is suitable for interferometric remote sensing with synthetic apertures. In a first implementation, it is equipped with a bistatic 24 GHz MIMO radar system to create a side-looking airborne radar, allowing for full interferometric SAR processing.

Classical SAR imaging is realized with long range radar systems mounted on satellites or planes, making it challenging to achieve the high signal-to-noise ratio and high system bandwidth needed for valuable radar images. With low altitude systems, such as the proposed UAV-based sensor platform, higher carrier frequencies and thus greater bandwidths can be implemented without degenerating the signal-to-noise ratio. However, an increased carrier frequency comes along with increased precision requirements regarding the flight trajectory measurement and control. This is especially challenging for lightweight UAVs, and alternative techniques should be considered where satellite-based position and trajectory estimation techniques are no longer efficient.

Our presentation will illustrate the concept and a first prototype of a wireless local positioning network based on regenerative backscatter transponders.

The approach allows for simultaneous trajectory estimation and SAR image generation with a single radar sensor. The hardware of the wireless positioning network is realized with low-cost, air droppable transponders. These reference transponders can easily be placed within or around a hazardous area to support the UAV during a high resolution SAR image formation. We will present first measurement results regarding the performance evaluation of the positioning technique as well as data acquired during flight that prove the effectiveness of our proposed concept in practice.

Performing Unmanned Flight Tests - Exemplified on an Operational Example

Tobias Paul

ESG Elektroniksystem- and Logistik GmbH

In close cooperation with German Bundeswehr, ESG has modified an UMS Skeldar R-350 UAS to offer a testbed for in-flight evaluation of payload and avionics – the UMAT (Unmanned Mission Avionics Testbed). The UMAT programme started in 2009, while flights have been performed since 2011. At that time, no comprehensive regulation was in place regarding the operation of RPAS of that size. Nevertheless, as safe operation is a prerequisite for ESG, the ESG RPAS Flight Organisation was established. This ESG RPAS Flight Organisation is based on the former JAR OPS 3: Commerical Air Transportation but tailored to the RPAS-specific demands.
The presentation starts with a short introduction to the company ESG. Afterwards, the unmanned aircraft system UMAT and the corresponding operational use case is introduced.
The body of the presentation is concerned with a current flight test project (e.g.: automatic landing site reconnaissance).
Undergoing the project development process, the several steps of performing flight trials are explained. Those comprise initial planning, safety assessment, approvals, flight planning, flight execution, and result evaluation.
The presentation closes with a summary of the activities to be undertaken to perform safe and successful flight trials.

Research within DDPS about Robotic Capabilities for Hazardous Environments

Markus Höpflinger

Federal Department of Defence, Civil Protection and Sport DDPS, armasuisse Science and Technology

The research program 'Unmanned Systems/Robotics' at armasuisse S+T, the Technology Center of the DDPS (Federal Department of Defence, Civil Protection and Sport) is looking at chances and risks of future robotic capabilities for defence and security. At the symposium, we present research activities of the program about using robots on the ground and in the air to support humans with applications in hazardous environments, e.g. in the domain of CBRNE/Rescue.

Research within DDPS about Robotic Capabilities for Hazardous Environments

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UAV with Sensor Platform for Mine Detection

Nando Docci, Lukas Ostgen, Basil Ruch, Heinz Eichin

FHNW Brugg-Windisch, University of Applied Sciences and Arts, Institute of Automation

The major obstacle in mine detection is that the minefield must be entered. A new approach attempts to circumvent this situation with an unmanned aerial vehicle (UAV) system combined with a broadband ground penetration radar (GPR). This system is intended to be able to fly the mine area in a previously calculated flight route. The main target is to give a centimeter-exact evaluation of existing mines in this area for decreasing the costs of intensive "manual" search of landmines.

The goal was to construct a lightweight sensor-platform, which is independent from any possible UAV. The presented sensor platform can be divided in multiple subsystems. The most important subsystem is the GPR sensor system, for the detection of mines. Furthermore, the sensor platform consists of a single board computer (SBC) for recording and synchronizing the measured values in a time-synchronized manner. Only if the position data exactly match the prevailing sensor data, a mine can be detected in a centimetre-accuracy. Especially for the GPR-system, there is the mechanical design with the gimbal, which is responsible for the regulation of the antennas.

For the low-cost UAV-system we use a modified, commercial available UAV with a Pixhawk flight controller. Depending on the high accuracy, we use a low cost RTK-System including a base antenna (stationary on the ground) and the rover antenna (mounted on top of the UAV). The RTK-system processing the both received GNSS-signals and calculating the position with a high relatively centimeter-accuracy.

Depending for the different sensor-systems (GPR, imagery-based sensors, etc.)

there are different flight missions required. Therefore, we programmed a mission-planning-software, which calculates the waypoints depending on a calculated elevation-model including obstacles like poles or trees and the used sensor.

As introduction, a brief overview of the overall system of the UAV based sensor platform and the UAV itself is given. Moreover, the individual subsystems and their difficulties are discussed.

Bistatic FMCW Based Ground Penetrating Radar for UAV Application

Ralf Burr, Winfried Mayer, Thomas Walter, Christian Waldschmidt

Ulm University of Applied Science, Endress+Hauser, Ulm University

Ground Penetrating Radar (GPR) is an essential tool for the detection of landmines. State of the art GPR systems are either mounted on vehicles or used as handheld devices, however encountering the problem, that mine fields have to be entered for mine detection. To overcome this limitation, a broadband Ground Penetration Radar sensor system that can be operated on an unmanned aerial vehicle (UAV) has been developed.

The bistatic GPR sensor system consists of a 1-4 GHz FMCW radar module and two broadband antennas. The selected frequency range results from requirements regarding ground penetration and resolution in combination with the size and weight of the antennas. The sensor module is partitioned into a main module and a receiver module. The architecture of the main module exhibits the broadband frequency synthesis, power supply, data acquisition as well as a communication interface for configuration and data logging. The receiver module is a separate unit, which can be directly mounted on the receiving antenna. The architecture and the partitioning of our sensor system will be presented in this contribution. Challenges with respect to power consumption and broadband operation will be discussed.

Two different types of linearly polarized broadband antennas have been simulated, manufactured and characterized: A logarithmic periodic dipole antenna (LPDA) manufactured on a low cost PCB and a transverse electromagnetic (TEM) horn antenna. The latter antenna consists of a thin conductive layer which is mechanically supported by a 3D printed plastic structure. The RF-characteristics of these antennas with respect to mutual coupling in the bistatic sensor and regarding the shift of the phase center in such a broadband system will be shown and discussed. Furthermore, challenges and solutions regarding the application on an UAV will be highlighted.

Finally, free space measurements with the Ground Penetration Radar system will be shown and the overall system performance will be discussed and benchmarked.

UAV-Based Synthetic Aperture Ground Penetrating Radar

Markus Schartel, Winfried Mayer, Christian Waldschmidt

Ulm University, Endress+Hauser

A novel approach for antipersonnel landmine detection using a UAV in combination with a Synthetic Aperture Ground Penetrating Radar (SAGPR) is presented. The objective of the system is to achieve a significant progress in humanitarian demining. To accelerate the process of land release, the focus is on the technical survey. The presence and approximate location of suspicious objects shall be detected by the radar and marked for further investigations using different sensor modules.

For a reliable mine detection it is beneficial if different sensor principles are used. Since the payload of a UAV is limited the overall system is separated into a carrier platform and independently operating sensor modules. The interface between the carrier platform and the sensor module is mechanical only.

As carrier platform, a 5 kg-payload octocopter in conjunction with a Pixhawk PX4 flight controller was chosen. The SAGPR module consists of a 1 GHz to 4 GHz side-looking FMCW radar, a single-board computer for data logging and a RTK GNSS for localization. The radar is a SISO system in a bistatic configuration.

The image processing is done offline using a backprojection algorithm. This SAR algorithm can handle low frequency UWB FMCW radar data obtained from a non-linear flight path in the near and far field of a wide-beamwidth antenna and thus meets all requirements.

As introduction, the fundamental system concept and the challenges of this approach with respect to the SAGPR module are presented. To verify the functionality, UAV-based Stripmap SAR measurements and linear rail based GPR measurements are shown in the experimental part of this presentation. Thereby, the challenges of Stripmap SAR in conjunction with a SISO radar system are discussed.

These results motivate an innovative method – Spotlight SAR – for UAV-based mine detection, which is presented in the following theoretical part of this presentation. Finally, a short conclusion is given.

Autonomous Mobile Robots for more detailed, repeatable and safe Environment Perception

Rik Bähnemann

**ETH Zurich, Department of Mechanical and Process Engineering,
Institute of Robotics and Intelligent Systems, Autonomous Systems Lab**

Growing capabilities of mobile robots allow unmanned exploration of inaccessible and dangerous terrains. Sensors, algorithms, and artificial intelligence provide a new degree of autonomy to simplify the deployment of ground robots, drones, and submarines, and to extend perception to new dimensions.

In this talk we will present our recent field deployments of autonomous mobile robots in search and rescue and surveying missions. In particular we will stress the potential of techniques from robotics in humanitarian demining and elaborate on state of the art capabilities and challenges of unmanned micro aerial vehicles as mine detection devices.

« AUBE » Paramotor Drone

Julien LERCH

Ihmati

The company Ihmati designs, manufactures and sells drones for professional usages, adapted to the demand and the problems of each customer.

We specialize in soft flight. This is the case of our paramotor drones „Aube“ which flies thanks to a miniature Paragliding wing, which allows it to be of great autonomy (45 to 60 min) and to carry a significant payload (up to 1.5kg) while remaining very compact.
This flight technique is particularly suitable at low speed moves (10 to 30 km/h) with minimal noise and disturbance due to the propeller.

This type of drone ensures a tight protection of the on-board sensors in the event of failure due to its low speed and falling pace at 0.5 m/s.

Our „Aube“ drone is available in several configurations depending on your needs. Autonomy, type of payload and even the conditions in which it must evolve. This flexibility is possible thanks to a production technique based on 3D printing as well as a powerful and scalable electronics.
Chassis and transmitter are 90% done from 3D printing with compostable plastic, endocrine disturber free garanty. Maintenance and evolution will have a limited environment impact, thanks to a quick and local production.

The fields of application are multiple:

- Aerial Safari
- Wildlife observation
- Wildlife reporting
- On field analysis
- Environmental study
- Tracking and protection
- Mine detection
- Gas detection
- …

The principle of flying a drone under a paraglider wing responds to problems where fixed wing technologies such as airplanes or rotary wings like helicopters and multi-rotor are not adequate.
„Aube“ can thus cover a large area of ground to be analyzed by carrying appropriate sensors and adjusting its flight speed for accurate and meticulous detection.

Our paramotor drones are positioned as professional and high quality aerial support tools, by adopting a modular, affordable and easy to use technology.

Downlooking GPR Activities at FHR 1999-2016

Dr. Udo Uschkerat, Dr. Fernando I. Rial Vilar

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This presentation gives an overview of the past 17 years the FHR UWB Team was working on GPR based mine detection and IED detection. The first measurements started in 1999 using a commercial GPR. At that time the use of a ROC curve was for the first time a measure to compare results of different GPR systems from different research teams. In 2002 the FHR UWB team joined the MsMs activity at the Joint Research Centre in Ispra and was the only team providing GPR data for all 7 soil types with sufficient ground truth. In 2005 the International Test and Evaluation Procedures (ITEP) Group working under an international MoU developed standardization procedures to test handheld metal detectors. Also handheld dual sensor systems were treated. Results from in-field tests of the Minehound system e.g. in Bosnia Herzegovina paved the way for this commercially available handheld dual sensor system. Under ITEP again, in 2009 a measurement campaign was conducted in Germany where the "Comité Européen de Normalisation" CEN Working Agreement (CWA) 14747 was applied. FHR attended these tests with the GPR equipment. Finally, there was no international agreement possible for a standardization document on the handheld dual sensor test. Due to the good GPR signature database from the JRC trials a PhD topic on the simulation of GPR-signatures of mine-like targets proved the applicability of RCS prediction for GPR target identification. As a very short overview we can show the status of the military development in Germany on GPR usage for route clearance.

The latest projects of the FHR UWB team focus on mine signature database issues and the classification, the applicability of a forward looking, vehicle mounted GPR, and polarimetric issues.

The FLOSSI demonstrator was an intermediate step towards an airborne GPR development. This topic should be dealt with in a separate talk.