AN INTEGRATED ROBOTIC SYSTEM FOR ANTIPERSONNEL MINES DETECTION

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Abstract: The terrible antipersonnel landmines plague represents a real challenge for the robotics community. The Royal Military Academy of Belgium intends to provide its contribution for solving this problem. The Belgian Hudem project involves different workgroups each focusing on different aspects: data fusion, sensor development and sensor positioning. The Robotics Workgroup develops semi-autonomous mobile systems which carry mine detection sensors. Mechanical, control and location aspects are considered in the different projects. We present in this paper the control and the communication architecture of our robotics detection systems.

Keywords: robotics, remote control, microcomputer control, human machine interface, sensors, positioning system.

1. INTRODUCTION

Antipersonnel mines kill or mutilate tens of people every day. Humanitarian deminers still use the classical manual methods because heavy demining vehicles cannot achieve a satisfying destruction percentage. This work is very slow, tedious, dangerous and costly and furthermore, the detection is not always reliable. Improvements can be made by developing new sensors, by automating the detection sequence and by using different sensors simultaneously (Baudoin and Colon, 1999).

The Royal Military Academy, leading the Belgian project Hudem, is focusing on the development of new data fusion algorithms, on improvement of Ground Penetration Radar and on vehicles able to carry mines sensors. Robotics systems could be used in different ways to help human deminers. The following scenario seems to be realistic.

Small autonomous vehicles equipped with different sensors can run around an area to delimit the area that is really polluted with mines. This phase when done manually is one of the most dangerous one because

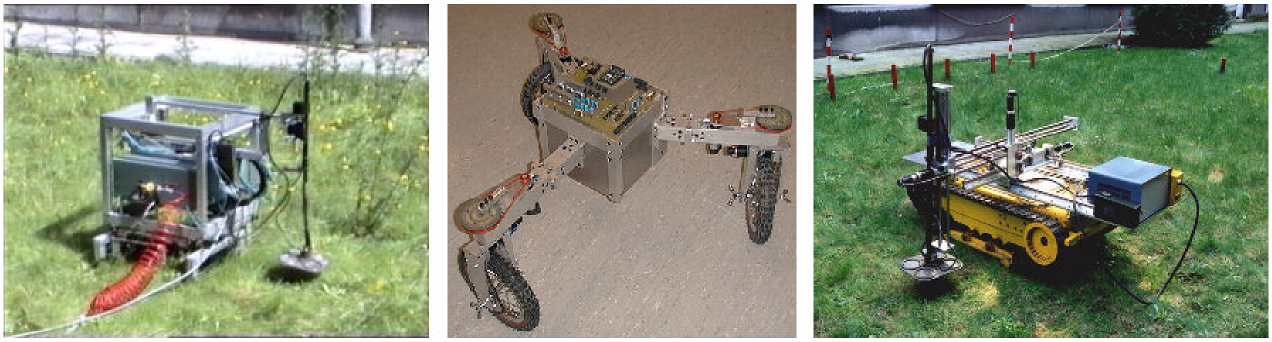

Figure 1 The 3 robots (respectively AMRU4, Tridem, Hunter)

deminers are working faster and are taking more risks than during systematic detection. To study this first aspect, we have developed a small wheeled electrical vehicle named Tridem (Figure 1, center image) (Colon, *et al*., 1998a).

Once the actual mined area has been delimited, a systematic scanning process can begin. In order to improve the detection efficiency and reliability, different sensors must be used. The data fusion process requires registering the data acquired by the different sensors. This aspect justifies the work done on the two other systems: the first one which is a sliding pneumatic robots with a 2 degrees of freedom scanner (Figure 1 left image) and the second one which is an exisiting EOD vehicle that carries a 3D cartesian scanning system (Figure 1 right image) (Colon, *et a.l*, 1998b).

During the development, some efforts have been done to develop a general framework concerning the control of those systems.

The last aspect we consider in this project is the localization of the robot in the field. This is required for control purposes but also to automatically generate detection maps. For this, we have developed a tracking and positioning system based on a pan and tilt color camera. (Hong, 1998).

Besides mobility trials, the systems have been tested on dummy minefields to record data for the other workgroups.

We present in this paper the general control framework we implemented for our multi-robotics system; we also describe the different components of the system and show some results of localization and data acquisition obtained during trials.

2. SYSTEM COMPOSITION

The whole system is composed of the following elements:

- The vehicles and
- Their scanning system,
- The vehicle and scanning control system,
- The communication and data acquisition system,
- The master control with the HMI,
- The tracking and localization system,

The vehicles and the scanners are described in this section, the control and communication architecture is presented in section 3.

Three different vehicles are available in the project (see Figure 1). The first one, named Hunter, is a small caterpillar vehicle that was used by the Belgian Army for anti-terrorism interventions. The original manual control system of the vehicle has been interfaced with a microcontroller such that the vehicle can now be controlled with a computer. The scanner itself has 3 degrees of freedom. A DC servomotor coupled with a planetary gearhead actuates each axis. An optical digital encoder is used for position and speed feedback. The useful area is 850 x 500 mm. The vertical axis has a travel distance of 500 mm. Contact switches have also been placed at each end of the three axis. The system can be used on both sides of the vehicle. It can be powered with batteries or with a lab power supply.

The second one (AMRU4) is a walking machine. Two sliding frames allow a linear motion and a rotating cylinder is used for changing the motion direction. On top of the walking robot we have a 2 degrees of freedom scanner that can carry different kind of mine detection sensors. As said in the introduction, in order to develop efficient detection methods, we need precise and reliable data. That is why we have developed those two systems, which are able to acquire multisensor data.

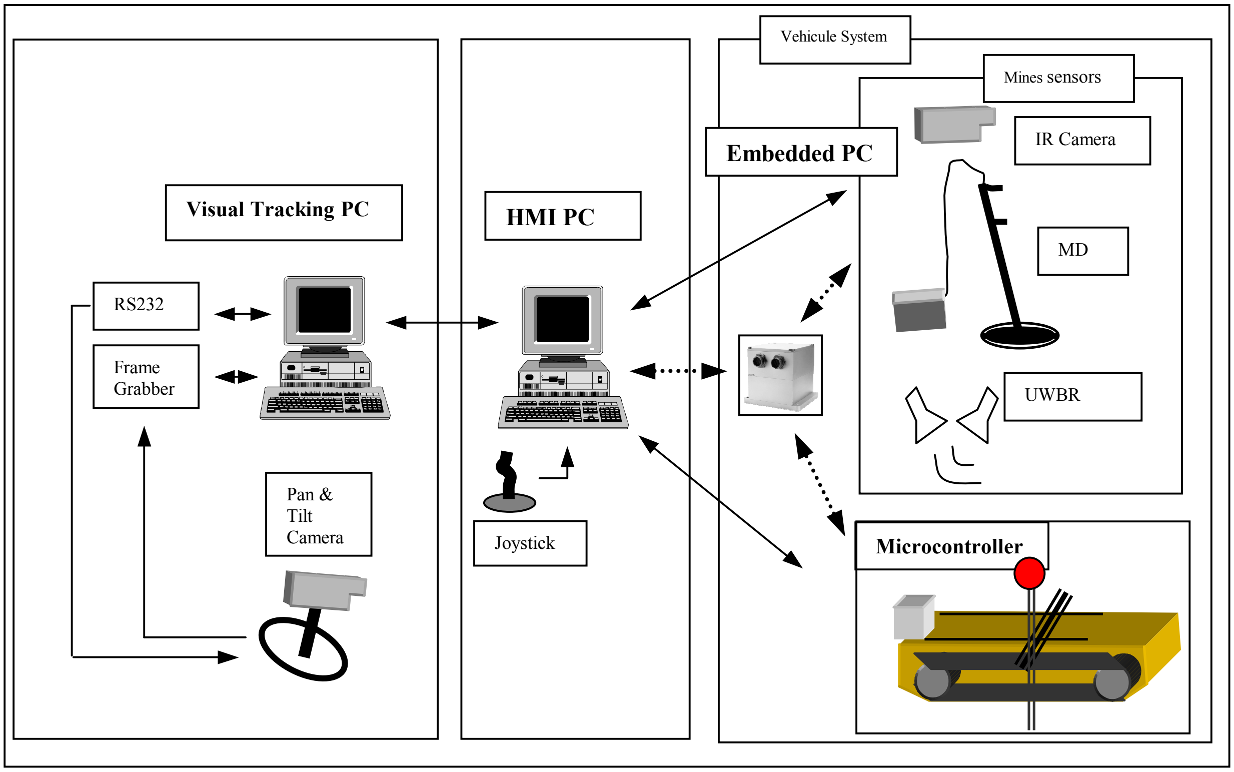

Figure 2 The System architecture

The third vehicle (Tridem) has a triangular shape and stands on 3 wheels. Two electrical motors actuate each wheel: one for the rotation and one for the orientation. It is an omnidirectional vehicle that can be used on high unstructured terrains. This platform could be used to locate minefields in areas which are difficult to reach by human deminers.

3. THE CONTROL ARCHITECTURE

3.1. The components of the control architecture

The whole system has a multi-processing architecture and comprises the following components (see Fig. 2):

- The HMI PC
- The Vehicles (legged, tracked, wheeled) with their
- Scanning systems
- A motion controller (microcontroller)
- An embedded computer for data acquisition and communication with the HMI PC
- Acquisition interfaces (RS232, GPIB, Frame Grabber)
- Sensors (mines, control, environment)
- Communications (RS232, Ethernet)
- Visual Tracking and Location system

3.2. The Master PC

The Master PC is responsible for the vehicle control and for the synchronization of the scanning process. It sends configuration and trigger commands to the microcontroller trough a serial link and performs the data acquisition.

The role of the Master PC can be played by the HMI PC, when this is directly connected to the vehicles and to the sensors, or by the embedded PC. It allows a TCP/IP communication with the HMI PC. This remote acquisition can for the moment only be made with the Metal Detector (RS232 interface). The direct connection is required when acquiring data from the GPR because the GPR we have is an instrumentation system that cannot be easily displaced and we use a normal PC HPIB interface card connected to a scope for acquiring data.

3.3. The Motion and scanning controller

The three vehicle systems use the same basic electronics; the low-level control is realised with a 32-bit microcontroller that communicates through a serial link with the Master PC. They can be remotely controlled through the same interface, a program named CoRoDe. The Human Machine Interface integrates all control aspects: environment, vehicle motion and scanning control, communication and data acquisition. A high interactivity and user-friendliness is reached through the use of up-to-date programming techniques (see section 3.7).

The 32-bit microcontroller is very versatile and can perform different functions depending on the system:

- it controls the electrical motors (scanner, Tridem), using its integrated PWM functions, a software PID controller is also implemented,
- it monitors the signal coming from contact switches,
- it generates the command (thus replacing a PLC) for controlling the valves on the pneumatic robot,
- it generates the analog signal needed for the tracks of the caterpillar vehicles,
- it runs the main communication loop with the Master PC.

3.4. Sensors and acquisition interfaces

We use 3 different sensors: a Metal detector (MD), a Ground Penetrating Radar (GPR) and an Infrared Camera. The data acquisition process requires different interfaces: the metal detector and the pyrometer have a serial interface, the GPR data are read through the GPIB interface of a high speed oscilloscope, the image coming from the infrared camera can be captured with a frame grabber (cable or radio connection).

3.5. Communication

A serial communication allows the transmission of commands between the Master PC and the microcontroller. The transmission speed is 9600 baud. Radio Ethernet links (protocol 802.11) are used to communicate between the HMI PC and the embedded PC.

3.6. Location and tracking

We are also developing a location system in order to know where the robot stands and to automatically generate a map of the detections. A pan-and-tilt colour camera tracks a coloured target mounted on the vehicle. Every frame we get an estimation of the position of the ball. As the robot moves, the camera follows the target in order to keep it in the centre of the image. Furthermore, the size of the target is kept constant because we use a motorised zoom. The value of the zoom gives us an estimation of the distance. As the orientation of the camera is also known, we can locate the ball in the field. In favourable conditions (uniform background, constant illumination) we can reach a precision of 30 cm at distances up to 15 m, which is enough for our application. We are now considering the coupling of the camera with a laser telemeter in order to increase the precision of the location process in varying conditions.

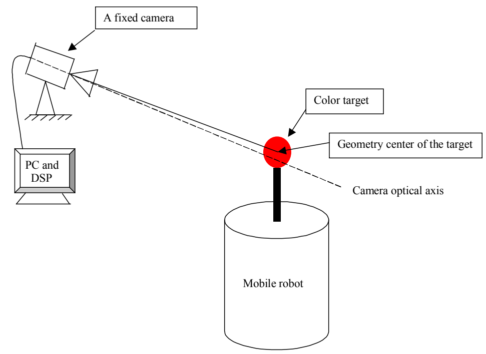

Figure 3.a The tracking principle

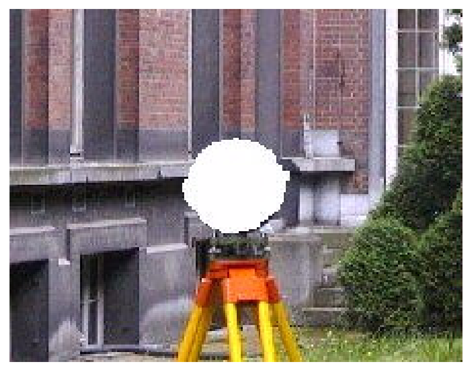

Figure 3.b The detected area is painted with white pixels

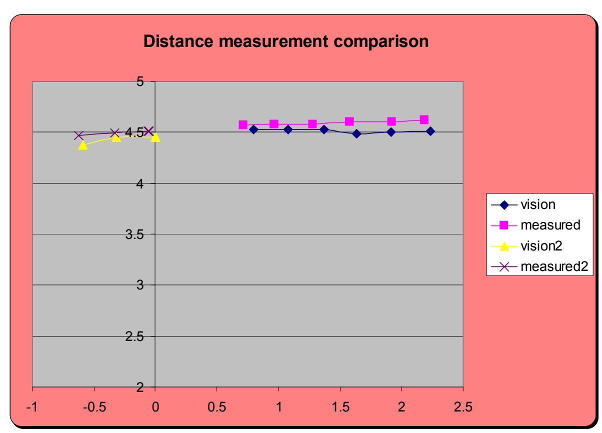

Figure 3.c Comparison of the real and tracked trajectories

3.7. Human Machine Interface

The Graphical User Interface of the control program CoRoDe is shown in figure 4. This program offers the following functions:

- Control of the vehicle,
- Configuration and control of the scanning system,
- Configuration of the sensors,
- Data visualisation,
- Data archiving,
- Mapping.

The main area is devoted to data visualisation. This area can alternatively display the map showing the locations of the robot or the scanned area and the possible detections.

We have 2 kinds of data to visualise:

- Global acquisition: IR image, video images (if we replace the IR camera or add a normal camera for viewing the scanned area. This could also be used to model the ground using image processing)

- Sequential acquisition:
    - Single value to form a 2D raw image (MD and pyrometer)
    - 1D to form a 3D raw image (UWB). The Visualisation Toolkit (VTK) (Schroeder, 2000) provides the needed functionnalities to show 2D and 3D data. It also allows the user to interact with the data.

To build a map we simply display a reference frame with indications of the consecutive positions of the robot and the scanned areas. The user can switch between the 2 configurations by clicking on a button in the top toolbar.

Data acquired during the scan process are saved in two different formats: first as binary data (double for UWB, DWORD for MD) and as 8 bits grey scale raw images for visualisation purposes. At this stage, retrieving actions have not yet been implemented (an independent program for reading and viewing UWB data have been written).

The data acquisition, scanning, location computation and vehicle motion are integrated into a sequence that is controlled by the user with button commands lying in a single toolbar. At every moment the user has the control and can pause, resume or stop the operations. Sensors' data are drawn on the screen as the scanning progresses. The position of the scanner relative to the maximum positions, the status of the scanning sequence and the main options are also presented to the user.

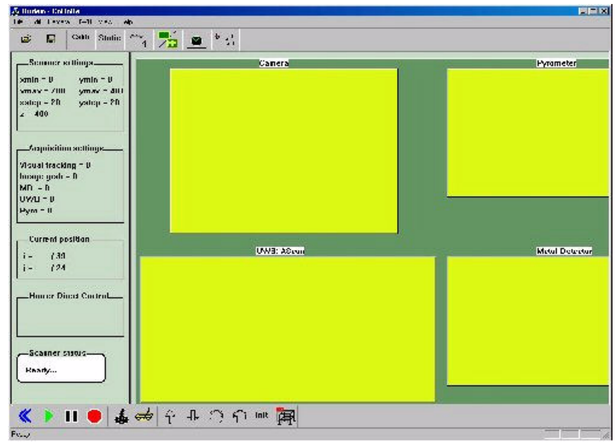

Fig. 4 The GUI of the CoRoDe program

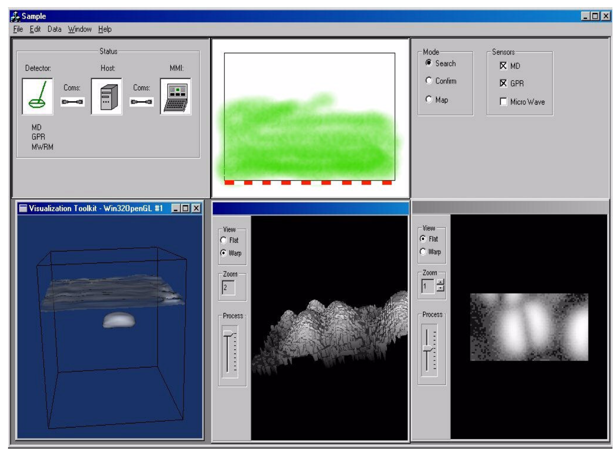

Figure 5 Visualisation of the different sensors' data using VTK

4. RESULTS AND FUTURE WORK

The two systems equipped with scanners have been successfully used to acquire registered multi-sensors data that have been used by other researchers of our project to develop fusion method and to test the GPR prototype (Figure 6).

The wheeled tridem will be demonstrated this summer as a mine searching system.

The following modifications will be made during the next months:

- Development of a dual control system: the first version using proprietary protocols and client and the second one using Internet standard components as a Web server, cgi links and a normal browser as HMI.

- Plug&Play capability: when a system is started, it should be automatically recognised by the Master and handshaking is started. The remote system provides a description of its components and capabilities to the Master. (Master, Slave, Nodes, Sensors) The HMI is automatically adapted to fit the properties of the current system.

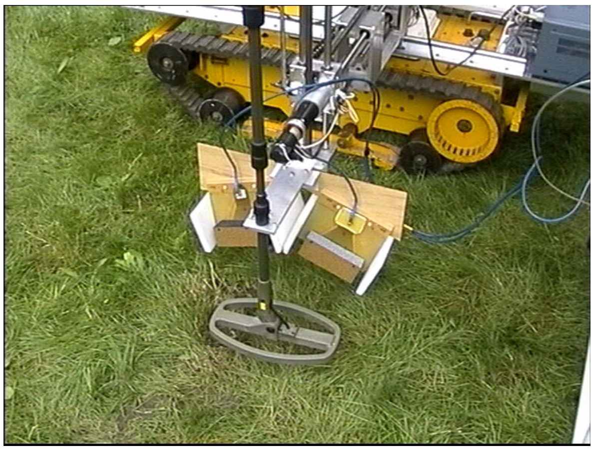

Figure 6. Data acquisition using the prototype GPR and a Metal Detector

5. CONCLUSION

At this stage, we cannot prove that robotics detection of mines works better or faster than human deminers. But the obtained results are encouraging and pave the way for an integrated solution that will one day help to solve this terrible plague.

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