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# A Wearable GUI for Field Robots

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**Summary.** In most search and rescue or reconnaissance missions involving field robots the requirements of the operator being mobile and alert to sudden changes in the near environment, are just as important as the ability to control the robot proficiently. This implies that the GUI platform should be light-weight and portable, and that the GUI itself is carefully designed for the task at hand. In this paper different platform solutions and design of a user-friendly GUI for a packbot will be discussed. Our current wearable system will be presented along with some results from initial field tests in urban search and rescue facilities.

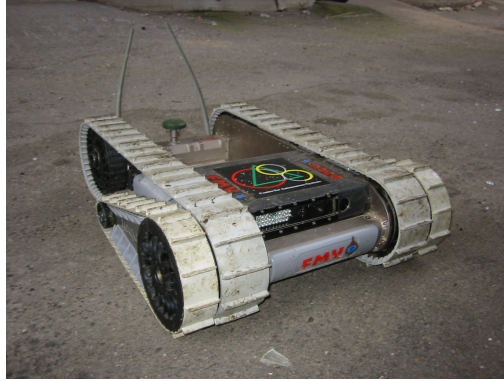
**Key words:** GUI, Field Robot, Wearable

## 1 Introduction

Deployment of robot systems for outdoor field applications poses a number of interesting challenges. The outdoor application of computer systems is in itself a challenge due to lack of screen contrast, limited availability of weather proof casings, etc. At the same time the mobile systems are often operated by inexperienced users, which calls for careful design of the interfaces. This involves both selection of a suitable hardware platform, and design of an associated interaction system with GUI etc.

In joint research between the Centre for Autonomous Systems, KTH and the Swedish Defense Materials Administration (FMV) a study is considering how rugged platforms such as a PackBot can be utilised for search and detect type missions by inexperienced users. As part of international peace keeping missions or as part of search for people after major disasters there is an interest to deploy PackBot systems (See Fig. 1). These systems are to be used for early intelligence gathering before people enter a building or a neighborhood.

A PackBot is by default delivered with an operator control unit (OCU) that is composed of a rugged laptop computer with an attached joystick for



**Fig. 1.** The PackBot system used as part of this study

tele-operation. The system has an operation time of about 1 hour between recharges. The user interface is designed around a GUI that is divided into four sub-windows. The windows can visualize information such as:

- Video from fish-eye / IR camera (streamed video)
- Present speed
- Battery capacity/remaining power
- Temperature of key motors
- Track of GPS position
- Payload information
- Status of WLAN Connection

In most cases the information is presented as a small scalable icon and a text snippet that specifies the type of information visualized. The system poses a number of challenges

- It is heavy and not easy to carry
- The system is not packaged for rugged outdoor operation with weak connectors etc.
- The screen has limited contrast outdoor due to use of a regular LCD panel
- The system has a limited time of operation

Consequently there is a need to consider how a suitable interface could be designed to enable realistic use of the system, and how it could be designed to enable easier use by inexperienced users.

The prototypical user for a system is a young male with a high school degree. The users often have experience using a cell phone and some experience with computer games, but they cannot be considered computer experts.

Some of the requirements for a system include:

- High contrast of video screen during outdoor operation
- Easy control interface with intuitive control of the vehicle

- An uncluttered visual interface with access to key information
- A manageable learning curve that enable use after no or limited training
- Highly portable for easy transportation and suitable battery duration.

In the present paper a design of a wearable control unit for a field robot is described. The unit has been used for tele-operation of a PackBot in urban search-and-rescue missions involving operation both in factory buildings and in area coverage.

Design of user interfaces for this type of robots has been described in the literature earlier. Fong et al. [1] describe use of a PDA for basic teleoperation using an on-board keypad and video feedback to the user. The interface also includes text messages from the supervisory control. Perzanowski et. al. [2] at NRL have also designed a speech / PDA interface for control of iRobot ATRV robots. The emphasis is here on integration of speech with simple commands for teleoperation in the context of a semi-autonomous system. Leskinpala et al [3] describe the use of a PDA based system for simple tele-operation of a mobile platform, but the tests have only been performed indoor in relatively accommodating environments. Edwards [4] outline the design of a wearable computer system that has been deployed in Afganistan for teleoperation of the iRobot PackBot and the Forster-Miller system. Few details are available on the actual interface design. Mayol et al [5] have also described a wearable systems for localisation and mapping, in which small visual platforms are remote controlled for mapping. Few details are available on the interface design. The most relevant work here seems to be the work by Fong, and Perzanowski, though none of them have designed a truly wearable system for robot operation. One would have expected a large number of wearable systems for robot tele-operation, but our review of the literature have not shown much reported research.

Initially the various options for design of a portable user interface are discussed (Section 2). The details of the actual design are then presented in Section 3. A number of observations on the use of the system is provided in Section 4. Finally a summary and outlook for future work is presented in Section 5.

## 2 Selecting a platform for control of a field robot

As mentioned above a number of people have already reported use of a PDA for control of field robots in everyday use. In earlier work we have also reported use of a PDA for control of an iRobot ATRV [6]. The PDA has the advantage that it is a well known platform, it is lightweight and has good battery performance. Almost all of PDAs have poor outdoor performance in terms of screen contrast. In addition most newer PDA have a problem for control of platform motion. The built-in joystick does not offer adequate control of the platform, it is too difficult to determine if a side-way or forward/backward motion is requested.

An alternative to PDA control is the use of a tablet PC as for example provided by HP/Compaq. These platforms have a large screen and but the same contrast issues as a PDA. The platforms are not rugged and in addition there is a need to use a special purpose pen for the control, which makes it difficult to use and at the same time the platform is relatively large and difficult to carry.

Recently there has been significant progress on small rugged computers that can be carried in a large pocket. These platforms have standard interfaces for networking, screen, USB, etc. The platforms are available with standard processors and are relative power efficient, as reported in [4]. It is thus possible to design a standard wearable computer solution in which a computer is fitted with an 802.11b network and a pair of batteries for easy use. Using the standard VGA connector it is possible to attach either a pair of computer glasses or a small touch screen for mounting on the lower arm. The touch screen has a standard mouse interface. The glasses, with an integrated screen, has the advantage that the contrast problem is more manageable as the backlighting from the background enhances contrast, which is the reverse effect of normal LCD screens. For the control of a platform it is possible to use a wireless gamepad, which is a well-known modality for computer games. It typically offers two analog joysticks and a number of push buttons for selection of different mode variables. The gamepad design is similar to what is frequently used for tele-operation of cranes and mining equipment.

For our studies we have chosen a 650 MHz ULV Celeron computer with standard ports for PS2, USB, VGA, LAN and serial COM. To ensure rugged operation in an outdoor setting it was decided to use the built-in Compact Flash interface to install a small linux system on a standard CF card. These cards can typically tolerate shocks in excess of 100G which makes it a suitable solution for the present application. For communication a USB - WLAN interface is used and it is mounted on a shoulder pad for maximum operation range. For feedback to the user, two solutions were tested. A 7" LCD touch screen was tested (see Fig. 2), but the contrast is similar to that achieved with a PDA. It is an acceptable solution for indoor operation but not a good solution outdoors. An alternative is a head-up display (HUD). We have chosen the SV-6 "eye-monitor" system from Micro Optics. It offers a resolution of  $640 \times 480 \times 18$  which provides adequate resolution when mounted in the accompanying glasses.

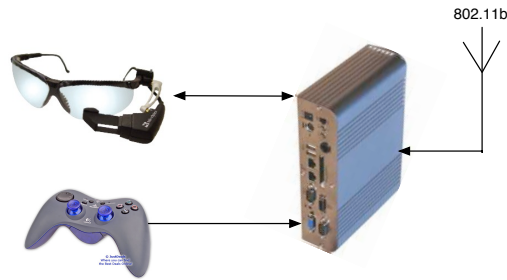
The overall hardware solution for a wearable system for PackBot control is shown in Fig. 3.

### 3 System Design

The PackBot comes with an on-board computer. The computer is used for local control of the PackBot in terms of speed, direction, and the flipper position. The control is purely in terms of speed. In addition the on-board



**Fig. 2.** Example LCD screen tested for lower arm mounting. The contrast is, however, a major challenge for outdoor usage. The screen is shown together with a corresponding iPAQ interface that can be used for portable control, but again with contrast issues

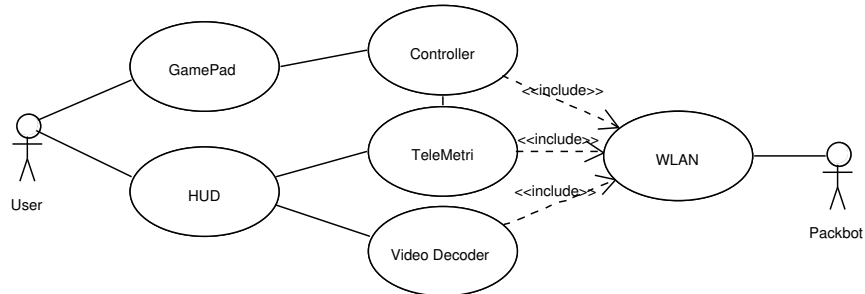


**Fig. 3.** The hardware setup for the control system

computer can stream video to the control unit. The PackBot has two on-board cameras. One is in the visual spectrum and has a fish-eye lens fitted. The other is an infra-red camera with a narrow field of view lens. The system also has a built-in IR illuminator that can be used for operation in complete darkness. The IR illuminator has binary control (on/off). All control and video is communicated using two 802.11b links. The video is multicasted for use by multiple clients. The computer system is not accessible to users and consequently it is used as a blackbox. All extra control functionality has to be achieved on the operator control unit.

To drive the system the wearable computer is setup with a small scale linux distribution that fits onto a CF card. Only the bare minimum is available. The DSL - Damn Small Linux distribution was used as a basis for our system. DSL is a 50Mb distribution designed to fit an X11 system on a small credit card sized cd. DSL was then modified to enable booting off a CF card.

The design of the software system is relatively simple. The overall system design is shown in Fig. 4



**Fig. 4.** The Software Components of the Wearable System

The controller handles the take-up of control of the PackBot, i.e. observer mode versus control mode. In control mode an active link to the system is maintained. The system is also responsible for handling telemetry feedback from the system. In the present setup the control is purely tele-operated, but other research is considering the addition of autonomy to the system. At present the telemetry that is feedback to the user / control process are velocity information, GPS coordinates (when available), battery status, temperature information, and orientation of the platform with respect to horizontal.

The user control of the platform is through the earlier mentioned gamepad. The gamepad is of the wireless variety, which provides a maximum of flexibility and at the same time it is for many people a natural interaction modality. The main interaction is through the two on-board joysticks. The left analog joystick is used for control of speed and direction of travel, which is the default behaviour of almost every video game. The right joystick controls the two on-board flippers. The flippers can only be moved in synchrony and thus only the forward/backward motion of the joystick is utilized. The gamepad has 11 on-board buttons. One is used for request of control of the platform and another is used to call up a help screen. The remaining buttons are mapped to frequently used actions such as toggle brake on/off, selection of video source (fisheye/IR camera), increase/decrease speed limit and finally also a GUI reset button.

The head-up display at all times streams the video data from the PackBot. The display is setup to have three modes of information: i) the bare video stream, ii) video plus velocity information, and iii) video, speed and telemetry information. The different types of video information is shown in Fig. 5 and Fig. 6.

The basic setup is so that one can toggle between the three types of information. For the beginner a minimum of information is typically the preferred



Fig. 5. The screen shown with video only information and with velocity information



Fig. 6. The screen shown with video, speed information and telemetry data

mode of operation. As the operator gains more experience the details can be added gradually.

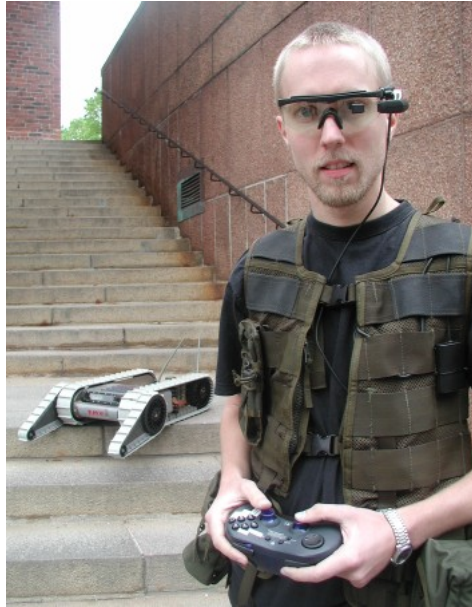
The system has been implemented using the Simple DirectMedia Layer (SDL) which is a cross-platform library. SDL has been designed to provide low-level access to audio, keyboard, joystick, video and framebuffer. It is supported on a large number of platforms including Linux and as such provides for easy portability across PDA, Wearable and Tablet systems. The library is written in C with MMX optimized code, which provides for efficient execution and a minimum load on the CPU, which is important for battery operated systems.

The entire system is capable of streaming video to the user at 15Hz with a video resolution of  $320 \times 240$  in real-time with a CPU load of 75 %. Actually it can show video of up to 25Hz (using more CPU) but this is only valid in the near proximity of the robot where the radio quality is good. As the radio quality drops, so does the frame-rate. For realistic scenarios, the frame-rate

varies between 5-15Hz which is enough to solve most tasks. It would be of interest to be able to stabilize the image, as there is significant shaking in the image during traversal of staircases etc., but this has not yet been achieved.

#### 4 Field use of the system

The wearable system has been tested in a number of pilot trials. The system mounted on a person is shown in Fig. 7



**Fig. 7.** The Wearable System in Operation

The system has been evaluated both for indoor operation in a factory setting, where the person is required to drive the PackBot into a building and up a staircase to search for a particular object, and in an urban setting where the system is deployed to enter an area with a number of buildings to determine if there are any suspicious objects. Here the system is required to drive up to a car and inspect the underside of the car for any unexpected objects.

For the operation indoor the main challenge is driving in a staircase. The shaky motion of the platform while traversing the staircase is a challenge for the operator.

In the outdoor setting the operation is natural and easily picked up by the operator.



For both cases it must be recognized that the goggles only feed video data to one eye of the operator. This poses a small challenge and in the beginning the disparity in information between the two eyes (the one with the screen and the eye with no feedback information) is a bit confusing. However, when entering an area there is an interest to be able to see the immediate surrounding with a minimum of obstruction of the field of view and at the same time shift to robot operation without any changes in the setup. This can easily be achieved with the present setup. After some training the users find that it is easy to drive the system and achieve efficient operation. The system has a battery time of about 3 hours, which is adequate for most interventions.

In comparison to the standard iRobot OCU a high degree of mobility is available, and the same information as is available through the OCU can be provided. The direct integration into the uniform is considered a major plus. At the same time the gamepad provides at least the same level of maneuverability as the OCU attached joystick. Initial comparative tests with the two systems demonstrate that a similar performance in terms of flexibility and speed is achieved for the wearable system and the OCU.

A wearable solution has been reported for the iRobot system in the paper by Edwards [4], unfortunately no information is available about the display of information, or the the modes of operation. In addition it has been impossible to get access to such a system for comparative experiments.

## 5 Summary

In the present paper we have discussed the design of a wearable computer system for tele-operation of a PackBot system. The system was designed to address many of the challenges that exist with using a normal laptop for field applications, in particular in an outdoor setting. Through use of wearable goggles in combination with a gamepad it is possible to design an efficient interface that can be used by people after only a brief introduction. The design has been implemented on a linux based computer system that is worn in a small belt together with the required batteries. The system has been implemented and tested in pilot trials indoor and in urban settings with highly satisfactory results. As more degrees of autonomy are added to the system the overall design of the user interface will have to be adopted to accommodate such functions. However the present design is efficient, portable and easy to use. It offers an ideal work environment for control of a small field robot such as the PackBot.

Future work will include more thorough field evaluation of the system and indepth comparison to the standard OCU unit delivered with the PackBot. In addition various degrees of autonomy and post-processing of information such as image stabilisation is clearly of interest.

### *Acknowledgements*

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