Integrated Mobile Robot System for Landmine Detection

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ABSTRACT: In this paper, we discuss the integration process of a mobile robot and multi-channel metal detector system intended for humanitarian demining applications within the EU FP7 TIRAMISU project. The paper describes how a standard tele-operated Explosive Ordnance Disposal (EOD) robot was upgraded with electronics, sensors, computing power, motor control units and power sources, such that it becomes able to execute humanitarian demining tasks. To be able to detect land mines we have integrated with the mobile robot platform a multi-channel metal detector system which is a specialized sensor system for demining platforms developed by Vallon GmbH. In order to evaluate the proposed system integration we have performed first test and validation activities done at the SEDEE-DOVO test field (dummy minefield and UXO test site) of the Belgium Defense. Our first data acquisition results obtained during test and validation activities with the systems are reported. Lessons learned during the work conclude this paper.

KEYWORDS: Mobile robot, Multi-Channel Metal Detector, Landmine Detector.

1. INTRODUCTION

The idea of using robotics for humanitarian demining and/or advanced light-weight modular low-cost robots for technical survey and/or close-in-detection has been proposed by numerous authors [1]. Even though none of the current robotics platforms seem to have reached production on a larger scale (except for military EOD/IEDD tasks), many lessons may be learned from several projects and experiences. Robotics solutions properly sized with suitable modularized structure and well adapted to local conditions of dangerous unstructured areas can greatly improve the safety of personnel as well as the work efficiency, productivity and flexibility. In this sense, mobile systems equipped with manipulators for detecting and locating antipersonnel landmines are considered of most importance towards autonomous/semi-autonomous mine location in a proficient, reliable, safer and effective way [2].

In this paper we describe the work effort done within the EU FP7 TIRAMISU project[1]. The TIRAMISU (which stands for Toolbox Implementation for Removal of Antipersonnel Mines, Submunitions and UXO) project aims to provide the foundation for a global toolbox that will cover the main mine action activities, from the survey of large areas to the actual disposal of explosive hazards, including mine risk education and training tools.

The results presented in this paper are developed within the WP 310 Tools for Close-in-detection for the Sub-WP314 Multi-Channel Metal Detector (MCMD). The goal of VALLON GmbH was to develop a Multi-Channel Metal Detector for integration with the mobile robotic platform tEODor, which was upgraded by RMA. In order to evaluate

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[1] More information about TIRAMISU (www.fp7-tiramisu.eu).

the proposed system integration we have performed first test and validation activities at the SEDEE-DOVO test field (dummy minefield and UXO test site) of the Belgium Defense. Our first data acquisition results obtained during test and validation activities with the systems are presented in the paper. The same platform may be used for in-field quality tests.

2. SYSTEM SETUP

2.1 tEODor MOBILE ROBOTIC PLATFORM

The mobile robotic platform used for the integration with the MCMD is shown in Figure 1. The base vehicle of this unmanned platform consists of an Explosive Ordnance Disposal (EOD) robot tEODor, a heavy outdoor robot. We chose to use a standard EOD robot platform for several reasons:

- As a platform, it has proven its usefulness in dealing with rough terrain with excellent maneuverability and good off-road performance.
- With a gross load weight of around 350 kg, it makes it possible to carry multiple sensors and on-board processing equipment.
- The rugged design of the platform makes it capable of handling unfriendly environmental conditions.
- Recycling a standardized platform is a good means of saving costs and avoiding buying expensive dedicated platforms.

Figure 1 tEODor mobile robotic platform with the MCMD

An important drawback of the standard tEODor platform is that it does not feature any autonomous capabilities. To overcome such a constraint the tEODor platform was upgraded by RMA with necessary electronics, sensors, computing power, motor control units and power sources in order to be able to execute remote controlled and semi-autonomous tasks. More information can be found in [3, 4].

During our past field demonstration tests we have discovered that the tEODor platform has proven its usefulness in dealing with rough terrain, with excellent maneuverability and good off-road performance. In addition, the rugged design of the platform makes it capable of handling unfriendly environmental conditions which is crucial for demining tasks. Some of the characteristics of the RMA tEODor platform are given in the table 1.

Table 1 Characteristic of the RMA tEODor mobile robot platform

Length:	1300 mm ≥1350 mm (system in packing position)
Width:	700 mm
Height:	(depends if we have the sensors or not attached to the robot) without sensors it is around 1000 mm
Weight:	350kg (standard configuration including batteries without sensors) the MCMD is around 27 kg
Speed of the platform*:	max. 3.0 km/h
Turning circle:*	1460 mm (theoretical)
Climbing ability (slopes):*	45 °
Climbing ability (obstacles):	250 mm
Wading depth:	≤ 250 mm
Payload:	≤ 200 kg
Power supply:	Lead-gel rechargeable battery; 4 x 12V, 85 Ah
Battery charger:	Standard AC connector input (AC 230 V/50 Hz)
Endurance (Nominal life)*:	approx. 2-3 h mixed operation
Temperature range :	-20 °C to +60 °C
Remote control operational range*:	around 50 m

* Depending on surface and environment conditions

2.2 MULTI-CHANNEL METAL DETECTOR SYSTEM

The MCMD system from VALLON, shown in Figure 2, is a specialized sensor system for demining platforms. It provides five 30 cm coils (overlapping perpendicular to the direction of movement to reduce sensitivity variation over the width) with a differential setup (which has lower sensitivity than absolute coils but is far less responsive to external EMI disturbance. The coils are arranged in a plane to allow for minimum standoff height of the coil plate and for best sensitivity.

The MCMD consists of 5 independent metal detectors; their data stream is gathered by an embedded platform based on an OMAP3 board with embedded Linux and is made available as streaming data via Ethernet. OMAP3 stands for is an *Open Multimedia Application Platform it is an image/video processors developed by Texas Instruments.*
For wireless connectivity a WLAN - Access point was used as an Ethernet to WLAN Bridge for the Metal detector (TPLINK consumer type).

Figure 2 Five Channel Metal Detector from Vallon GmbH

2.3 MOUNTING MECHANISM

Figure 3. shows the mounting mechanism of the coil plate. On the back and front side of the coil plate spoilers are mounted that enable the plate to slide over obstacles.
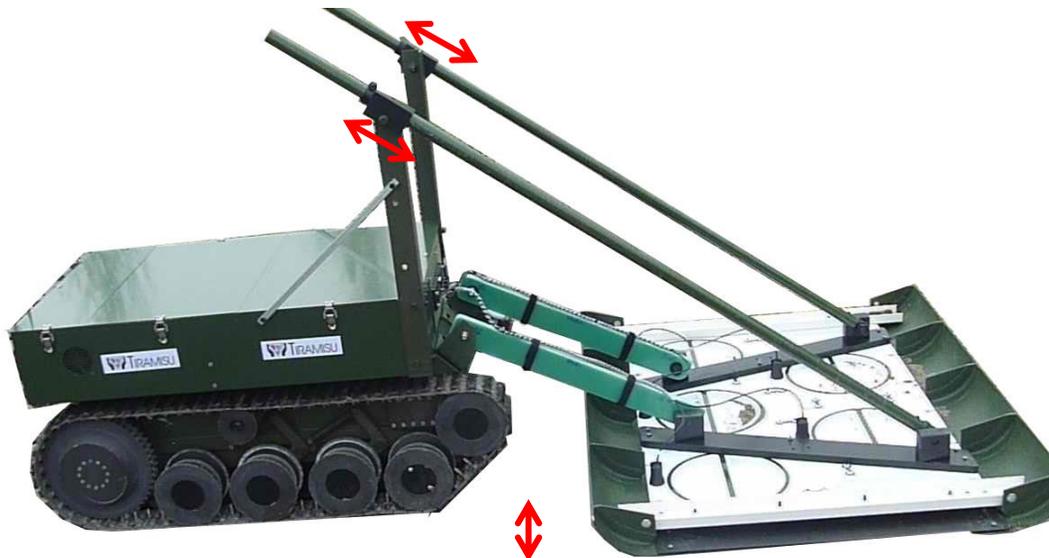
Figure 3 Mounting mechanism with the MCMD and the tEODor platform

3. ADDRESSED ISSUES DURING INTEGRATION

During the integration work we have discovered several issues:

- Electromagnetic interference from the motor drivers of the tEODor coupling into the coils (radiated): We measured the rms noise with the motors either off or on (a handheld detector was lying in 50 cm distance on the ground in front of the vehicle:
  - Differential 30 cm coil: 53 LSBrms w/o motor, 58 LSBrms with motor.
  - Absolute 30 cm coil: 62 LSBrms w/o motor, 66 LSBrms with motor.

This proved the tEODor mobile robot as an ideal platform for integrating the Multi-Channel Metal Detector System as it did not significantly decrease the signal to noise ratio of the sensor.

- Electromagnetic interference from the power supply into the detector electronics (conducted): Noise of the MCMD was app. 280 LSB when beingwas app. 280 LSB when being supplied directly from the tEODor mobile robot. An additional filter in the power supply line could improve the noise to the values shown above.

4. TEST AND VALIDATION ACTIVITIES

In order to evaluate the proposed system integration we have performed first test and validation activities done at the SEDEE-DOVO test field (dummy minefield and UXO test site) of the Belgium Defense (located in the city of Meerdaal, Belgium). A conceptual view of the Dummy Minefield and UXO Test Site can be seen in Figure 4. The test site is delineated by three zones with a total size around 15 x 7.5 m.
The configuration of the zones is given below:

- Zone 1: Anti-personnel mines & grenades (depths from 1 to 3 cm)

- Zone 2: Anti-tank mines (depths from 10 to 20 cm) & UXO (depths from 10 to 30 cm)

- Zone 3: UXO's (depths from 10 to 30 cm)
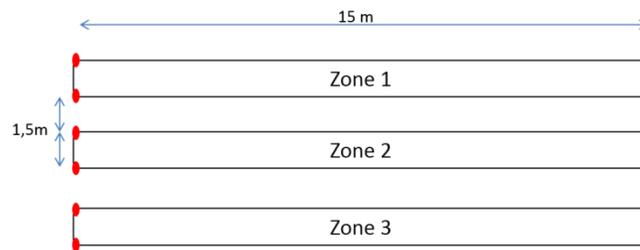
Figure 4 Conceptual view of the Dummy Minefield and UXO Test Site

Examples of field demonstrations are shown in Figure 4.

Figure 4 Presents some instants of the Dummy Minefield and UXO Test Site activities.

5. RESULTS OF THE TEST AND VALIDATION ACTIVITIES

The test zones 1-3 were scanned with the sensor, however a geo-referencing system based on GPS navigation device (e.g. TCP box) was not available at the time of the test so the sensor data could only be referenced by time. This leads to a time shift of objects between the scans. First R&D measurement data were gathered with the Vallon client software, which under development for TIRAMISU. Then data were evaluated in an experimental manner by Scilab 5.4.1.

The Figure 5 shows the color maps of all three zones, as the exact location of the objects is not yet known the probability of detection cannot be calculated yet but will be once the positioning data is available.
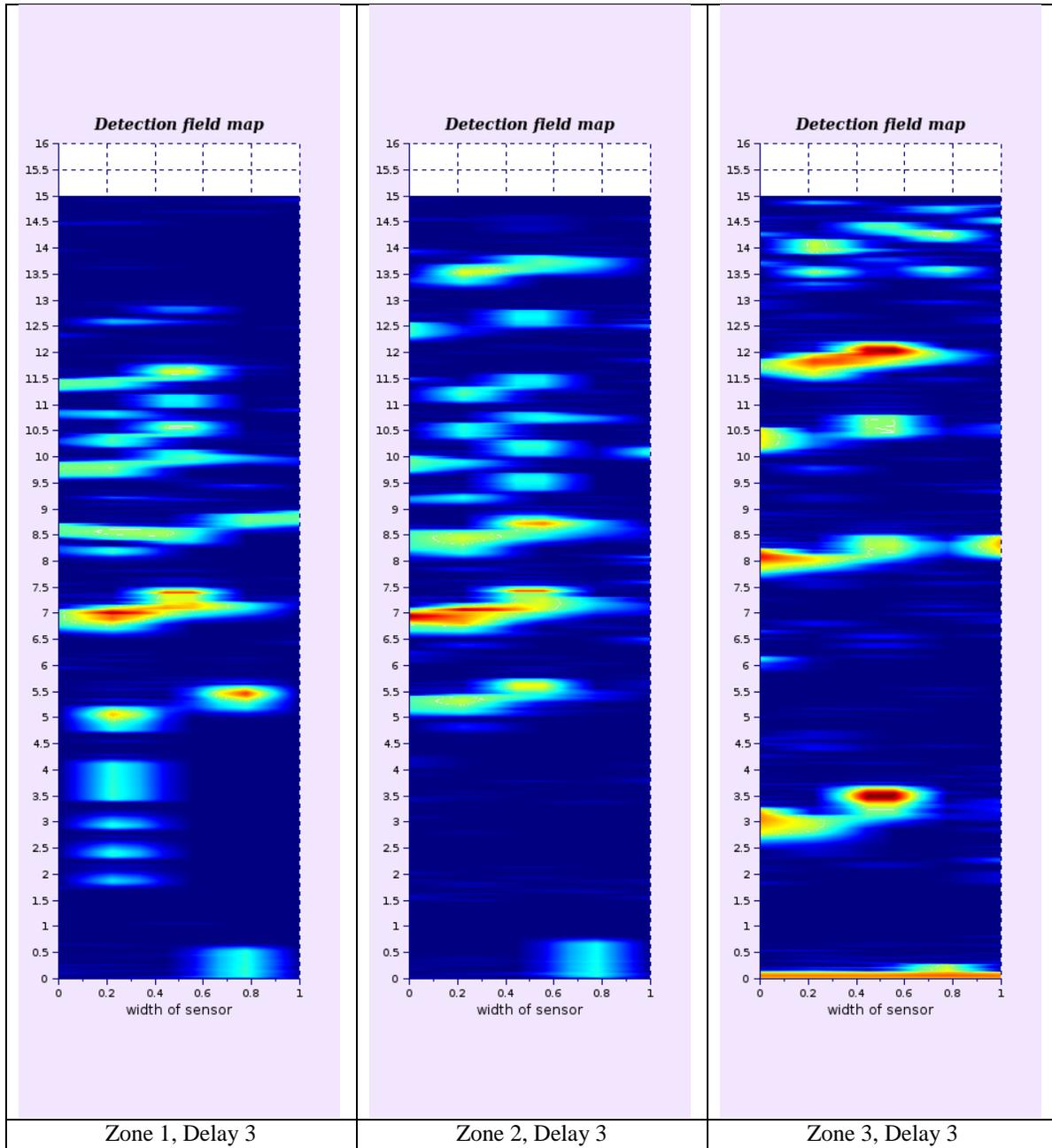

Figure 5 Color plot of all three zones

6. CONCLUSION

In this paper, we have presented an Integrated Mobile Robot System for Landmine Detection. We show how an upgraded tele-operated Explosive Ordnance Disposal (EOD) mobile robot was integrated with a multi-channel metal detector system which is a specialized sensor system for demining platforms developed by Vallon GmbH. In order to evaluate the proposed system integration we have performed first test and validation activities done at the SEDEE-DOVO test field (dummy minefield and UXO test site) of the Belgium Defense. Our first data acquisition results obtained during test and validation activities with the systems are reported.

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