Unmanned Ground and Aerial Robots Supporting Mine Action Activities

P Yvan Baudoin, Daniela Doroftei, Geert de Cubber, Jean-Claude Habumuremyi, Haris Balta and Ioan Doroftei.
Royal Military Academy (RMA), Brussels, Belgium

Abstract
During the Humanitarian-demining actions, teleoperation of sensors or multi-sensor heads can enhance-detection process by allowing more precise scanning, which is useful for the optimization of the signal processing algorithms. This chapter summarizes the technologies and experiences developed during 16 years through national and/or European-funded projects, illustrated by some contributions of our own laboratory, located at the Royal Military Academy of Brussels, focusing on the detection of unexploded devices and the implementation of mobile robotics systems on minefields.

1. Introduction
Mobile robotics systems are beginning in applications related to security and the environmental surveillance: prevention of disasters and intervention during disasters with all possible kinds of missions ensuring the security. The paper focuses on the development of Robotics systems for Humanitarian demining, at the Royal Military Academy (RMA)

2. Robotics systems developed at RMA
2.1. 1997–2002
Under the HUDEM’97, project funded by the Belgian Ministry of Defence, with the close cooperation of our partners of the European Network CLAWAR [1], we focused on the design and development of small low-cost legged robots [2]. Wheels have the advantages of engineering simplicity, low friction on a smooth surface and they enable the robot to move at a high speed. Laying down a track for wheels to run on is a way of extending the use of wheels to soft and rough ground. But wheels and tracks have a main weakness. They have poor performance in an unstructured environment when faced with a vertical step or a discontinuous surface. More than half of Earth’s land area precludes wheeled and tracked vehicles. In many of these natural terrains, legs are well suited.

2.2. 2002–2006
From the previous experience and the cost-effectiveness requirements, it quickly appeared that a basic constraint on the design of a robot was the modularity and the conviviality of the human-machine interface (HMI) in order to ease the interpretation of the operator. Our next design focused on a three-wheeled lightweight teleoperated platform (TRIDEM) that
was refined under the project FP7-TIRAMISU [3,4].

2.3. 2006–2010
Although multi-legged or similar multi-wheeled robots offer promising solutions and despite the current maturity of such platforms, the preference was given to the conversion of existing commercial platforms. Exchange of information was then pursued through the organization of annual IARP workshops, some of them located in countries confronted with mined areas; at the RMA, we then focused on the adaptation of two commercial platforms: the ROBOSOFT, renamed ROBUDEM, laterally equipped with a three-dimensional (3D) scanning carrier of a VALLON metal detector and progressively adapted for an autonomous behavior-based navigation control [5], finally tested in the context of the FP6 project VIEW-FINDER focusing on the Robotics assistance of security services. An optimal combination of sensors (location of the robot, detection of explosives and vision sensory package) was analyzed and tested under the project FP7-TIRAMISU. A partial combination has been developed at the RMA, focused on the use of a limited number of sensors: a behavior-based architecture for mine detection (project RSTD MB07 [6]) and a behavior-based navigation for search and inspection interventions (project VIEW-Finder [7]).

2.4. 2011–2015
Under the FP7-TIRAMISU project [20], another commercial mobile robotic platform (the tEOEor) was used for the integration with a metal detector array developed by VALLON (the MCMD) (see Figure 1). An important drawback of the standard EOD tEOEor platform is that it did not feature any autonomous capabilities. To overcome such a constraint, the platform was upgraded by RMA.

![tEOEor equipped with metal detector array from VALLON](image)

Furthermore, a similar platform was adapted under the FP7-ICARUS project (2012–2016—Robotics Assistance for Search and Rescue Operations), including vision capabilities enabling an assessment of terrain traversability and thereby allowing a semi-autonomous navigation facing the traversability issues.

3. Remotely piloted aircraft system (RPAS) deployment for mine action
The deployment of the remotely piloted aircraft system (RPAS) was extensively used within the TIRAMISU project [8] for the support of different scenarios. Over the 3 years (2012–2015), the RPAS was deployed in test areas as well as in real
missions. The next sections shortly introduce some of the missions done with the RPAS.

### 3.1. RPAS Survey of honeybees

Survey of honeybees with an RPAS was a cooperation we did in 2014 together with the Croatian partners CTRO and the University of Zagreb within the TIRAMISU project. We used the RPAS in order to make the survey of honeybees by monitoring their activities and to analyse their ability to detect buried mines (see Figure 2)

### 3.2. RPAS use for suspected hazardous areas

In 2015, we prepared a campaign for operational validation of RPAS. This work was conducted together with CTRO and ULB, Belgium, and partially with the support of the University of Zagreb. We used the RPAS in order to perform oblique flights and near infrared (NIR)-mapping flights of the suspected hazardous area (SHA)

![Figure 2. RPAS in TIRAMISU project](image)

### 4. Conclusions

The development of a Robotics System for demining operations has to take several constraints into account: a high level of protection against the environmental conditions (dust, humidity, temperature, etc.), protection and resistance against vibration, mechanical shocks and instability factors, a sufficient autonomy and reliable communications between the mobile platform and the operator.

### Acknowledgements

These activities were partially funded by the Belgian Ministry of Defence (HUDEM’97, 1997–2002) (BEMAT and MB07, 2003–2008), by the European Commission (CLAWAR 1998–2002) (FP6 VIEW-FINDER Project Contract 045541 2007–2010), (FP7 TIRAMISU Contract 284747 2012-2015), and (FP7 ICARUS Contract 285417 2012-2016).

### References

[1] CLAWAR. www.clawar.org (accessed on 2016-06-22). Clawar Task 9 report, 1999.
[2] Baudoin Y., Doroftei I. Hierarchical control of a Hexapod walking robot. International Journal of Robotica & Management 14-1, 2009, ISSN 1453-2069.
[3] Doroftei I., Baudoin Y. Using mobile robots for a clean and safe environment-a difficult challenge, in Proceedings of 2012 International Conference and Exposition on Electrical and Power Engineering (EPE), Iasi, Romania, 2012, pp. 41-46.
[4] Doroftei D., Baudoin Y. Development of a semi-autonomous demining vehicle. Proceedings of the 7th IARP WS HUDEM’2008, The American University in Cairo (AUC), Cairo, Egypt, 28-30 March 2008.
[5] De Cubber G., Berrabah, S.A., Doroftei D., Baudoin Y., Sahli H. Combining dense structure from motion and visual SLAM in a behavior-based robot control architecture. International Journal of Advanced Robotics Systems, vol. 7, issue 1, 2010.
[6] Doroftei D. Behavior based navigation techniques. Internal report MoD Study MB07, October 2006 (http://mecatron.rma.ac.be/Research/Behavior-based_Robot_Control.html).

[7] De Cubber G., Dorofeti D., Marton G. Development of a visually guided mobile robot for environmental observation as an aid for outdoor crisis management operations, Proceedings of the IARP Workshop on Environmental Maintenance & Protection, July 22-23, 2008, Baden-Baden, Germany.

[8] www.fp7-tiramisu.eu