EDURO - Mobile Robotic Platform For Education

Martin Dlouhý
Faculty of Mathematics and Physics
Charles University in Prague
Malostranské náměstí 25, 118 00 Praha 1
Czech Republic
md@robotika.cz

Jan Roubíček
RobSys Czech Republic
jr@eduro.cz

Tomáš Roubíček
RobSys Czech Republic
tomas.roubicek@robsys.cz

***Abstract*—Eduro is a modular mid-size mobile robotic platform designed as both a teaching tool for higher education and a research platform for academia and industry. In this paper we describe the technology used within the Eduro (indoor) and Eduro Maxi HD (outdoor) product lines. Both platforms are designed around a tricycle base with two differentially driven wheels and one caster wheel. The on-board electronics consists of smart sensors and actuators connected by a CAN bus. The main controller module is implemented as a single board x86-based computer running Linux OS. This platform participated in several competitions including Eurobot, RobotChallenge and Robotour.**

Keywords: education robot, mobile platform, CANopen

I. Introduction

Eduro is a generic robotic platform intended for education and research. It was initially created as a teaching tool for Charles University, Prague in 2007, further development has continued independently at the initiative of the development team. At that time, none of the commercially available robots met the low cost/high performance requirements posed by the University's educators.

The Eduro platform is a successor of older platforms Berta, Daisy and Explorer. Berta - a triangle-shaped robot with vacuuming extension - won the 1st Annual Cleaning Contest in 2002, Lausanne, Switzerland [1]. The same triangular base was used in Daisy, a robot which ranked 7th at Eurobot 2003 in La Ferte Bernard, France [2]. Finally, the outdoor prototype Explorer - a 4-wheel waterproof robot - was demonstrated on Robotour 2006 in Prague [3].

The basic idea was to develop a platform that is highly modular on three levels: mechanics, electronics and software. The mechanics is designed as a construction kit with numerous mounting holes with pressed nuts. The electronic is based on a set of independent modules connected via a CAN bus. Finally, the low-level software modularity is achieved through the CANopen protocol and high-level modularity is facilitated through Player devices.

This paper is structured as follows: Section II describes the hardware platform in more detail. Section III outlines the software. Finally, examples of various configurations are provided in Section IV.

II. Hardware

A. Mechanics

The base of the robot is a construction module that includes the battery and motors. Modules such as the caster wheel or the control panel with buttons and indicators are attached to the base. These modules are made from aluminium profiles and sheets and have many mounting points for simple extending.

The Eduro is not waterproof by default but outdoor versions can be optionally sealed against dust and water.

Rugged plastic wheels are used in the indoor robot design. Such wheels have very good contact properties while they are still sufficiently sturdy for reliable encoder measurements. In outdoor scenario we tested two sets of wheels. The first approach involves smooth inflatable wheels with shallow tread pattern as demonstrated in Field Robot Event 2010 in Germany. These wheels were found suitable for park roads and other easy terrain. The second option utilizes arrow shaped wheels commonly used for small ploughing tractors. These wheels are recommended for rough terrain. They performed very well on muddy terrain when tested on RoboOrienteering contest. In the case of uneven surface with steep slopes, 4-wheel-drive configuration becomes a necessity.

B. Drive

Current members of the Eduro product line use SMAC (Stepper Motor - Adaptive Control) drives. This is original Robsys technology for gearless drives, which are based on closed loop controlled stepper motors. The motors are attached directly to driven wheel for indoor robots (Eduro) or by simple belt transmission for outdoor robots (Eduro Maxi HD). This gearless solution is very durable and easily withstands operations by unexperienced students.

Simple speed control with interpolation is presently used. The control system sends speed commands periodically, speed is represented by a 16bit signed integer, where 1000 corresponds to one shaft rotation. The drive sends back an encoder value - 32bit signed integer, where 65536 means one revolution of the motor. The drive has preset software limits for maximal acceleration and speed. Smooth motion can be obtained for speeds between 1 cm/s to 2 m/s given 150 mm wheels (diameter). It is recommended to maintain continuous flow of speed requests such that the wheels remain in permanent

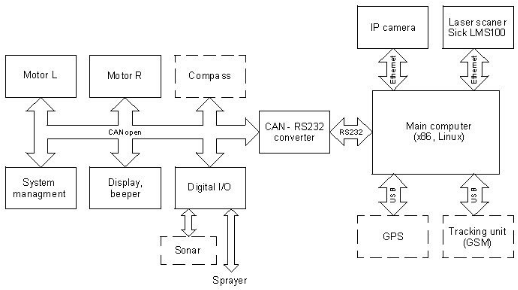

Fig. 1. Hardware structure

contact with the ground. The drives have implemented a communication watchdog which stops motors if speed command is not received within a predefined period.

C. Processing Power

The brain of the robot is a single-board computer running Linux OS. The computer is equipped with AMD Geode CPU running at 500 MHz, 256 MB RAM, compact flash card, wi-fi, 3 Ethernet, 1 RS232 and 2 USB ports. RS232 port is dedicated for CAN bus connection via transparent RS232-CAN bridge. High data throughput without data loss is secured by real-time serial driver.

D. Communication network

The Eduro uses CAN bus as its main communication network. All sensors and actuators with low data rate requirements are connected through the CAN. CANopen is the preferred communication protocol but other proprietary protocols can be used as well. CANopen is widely used in industry and hence many available sensors are directly compatible.

Cameras, laser range finders and other sensors with high data throughput are connected directly to the main computer via Ethernet or USB. Except for CAN and Ethernet, I2C and 1-wire Dallas buses are used in robots. I2C is a widespread interface for low-cost sensors, therefore it is supported. However I2C is not designed for large distances (I2C = inter-integrated circuits), therefore it is used only for short local buses. The 1-wire is used for a diagnostic network and advanced power management. Distributed power switches, thermometers, battery chips and other simple sensors and modules are connected via the 1-wire bus. I2C and 1-wire bus are connected to the CANopen network through the gateways.

E. Energy source and power management

The power supply is provided by sealed lead acid batteries. The outdoor version Eduro Maxi uses two 12 V/8 Ah batteries while for smaller indoor robot one third of the capacity is sufficient. The whole robot uses a single power source to simplify management. The motors are powered from 24 V supply branch, directly from batteries. The main computer, CAN network and most of sensors are powered from a stabilized 12 V branch. The auxiliary 5 V power supply is present for simple connection of the low cost sensors.

A standard off-the-self charger allows continuous charging while the robot is in operation (e.g., code debugging). When compared to other platforms it allows several hours of autonomous operation and swapping batteries is usually not necessary although it is possible.

An important part of any mobile robotic platform is power management. Energy is a limited resource and thus it needs to be monitored regularly. Two level power management is used in robots. The base is a standalone electronics providing basic function as charging, voltage monitoring and power distribution. An optional module is connected to the CAN bus and adds remote monitoring and advanced functions. The module sends messages about system voltages, temperatures and other important information. When the voltage falls below the given threshold, temperature rises or other exception occurs, the module can automatically blink LEDs, turn on the beeper or even turn off motors independently on the main computer. The thresholds as well as the consequent actions can be preconfigured from the control software via CANopen. RF remote key is an invaluable accessory to the power management module and allows the operator to turn the robot off in case of an emergency.

F. Sensors

This section describes sensors which are used in robots and are connected via the CAN bus. A robot often includes other sensors such as cameras, laser range finders, a GPS unit, etc. These sensors are connected directly to the main computer via Ethernet or USB.

1) Compass: A compass is a part of the inertial unit. Currently, we use a two-axis compass HMC6352 from Honeywell. It is a one chip solution with I2C bus, however the chip is not visible from CAN. The data from compass and other sensors are periodically polled by the CAN module, processed and only then forwarded to the central unit. The azimuth readings from the sensor are converted into 1/100th of degree and sent over CAN bus as 16bit integer. The update rate is 20 Hz.

The sensor itself is represented as one of the layers in the ”sandwich” of inertial unit, other layers can include an accelerometer or a gyroscope. The HMC6352 is only a two-axis magnetometer, therefore tilt compensation is not possible. We plan to integrate a three-axes magnetometer to facilitate tilt compensation in the future.

The inertial unit including the compass is mounted on top of the pole away from sources of magnetic fields and ferromagnetic objects. The module itself is covered by a plastic case and no steel parts are used. During experiments we observed substantial changes in sensor readings caused even seemingly minor attachments to the pole such as a small umbrella, therefore caution is needed. A presence of ferromagnetic objects can be compensated by the system but that requires recalibration and usage of non-linear transformation.

2) ”Sharps” distance sensors: ”Sharps” distance sensors are cheap IR triangulating sensors for distance measurement. They are often used for obstacle detection and simple navigation in indoor. They have an analog or binary outputs with various operation ranges. The analog or binary signal is routed to universal CAN I/O module SC-DM04. This module has four analog or digital inputs and four digital outputs. The module can have additional function, for example outputs for RC servos or switch array decoder.

3) Sonar: Sonar is another sensor which can be connected via the universal I/O module SC-DM04. With special firmware the module behaves as a pulse decoder coming from sonar. The decoder accepts the SRF05 module from Devantech or compatible. There is also the option to connect the sonar with I2C interface via I2C to CAN gateway.

4) IR beacons: IR beacons were originally designed to facilitate precise robot navigation into the docking station but they can be used for wide variety of other applications. The transmitter consists of a circular IRED array. It transmits coded omnidirectional signal. The beacon has selectable code and signal intensity.

The receiver is also of circular shape with IR photodiodes attached on the perimeter. It can evaluate distance and angle for up to four beacons. The angle is calculated from the ratio of photodiodes currents and distance from intensity. Angular precision is 2-3 degrees and intensity corresponds to logarithm of distance in approximately 32 steps. The readings are reliable in most environments up to 3 meters.

The IR beacon system was tested both indoors and outdoors. It was presented at Eurobot 2009 as a sensor for absolute localisation on the playground and for opponent detection. Outdoor application was demonstrated at Robotour 2008. The set of one transmitter and two receivers facilitated reliable robot colony guidance. The following algorithm was actually simple enough so one of CAN modules was used for the control.

5) Bumpers: Robots often require various bumpers for object and collision detection. There are several options. The simplest one is set of micro-switches connected to digital I/O module. The status message is sent immediately after change (with limited frequency), and regularly once every second.

Another option is to use digital sharps. They are contactless sensors with detection range of 5 cm and 10 cm. The output is again digital and is handled the same way as with micro-switches.

6) Other modules: The set of available sensors and actuators is much wider and grows over the years. Among those not mentioned is a thermometer which is useful for gyro offset compensation and as a guard for battery charging. A light gate can be configured together with a servo module for automatic gripper action. Ultra bright LEDs can provide light for a camera in darkness[1].

G. User Interface

Eduro has a simple user interface, primarily used for Eurobot contest. There is a set of color LEDs, a selection switch, an easily accessible emergency stop button, recently an alphanumeric display and a beeper were also added.

[1]Used in robot Explorer in pipe investigation task

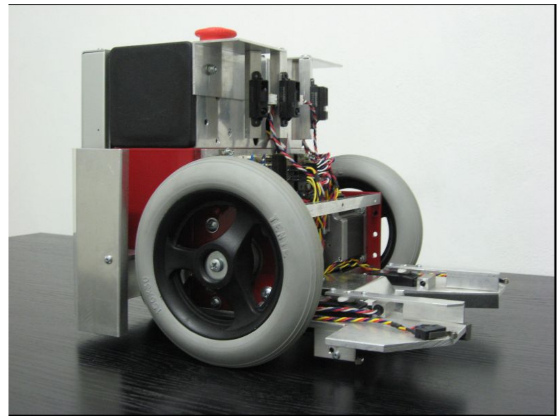

Fig. 2. Eduro prepared for Eurobot 2008 contest

The emergency stop feature deserves an extra note. Eurobot contest rules require that in case of an emergency pressing the emergency button disconnects all powered components - typically drive motors - from the power source. In reality, this simple solution would not stop the robot due to inertia. The implemented algorithm first sends stop commands to motors and shortly after that it disconnects the power. This solution at least slows down the robot.

III. Software

Application software can communicate with the base platform on several levels. The most commonly used include high-level standard Player interface and low-level direct access to CAN bus via RS232-CAN bridge. Another option is to leverage the set of Python library modules and functions which can be used for quick prototyping and was successfully used in most of this year's contests (see section with presentations).

A. Player

The Player/Stage (P/S) project [4], [5], [6] has been hosted on sourceforge since 2001 and it has become a de-facto standard interface for mobile robotic platforms. P/S is an open source project that originally targeted Active Media robots. However, the current set of supported platforms and devices is much larger, mostly thanks to the open source nature of its distribution which allows it to be easily extended to new machines.

The Eduro platform started supporting Player 2.1 in 2008 due to the interest from the development team members and collaborators who were familiar with this system from their work on other projects. Even though some of these contributors stopped using this system and moved to proprietary Python code due to problems with binary incompatibility between versions and bugs in even simple tools, we plan to support Player 3.0 on all Eduro platforms.

B. Pyromania

While it may seem unwise to build robotic control around a scripting language like Python, we found this approach to

Fig. 3. Eduro on Robot Challenge 2009 contest

be quite appropriate and plan to keep leveraging it for even larger and more complex systems.

The time-critical control routines in Eduro are implemented through dedicated CAN modules. Computationally intensive tasks such like image processing can run in separate threads using Python's binding to OpenCV [7] or, if necessary, in separate programs written in more efficient languages (e.g., the C language). Even in these scenarios, Python remains present in its role of the integration language.

One of the major features, which Player lacked[2], was simple portability between Windows and Linux operating systems. We developed code for both platforms since limiting ourselves to only one would limit its appeal to potential users.

C. Direct control

The lowest level of robot control can be realized via direct access to CAN bus through serial line and RS232-CAN bridge. Programming on this level requires basic knowledge of CAN and CANopen protocols respectively as well as familiarity with detailed specification of incoming and outgoing messages for all modules.

IV. Configuration Examples

A. Eurobot

Eurobot [8], [9] is an annual international indoor competition for autonomous robots. Robots compete in solving a specific task that differs year to year but generally involves reaching certain goals within an operating space of about $2m \times 3m$ and within 90 seconds time limit.

The Eduro platform participated in three Eurobot events using the same base but varying mechanical attachments designed for that year's specific tasks. In "Mission to Mars"-themed event in 2008, this attachment was an automatically-triggered gripper. This gripper was implemented using servos, a lightgate module connected to the CAN network using bumpers, digital Sharps distance sensors (boundary detection) and analog distance sensors (feeder and opponent detection).

In 2009, the task involved building "temples". That year the attachment was a simple passive plowshare while an IR

[2]Player 3.x was already fully ported to Windows OS.

Fig. 4. Eduro Maxi HD on Field Robot Event 2010

beacon system was used for opponent detection. The same system was also used for global Monte Carlo Localisation via triangulation.

In "Feed The World"-themed event in 2010, the Eduro platform was equipped with a ball collector in front of the robot. The previously used modules were enhanced with a beeper and an alphanumerical display. The beeper was used to generate acoustic warnings in case of inconsistency between localisation detected by the beacons and the color of the team. The alphanumerical display was used to show the selected strategy.

B. Robot Challenge/Puck Collect

Videos showing Eduro's participation in Robot Challenge 2009 and 2010 contest [10] in Vienna are available. This event's theme and rules stay the same every year. The Eduro platform fits best in the "Puck Collect" category. In this competition, the goal is to collect red and blue pucks scattered around a white playing field ($2.8m \times 2.8m$) and carry them to the "home base" (colored squares $0.7m \times 0.7m$ located in opposite corners).

Eduro was equipped with a U-shaped passive collector so pucks were collected when the robot moved forward or turned in place. Dropping the pucks was implemented through backup motion. IP security camera with wide fish-eye lens was used for color recognition. Finally, long range Sharps (1.8 m) were sensing the border of the playground and also facilitated localisation services.

C. Field Robot Event

The outdoor version of Eduro (Eduro Maxi HD) participated on several outdoor competitions. In Field Robot Event [11] held in 2010 in Brawnschweig, Germany the robot was expected to perform various farming-related tasks in a mature corn field. The robot was equipped with an IP camera, LMS100 laser scanner, a compass, a GPS unit and other modules previously used in indoor competitions (e.g., beeper, display, user panel). A sprayer was connected to Eduro Maxi with a 3pin connector. Two logic outputs independently

Fig. 5. Authors and Eduro Maxi HD on RoboOrienteering 2010

controlled the spraying operation on the left and right of the robot.

For freestyle part of the event, the robot was equipped with a VTU10 tracking unit on loan from MapFactor [12] which in addition to tracking also facilitates two-way communication via a GPRS modem. The unit was attached to the robot via an USB port through which it accepted remote commands (GPS waypoint where the robot should autonomously navigate).

D. RoboOrienteering

A week after the Field Robot Event the same robot participated in RoboOrienteering event [13] in Rychnov nad Kněžnou, Czech Republic. This contest is similar to better known Robo-Magellan [14]. In both cases, the robots receive GPS coordinates for the starting point, waypoints and the end point and are expected to autonomously travel through the terrain between these points.

For this event the Eduro platform was equipped with tractor tires. Sonar was added in order to achieve better obstacle detection of benches and low placed tree branches.

V. Summary

In this paper we introduced Eduro, a robotic platform designed for education and research. Its modular design was proven successful through high rankings in numerous international competitions - 1st place in Professional Task of Field Robot Event 2010, 2nd place in Puck Collect at Robot Challenge 2009, or 2nd place in Czech Eurobot National Cup 2010. The Eduro platform has attracted enough interest for us to start its serial manufacturing planned for the end of 2010.

References

[1] Cleaning contest, "1st International Contest For Autonomous Cleaning Robots," http://www.service-robots.org/applications/cleaning.htm, 2002.

[2] Daisy, "quarter-finalist of Eurobot 2003," http://robotika.cz/robots/daisy, 2003.

[3] robotika.cz, "Robotour 2006 - robotika.cz outdoor challenge," http://robotika.cz/competitions/robotour2006/, 2006.

[4] Player/Stage, "device interface and simulator," http://playerstage.sourceforge.net/, 2001.

[5] Brian P. Gerkey, Richard T. Vaughan, Andrew Howard, "The Player/Stage Project:Tools for Multi-Robot and Distributed Sensor Systems," *Proceedings of the International Conference on Advanced Robotics (ICAR 2003)*, June 2003.

[6] Richard T. Vaughan, Brian P. Gerkey, "Really Reusable Robot Code and the Player/Stage Project," *Software Engineering for Experimental Robotics*, 2006.

[7] OpenCV, "image processing library," http://www.sourceforge.net/projects/opencvlibrary, 1999.

[8] Eurobot, "Contest for amateur robotics," http://eurobot.org/, 1997.

[9] David Obdržálek, "Eurobot 2010," *Robot Revue*, May 2010.

[10] Robot Challenge, "Indoor robotic competitions," http://robotchallenge.org, 2010.

[11] Field Robot Event, "Agricultural robotic competition," http://fieldrobotevent.de, 2010.

[12] MapFactor, "VTU10 tracking unit," http://mapfactor.com/, 2010.

[13] RoboOrienteering, "Outdoor robotic competition," http://www.vosrk.cz/roboorienteering, 2010.

[14] RoboMagellan, "Outdoor robotic competition," http://www.robothon.org/robothon/robo-magellan.php, 2000.