Orpheus – Universal Reconnaissance Teleoperated Robot

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Abstract. Orpheus mobile robot is a teleoperated device primarily designed for remote exploration of hazardous places and rescue missions. The robot is able to operate both indoors and outdoors, is made to be durable and reliable. The robot is remotely operated with help of visual telepresence. The device is controlled through advanced user interface with joystick and head mounted display with inertial head movement sensor. The functionality and reliability of the system was tested on Robocup Rescue League 2003 world championship in Italy where our team placed on 1st place.

1 Introduction

The Orpheus robotic system have been developed in our department from the beginning of year 2003. The project is a natural continuation of "mainly research" U.T.A.R. project [1], [2], [3] and is intended as a practically usable tool for rescue

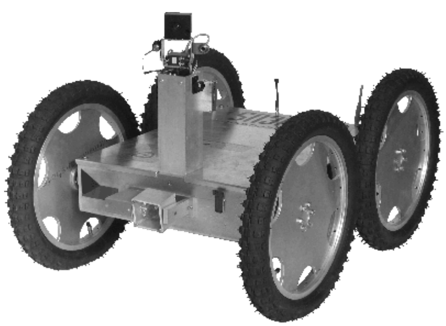

Fig. 1. Orpheus

teams, pyrotechnists and firemen. The Orpheus robotic system consists of two main parts: Orpheus mobile robot itself and operator's station.

D. Nardi et al. (Eds.): RoboCup 2004, LNAI 3276, pp. 491–498, 2005.

2 Mobile Robot Description

The robot itself (see Fig. 1) is formed by a box with 430x540x112mm dimensions and four wheels with 420 mms diameter.

The maximum dimensions of the robot are 550x830x410mm. The weight of the fully equipped robot with batteries is 32.5Kg. The mechanical construction of the robot is made by aluminium.

2.1 Locomotion Subsystem

Our department has developed a new Skid-steered Mobile Platform (SSMP) for the Orpheus mobile robot. The SSMP is intended to be both indoor and outdoor device, so its design was set up for this purpose. Another our important goal was to design the device easy-to-construct because of our limited machinery and equipment.

Finally we decided to make the platform like shown in Fig 2. The base frame of SSMP is a rectangular aluminium construction. Two banks of two drive wheels are each linked to an electrical motor via sprocket belt. The two drive assemblies for the left and right banks are identical but they operate independently to steer the vehicle. The motors can be driven in both directions, thus causing the vehicle to move forward, backward, right or left. Motors are equipped with incremental encoders and can be controlled either in velocity loop.

Two 24V DC motors with integrated incremental encoders and three-stage planetary gearheads are used.

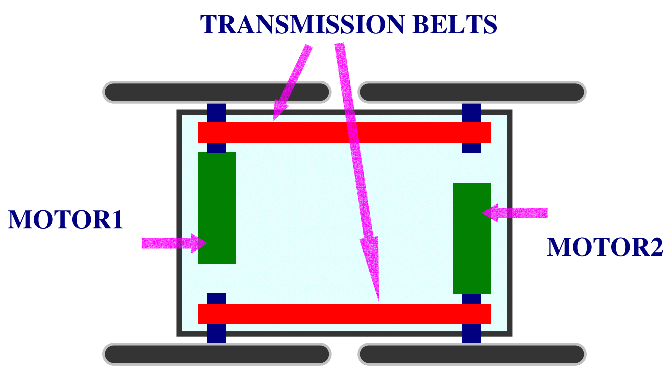

Fig. 2. Simplified Scheme of the Locomotor

2.2 Electronics

Most of the electronics is developed on our department. See Fig. 3 for a photo of the electronic subsystem of the Orpheus mobile robot.

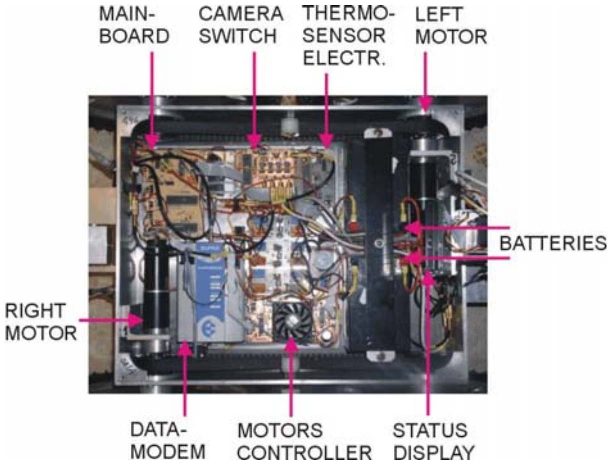

Fig. 3. Interior of the Orpheus

Microcontroller System

The Orpheus microprocessor system consists of 8 microcontrollers. Atmel AVR micro and Mega 8-bit RISC microcontrollers were used. The processors communicate by RS-232 serial interface using TTL levels.

Communication Processor - this processor serves to make an interface between ELPLRO datamodem and main processor. The main purpose of this processor is to transform the messages to and from the datamodem.

Main Processor - the main processor controls the whole system. It receives messages from the operator (through datamodem and communication processor). The architecture is master-slave, so the processor cyclically asks the other processors for the data.

Thermosensor Controller - the processor makes an interface between the thermosensor's RS-232 protocol and robot's internal RS-232 line. It is necessary because the thermosensor's protocol is too easy and has not any ID – responds to each message.

Servo Controller - this processor makes 6-channel standard modeller servo controller. The pulse-width may vary from 1.0 to 2.0 ms, is repeated each 20ms and may be set for each channel.

LCD Controller - four databit transfer mode for standard Hitachi LCD drivers is implemented in this microcontroller. The used LCD has four lines with 20 characters each, but the driver is universal and may be reconfigured for different LCDs.

Camera Switch and Analog Measurement Processor - Up to four cameras may be connected to the system. The camera switch board may switch among them. The processor also may be used for analog-to-digital conversion of various analog signals.

Motor Controllers - To control wheel velocities and direction a control and power switching board was developed. It consists of PID controller, H-bridge controller and full MOSFET H-bridge. There is one channel for each motor.

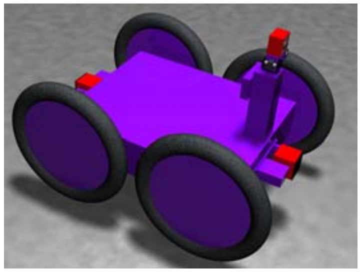

Fig. 4. Spatial Placement of Cameras

2.3 Sensory Subsystem

The robot contains three cameras. Their spatial placement is shown on Fig. 4. The main camera is on a sensory head. It has two degrees of freedom – may move left to right and up to down. The movements limits are similar to the ones of a human head.

The camera is a sensitive high resolution color camera with Sony chip. The other two cameras are black&white high-sensitive cameras with one degree of freedom. The front camera has IR light to work in complete darkness.

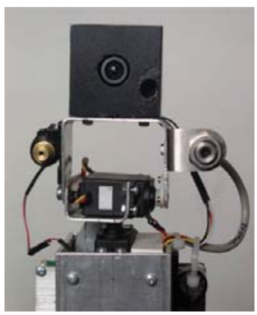

Fig. 5. The Sensory Head with Main Camera, Directional Microphone and Thermosensor

An infrared thermosensor Raytek Thermalert MID is used for object temperature measurement. The sensor provides three independent temperatures – the object temperature measured by IR, the sensory head temperature (the sensor measures the difference between temperatures in principle, so the derivation of this temperature is crucial to know if the measurement is precise), and the temperature of the electronics box, which we use to measure the temperature inside the robot. The thermosensor is placed beside the main camera and rotates with it (see Fig. 5). It causes the temperature of the object in the center of the camera picture is measured.

Standard walkie-talkie is used for one-directional audio transmission. One of two microphones displaced on the robot may be used during a mission.

The first one is integrated in the sensory head (see Fig. 5) and is directional. Since it moves with the main camera, the operator can hear the sounds from the direction he/she is looking to. The operator also may use the second – omnidirectional – microphone placed on the body of the robot.

We have made several experiments with two microphones and stereo audio perception on our older reconnaissance robotic system U.T.A.R. and we plan to use it on Orpheus as well, since it seems to be much more natural for the operator to have stereo perception similar to real-world than one omnidirectional microphone with perception axes parallel to the optical one.

It also seems to be very profitable to use electronically amplified microphones with user-variable gain.

2.4 Communication

Two independent devices are used for wireless communication with Orpheus: analog video transmitter for one-way video transmission and digital datamodem for bi-directional data communication between the robot and operator's station.

Fig. 6. Orpheus Operator's Station for Telepresence Control

3 Operator's Station

The operator's station for remote control of the mobile robot consists of several main parts: notebook, Imperx PCMCIA grabber, SAITEK Cyborg 3D Gold joystick, head mounted display: I-Glasses SVGA, INTERTRAX 2 headtracker – Intersense, Elpro Datamodem, video-receiver.

3.1 User Interface

The robot is controlled by operator with help of so called visual telepresence (see Fig. 6). The operator has a head mounted display with inertial head movement sensor. His/her movements are measured, transformed and transmitted to Orpheus. The user interface of Orpheus mobile robot system is programmed in C++ programming language under Microsoft Windows XP system.

The main advantage of the used user interface is that the digital data may be easily displayed over the video, so the operator does not need to switch among displays. The principle is that the added data are painted to small dark windows and these windows are blitted to the video image. The windows are semi-transparent, so the objects in video (or at least some of them) can be seen through the windows.

In the following text the small windows with additional data are called as displays.

Three main windows with different level of displayed data were designed. The full view, the quick view and the empty view.

Full View

All the accessible data are displayed on this display (see Fig. 7).

In the center part there is a Head Mounted Display Heading Display. This display shows the relative rotation difference between the camera and the body of the robot. This difference is derived from the operator's head movements.

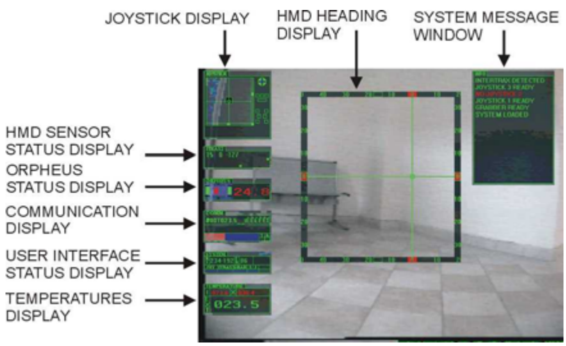

Fig. 7. Full view

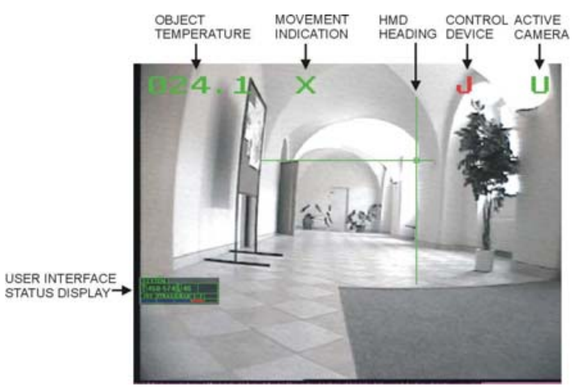

Fig. 8. Quick view

The System Message Window represents the system messages like overall system status, list of devices currently connected to the system (joysticks, grabber, etc.). This is a tool to show events that happen once rather than continuous display (as against all of the other displays). The data are expressed as a text messages that roll on an "infinity paper roll".

From our experiments and testing it became obvious the full view is too complicated for operator in most standard situations and the operator may become overloaded by the amount of not-so-important data. For this reason a more simplistic quick view was developed (see Fig. 8). It contains only the most important data needed for the operator: user interface status display, HMD heading cross, and several indicators.

4 Conclusions and Perspectives

The system proved to work reliably during five-days period of the Robocup 2003 competition. Although the operator (author) had not preceeding experience of the system's remote control (the whole system was constructed in less than five months and they was no time for training) the control by visual telepresence was precise and reliable. It may be said the operator has a good view of the situation in the robot's environment. The control of camera movements by operator's head proved to be both intuitive and reliable. The design of the user interface including the virtual HUDs placed over the video image in head mounted display seems to be a good way to display important digital data to operator.

The Orpheus robotic system will be significantly improved in future. The new version marked as Orpheus-X1 is already in progress. The improvements include mechanical construction (see Fig. 9), electronics and user interface.

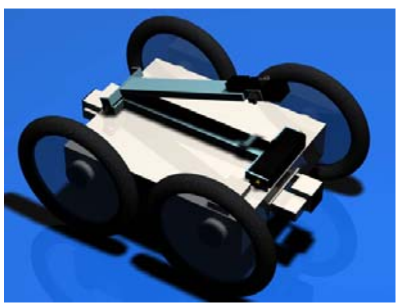

Fig. 9. Orpheus-X1with 2-DOF manipulator

Acknowledgement

This project was supported by the Ministry of Education of the Czech Republic under Project LN00B096.

References

1. Žalud L. (2001), Universal Autonomous and Telepresence Mobile Robot Navigation, In: 32nd International Symposium on Robotics - ISR 2001, pp 1010-1015, Seoul, Korea, April 19-21, 2001
2. Žalud L., Kopečný L., Neužil T. (2002), Laser Proximity Scanner Correlation Based Method for Cooperative Localization and Map Building, In: Proc. 7th International Workshop on Advanced Motion Control. Maribor, Slovenia: University of Maribor pp 480-486
3. Neužil, T.; Kopečný, L. & Žalud, L., Vision System of Universal Telepresence and Autonomous Robot, In: The 12th International Danube Adria Association for Automation & Manufacturing Symposium, pages 323-324, Jena, Germany, 24 - 27th October 2002, ISBN 3-901509-19-4
4. Wise, E., (1999). Applied Robotics, Prompt Publications, USA, ISBN: 0-7906-1184-8.
5. Everett, H.R., (1995). Sensors for Mobile Robots, Theory and Applications, AK Peters, Ltd., USA, ISBN: 1-56881-048-2.
6. Sheridan, T.B., (1992). Telerobotics, Automation, and Human Supervisory Control, MIT Press, Cambridge, USA.