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Robotics and Remote Sensing for Humanitarian Mine Action & ERW Survey (RRS-HMA)

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Abstract

A number of initiatives have been undertaken using robotics and remote sensing in the humanitarian mine action (HMA) sector over recent years. A new consortium of specialists from space and robotics sectors in the United Kingdom (UK) has been formed to determine how to build upon previous knowledge, in taking robotics and remote sensing to the next level in HMA. Focussing on de-risking and applying novel technological solutions to surveying activities. This paper provides an overview of the consortium's proposed strategy and objectives for tackling the current challenges in HMA as well as a brief overview of relevant technologies. The paper shall also outline the objectives of an on-going GCRF funded project, whose outcomes shall lay the foundation for future technological developments and field demonstrations.

Introduction

The UK consortium led by STFC RAL Space, together with Cranfield University and Fardoulis Robotics is investigating how to gain the most impact in coming years from spinning in current state-of-the-art space and terrestrial robotics, unmanned aerial systems (UAS) and satellite technology.

Currently there are over 100 million active landmines around the world, with contamination from explosive hazards increasing due to new conflicts. Traditional methods of dealing with landmines involve manual techniques using prodders, metal detectors, heavy machinery, dogs and rats. However, these methods are dangerous, time-consuming, potentially error prone and labour intensive. Current state-of-the-art techniques can benefit from the integration of higher technology and automation.

Large projects such as Tiramisu [1], D-BOX [2], SADA [3], SAFEDEM [4] and others prior have investigated how to assist HMA processes using more advanced technology and systems. Our goal is to build upon previous learning, using past research as a starting point to help streamline workflows and allow time to spend on sensors, system integration, software & techniques. This can take place whilst simultaneously deploying equipment with a high technology readiness (TRL) during field trials. The key will be a balanced research and development (R&D) portfolio - ranging from immediate fieldwork using currently available UAS technology, through to more intensive R&D required to instrument ground rovers and make operation autonomous.

Sensing Scales

A holistic, toolkit approach is important, as contamination and environmental conditions vary significantly across the world. Three scales of sensing will be required, earth observation from satellites, for relatively low-resolution surface data on a wide-area, country scale. UAS sensing for high-resolution surface data on regional scale, which is explained in [3]. Plus, high-resolution surface and ground-penetrating data from rovers on a site-specific scale. The focus of this paper is on the potential from ground rover and UAS platforms, with plans

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in the use of satellite technology reserved for explanation in more detail at a later stage.

Overview – Ground Rover System

In this section, we present an overview of the Ground Rover System (GRS) and a review of relevant technologies, building upon the consortium's prior work and reviewing prior HMA activities. The GRS consists of a rover platform with on-board autonomy capabilities, which has a select sensing payload integrated for surveying activities. The GRS is monitored and can be tele operated by an on-site ground segment.

A. Rover Platform

Several mechanical demining and landmine surveying systems have been proposed and demonstrated in the past. A recent FP7 project [5] notes that many lessons have already been learned, however there are still outstanding requirements to be satisfied before small robotic platforms can be effective within HMA. [5] concludes that robotic hardware research should focus on advanced mechatronic designs and robot mobility while reiterating that such systems are best adopted in collaboration with other systems, supporting the proposed holistic approach.

The rover platform shall be based upon the existing All Terrain Rover designed and built by RAL Space (RAL-ATR) [6]. The RAL-ATR's development has been primarily driven by the requirements of Agricultural Technology research, which calls for a small, rugged yet low-cost instrumentation platform with advanced mobility capabilities. From such a direct crossover and synergy of applications and field deployment heritage. Further, competitive functional and performance characteristics enforce the suitability of the platform for adoption within HMA surveying. A brief overview of the RAL-ATR is provided in Table 1, where a direct comparison to similar platforms can be made in [5].

Table 1, RAL-ATR Platform Overview

Type	Four-wheeled, All Terrain, Independent Wheel Steering
Autonomy	Autonomous (with payload), Semi-Autonomous, Tele operated
Cost	~£10,000 (without autonomy payload)
Dimensions / Weight	0.5m x 0.5m x 0.25m / 20kg
Speed (m/s)	Max: 0.5
Operation Time	Max: 8hrs, Li-Ion Batteries, 24V, ~20Ah
Payload	Max: 20kg

B. Landmine Detection Techniques

Previous work studying landmine detection used different techniques, and a review is provided by [7]. Five techniques have been proposed: Metal Detector Technologies; Electromagnetic Methods; Acoustic/Seismic Methods; Mechanical Methods; and Biological Methods.

Both Ground Penetrating Radar (GPR) and hyperspectral technologies have shown promising results for landmine detection. GPR technology transmits a regular sequence of packets of electromagnetic energy into the material or ground, and detects signals reflected from the buried target. Then, the presence of the landmine can be detected by analysing reflected signals. Some notable existing works have used GPR for landmine detection [8] and shown good performance. However, it has some challenges such as: GPR measurement is sensitive and can be affected by complex interactions among mine metal content and soil moisture profiles [7]. Therefore, in our study we will overcome this limitation by considering different configurations, and fuse GPR data with other sensors to reduce the false alarm rate.

On the other hand, Infrared (IR) and hyperspectral imaging have been used for landmine detection, with methods in [7] [9] showing promise. They have the advantage of performing the detection remotely, and thus more safely than metal detectors. However, some factors (e.g. wind and rain) should be considered which might affect measurements.

C. Autonomy Capabilities for Landmine Surveying

Autonomous rovers are becoming a more popular and viable method for landmine surveying [10]. There are several advantages such as being; safe, fast, and provide a platform for integrating multiple sensors. However, developing a real time autonomous rover navigation system is a challenging task. Recently, the signal and autonomy group at Cranfield University has developed different techniques for real time autonomous navigation systems, including multispectral navigation for self-localisation [11] and trajectory analysis methods [12], with a review provided by [13].

Overview – UAS Platform

Small unmanned aerial systems (sUASs), are made up of an unmanned aerial vehicle (UAV or 'drone'), a payload, ground control system, live video feed and other peripherals. The level of field-readiness can be split into commercial off-the-shelf (COTS) equipment, or more novel bespoke, scientific systems. Using sensors operating in the visible light and IR spectrum can provide utility for a range of purposes, as outlined in Table 2. Identifying anomalies from buried contamination near vegetation via sUAS hyperspectral imaging is another option, requiring field trials to determine the feasibility of such a technique. Integrating novel sensors will require a longer timeframe and a greater investment in R&D. Hence, the emphasis in this paper is on firstly deploying COTS equipment, with potential for immediate impact.

A. Deployment Gap

sUASs can be better leveraged in the HMA sector. Hence, a case-study approach is part of our strategy, to capture and publish real-world data from field trials, using experienced sUAS operators to closely collaborate with national authorities and HMA actors across a range of operating environments. Such an initiative will help build confidence, explain techniques, and outputs can be used by national authority and INGO partners to help secure donor funding for sUAS capacity building programs.

B. sUAS Utility

The utility available from sUASs spans a range of operations from; Non-Technical Survey (NTS) to mapping, cartography, GIS, as an airborne asset during EOD operations, QA/QC, through to post clearance assessment, and donor reporting. Gathering decision making data is the key, rather than getting too caught up with technology. Hence starting with COTS, to help stimulate the category.

Goals & Future Work

The current phase of the project is focussed on a feasibility study and building collaborations with national authorities,

Figure 1- shows how a FLIR sUAS thermal camera can see AV and AP mines in long grass.

Approach/ Technique	Technology Readiness Level (TRL)	Examples of sUAS Uses – Deployable Today
Visual (RGB) & V-NIR sensors	High (COTS) Now	* Rural NTS * Urban NTS * Site progress reporting & QA/QC * Recce * Cartography, GIS & base maps * Pre-deployment planning * TS & clearance, demolitions (airborne asset) * ASA/PSSM - stockpile management * Route clearance * Risk assessment * Advanced sentry * HIED operations
Thermography	High (hardware) Medium (field trials)	* Evidence gathering * Spotting in long grass (light vegetation) * Near surface anomalies (needs field testing) * Secondary evidence capture (NTS) * ERW characterisation * Infrastructure inspection * Night ops * Locating animals/people * Security & HIEDC operations

Table 2- shows example uses of sUAS in HMA & ERW clearance, using COTS equipment available today.

INGOs and major stakeholders operating in contaminated environments. Collaboration will be essential, to build upon previous learning, gain input into system requirements and to develop methodology. Field trials will be required, which need to take place under the auspices of national authorities, in conjunction with operators. The priority is trying to assist contaminated low and middle-income countries (LMICs), initially staging a collaborator workshop in one of the SE Asian countries of Cambodia, Lao PDR or Vietnam. The consortium is also seeking collaborations with representatives from other LMICs requiring assistance.

Subject to the outcome of the feasibility study, the next phase will be to apply for funding to secure a longer-term R&D, and field demonstration program. COTS sUAS systems could be deployed for immediate field trials, taking place in parallel whilst more intensive R&D takes place for novel rover and sUAS system integration, sensor, and software development. The long-term goal of the UK consortium is to develop and deploy novel, flexible tools to gain better situational data, increase productivity, improve safety and reduce costs for the land release process in post-conflict arenas.

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References

[1] "FP7-Tiramisu," [Online]. Available: http://www.fp7-tiramisu.eu/.

[2] "Demining tool-BOX for humanitarian clearing of large scale areas from anti-personnel landmines and cluster munitions.," [Online]. Available: https://d-boxproject.eu/.

[3] M. Kruijff, D. Eriksson, T. Bouvet, A. Griffiths, M. Craig, H. Sahli, F. V. Gonzalez-Roson, P. Willekens and A. Ginati, "Space assets for demining assistance," *Acta Astronautica,* vol. 83, pp. 239-259, 2013.

[4] "SAFEDEM - Space Assets For Enhanced DEMining | ESA Business Applications," [Online]. Available: https://business.esa.int/projects/safedem.

[5] D. Portugal and L. Marques, "Deploying Field Robots for Humanitarian Demining: Challenges, Requirements and Research Tends," in *17th International Conference on Climbing and Walking Robots*, 2014.

[6] M. Post, B. Alessandro and T. Xiu, "Autonomous navigation with ROS for a mobile robot in agricultural fields," in *14th International Conference on Informatics in Control, Automation and Robotics (ICINCO)*, 2017.

[7] I. Makki, C. Younes, C. Francis, T. Bianchi and M. Zucchetti, "A survey of landmine detection using hyperspectral imaging," *ISPRS Journal of Photogrammetry and Remote Sensing,* vol. 124, pp. 40-53, 2017.

[8] S. Lameri, F. Lombardi, P. Bestagini, M. Lauldi and S. Tubaro, "Landmine detection from GPR data using convolutional neural networks," in *25th IEEE Signal Processing Conference (EUSIPCO)*, 2017.

[9] S. Kaya and U. Leloglu, "Buried and Surface Mine Detection from Thermal Image Time Series," *IEEE Journal on Selected Topics in Applied Earth Observations and Remote Sensing,* vol. 10, pp. 4454-4552, 2017.

[10] P. Dasgupta, J. Baca, K. Guruprasad, A. Munoz-Mel'endez and J. Jumadinova, "Thercomrade system for multirobot autonomous landmine detection in post-conflict regions," *Journal of Robotics,* vol. 2015, no. 19, 2015.

[11] A. Beauvisage and N. Aouf, "Multimodal visual-inertial odometry for navigation in cold and low contrast environment," in *IEEE European Conference on Mobile Robots (ECMR)*, 2017.

[12] A. AlZoubi, B. Al-Diri, T. Pike, T. Kleinhappel and P. Dickerson, "Pair-activity analysis from video using qualitative trajectory calculus," in *IEEE Transactions on Circuits and Systems for Video Technology*, 2017.

[13] C. Wong, E. Yang, X.-T. Yan and D. Gu, "Adaptive and intelligent navigation of autonomous planetary rovers - a survey," in *NASA/ESA Conference on Adaptive Hardware and Systems (AHS)*, 2017.