RoboCup Rescue Robot League Competition
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TEAM: **RoBrno**
COUNTRY: **Czech Republic**
AWARD: **1st Place**

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Abstract— **Orpheus mobile robot is a teleoperated device primarily designed for remote exploration of hazardous environment and rescue missions. The robot is able to operate both indoors and outdoors, is made to be durable and reliable. It is small enough to pass through standard doors (is less than 60cms wide).**
The robot is remotely operated with help of visual telepresence. The robot is controlled by joystick and head mounted display with inertial head movement sensor. column.

***Index Terms*— Mobile Robot, Rescue Mission, Telepresence, User Interface.**

1 ROBOTIC SYSTEM DESCRIPTION

he Orpheus robotic system consists of two main parts:

- the Orpheus mobile robot
- operator's station

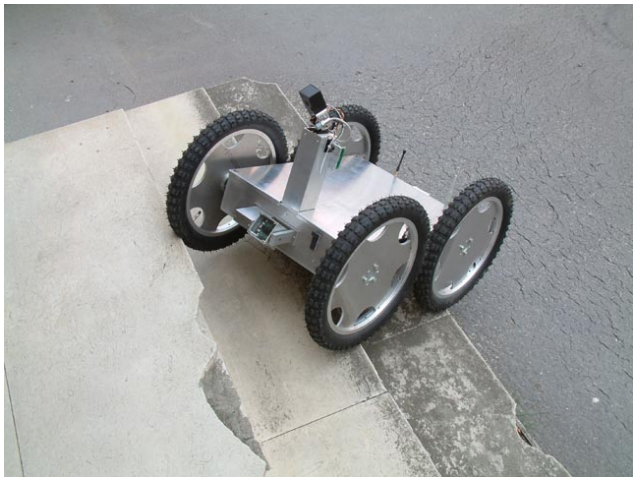

Figure 1: Orpheus

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2 MOBILE DEVICE DESCRIPTION

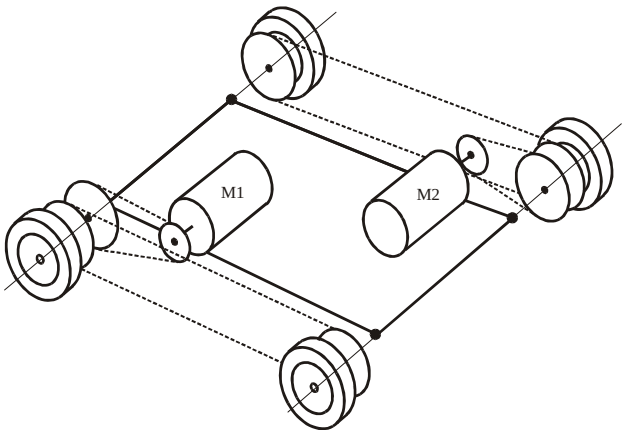

Figure 2: Simplified scheme of the locomotor

The robot itself is formed by a box with 430x540x112mm dimensions and four wheels with 420 mm diameter.

The maximum dimensions of the robot are 550x830x410mm. The weight of the fully equipped robot with batteries is 32.5Kg. The body and most of the inner parts of the robot are 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

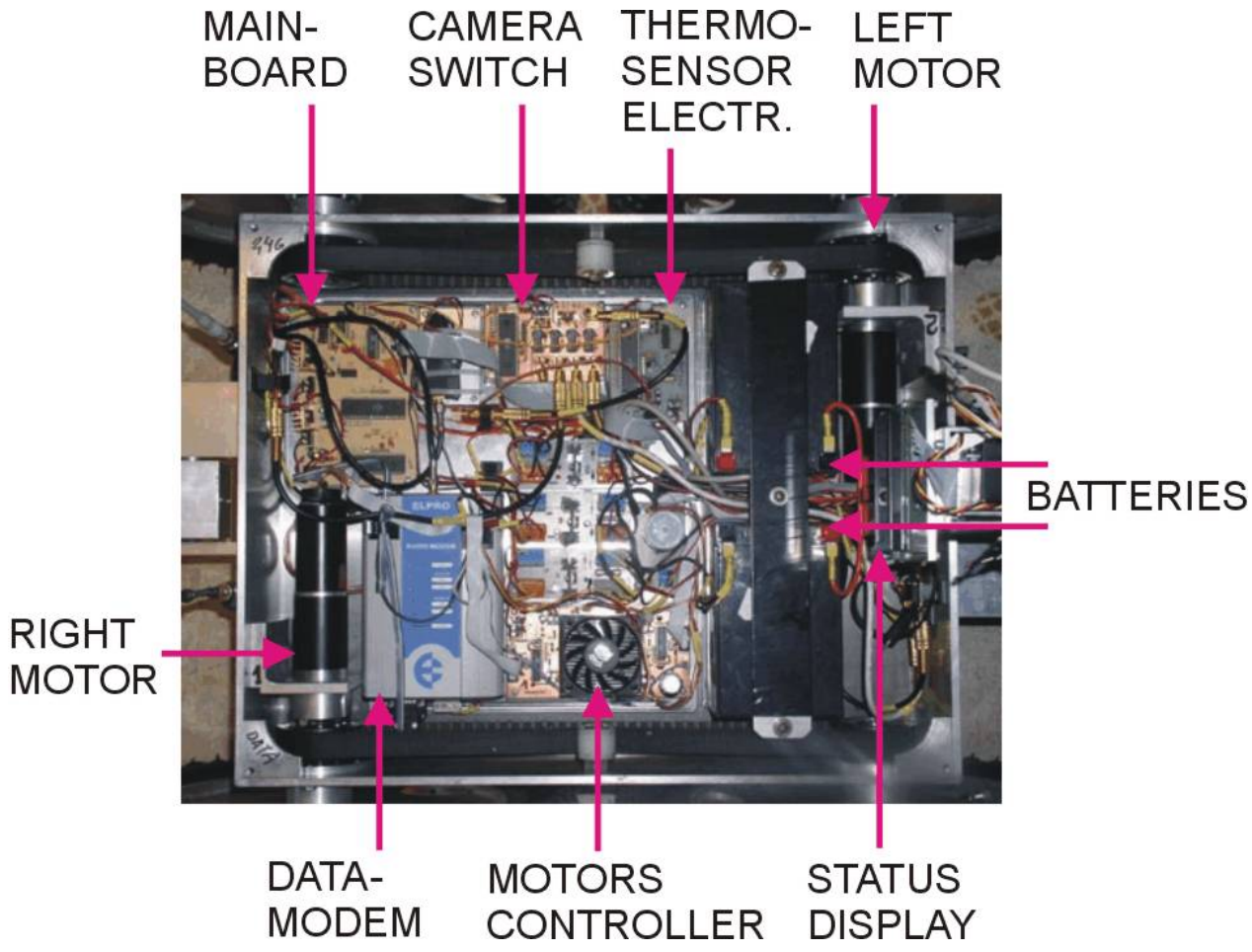

Figure 3: Interior of the Orpheus

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 in velocity loop.

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

2.2 Electronics

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

2.2.1 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.

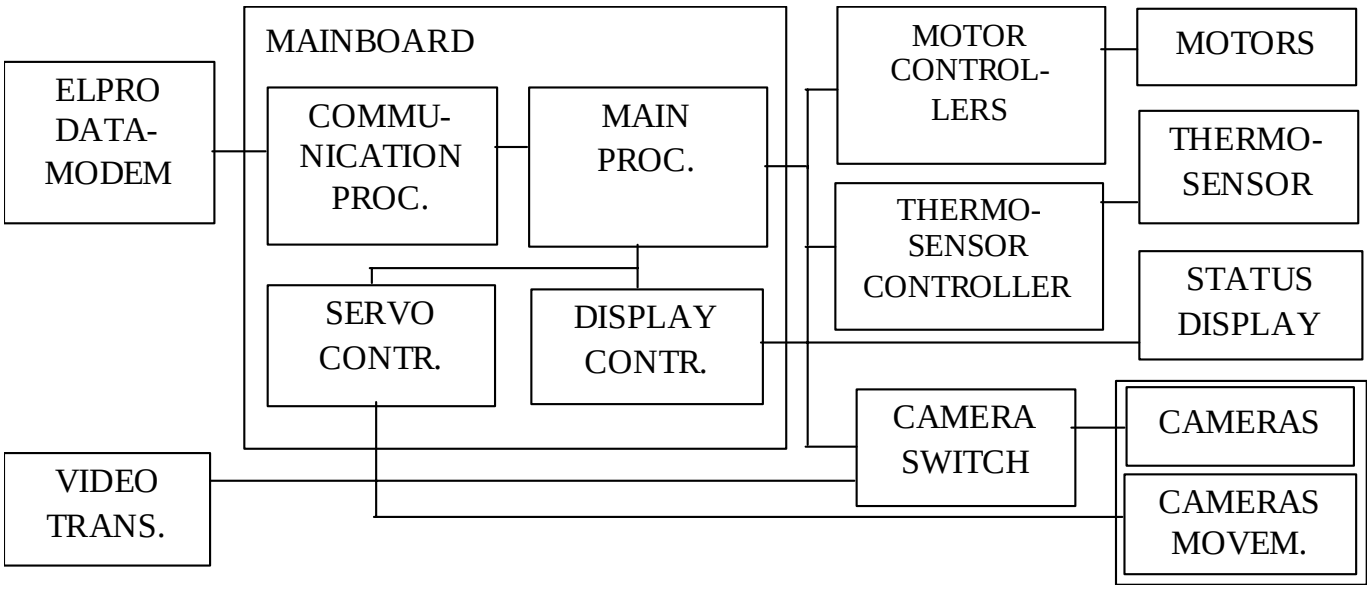

Figure 4: Electronics subsystem scheme

The processors used:

- ATMEL AT90S2313
  - servo controller
  - LCD display controller
  - two motor controllers
- ATMEL AT90S8535
  - camera switch and analog measurement
- ATMEL ATMega161
  - main processor
  - communication processor
  - thermosensor controller

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. The messages going through the wireless channel are more safe, but longer – contain checksum, device id, etc. The processor also detects errorneous messages and will not send them further to the main processor.

Main processor:
The main processor controls the whole system. It receives messages from the operator (through datamodem and communication processor). It communicates with the other processors in the system by RS-232 based serial protocol. The architecture is master-slave, so the processor cyclically asks the other processors for the data. The processors are differentiated by processor IDs.

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. The communication speed of the thermosensor's electronics is also different.

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 display 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. The microcontroller also controls the LCD backlight by PWM.

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 switching time is about 3 miliseconds. The processor also may be used for analog-to-digital conversion of various analog signals. It contains 8-channel 10-bit A/D converter. Currently it is used only to measure the voltage of the main batteries.

Motor controllers:
To control wheel velocities and direction a control and power switching board was developped (see Fig. 5). It consists of PID controller, H-bridge controller and full MOSFET H-bridge. There is one channel for each motor.
The PID controller is implemented in 8-bit microcontroller, it reads and processes the motor encoder signals, reads serial input line, computes controller output, ramp limitation and directly drives H-bridge controller by generated PWM signal. On the other side the microcontroller receives from the H-bridge driver information about under-voltage and over-current.

The H-bridge driver, except of driving of power MOSFETs, senses the input voltage and motor current and switches the MOSFETs off in case of exceeding of given limits.
The full N-MOSFET H-bridge consists of four discrete TO-220 packed N channel MOSFETs placed on a common insulated cooler. The maximum continuous current of the bridge is 30 A.

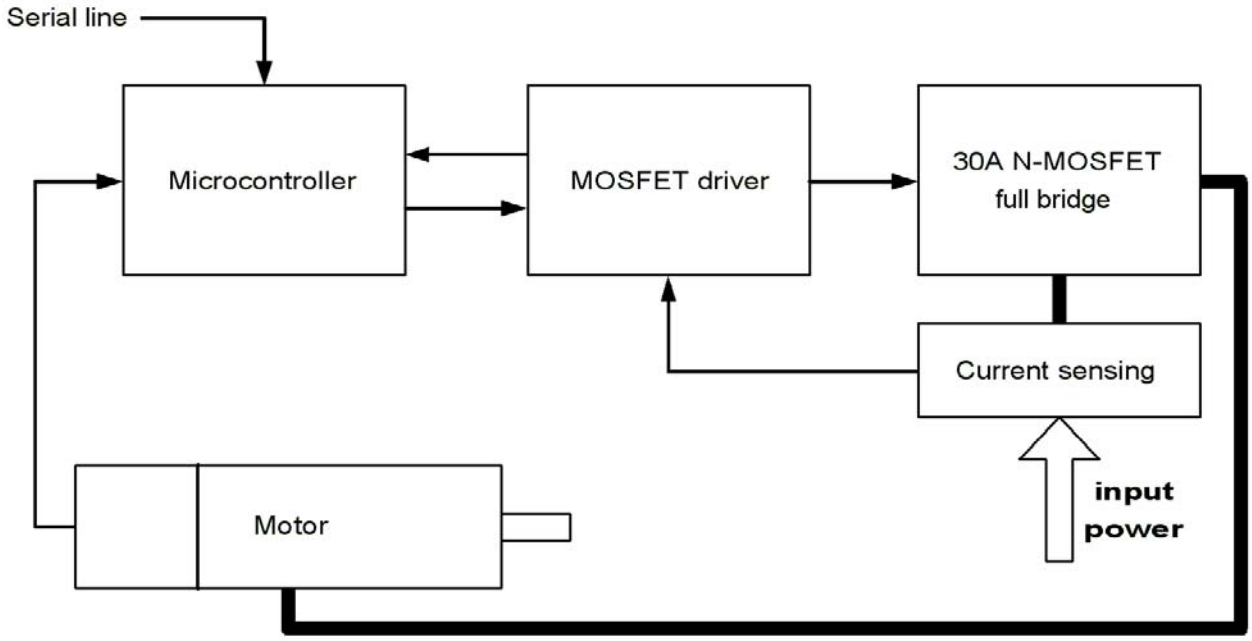

Figure 5: Block diagram of control and power switching board

2.3 Sensory subsystem

The robot contains three cameras. Their spatial placement is shown on Fig. 5. The main camera (1) 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 cameras (2) and (3) are black&white sensitive cameras with one degree of freedom. The front camera (2) has IR light to work in complete darkness.

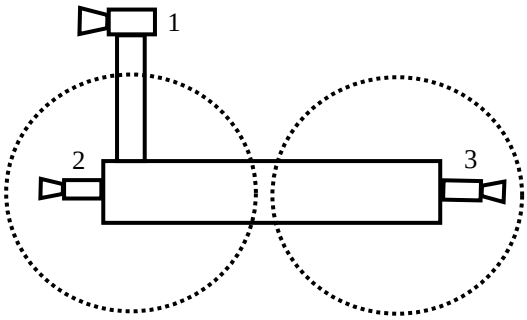

Figure 5: Spatial placement of cameras

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. 6). 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. Although a directional microphone is present on the sensory head it was not used in the competition, because of the high sensitivity of the microphone and too high noise level in the competition area.

2.4 Communication

Two independent devices are used for wireless communication with Orpheus:

Elpro Datamodem:

- frequency: 869.525MHz
- output power: 0.5W
- maximum communication frequency: 76KBit
- power requirement: 12-30V DC or AC

Video-transciever: manufacturer unknown:

- frequency: 2.4GHz
- fine frequency selection by a trimmer

power requirement: 9-12V DC.

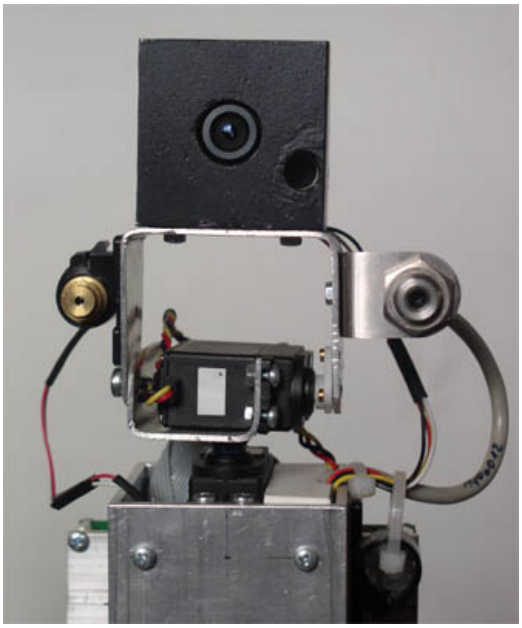

Figure 6: The main camera with thermosensor

3 OPERATOR'S STATION

The operator's station for remote control of the mobile robot consists of several main parts:

- notebook computer with PCMCIA video-grabber
- joystick
- virtual reality head mounted display
- headtracker
- Elpro datamodem
- analog video receiver

The notebook – standard ACER TravelMate 260 computer:

- 1GHz Pentium III processor
- 256MB RAM
- 20MB HDD
- 14'' LCD

The operating system of the notebook is Microsoft Windows XP Home Edition

Imperx PCMCIA grabber:

- resolution up to 640x480
- framerate up to 30Hz

- NTSC, PAL
- up to 24-bit colors
- Brightness, Contrast, Saturation control
- SDK included free of charge

Joystick – SAITEK Cyborg 3D Gold:

- USB - digital output
- optical technology
- 4 analog axes
- for both left and right-handed
- 10 programmable buttons
- 8-dirctional HAT switch

Head mounted display: I-Glasses SVGA

- 800x600 pixel resolution
- 60Hz refresh frequency
- 12V DC

Headtracker – Intersense INTERTRAX 2

- 3 measured degrees of freedom
  - pitch ±80°
  - yaw ±180°
  - roll ±90°
- maximum angular rate: ±720°/sec yaw, ±360°/sec roll
- minimum angular rate: ±3°/sec
- angular resolution: ±0.02°
- internal update frequency: 256Hz
- HID compatible
- USB output

Elpro Datamodem:

- frequency: 869.525MHz
- output power: 0.5W
- maximum communication frequency: 76KBit
- power requirement: 12-30V DC or AC

Video-receiver: manufacturer unknown:

- frequency: 2.4GHz
- 8 jumper-selectable channels
- power requirement: 9V DC, 500mA

The operator's station needs 230V AC to supply the devices.

3.1 User interface

The robot is controlled by operator with help of so called visual telepresence. The operator has a head mounted display with inertial head movement sensor. His/her movements are measured, transformed and transmitted to Orpheus. The camera makes almost the same movements like the operator's head and since the operator can see the picture from it, he/she feels to be in the place where the robot is. The movements of the whole robot are controlled by joystick (see Fig 8).

Figure 8: Orpheus control with joystick and head mounted display

The user interface of Orpheus mobile robot system is programmed in C++ programming language under MS Windows system. It uses Win32 and GDI functions. All of the input-output devices are manipulated by standard Windows (mainly Win32) functions, only the Imperx VideoGrabber uses SDK provided free-of-charge by the card manufacturer.

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.

The full view (see Fig. 9):
All the accessible data are displayed on this display.

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. The display seems to be a very important tool for the operator, since in

many situations there is no other evidence of the head-to-body

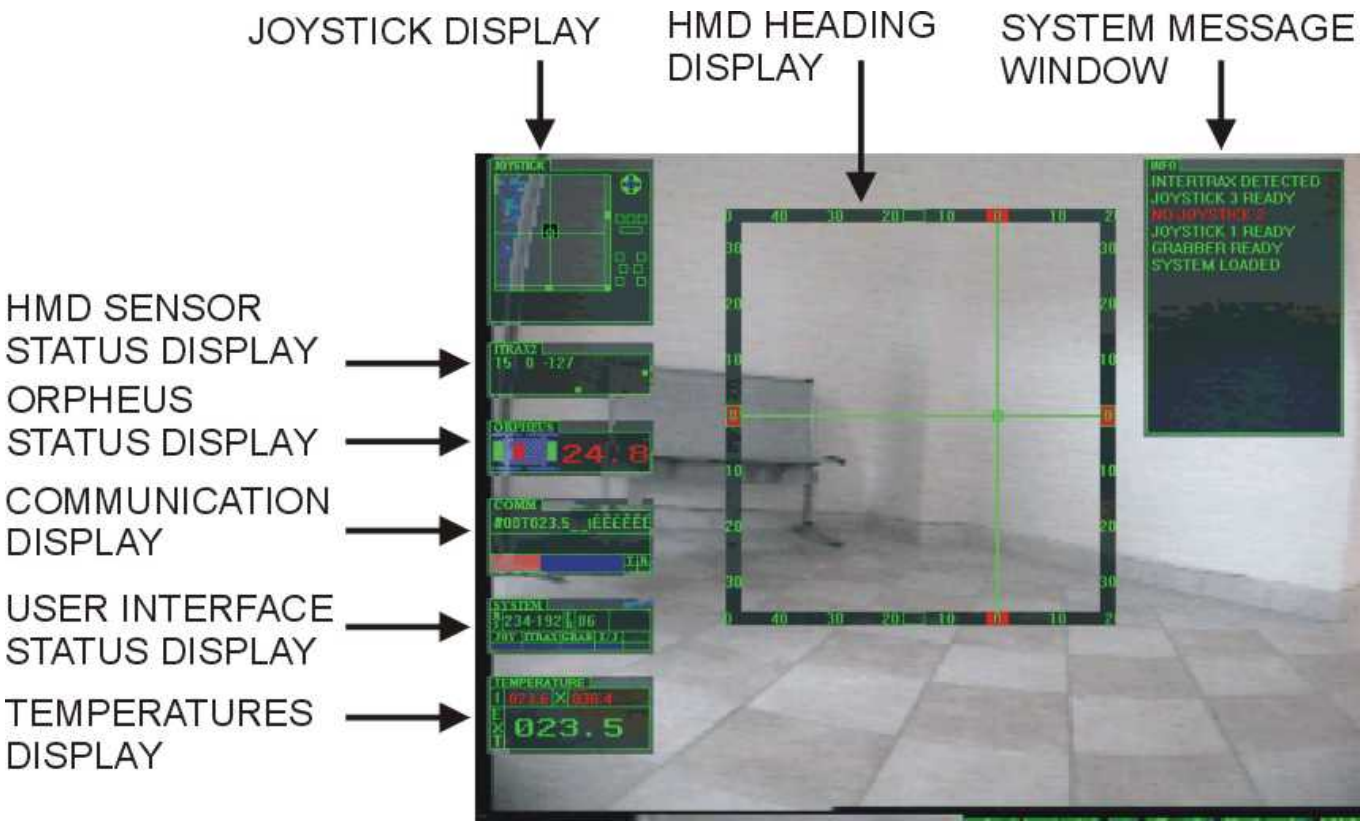

Figure 9: Full view

relative rotation. The cross in the center of this display serves to show the rotation roughly, the exact position may be read from the numbers around it.

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". Different colors are used for different message significance level.

The series of small displays on the left side of the screen will be described now (from the upper to the lower):

- **joystick display** – shows the status of the main joystick. It shows the actual position of the joysick, the pressed buttons, hat and throttle position. It may also display the precomputed motor speeds. If the joystick is not connected or is not working properly, the red warning message is displayed and zero motor speeds are set up,
- **hmd sensor status display** – this display shows the Intertrax head position sensor status and measurements. The data are displayed in the form of numbers (in degrees), graphical representation of the data is also provided. If the Intertrax is disconnected, red warning message is displayed and zero values are transmitted to the robot. If this happen, the camera movements may be controlled by the joystick (the joystick, in general, may control all of the accessible functions of Orpheus – so no other device is needed),
- **communication display** – is not completely implemented. Currently it shows only the received decoded messages, so the operator can see that the robot is on-line and responds. It also may show the message statistics,
- **user interface status display** – shows the current status of the user interface. The video resolution, and actual framerate are displayed in the form of numbers. In the lower part of the display there are

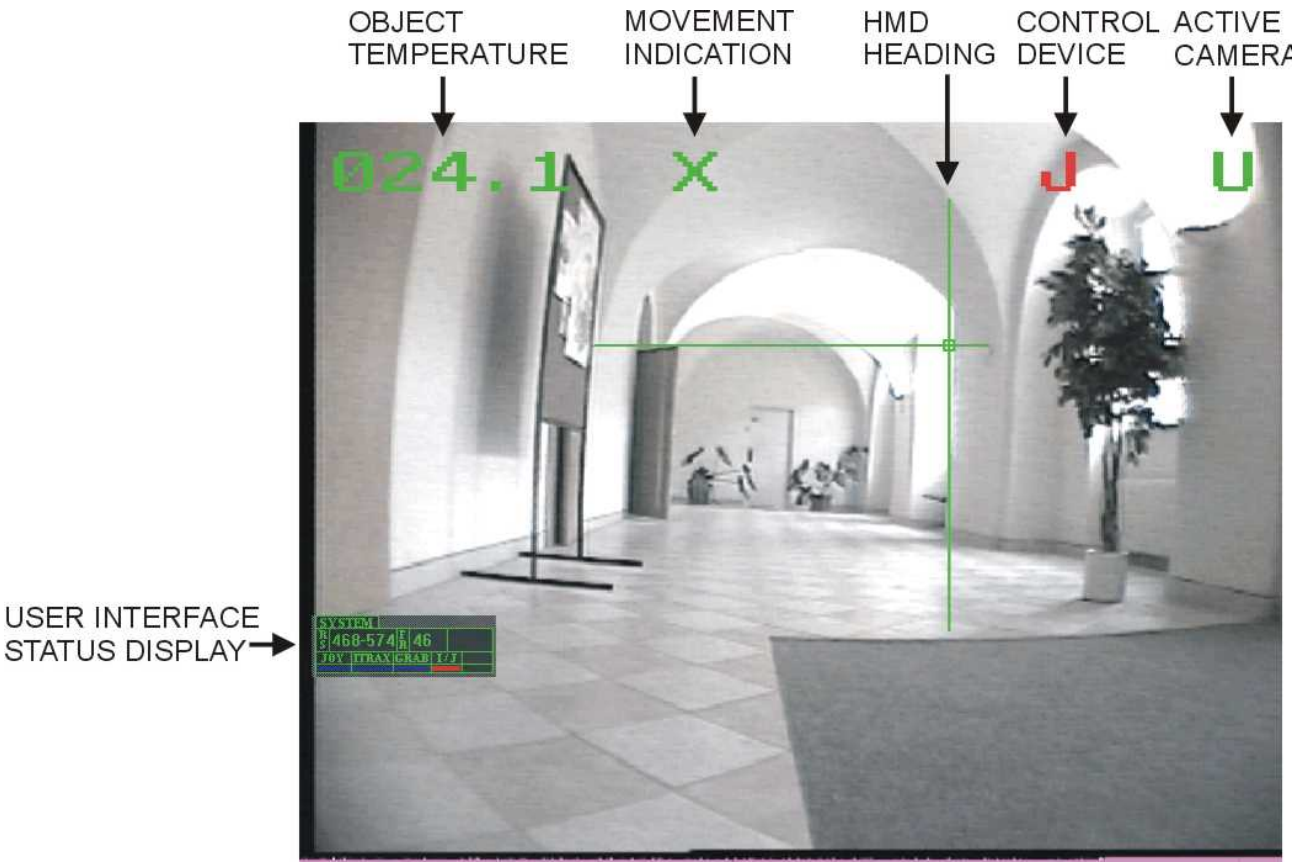

Figure 10: Quick view

three LED-like displays showing if the joystick, HMD-sensor, grabber are connected. The last LED shows the type of control,

- **temperatures display** – in the central part there is an object temperature measured by the infrared sensor. In the upper part there is an ambient temperature (temperature of air) and the temperature inside the robot.

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. 10).

It contains only the most important data needed for the operator: user interface status display, HMD heading cross, and several indicators.

The indicators (from left to right):

- **object temperature indicator** – shows the temperature of distant object measured by Raytek sensor in degrees,
- **movement indicator** – informs the joystick is off the blind area and a signal to move is transmitted to the robot,
- **control device indicator** – informs the operator which of the control cameras movement control devices are currently selected as active – Intertrax 2 or joystick
- **active camera indicator** – shows which of the three cameras is active