GICHD ICRC

Webinar Report

The Use of Remote Sensing and Artificial Intelligence in the Mine Action Sector

20th and 22nd April 2021, Geneva

(Online Webinar)

Contents

List of Abbreviations 2
Introduction: What advances in technology are needed for the mine action sector? 3
Webinar Objective 3
Day 1: Introduction to Artificial Intelligence in weapon contaminated environments and its challenges 4
- Innovation in the humanitarian space: the beneficial impact of cross-pollination 4
- Looking backwards to look forwards: the evolution of sensor technology 4
- Operational use of remote sensing – The Skallingen case 5
- UAV-based remote sensing for mine detection: FindMine 5
- Ground-based geophysical surveying in archaeology 6
- Legal perspectives for humanitarian operations 7
- Using advanced AI for improving Risk Assessment for Non-Technical Surveys 7

Day 2: How remote sensing and deep learning could be used to help identify mines and weapon contaminated areas during Non-Technical Surveys and other activities 8
- Using Airborne IR Thermography: Odyssey 2025 8
- Information Management and AI in mine action – Imagery Service Toolbox 9
- Thermal Sensing and Deep Learning – how to increase probability of detection and lower false alarm rate 10
- Mine Action Remote Sensing 10
- Guidelines for AI procedures – True color images for identification of landmines 11
- Database of EO global events (Natural Language Processing) 12

Conclusion and Way Forward 12
- Next to watch out for 13
- Participant's feedback 13

Annex A 15
- Important Links 15

Annex B 16
- Contributors 16
- Acknowledgments 16

List of Abbreviations

ABMBC	Anti-Personnel Mine Ban Convention
AGC	Advanced Geophysics Classification
AI	Artificial Intelligence
CCM	Convention on Cluster Munitions
CCW	Convention on Certain Conventional Weapons
CGI	Computer-Generated Imagery
EO	Explosive Ordnance
ERW	Explosive Remnants of War
GICHD	Geneva International Centre for Humanitarian Demining
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPSAR	Ground Penetrating Synthetic Aperture Radar
ICRC	International Committee of the Red Cross
IED	Improvised Explosive Device
IM	Information Management
IMSMA	Information Management System for Mine Action
InSAR	Interferometric Synthetic Aperture Radar
MD	Metal Detection
ML	Machine Learning
NLP	Natural Language Processing
NTS	Non-Technical Survey
SAR	Search and Rescue Drones
TS	Technical Survey
UAV	Unmanned Aerial Vehicle
UXO	Unexploded Ordnance

Introduction: What advances in technology are needed for the mine action sector?

Landmines, cluster munitions, and explosive remnants of war continue to be major threats that people and communities face in post-conflict settings. The threat posed by explosive ordnance is one that affects lives and livelihoods, causing death and injury, but that also blocks access to health, water, food, markets, education, and other essential services necessary for robust protection outcomes. In recent conflict theatres, more urbanised warfare poses a challenge to the accurate identification and safe removal of explosive ordnance, using traditional instruments and methods of work. Equally, as many countries near the completion of their mine action programmes, the contaminated areas that remain to be released are becoming harder to process as they are remote and cover large areas, often with challenging terrain. The continual improvement and development of new procedures, processes and tools will be vital in contributing to increased operational efficiencies. This will also support more effective planning, prioritisation and tasking of mine action assets.

The ICRC and GICHD firmly believe that the integration of remote sensing and AI into the mine action sector will enhance evidence-based decision making. This will aid the setting of priorities for the surveying and clearance of contaminated areas and allow the scarce recourses available for mine action activities worldwide, to be appropriately directed and used as efficiently as possible. AI, and machine learning, will also support the mine action sector in articulating the positive impact of the work.

This webinar invited APMBC/CCM/CCW member states, mine action authorities, specialists from mine action operations, academia, research & development, innovation, and manufacturers of state-of-the-art equipment joining colleagues from the ICRC and GICHD for a two-day discussion on remote sensing and AI. One of the visions behind this joint ICRC/GICHD webinar was to invite in a few speakers external to the mine action sector that have been doing research and field work on remote sensing technologies. We were hoping that cross pollination could inspire and help finding solutions to challenges in mine action, and vice versa. Mine action has unique challenges but should not be siloed and it is important to main-stream humanitarian action and development.

This report is designed to provide an overview of the presentations and discussions held during the webinar, helping to identify which technology is best suited to contribute to improving land release activities, the survey and clearance of explosive ordnance.

What did we hope to achieve through this webinar? We hoped that by bringing together your perspectives and experience, that we could advance a few ideas and threads of work that will contribute to making technology in mine action smarter, faster, safer more cost effective and, as a result, contribute to a reduction in human suffering.

Webinar Objective

Day 1 introduced the topic and discussed the challenges in the technology and its operationalization in weapon contaminated environments. Day 2 discussions examined in depth how remote sensing and deep learning could be used to help identify mine and EO contaminated areas during non-technical surveys and other activities.

Day 1: Introduction to Artificial Intelligence in weapon contaminated environments and its challenges

Innovation in the humanitarian space: the beneficial impact of cross-pollination

Speaker: Nan Buzard, ICRC
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The mine action sector is certainly not new to innovation. Surveys have become safer and more accurate over time, land release efforts have improved, and the articulation of the sector's impact has developed. However, although humanitarian mine action is unique in its activities and expertise required, it should not remain siloed in its innovation endeavours, but rather open to technical advancements from other sectors.

In this regard, a precious opportunity is represented by the cross-pollination between the humanitarian space, academia, and the private sector. The latter is currently investing notable amounts of funds in new start-ups and technology companies that can handle and manipulate the huge amounts of data generated by civilians, using AI for object detection. In contrast, humanitarian organizations have just begun exploiting the potential of big data to improve decision-making and could therefore positively benefit from the involvement of the private sector and academia in their activities. Due consideration must certainly always be granted to the specific contexts and circumstances in which such cross-pollination is introduced, as its benefits would highly depend on the nature of each humanitarian crisis.

Looking backwards to look forwards: the evolution of sensor technology

Speaker: Steve Priestley, Tetra Tech
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In the last 30 years, the technology used for sensor application has significantly evolved, as documented in academic journals. The path of evolution started in 1990, when the first detector was issued, soon to be replaced, and arrives to 2019 when, at the GICHD 7th Mine Action Technology Workshop, discussions focused on platforms including UAV's with magnetometers, GPR, fluxgate sensors, thermal and multi-spectral imagery, supported by Artificial Intelligence. Within the broader remote sensing envelope, airborne digital geophysical mapping was developed in the mid-1990's for rapid wide-area assessment, registering perfect flight safety records and proving to be up to ten times less expensive than ground-based detection. Advanced Geophysics Classification (AGC) was developed for terrestrial and marine applications. Artificial intelligence and machine learning have been supporting airborne, autonomous, and multi-sector detection making it possible to extract knowledge.

Currently, some of the applications of remote sensing include autonomous road assessments and autonomous rail assessments. Challenges are however not missing and include identifying viable real-world scenarios, differentiating munitions from clutter, affording the cost of such technologies, obtaining reliable and replicable results as well as sustainability in the operational environment.

Operational use of remote sensing – The Skallingen case

Speaker: Bo Bonemann Bischoff, Bischoff Advisory and Martin Jebens, ICRC
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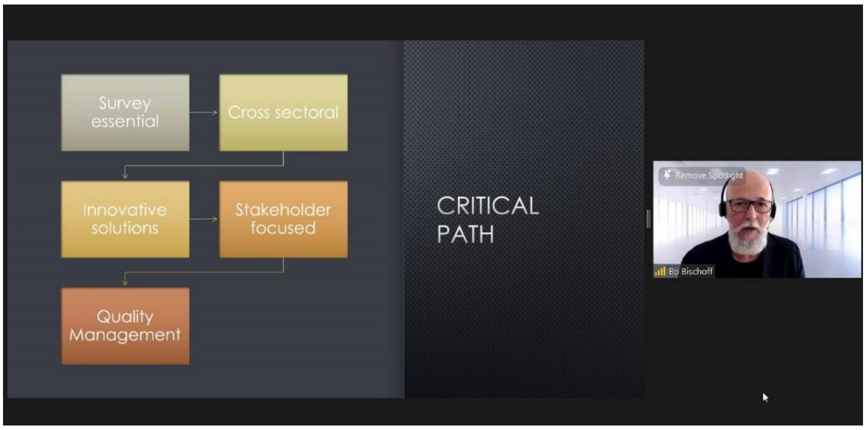
The Skallingen case represents the first major clearance project where remote sensing was used, marking the first application of this technology to mine action and, most importantly, the first cross-pollination between demining activities, academia, and the private sector.



Back in 2005, when a new minefield from the Second World War was discovered in Skallingen, Denmark, a small but unique task force was established to take on clearance. Being a unique natural reserve, part of the UNESCO World Heritage, the Skallingen area is one of the main touristic attractions in Denmark. Given the timeframe and the environmental concerns relating to the site, as well as the difficulty in managing stakeholders, reengineering, and reorganizing the traditional demining operational path by looking at new solutions was critical in Skallingen.

The collaboration between the private sector, mine action, and academia – including coastal morphologists - allowed the creation of 3D models of the historical terrain and to complete terrain analyses to determine the depth of the minefield. Knowing the position of the hazard layer made it then feasible to remove the top of the sand dunes without clearing them, before reaching the hazard layer. Due to the national and international environmental restrictions, the dunes were then rebuilt after mine clearance using a LiDAR scan. The clearance of Skallingen, which began in 1945 and was restarted in 2006, was finalized in June 2012, allowing the Danish Government to ratify the Ottawa Convention.

UAV-based remote sensing for mine detection: FindMine

Speaker: Urs Herbert Endress, Urs Endress Foundation
Email: urs.endress@endress.com

The R&D project FindMine represents a concrete application of UAV-based remote sensing to mine action. The project was started in 2016 by the Urs Endress Foundation and is based on the use of Unmanned Airborne Vehicles (UAV) with different remote sensing methods, including aerial imaging, Ground Penetrating Synthetic Aperture Radar (GPSAR), Interferometric Synthetic Aperture Radar (InSAR), Metal-Detection (MD) and A-Scan-Radar (GPR).

Regarding metal detection, the original idea of the project was to start from a single handheld device and move towards an array of metal-detector coils carried by an UAV, in combination with a ground penetrating radar, also called A-Scan-Radar. After getting aerial images and deducting up-to-date digital surface models and imagemap of a suspected hazardous area, a non-technical survey mission will be planned, performing GPSAR and MDGPR data acquisitions of the same area. GPSAR and MDGPR signal processing will be followed by the analysis and visualization of results.

Ground-based geophysical surveying in archaeology

Speaker: Carmen Cuenca-Garcia, Norwegian University of Science and Technology
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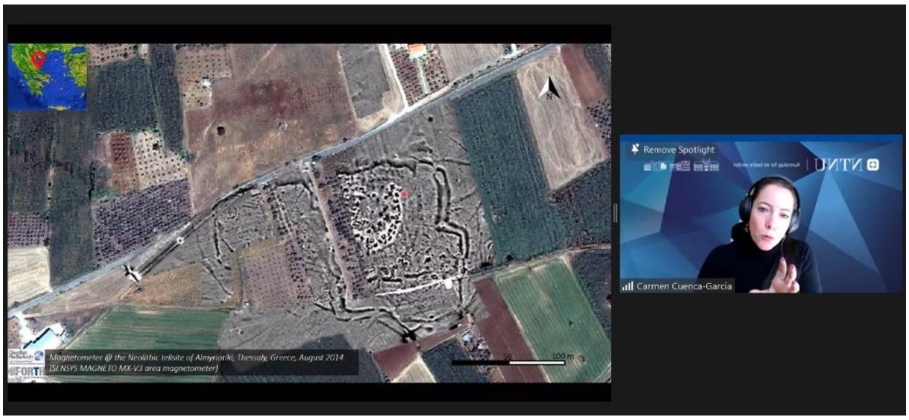
Geophysical surveying has been extensively used in the field of archeology for a long time and could represent an opportunity for innovation and advancements in mine action. The first Ground Penetrating Radar (GPR) survey in European archeology was concluded in Cyprus in 1980. Thanks to this technology, archeologists can find buried archeological sites measuring and mapping the spatial variations (with contrast) of a range of geophysical parameters. These variations can be representative of a subsurface archeology. In this process, contrast between targets and the surrounding matrix is a fundamental prerequisite and survey environmental factors thus prove to play a crucial role.



The application of geophysical technology in archeological surveys has made it possible to identify new valuable solutions for data collection. However, remaining challenges include covering larger areas, conducting rapid surveys, finding solutions to difficult access, and reaching a higher resolution of images. In addition, the main difficulty is currently represented by the necessity to provide solutions for data analysis and interpretation, including dealing with large datasets and data fusion/integration.

Legal perspectives for humanitarian operations

Speaker: Massimo Marelli, ICRC, Louis Maresca, ICRC and Rob White, GICHD
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There are two primary legal challenges that immediately rise to the surface regarding the use of remote sensing and AI in humanitarian operations: Data Protection and the national and international regulatory frameworks that may apply. The latter normally regulate the import/export of the equipment, not only regarding the actual physical drone and its accessories, but also the software, especially for those countries under United Nations Security Council sanctions.

On the hardware side, the main concern is represented by the risk of theft. In case the drone platform is stolen, it could be used to conduct attacks, for instance by a Non-State Armed Group. A tool capable of detecting weapons would be highly valuable in certain unstable settings, especially as a source to find the items needed to construct Improvised Explosive Devices (IEDs). Therefore, adequate measures to protect the data from this angle would certainly need to be taken.

Using advanced AI for improving Risk Assessment for Non-Technical Surveys

Speaker: Flavio Cirillo, NEC Laboratories Europe
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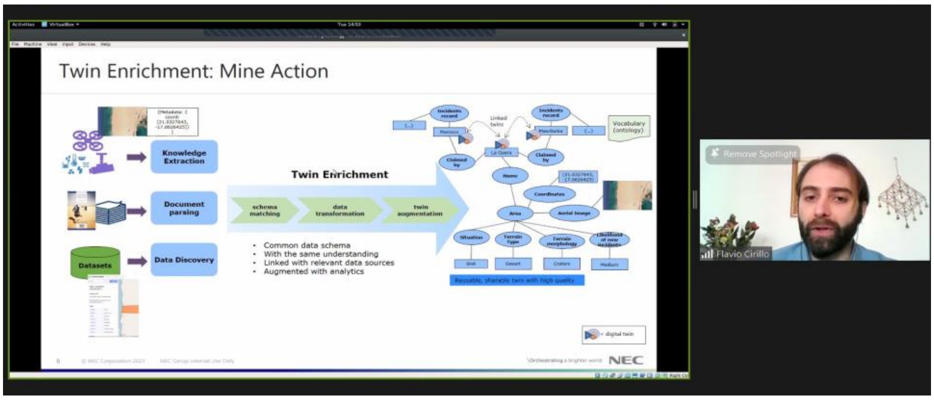
Artificial Intelligence (AI) refers to any technique that enables computers to mimic human intelligence, using logic and machine learning (including deep learning). Machine learning is a subset of AI that includes statistical techniques that enable machines to improve at tasks with experience. Deep learning is the subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like image recognition, by exposing multi-layered neural network to vast amounts of data.



The application of AIto mine action makes it possible to analyse big amounts of data. However, current analytics consist in many-to-one linkages from multiple data sources to one enterprise cloud. From such cloud, data is transferred to analytics services, in a one-to-one linkage. From such silos, the mine action sector should move towards hyperconnected data lakes, where produced data is shared among multiple applications and many-to-many linkages are created between objects, devices, edge devices, actuators, agencies, and services.

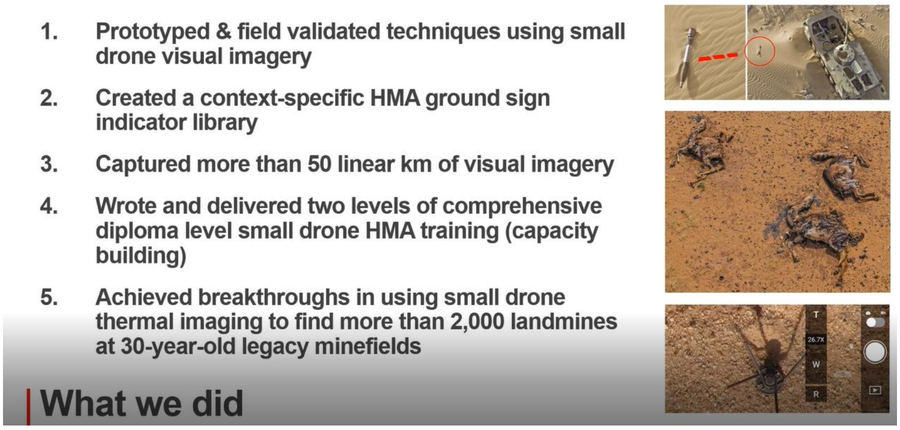
NEC Laboratories Europe is currently working to automate data enrichment towards this direction.

Day 2: How remote sensing and deep learning could be used to help identify mines and weapon contaminated areas during Non-Technical Surveys and other activities

Using Airborne IR Thermography: Odyssey 2025

Speaker: John Fardoulis, Mobility Robotics
Email: john.fardoulis@gmail.com

Limited use of remote sensing in mine action points to the paramount importance of field validation, coupled with the cross-pollination between different sectors, which was demonstrated by the successful outcome of project Odyssey 2025, implemented in the Sahara Desert, in Chad, by the NGO Humanity & Inclusion and the private company Mobility Robotics. The project included a capacity building campaign, achieved breakthroughs using small drone thermal imaging to find more than 2.000 landmines at 30-year-old legacy minefields: this is, so far, the greatest number captured in the sector. A static test kit was designed and prototyped to determine if thermal imaging is viable at and to prescribe optimal operating times at each contaminated location. Odyssey 2025 acted as a catalyst through evidence-based fieldwork, dissemination, and outreach to the mine action sector in justifying the value added for small drones.



Some of the lessons learned convey that IR thermography could speed up clearance activities by years and save millions of dollars in some countries. The study emphasized the following lessons learned; 1) there is no generic landmine or minefield, each type of design can emit a different anomaly and local conditions play a role in anomaly strength and timing; 2) real-world thermal anomalies from buried landmines look different than those reached through academic experiments, encouraging academia to work with real-world data; and 3) thermal anomaly capture is an NTS tool to gain better productivity from technical surveys and clearance assets and not a substitute for demining, so missing some mines is acceptable. Finally, national capacity can be created immediately using local staff to analyze data, through appropriate training programs.

Information Management and AI in mine action – Imagery Service Toolbox

Speaker: Wendi Pederson, GICHD
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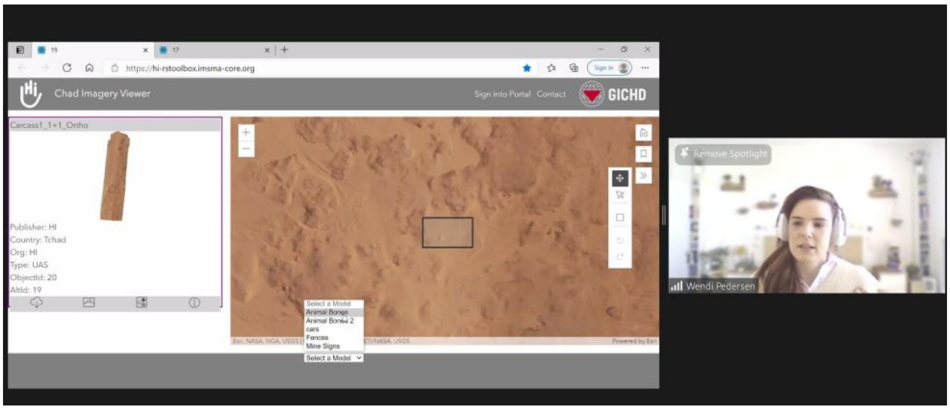
Effective decision-making in mine action is driven by geographic factors such as population distribution, infrastructures, terrains, and vegetation. Once coordinates are identified using the analysis of the vector data, improved and informed tasking of drone operations can be made. Knowing where to best direct UAV image capturing saves operational time and focuses the data captured.



Imagery Service Toolbox is an interactive browser-based tool which provides connectivity with GIS applications and IM systems. The toolkit can be used as a plugin to IMSMA Core and be customized for use in additional IM systems. For mine action, it provides a user-friendly image catalogue, image analysis using machine learning models developed in PicTerra, the ability to bring a selected image to a mapping project and a customizable imagery request function.

Thermal Sensing and Deep Learning – how to increase probability of detection and lower false alarm rate

Speaker: Martin Jebens, ICRC and Shen Junjie, Waseda University, Tokyo
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Since November 2018, the ICRC, and Waseda University (Tokyo) have been researching the extent to which the development of an airborne thermal detection system can contribute to improving the pace of detection and disposal of mines and explosive remnants of war. The challenge is to secure a flow between an aerial platform, camera unit, and GPD recorder, and to develop deep learning capable of classifying patterns of landmines and weapons. The aim is to create a solution in which a thermal camera can be mounted on different drones.

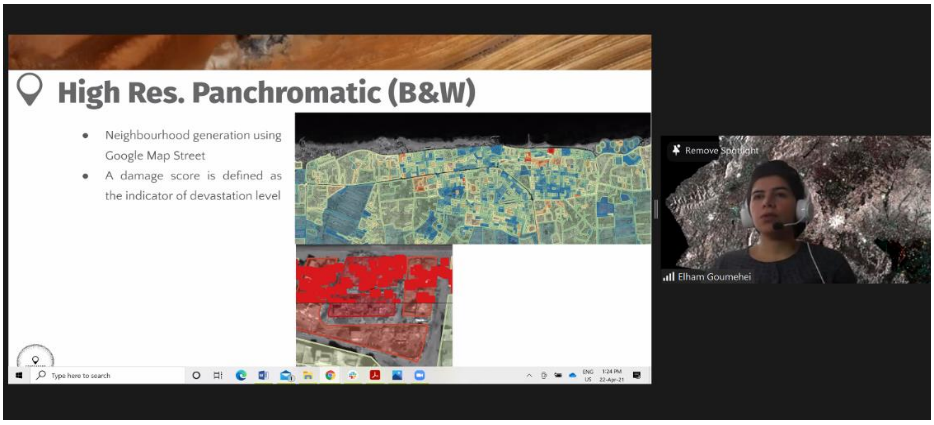
Although Covid-19 unfortunately limited the testing phase of the project, a testing field has been recently established in Denmark. It includes sub-areas in which stock mines and PMN3 have been buried, areas without vegetation in which different objects have been placed, and areas with dense vegetation. Different types of sediment have been purchased to bury items in or put them on top of, and the test area has been chosen so that part of it is in the sun and part in the shade. So far, testing has shown that thermal sensing can be used in areas with vegetation, but it needs some wind, which could constitute a challenge. On the contrary, the direct sun has so far proved to positively contribute to the recognition of objects placed on the surface. At this stage of the project, it is possible to confirm that thermal sensing is a promising additional tool for the detection of explosive weapons. In addition, the project also confirms that the application of deep learning on quantitative data improves the probability of detection and with more data and adapted algorithms, an even higher probability could be reached.

Mine Action Remote Sensing

Speaker: Elham Goumehei, Space4Good
Email: elham@space4good.com

Space4Good is a social enterprise founded in 2017 working on geospatial innovation for social and environmental impact which provides linkages between remote sensing, geoinformation and artificial intelligence.

The Carter Centre project implemented by Space4Good explores the possibilities of how satellite data could help in verifying, assessing, and monitoring the consequences of military conflict with regards to explosive weapons contamination, as well as providing support for advancing the methodologies used in Al Bab District (Aleppo Governorate) and Harim Districts (Idlib Governorate). The team used optical change detection (pixel based, and object based) and radar multi-temporal change detection (using maps). The conclusions from the optical detections explored detected changes, however there were too many changes to find relevant ones. The land-use patterns follow impacts and the resolutions of images were of poor quality with no significant details. The optical detections also could not fully validate explosions with certainty. On the other hand, Radar Multi-temporal change detection bombarded locations for each year which were overlaid on change detection maps and checked for correlations. The results showed that Sentinel 1 imagery can detect a change in the area of interest, but the results only consider the changes occurring around the bombardment location and time. Another complicating factor was that the resolution of pixels in urban areas was saturated and information could not be retrieved completely.



The Sirte Ruin Detection project with HALO Trust used an optical time series approach which is noisy, but promising, radar amplitude differencing, high resolution panchromatic and machine learning approach. High-resolution is a huge advantage for discrimination but also a curse for time-series where as radar coherence approaches work on better resolution.

Guidelines for AI procedures – True color images for identification of landmines

Speaker: Alex Nikulin, Gabriel Steinberg, Tim de Smit and Jasper Baur, Binghamton University
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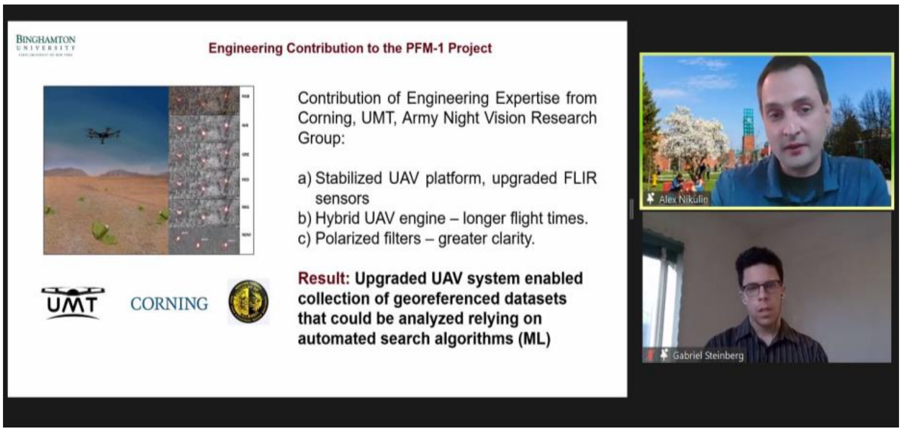
The Humanitarian Geophysics Research Group of Binghamton University focuses its research on several streams: an unexploded ordnance research stream; a scatterable landmine research stream; an environmental contamination research stream; an automated surveys and robotics research stream; and, a remote sensing research stream. Since the end of the WWII, development of landmines followed three complementary vectors - a reduction of explosive charge, reduction of metal content and randomized distribution. This has resulted in the conclusion that nonconductive scatterable landmines present a particularly challenging target for EMI-driven mine detection methodologies.



The research group conducted 2 phases of experiments, phase one for the proof of concept using stationary experiments to test methodologies for rapid detection of aerially deployed plastic land mines from UAVs proceeding, and phase 2 focusing on field trials. The protocol demonstrated strength is in the ability to rapidly detect PFM-1 mine presence, PFM-1 minefield orientation and PFM-1 field overlap. As a result, the experiment dramatically constrained the areas with highest associated risk of landmine contamination. In subsequent trials, significant increase of search area by using UAVs with 1) expanded flight times; 2) greater payload; and 3) automated anomaly detection, is anticipated.

Database of EO global events (Natural Language Processing)

Speaker: Leon Harris and David Hewitson, Fenix Insight Ltd
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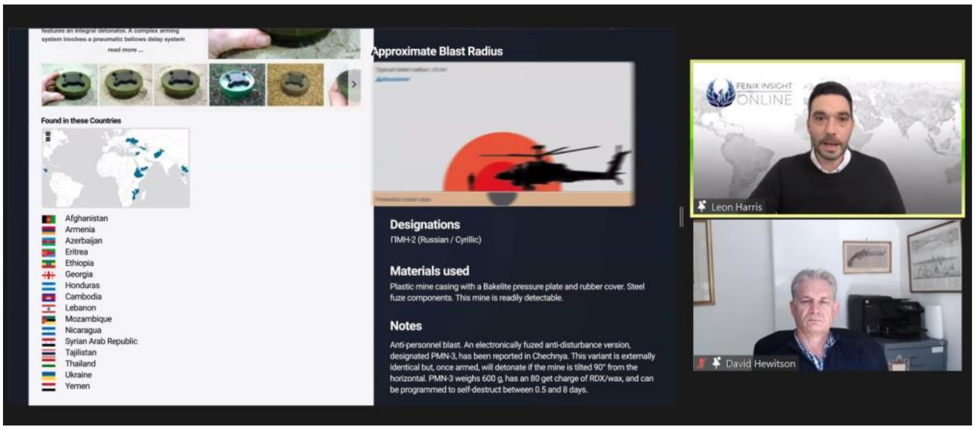
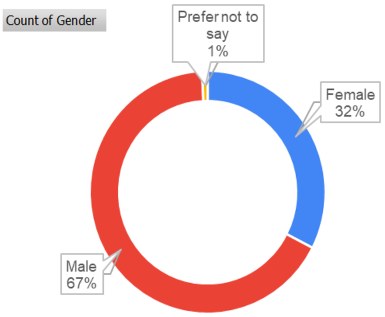
Fenix Insight has been looking at innovations in mine action through natural language processing and ML image recognition using data science, machine learning and AI. The methodology differentiates between relevant and irrelevant information and provides a text analysis using word search (for example, ERW/ Explosive reports mentioning children). It also combines the word searches and relevant photographic evidence, further dividing it by location and type. The ML/AI systems are trained to look for specific sets of information, as well as complete and accurate datasets.

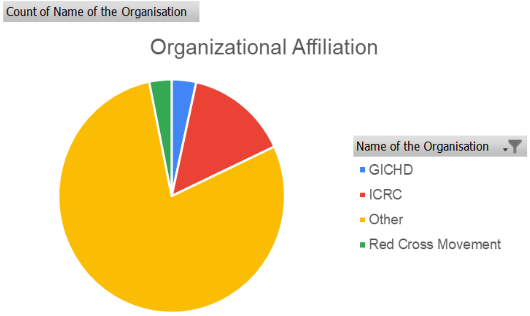
In the future, resources for gathering and training ML datasets should be based on real world data, especially in new or evolving conflict zones. Human experience should be used for analysis and expertise to train systems. In order to make big data problems manageable ML and NLP, along with CGI, should be used early on.



Conclusion and Way Forward

The webinar brought together many participants from diverse backgrounds, including but not limited to, the mine action sector, private companies, academia, and organizations from other sectors that use remote sensing and AI in their operational work. The webinar also recorded registrations from 43 countries.





The participants engaged in an insightful discussion with the presenters and speakers after each session. Many questions of technical and theoretical interest were shared, and all attendees benefited from the cross pollination of knowledge. Ultimately, the webinar discussed the challenges faced in using new technologies and their operationalization in weapon-contaminated environments. The event also highlighted the perception and legal issues that may arise in the use of such technology in sensitive areas and importance of collaboration with national authorities.

Next to watch out for

GICHD's Eighth Mine Action Technology Workshop

The Mine Action Technology Workshop gathers together mine action professionals, including national authorities, UN, international organisations, operators, manufacturers and other experts to discuss and share ideas and experiences that promote efficient use of innovation and technology in mine action.

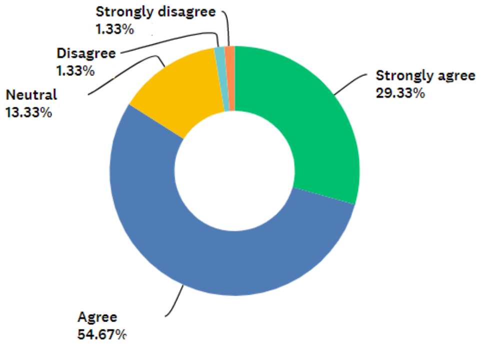
The Eighth Mine Action Technology Workshop will take place in Switzerland in the fourth quarter of 2021, provisionally during the first week of November.

Upcoming Discussion Forum

The webinar provided a medium to exchange views and collaboration among the mine action community and with other sectors, on the possible benefits and limitations of remote sensing and deep learning, and perspectives on the way forward. This engagement will be kept live through an upcoming platform for an on-going discussion forum for these issues. The platform is under development and will be launched soon, but it is hoped that it will further inspire stakeholders inside and outside the mine action sector to push forward with new areas of inquiry, as well as continue on-going research.

Participant's feedback

The GICHD and ICRC conducted a brief post-webinar survey to receive feedback from all participants. Overall, the feedback has been positive, and the webinar has been very well received, from its planning phase to the final event. The facilitation of the event was highly rated with an average of 4.5/5 score. Some of the sessions that received special mention included the case study on Skallingen, FindMine, use of airborne IR thermology, and Guidelines for AI procedures. All sessions were well received, however, with an average score of 4/5.



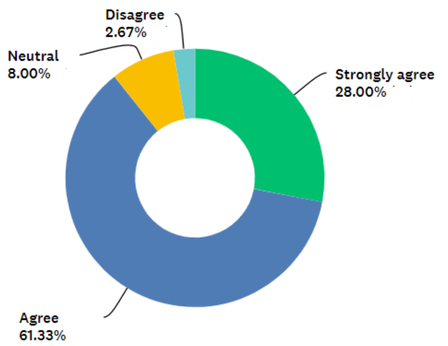
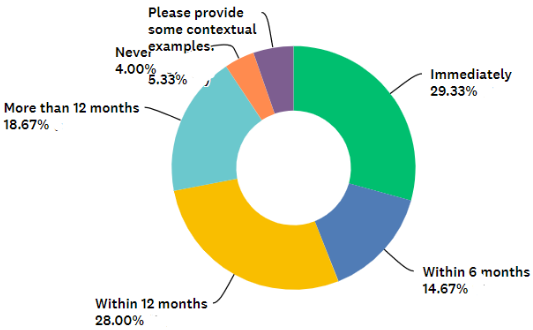


Fig 1: Did the webinar meet your expectations? *Fig 2: The content covered during the webinar was appropriate and relevant.*



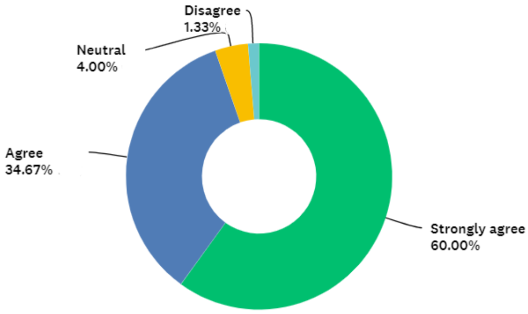


Fig 3: Will the content covered help in your work? *Fig 4: Will you be interest in more events of similar theme?*

29% of the participants responded that the content covered during the webinar will support them in their daily operational work immediately and over 28% felt it would help within 12 months. The successes of the webinar included appreciation for the technical set up, for the inclusion of a gap day between the live events, and the fact that it discussed relevant themes. The formation of a consortium for the creation of a data archive for multiple technologies (on and off ground) was identified as something that will help to develop more general and robust AI based methods. It was thought that this webinar served as a starting point only for the topics covered, and that many more areas can be identified for discussion. The fact that future events should expand the scope of subjects covered (for example, including SAR imagery or hyperspectral applications), was also highlighted.

Lastly, the participants encouraged the use of more case studies or examples of clearance operations to better understand the use of technology, future events and trainings, and forums to continue the discussions. Technical comments also included use of recording in the future events, as well as translations where possible.

Annex A

Important Links

[Speaker and Panelist presentations]

[ICRC Handbook on Data Protection in Humanitarian Action]

[Johns Hopkins University Researchers Advancing Safety of AI, Autonomous Machines in Society]

[Demining Research Community]

[Drones and "Butterflies": A Low-Cost UAV System for Rapid Detection and Identification of Unconventional Minefields], *The Journal of Conventional Weapons Destruction*

[Proof: How Small Drones Can Find Buried Landmines in the Desert Using Airborne IR Thermography], *The Journal of Conventional Weapons Destruction*

Annex B

Contributors

[International Committee of the Red Cross (ICRC)]

The ICRC is an independent, neutral organization ensuring humanitarian protection and assistance for victims of armed conflict and other situations of violence, often with its Red Cross and Red Crescent partners. It acts in response to emergencies, carrying out life-saving activities in conflict zones, including helping to reduce the danger of landmines and unexploded ordnance. The organization works closely with communities to understand and meet their needs, using its experience and expertise to respond quickly and effectively, without taking sides.

The organization also seeks to prevent hardship by promoting and strengthening humanitarian law and championing universal humanitarian principles. As the reference on international humanitarian law, it helps develop this body of law and works for its implementation.

[Geneva International Centre for Humanitarian Demining (GICHD)]

The GICHD is a neutral, independent, and well-trusted Centre of expertise and knowledge. The GICHD works towards reducing risk to communities caused by explosive ordnance, with a focus on landmines, cluster munitions and other unexploded ordnance and ammunition stockpiles.

It helps national authorities, international and regional organizations, NGOs, and commercial operators to develop and professionalize mine action and ammunition management. The GICHD supports around 40 affected states and territories every year.

Acknowledgments

The ICRC and GICHD would like to extend their sincere thanks to all esteemed speakers, presenters and participants for their time and contributions.