DESIGN OF THE HUMAN MACHINE INTERFACE FOR TRAINING ACTIVITIES WITH HAND-HELD DETECTORS

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Abstract

This paper presents the preliminary design of the Human Machine Interface (HMI) that has been conceived for improving the training activities of demining operations carried out with hand-held detectors. The proposed system can be used in two different scenarios: when the expert's skills are studied in order to quantify some critical performance variables that could help to update the training goals and strategies, and when the deminers' performance is evaluated during the close-in-detection training tasks, in order to provide significant feedback for improving the human operators' competences. The HMI will assist in gathering, analysing, presenting and consolidating the information acquired with the hand-held detector sensory tracking system that has been especially designed for interacting with this application. The friendly graphic user interface will present the data received in an efficient format, maximizing the instructor's ability for monitoring, processing and assessing the trainee and/or the expert performance. The different components, features and functions of the HMI are described in detail through this document.

Introduction

Today, most humanitarian demining is done by using hand-held detectors, attempting to carefully locate each explosive item and then either blow it up or burn it in situ, or render it safe and remove it for dismantling or disposal elsewhere. Although metal detectors are utilised as the principal equipment for detection due to its simplicity and affordability, dual sensors are taking increasingly acceptance in the demining community [1]. Those dual sensors that combine an electromagnetic induction sensor, ground penetrating radar (GPR) and sophisticated algorithms offer better and more reliable detection capabilities than other options that are still under research, such as the nuclear quadrupole resonance technology and trace/vapour detection [2-5].

The way human operators interact with the hand-held detectors during the close-in detection tasks largely determines their effectiveness and inherently the safety of the operations. That is the reason why training offers the possibility to optimise efficiency and get the best out of both user and equipment. A training tool for analysing with the final goal of improving the use of hand-held detectors in humanitarian demining has been proposed within the framework of the TIRAMISU EU Project [6-7]. The tool consists of a Human Machine Interface (HMI), and a hand-held detector sensory tracking system. 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:

1. The study of the expert's skills by quantifying some critical performance variables, so that they can be used later as reference values for the training tasks.
2. The efficiency evaluation of novice operators during the training tasks with hand-held detectors in order to give them feedback about important information for improving their competencies.

The emphasis in this article will be put on the design approach selected for the HMI. The interface will be responsible of collecting the data acquired by the hand-held detector sensory tracking system, processing and analysing the measured performance variables, and presenting the essential information required during the training sessions. The rest of the paper is organised as follows. Section 2 briefly introduces the hand-held detector sensory tracking system responsible for acquiring the performance data during the training sessions. Section 3 explains the methodology adopted for the design of the HMI. Section 4 describes the screen components, links and functions of the HMI and finally, Section 5 summarises major conclusions.

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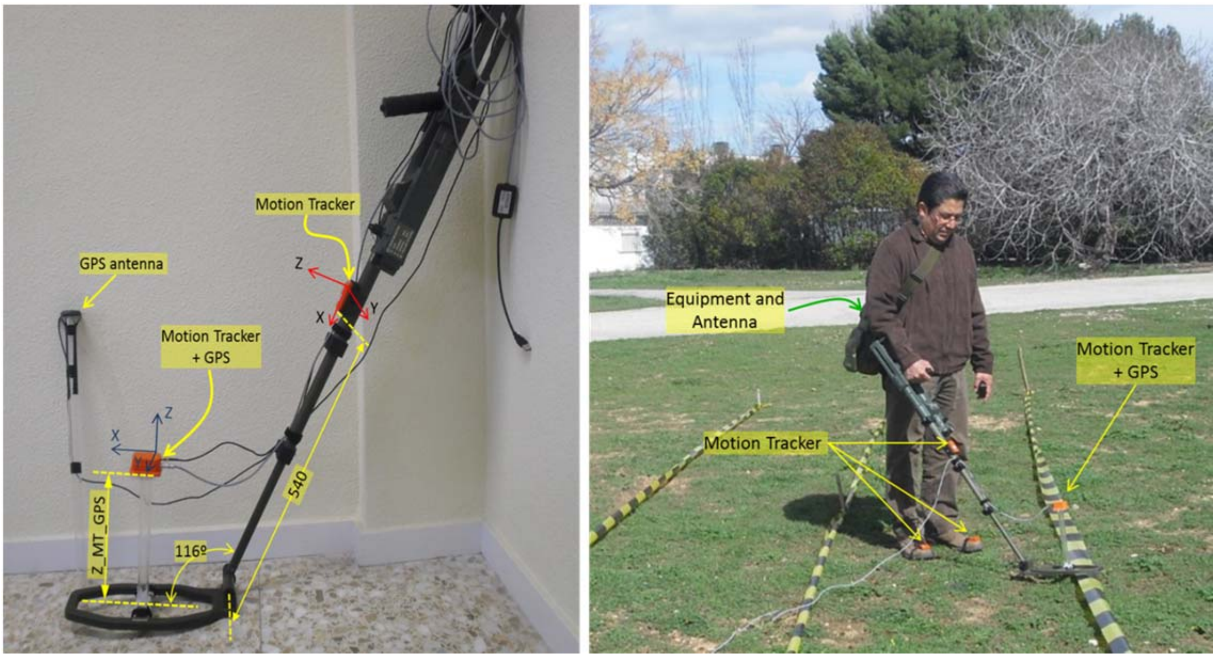
Hand-held detector sensory tracking system

A metal detector VMC1 manufactured by Vallon [8] has been selected as hand-held detector for the sensory tracking system. 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.



(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).

HMI design process overview and methodology

The HMI design process consists of three differentiated phases: (i) Assessment of HMI needs and requirements, (ii) Design of the graphical user interface, and (iii) Identification of HMI design considerations. A fourth phase that includes post-implementation activities would start after the design of the HMI is complete and it would close the design cycle.

Following the flow described above (see Fig. 2), the design process started with a review of the SOP carried out with hand-held detectors, the functional needs, systems requirements and the objectives of the training activities. The review performed is based both on findings from literature and on dedicated interviews and workshops with representatives of various institutional and private organisations that are concerned with training for humanitarian demining. Next, main functionality and key components of the HMI were identified and defined, and a draft version of the HMI was developed. Finally, system capabilities were evaluated to ensure that the HMI design would fulfil all of the needs and requirements identified for it.

Once the preliminary design of the HMI is achieved, it is still need to complete the post-implementation activities, which involve conducting user acceptance and user verification tests. Results from these tests could lead to additional modifications of the HMI design.

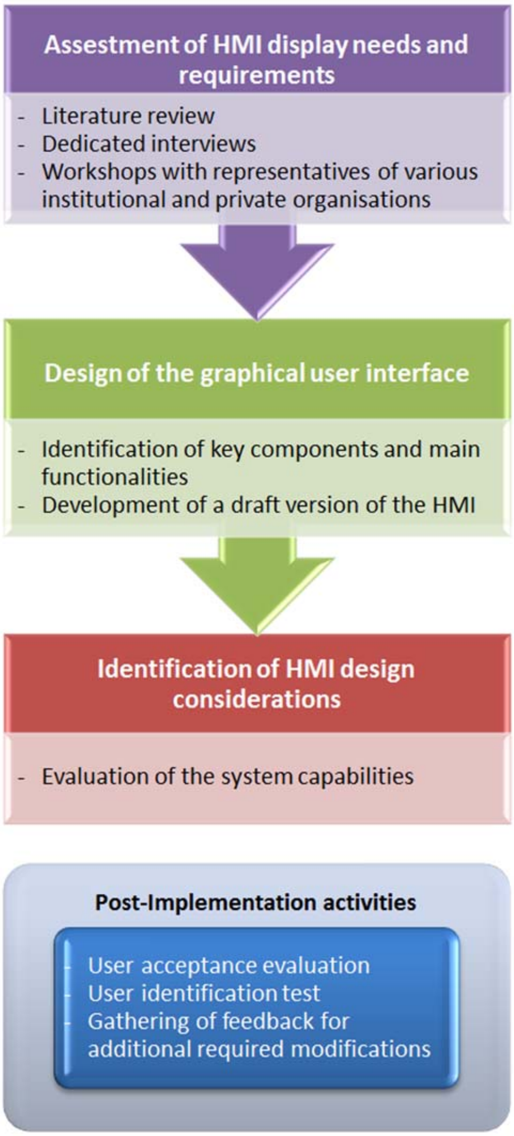


Fig. 2. HMI design process.

During this design process, special attention has been paid in make a clear distinction between tasks for the overall system and the skills required for the human operator. Performing the same task under different circumstances can involve totally different skill, and this should be taken into account during the definition of the training requirements. In general, there are two methods to analyse human tasks and skills:

- Theoretical or analytical analysis: in this case, anticipated skills are identified and the training is prepared based on available system and mission scenario description.
- Empirical analysis: by observing and measuring actual performance, new knowledge is acquired on the real skills and the causes of the training problems.

The first theoretic approach defines the tasks to be performed by the humans operators based on insights on the characteristic of future systems and the environmental context. The second approach is more practical and uses observations and studies of human operator behaviour while performing their work in reality. The advantage of the latter is that the environmental context is actually present, so critical interactions and features can be defined or even measured objectively. These approaches have not been considered as mutually exclusive during the designed process, but as complementary. Therefore, the proposed tool will enable the development and implementation of instructions based on scientific knowledge rather than on personal introspection and intuitions of the training designers.

The key performance variables that have been identified as essential for being monitoring during the training activities are the safety distance to advance the detector search-head on each sweep, the swept velocity, the scan height, and the inclination of the hand-held detector head with respect to the ground.

Key characteristics identified for the graphical user interface design include:

- Clear and meaningful presentation of the information
- User-friendly display layout
- Convenient and efficient process for automatic storage and analysis of data acquired with the hand-held detector sensory tracking system.

HMI console

The HMI console, also called graphical user interface for the 3D tracking sweep monitoring, is the principal mechanism though which instructor interacts with and controls the performance of both expert operators and trainees. The design of the HMI console is based in the key need for instructors to quickly and intuitively interpret all the data captured by the hand-held detector sensory tracking system. The main goals in the design of the graphical user interface are to reduce the fatigue error and discomfort during its utilisation, as well as improve productivity and the quality of the interaction.

The main HMI console is divided into six sections. These six sections are described below (see Fig. 3).

Session Info
This section contains three different elements. The first one consists of two radio buttons mutually exclusive for selecting if the session will be devoted to study the expert's skills in order to quantify some critical performance variables or if will be directed to evaluate the performance of the deminers during the training tasks. The second and third elements enable to introduce the session id and the name of the operator that is being monitored with the proposed tool. These texts entries will facilitate the orderly storage of the data and the reporting phase.

Initialisations
This section encloses one button called "*Config file*" that permits to load a configuration file for modifying the objectives of the training session, and a second button called "*New Session*" that is activated only after the communication with the hand-held detector sensory tracking system has been established by pressing the "Search H-H Detector" button of the *Controls* section, and enables to reset all the data contained in the interface, without losing the aforementioned communication.

Controls
Four different buttons are included for starting the interface activities. The "Search H-H Detector" button begins the WIFI or USB communication with the sensory tracking system installed on the hand-held detector. The "Sync Initial Point" button permits the definition of the home position for all the measurements. The "Start" button initiates the acquisition and visualisation of data, and finally the "Stop" button halts all the functions of the HMI.

Sweep Monitoring
The graphic displayed on this section reconstructs in real time the sweep movements carried by the human operator. The sweep movements are shown over a simulated training lane. This graphic permits a clear visualisation of the sweep coverage area and enables the instructor to check if each sweep across the lane is overlapping the previous one by about one-half the width of the metal detector head, which is one requirement for ensuring the safety of the operator during the detection tasks. In addition, colours are utilised in this graphic to indicate if the performance is holding or not within the training objectives: green is used for indicating that all the evaluated variables are within the training objectives, yellow for warning that the values are starting to deviate from the goals and red for values out of the defined safety ranges.

Speed, Height and Inclination Data
In this section, data acquired by the hand-held detector sensory tracking system is turn into useful information that will help the instructor to monitor the current situation. Four performance variables have been selected for this purpose: the velocity or sweep rate in m/s, the height of the head detector above the ground in cm, and the

pitch and roll angles in degrees for checking if the search head is keeping parallel to the surface. Analog representation of these values, indicating their value relative to normal, abnormal and alarm conditions are displayed. The alarms included for each variable will enable the operator to quickly detect values outside the safety range, so he wouldn't have to relay in his memory and mentally compare each value to its corresponding defined range to discover deviations of trainee objectives.

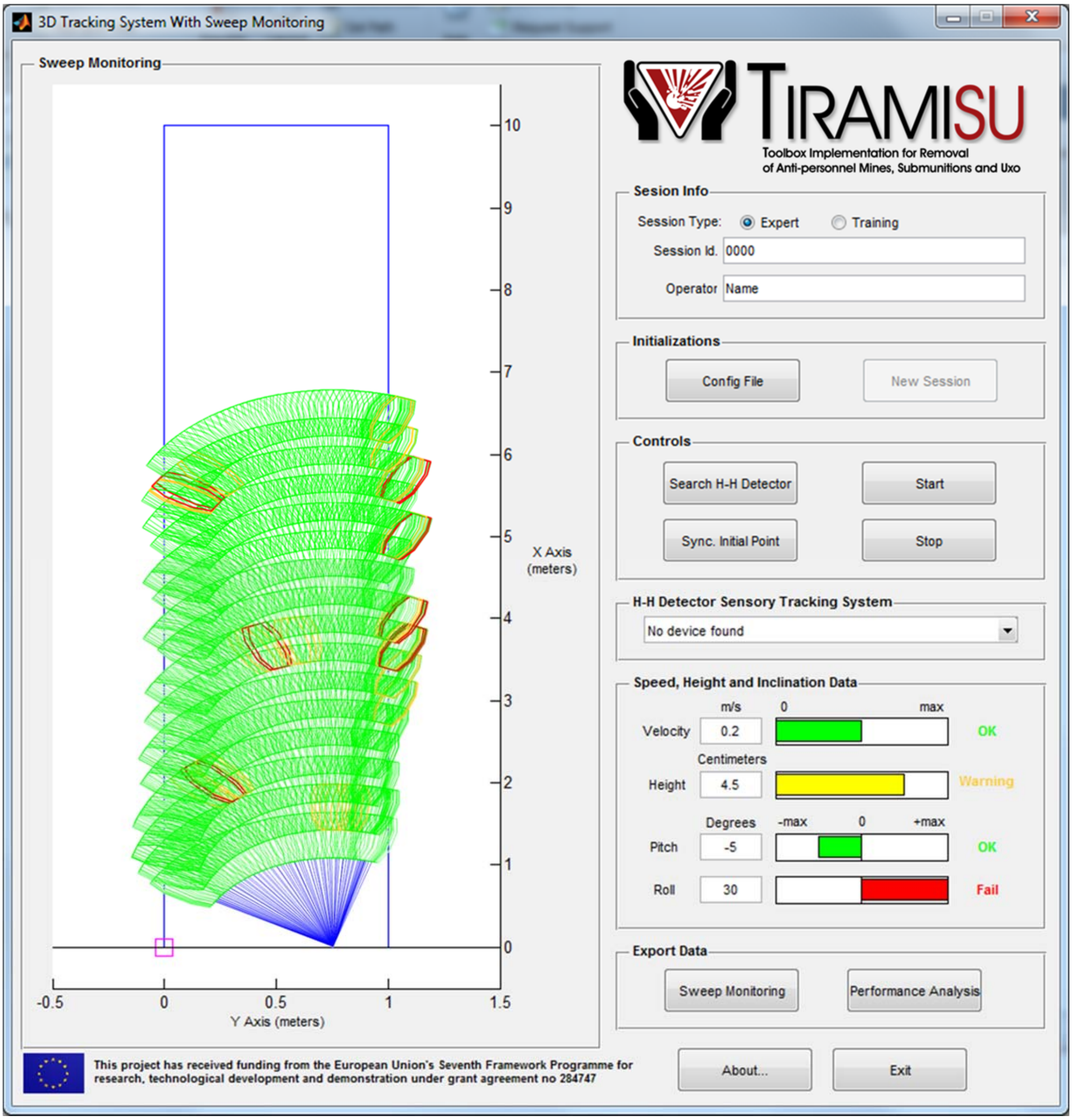


Fig. 3. HMI console.

Export Data

This section encloses two buttons called "Sweep Monitoring" and "Performance Analysis". The first one saves all data acquired by the hand-held detector during the active session in a MySQL data base. Lastly, the second button links with an external application that conducts the performance evaluation of the operator and generates the corresponding evaluation report. The performance analysis can be done from the last active session, or from any other session that had been previously stored in MySQL data base. The external application could be implemented in Matlab, Java or by means of a web page with PHP.

In addition, the graphical user interface has:

- Grey background to minimise glare
- No animations, except for the sweep monitoring
- Analog representation of important measurements, indicating their value relative to normal, abnormal and alarm conditions
- A proper hierarchy of display content providing for the progressive exposure of detailed information as needed

Therefore, with the proposed easy-to-use interface, the instructor is capable of:

- Monitoring all the performance variables of the operator
- Recording all the acquired information in a database.
- Studying the experts' skills
- Assessing the performance operation of the trainees.
- Automating the reporting tasks.

Discussion

In this work a HMI has been proposed as part of a training tool for improving the deminers' skills during close-in detection tasks with hand-held detectors. The approach taken to develop the HMI interface design, as well as an outline of the main features, functions and components of the HMI, has been presented. The HMI designed has the advantage of providing an overview of the entire scanning operation carried out with the hand-held detector and a limited number of well-defined alarms. In this way, the instructor, or the trained operator could see the entire operation almost at-a-glance. Therefore, it is envisioned that the graphical user interface will improve the instructors' ability for monitoring, processing and assessing the performance training data, reducing the total cognitive load required.

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