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Semi-Autonomous Low-Cost Mobile Robot for Inspection

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1. Introduction

It is widely accepted that service robots can significantly contribute to better human working conditions, improve quality, profitability and availability of services. Currently more than 1200 service robots are in operation worldwide and first service robots have become commercially available [2].

The inspection mobile robots are outstanding representatives of the service robots. They have broad areas of applications: inspection of nuclear power plants, chemical laboratories, potentially dangerous or hazardous places, where human beings cannot go or enter.

The human-machine interface is considered to be crucial in a real-world application – that is why a special attention has to be paid to the Graphical User Interface (GUI) [4]. The aim of the developers of this software application is to offer a GUI, which represents and demonstrates all features of the up-to-date software applications and it is implemented by using the advantages of the modern programming tools.

After considering the requirements towards the GUI and the advantages of the scripting languages [1], compared to the system programming languages, the GUI is implemented in Tcl.

Nevertheless of all the benefits from the use of such a robot system, there are many problems associated with these robots, which are not solved yet, and some of them are:

– technological requirements;
– high costs;

– safety requirements;
– acceptance.

The mobile inspection robots have a great market potential if these problems are overcome.

In order to achieve a significant price drop and a massive spread of service inspection robots, the goal of the designers is to develop robot systems, which could be compared in acceptance, ease of use, user interaction, multifunctionality and diversity with nowadays personal computers.

2. Considerations on the design process of a mobile robot sytem and description of the robot ROBY 1

The general idea in the creation of the presented robot system, called Roby1, is to use the advantages of the modular design. Different, ready, standard modules are combined in order to be constructed the whole system. The designer has to select the most appropriate components. He has to organize their communication and interaction in order to be ensured the proper work of each sub-system and also the proper work of the robot system as a whole.

Modular design offers the following opportunities:

► To standardise the system and to reduce its overall price.

► The product can be customised by the use of different combinations of different modules. This advantage is very important since the robot can be adapted to perform easily new tasks and also other functional modules can be added without a high cost and within short development times.

► Easy and cheap maintenance and repair because the defective module can easily be replaced by a new one.

Each component affects greatly the performance of the system and that is why the selection of the sub-units is very important, but also it should be done according to the imposed set of requirements and constraints such as price, environmental conditions, etc.

The designed system must perform both effectively and efficiently and therefore a compromise must be made between:

► Performance and physical parameters like capacity, accuracy, speed, size etc.

► Operational and support features like machine-user interface, reliability, maintenance, ease of programming etc.

► Economic factors such as initial cost of the robot, life cycle cost etc.

Two pictures of the robot Roby1 are shown in Fig.1.

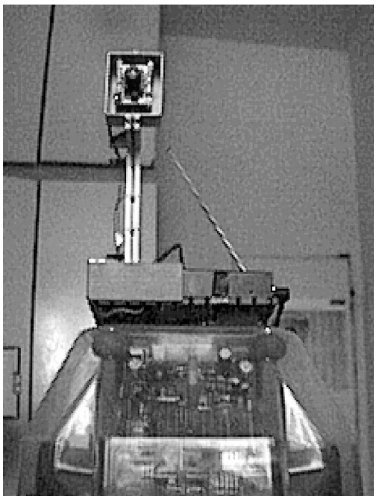
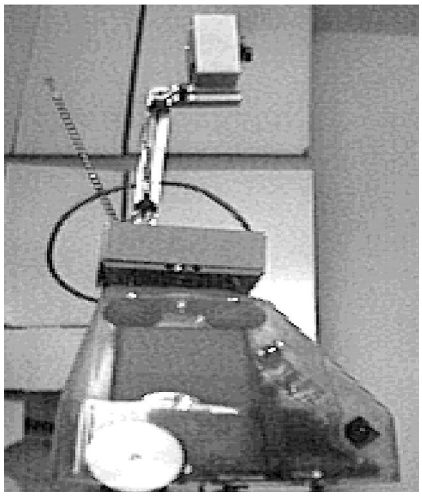



Fig. 1. Different views of the robot Roby 1

Efforts are made to achieve an optimum balance between the performance of the robot, the operational and cost factors. The analysis carried out during the design process is essential and very important in order to be minimized the uncertainties and the contradictions among those factors. Another important aspect of the design is that the robot system has to comply with the regulations and the accepted safety standards.

The robot described in this paper is a low cost vehicle that is intended for research purposes, but with a few changes in some of its components it can be used for real-life tasks. It is constructed in the following way:

1) The basic components of the robot are determined in order to be fulfilled the specified tasks.
2) the design considerations for each part of the robot are taken into account and a ready component is chosen. For example the CCD camera, the TV sender, the mobile platform.
3) the connection among the components is created to be ensured their interaction, the construction for the mounting of the camera and the sender over the platform is made.
4) the Graphical User Interface is created on the basis of the abilities of the chosen platform that will be controlled through it.

3. The structure of the robot

The mobile robot Roby1 comprises of a mobile platform, manufactured by the French company “Jeulin” with an on-board controller with a central processing unit (CPU) – M 6805, with RAM – 8 KB, and EPROM – 8 KB. The controller receives the commands sent by the operator and determines the movement of the robot. The controller is powered from one lithium battery of 2 V.

The driving system of the robot consists of two driving wheels coupled with two independently controlled stepper motors. The stepper motors are without a feedback control, and powered from one battery – 12 V and 2.2 A.h. The operation time of the robot is eight hours of permanent usage between the recharges of the battery. The speed of the platform is 0.2 m/s.

The use of a sensing system, such as touch sensors, allows the vehicle to interact with the environment in a more flexible manner, to detect the obstacles and to avoid them. This is done with the help of four micro switches.

The robot uses an infrared communication system for the data transfer between a remote station and the robot. The infrared sender is powered with two alkaline batteries of 9 V each.

There is a CCD camera mounted on the mobile platform and a TV sender. The catalogue data for the CCD camera is: B/W 1/3″ interline transfer CCD board camera, 0.1 lux, CCIR: 512(H) x 580(V) picture elements, 380 TV lines, auto shutter control 1/50 – 1/100 000 s, DC 12 V; 110 mA, f = 3.6 mm, 92 deg. diagonal, 32x32 mm board +AUDIO.

The CCD camera perceives the image from the surrounding environment and transmits it to the sender. The sender works in the ordinary radio frequency region. Every TV set can receive the signal from the sender. There is also a possibility the image to appear on the screen of the TV set.

The graphical representation of the main components of the robot and their interaction is given in Fig. 2.

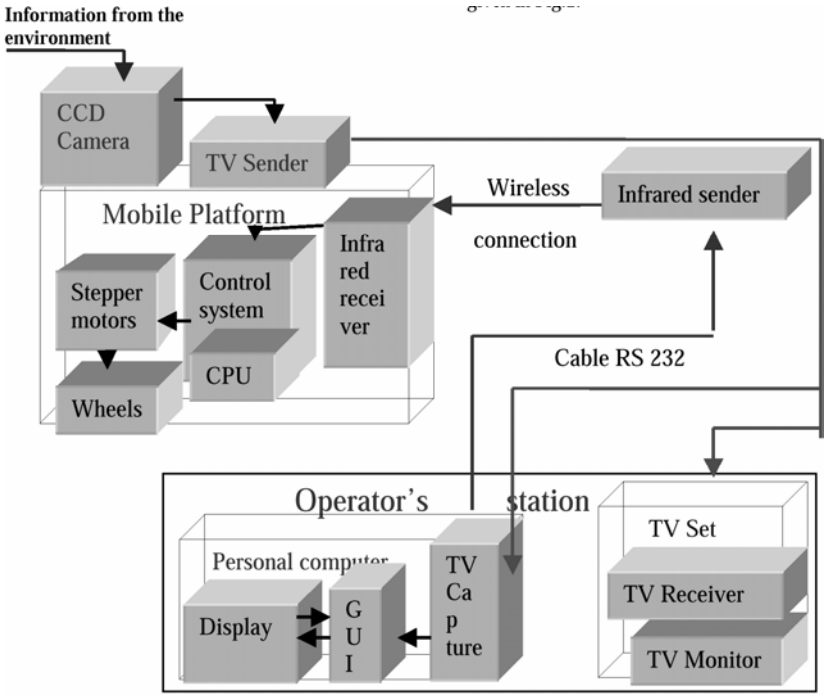


Fig. 2. Simplified graphical representation of the structure of the robot Roby1. The arrows represent the flow of information

4. The program control

The remote station possesses a specially designed graphical user interface (GUI), which helps the operator in the creation and sending of the commands to the robot. The ready program for the movement of the robot is sent via a cable RS232 connected between the PC and the infrared sender. The user can see the mage from the camera of the robot on the screen of the personal computer, if a video-capture circuit board is available. The image can also be seen on an ordinary television set, if there is no capture installed on the personal computer.

The whole application is divided into different sub-programs. Each sub-program represents the code for the different options of the application. When entering the program the operator will see the window, given in Fig. 3. The texts “ROBY1” and “Tcl/Tk” are active, so by clicking on them one can see a short presentation of the robot, or explanation about the scripting language Tcl [3].

Active buttons are all given options, so by choosing one of the lines, the operator can enter either a way for programming the robot – the options from the “Robot Control”, or to see the list of the active commands of the robot with “Basic ROBY1 Command Description”, or to generate a new complex command by using the available simple commands – “New Command Generation”. There are 45 active commands, which are associated with the motion of the robot. There are commands for rotation at a different angle and also commands for forward or backward movements with different length.

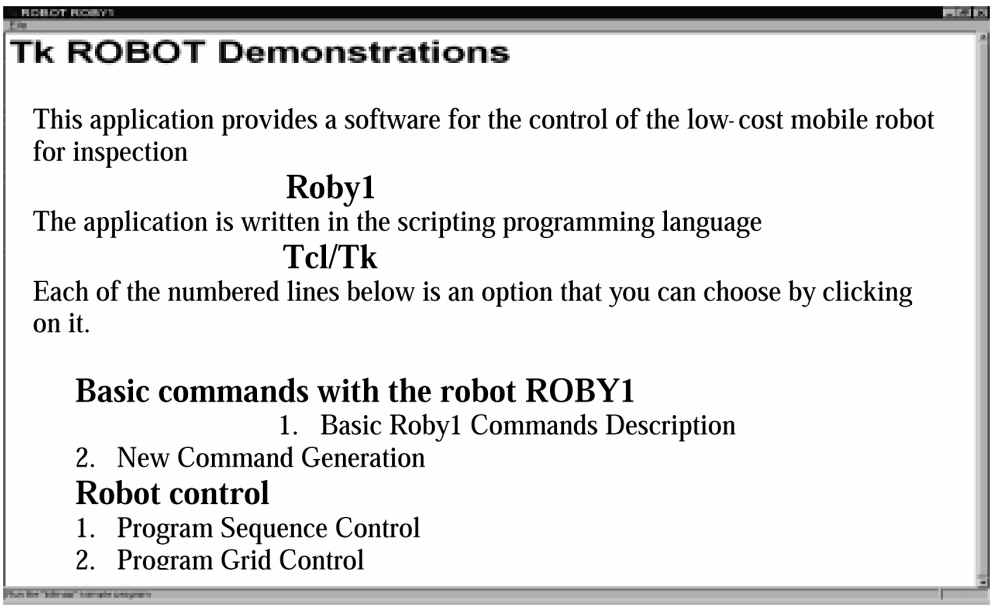


Fig. 3. The main window of the program

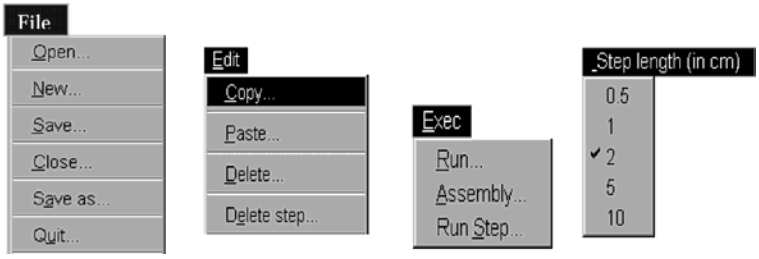
If the operator chooses “Basic ROBY1 command description”, then he will have the opportunity to see all available standard commands for control of the robot. The screen, shown in Fig.4 will appear in front of him. When clicking on a button with the numbers of the commands, a list with the commands and their description will appears.

The regimes Program Sequence Control and Program Grid Control of the program are provided for the control of the robot. It gives the operator the possibility to write a program for the motion of the robot, and also to receive a visual feedback information from the robot. The layout chosen allows for all windows to be visible at one time – the place where the program is written and the place where the video image is placed.

When using the Program Sequence Control the operator writes the program of the robot by choosing commands from those, given at the top of the screen. A menu bar with three options is placed at the top of the screen: File, Edit, Exec (Fig. 5)

Five buttons are placed at the bottom left corner of the screen. The button "Code" is used in order to be seen the code of the program. The button "Demo" gives the possibility of the operator to see several photos of the robot ROBY1. If the button "Video" is pressed, then the image from the camera of the robot will appear on the screen and the operator will obtain information for the environment, which is inspecting. The button "Clear" will remove the video image or the photos from the demonstration, and will clear the left half of the screen. The button "Steps" shows how many steps the program comprises of.

Fig. 4. The window of the regime "Basic Roby1 command description", when a button from the menu bar is chosen



a) b) c) d)

Fig. 5. The menu options of the Program Sequence (a, b, c) and Program Grid Control (a, b, d)

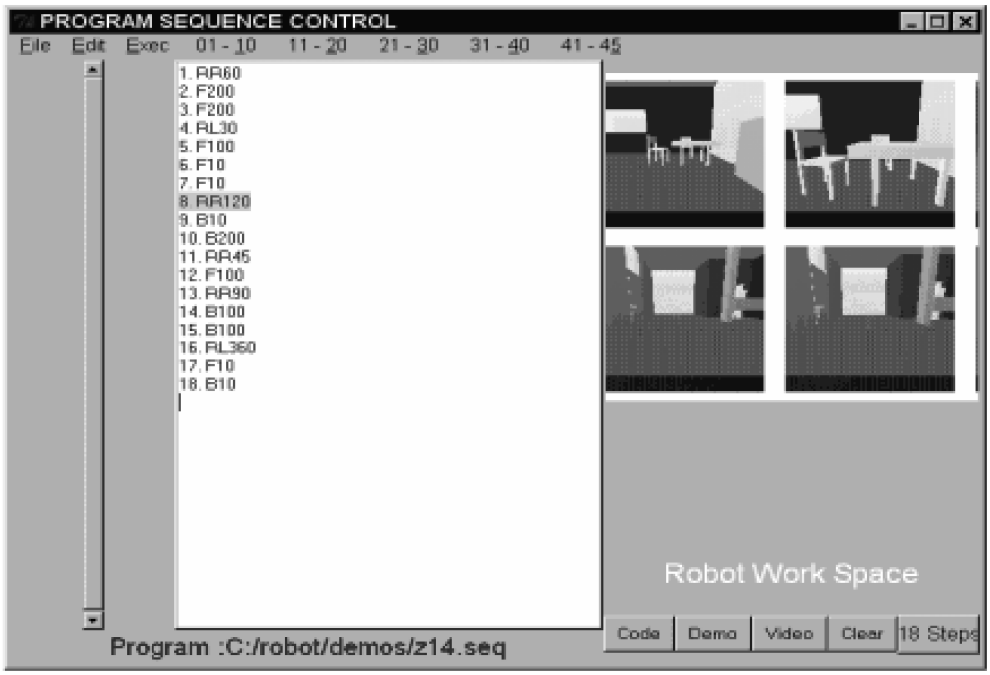


Fig. 6. A view of the screen when the Program Sequence Control is used

A grid comprising of 10 000 squares – 100x100 is available in the Program Grid Control and it gives the programmer the opportunity to write the programme of the robot only by clicking on different squares, which generates the path of the robot. The length of the sides of the squares is variable and can be changed from the menu “Step length”.

The program is compact and can be easily adapted a variety of remotely operated robots, due to the scripting language – Tcl. The whole program is about 100 KB (without considering the files with the video images of the robot, used for its presentation). The preliminary determined criteria for the development of this software application are fulfilled [6], because it is user-friendly, and there is an ease of access to all information, required for the control of the robot. No special training is needed for the operator, in order to start to work with the program. The application can be easily transferred form one computer to another as long as a standard hardware configuration is used for the installation of the program.

R e f e r e n c e s

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Полуавтономный нискокостуемый мобильный робот для исследований

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(Р е з ю м е)

Представлены некоторые аспекты развития мобильных роботов для исследований. Система роботов, которая дискутируется, предназначена для целей исследований и образования, но с некоторыми модификациями ее можно использовать и для практических целей реальной жизни. Внимание направлено к создании софтверной применении и подходящего интерфейса с потребителем для управления системы робота. Програма компактная и ее можно легко адаптировать к разнообразным дистанционно управляемым роботам благодаря языку Tcl, на котором написана. Рыночный потенциаль мобильных роботов огромный, но цель достичь нискую стоимость этих систем.