EVALUATION OF A SENSORY TRACKING SYSTEM FOR HAND-HELD DETECTORS IN OUTDOOR CONDITIONS

Roemi Fernández[*], **Héctor Montes**[*, †], **Javier Sarria**[*], **Carlota Salinas**[*], **Manuel Armada**[*]

Abstract

This paper presents the experimental results obtained throughout the outdoor testing of a sensory tracking system specifically designed as part of a training tool for improving the utilisation of hand-held detectors. The proposed system is able to acquire information in two different scenarios: when the expert's skills are studied in order to quantify some critical performance variables and when the deminers' performance is evaluated during the close-in-detection training tasks, in order to give the operator significant feedback for improving their competences. Additionally to previously studied variables such as the safety distance to advance the detector search-head on each sweep, the sweep velocity, the scan height, the inclination of the hand-held detector head with respect to the ground and the coverage area, a special emphasis related to the geo-referencing of the hand-held detector head in real-time is provided.

Introduction

Training is one of the most crucial aspects in order to improve the safety and effectiveness of the mine detection activities performed by the human operators. Training is not only required for novice operators but also when new detection technologies are introduced. For instance, the proper use of dual sensors requires more training and practice compared to metal detectors [1]. Retraining is also essential for maintaining a high level of efficiency. Deminers who do not conduct humanitarian demining operations uninterruptedly during the period of two years are obliged to attend additional training courses [2]. Some studies also indicate that the poor retention of operator skills is a common problem that endangers the success of the countermine operations and jeopardizes the personnel involved. A decline in the proportion of mine simulants detected was observed with as little as 30 days without practice. Solving this problem involves improving training to prevent or minimize such decrements from occurring, and developing intervention to restore performance to requisite levels as efficiently and as economically as possible through refresher training [3].

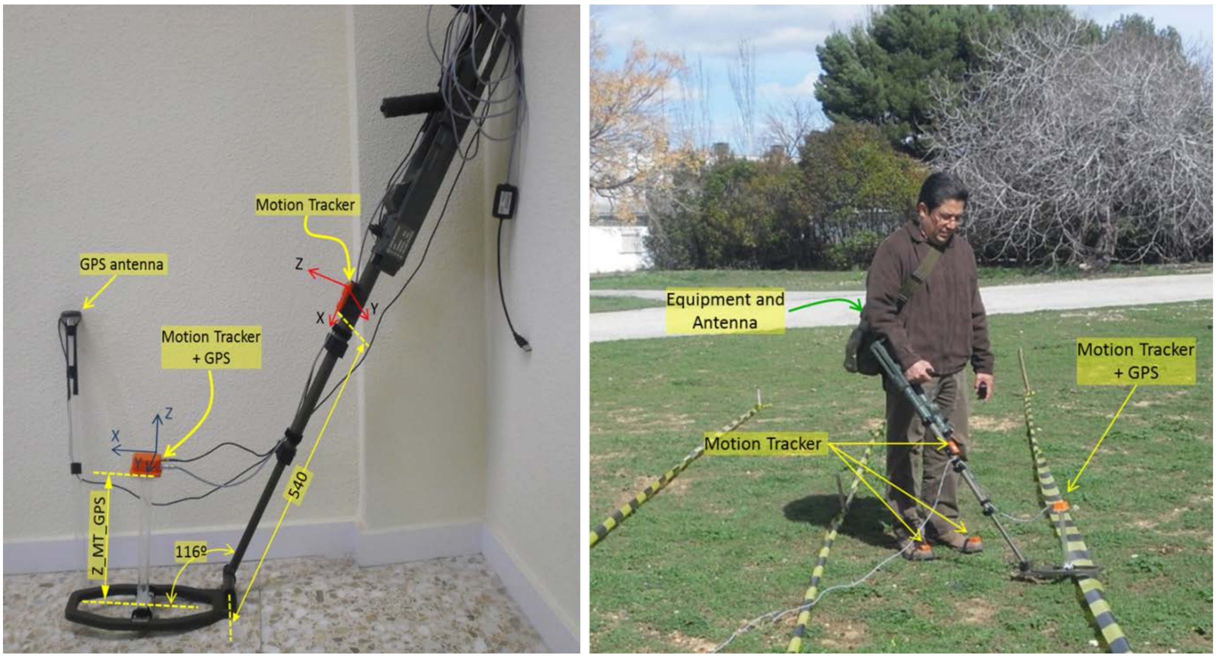
This paper presents a training tool intended for analysing operators' performance with the final goal of improving the use of hand-held detectors in humanitarian demining. The tool consists of a Human Machine Interface (HMI), and a hand-held detector sensory tracking system [4, 5]. The training tool can be easily adapted to be used with different kinds of hand-held detectors. The purpose of the proposed tool is twofold: (i) the study of the expert's skills by quantifying some critical performance variables, so that they can be used later on as reference values for the training tasks; and (ii) the efficiency evaluation of novice operators during the training period with hand-held detectors in order to give them feedback about important information for improving their competencies. Therefore, the proposed tool will enable the development and implementation of instructions based on the scientific analysis of the problem and the formative and summative assessment of trainees. The emphasis in this article will be put on the outdoor testing of the elements that composes the hand-held detector sensory tracking system.

Sensory tracking system

The metal detector that has been selected as hand-held detector for the experiments in this study is the VMC1 manufactured by Vallon. However, the training tool could be adapted to be utilised with other kinds of hand-held detector. The chosen device (VMC1) is able to detect mines with a very small metal content below the surface of the ground and in fresh or salt water. Its rugged search head contains the Digital Pulse Induction Sensor with integrated noise reduction features. Its shape allows easy operation in difficult and dense vegetation, rocks,

[*] Centre for Automation and Robotics CSIC-UPM. Ctra. Campo Real Km 0,200 La Poveda, Arganda del Rey, 28500 Madrid, Spain. E-mails: {roemi.fernandez, hector.montes, javier.sarrria, carlota.salinas, manuel.armada}@car.upm-csic.es
[†] Faculty of Electrical Engineering, Technological University of Panama, Panama City, Panama.

shallow water and mud. This unique design provides precise pinpointing and an excellent separation between narrow placed targets without loss of detection speed. The telescopic pole consists of three tubes. The length is easily adjustable even during operation in just a few seconds so that detection work can be done in standing, kneeling or proning position [6]. For the experiments, two motion trackers (Inertial Measurement Units) are installed in the hand-held detector (see Fig. 1). One of these units is mounted in a light plastic pole located above the centre of the search head. This light plastic pole is utilised to eliminate any chance of interference of the motion tracker on the metal detector. The second motion tracker is mounted in the wand, at 540 mm from the joint that links the search head with the pole. Both motion trackers provide with a highly dynamic response, drift-free and accurate 3D orientation (pitch, roll, and yaw), as well as kinematic data: 3D acceleration and 3D rate of turn (rate gyro). They are configured to output data from each triad of accelerometers and gyroscopes at 100 Hz. In addition, the motion tracker that is located over the search head provides GPS measurements. An active antenna is connected to this motion tracker in order to receive the satellite signals (see Fig. 1). The reduced size and weight of this antenna permits its location on the operator's backpack.



(a) (b)

Fig. 1. (a) Hand-held detector instrumentation. (b) Operator with hand-held detector training tool during outdoor experiments at the Centre for Automation and Robotics – CAR (CSIC-UPM).

The sensory tracking system described above will be utilized for acquiring information in two different situations: when the expert's skills are studied in order to quantify some critical performance variables and when the efficiency of the deminers is to be evaluated during the training sessions.

Previous analysis of the expert's hand-held detection activities shows that their techniques and strategies differ from conventionally taught operating procedures. Whereas novice operators perform detection on the basis of auditory outputs pointing out the existence of conductive materials, experts use the onset and offset of outputs that occurred during sweeping motions of the hand-held detector to create spatial patterns that they compare to learned models [7]. Experts also modify their detection techniques to adapt to environmental variations (deserts, hilly rocky terrain, lands with a wide variety of vegetation). For this reason, the projected methodology proposes the utilization of the sensory tracking system to study the experts' skills in different environments and with different kinds of hand-held detectors. With the compiled information, some critical performance variables will be extracted, assessed, and quantified off-line, so that they can be used later on as reference values for the training sessions. The critical variables chosen preliminarily that will be analysed are the safety distance to advance the detector search-head on each sweep, the sweep velocity, the scan height, and the inclination of the hand-held detector head with respect to the ground. Principal Component Analysis (PCA) could also be used to explore the behavioural data. PCA is a well-established, standard approach for reducing the dimensionality of a large dataset, in order to identify any structure in the relationships between the variables that might otherwise be hidden. Therefore, PCA could highlight those underlying components that explain the most variance in the datasets as a whole. Cognitive engineering has proved to be a proper approach for solving applied problems in which human performance depends upon the quality of participants' thinking and skills. Cognitive models of expert skills have been successfully adopted for training in quite different domains such as medicine (surgery and dentistry) [8], aviation [9] and landmine detection [10, 11]. Therefore, cognitive engineering will be used for translating the information acquired from the expert performance into modelling targets for unified, integrative theories of intelligence. In this way, instruction will be based on scientific knowledge rather than on personal introspection and intuitions of the training designers.

For the analysis and assessment of the trainee skills, the same set of critical variables proposed to parameterise the experts' performance will be acquired and compared in real time with the reference training goals. In this way, the training tool will be able to evaluate the deminers' efficiency during the scanning tasks on-line and give them feedback about essential information for improving their competences. However, this evaluation can also be carried out off-line, recording the whole performance of the deminer, analysing it and finally, producing a report indicating the success of the learning process and identifying the points that should be enhanced. If the experts' skills have been studied previously, the reference training goals required for the assessment will be obtained from the results of the experts' performance. In case experts are not available for these experiences, trainee operators will be evaluated according to the reference values established in the standard procedures.

Standard procedures define some minimal requirements for the sweeping technique that should be followed in order to ensure the safety of the deminers. For the VMC1 metal detector these requirements are:

- Each sweep across the lane must overlap the previous sweep by about one-half the width of the detector head to ensure full coverage of the area being searched. Otherwise, a gap is left between sweep paths and mines can be missed. This is especially true for low-metal mines, which emit a very small electric field, often less than the width of the detector head.
- Operators' manual recommends a sweep rate of 0.2-1 m/s. However, in pinpointing mode, the detector head should be swept no faster than about 0.2 m/s.
- Height head above the ground is the most important factor. The search of the metal detector should be moved not more that 5 cm about the ground. The closer the detector head is to the ground, the deeper the electrical field is projected and the greater is the possibility to detect the mines.
- When sweeping, the search head of the detector must remain horizontal to the ground at all times. If the detection task is being carried out on an irregular surface, the search head should be kept parallel to and at a constant height from the ground, following the variations in the surface.
- To prevent interferences, the distance between different search heads should not be less than 2 meters.

Experimental results

The main goal of the experimental phase was to evaluate the effectiveness of the sensory system to track the hand-held detector during the training sessions as well as assessing the feasibility of the GPS measurements for geo-referencing the hand-held detector in real-time.

To simulate a real demining field scenario, a training lane was prepared. This lane is free from metal contamination and it is 1 m width and has a length of 10 m (see Fig. 1(b)). The sweep coverage area, obtained from the data acquired with the motion trackers located in the hand-held detector, is displayed in Fig. 2. To ensure the safety of the operator during the detection task, each sweep across the lane must overlap the previous one by about one-half the width of the detector head. This requirement is difficult to be achieved by novice operators that should keep in mind a spatial image of the last sweep motion carried out. The feedback provided by the training tool could be especially useful in this case, helping the novice operator to create the required mental patterns.

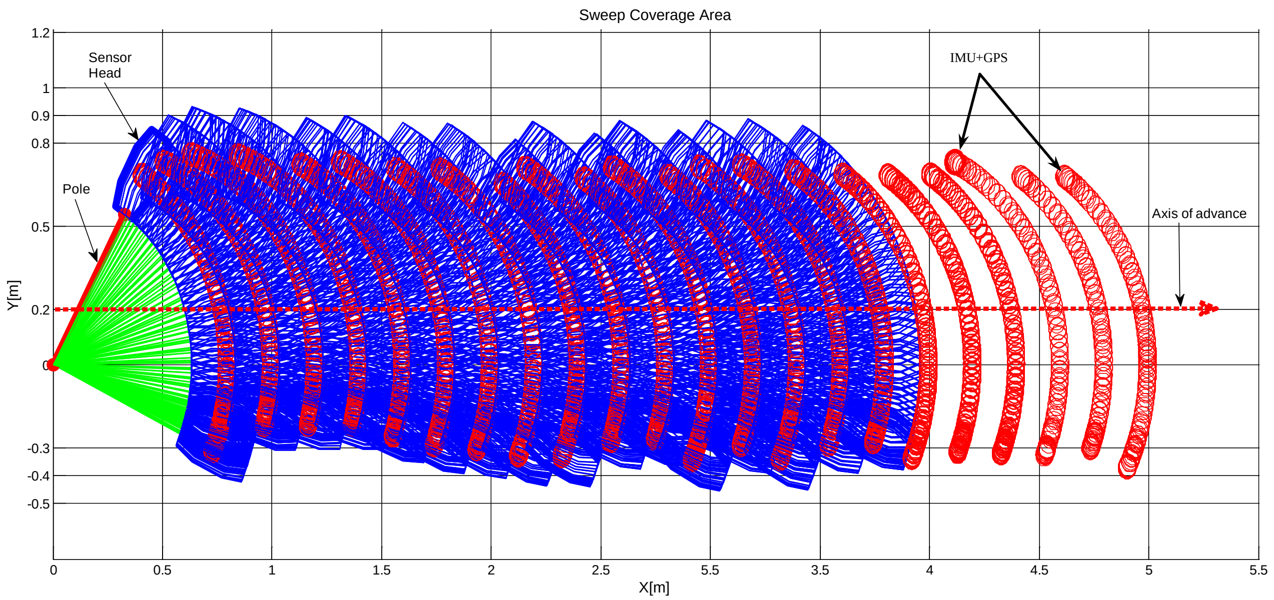


Fig. 2. Sweep coverage area reconstruction using experimental data from motion trackers.

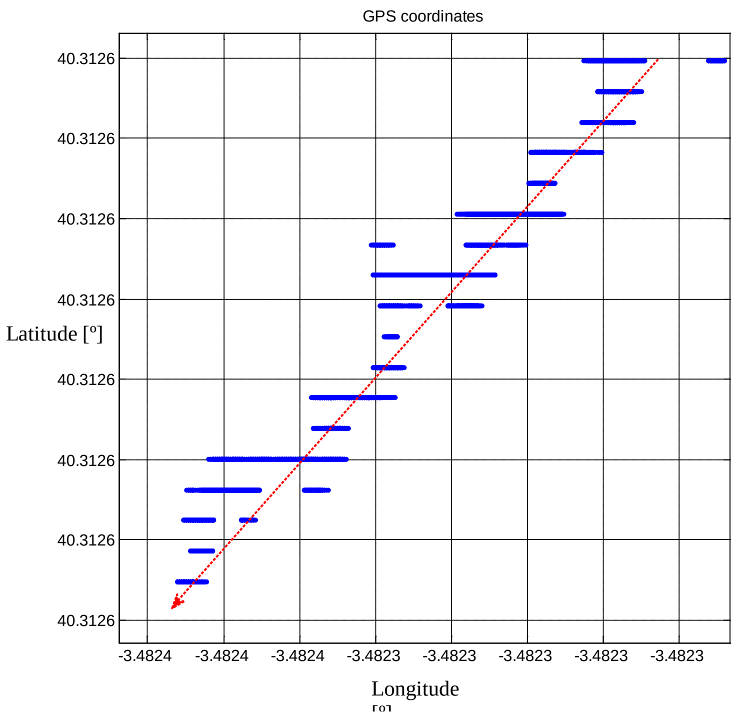


Fig. 3. GPS coordinates: Longitude and Latitude in decimal degrees. Arrow indicates motion direction.

Experimental measurements obtained with the GPS of the motion tracker that is installed in the search head of the hand-held detector are shown in Fig 3. Longitude and latitude are displayed in decimal degrees. In this graph it is possible to appreciate some discontinuities during the sweeping motions, indicating that the sampling rate should be increased in next experiments in order to improve the tracking performance. Nevertheless, obtained results are very promising, showing that the geo-referencing of the hand-held detector is feasible.

Discussion and future research

In this work a sensory tracking system proposed as part of a training tool for improving the deminers' skills during close-in detection tasks with hand-held detectors has been evaluated experimentally in outdoor conditions. Special emphasis has been placed on testing the possibilities of geo-referencing the hand-held detector head in real-time. Experimental results show that the proposed sensory system could be successfully utilised for tracking the hand-held detector during the sweeping motions. Moreover, GPS measurements are very promising for geo-referencing the hand-held detector in real-time. This last characteristic will be very useful for providing the training tool with the capability to analyse in detail the behaviour of the operators in the presence of buried (inert) landmines. In this way, spatial patterns could be created and incorporated into demining training, enhancing the detection performance and reducing the skill differences amongst participants. This is the major objective for future research.

Acknowledgment

The authors acknowledge funding from the European Commission under 7th Framework Programme (TIRAMISU Grant Agreement Nº 284747) and partial funding under Robocity2030 S-0505/DPI-0176 and FORTUNA A1/039883/11 (Agencia Española de Cooperación Internacional para el Desarrollo AECID). Dr. Héctor Montes also acknowledges support from Universidad Tecnológica de Panamá. Special thanks are for Vallon, partner of TIRAMISU project, who provided to the CSIC the VMC1.

References

[1] K. Takahashi, D. Gülle, ITEP Dual Sensor Test in Germany, in: International Symposium "Humanitarian Demining 2010, Šibenik, Croatia, 2010.
[2] D. Laura, Training of personnel participating in humanitarian demining operations in the Republic of Croatia, in: International Symposium "Humanitarian Demining 2011", Šibenik, Croatia, 2011.
[3] R.A. Hancock, Decay in AN/PSS-14 Operator Skill at 30, 60, 90 Days Following Training, in: Landmine Detection Research Center Technical Report, Department of Social and Behavioral Sciences, Lincoln University: Jefferson City, MO, 2006.
[4] R. Fernández, C. Salinas, H. Montes, M. Armada, Omnidirectional stereo tracking system for humanitarian demining training, in: International Symposium "Humanitarian Demining 2011, Šibenik, Croatia, 2011.
[5] R. Fernández, H. Montes, C. Salinas, P. González de Santos, M. Armada, Industrial Robot: An International Journal, 39 (2012) 450-463.
[6] Vallon, VMC1 Mine Detector, in, http://www.vallon.de/pdf/VMC1_leaflet_10_2012.pdf, 2012.
[7] J. Staszewski, Models of expertise as blueprints cognitive engineering: applications to landmine detection, in: Proceedings of the 48th Annual Meeting of the Human Factors and Ergonomics Society, 2004, pp. 458-462.
[8] M. Hegarty, M. Keehner, C. Cohen, D.R. Montello, Y. Lippa, The role of spatial cognition in medicine: applications for selecting and training professionals, in: G. Allen (Ed.) Applied Spatial Cognition, Lawrence Erlbaum Associates, Mahwah, NJ, 2007.
[9] N.B. Sarter, R. Amalberti, Cognitive engineering in the aviation domain, Taylor & Francis, New Jersey, 2009.
[10] A. Davison, J. Staszewski, G. Boxley, Engineer, 31 (2001) 17-21.
[11] J. Staszewski, Spatial thinking and the design of landmines detection training., in: G.A. Allen (Ed.) Applied spatial cognition: From research to cognitive technology, Erlbaum Associates, Mahwah, NJ, 2006, pp. 231-265.