PI2: A new initiative in educational mobile robotics

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ABSTRACT

PI2 platform provides a robust and powerful platform to develop projects related to mobile robotics in the educational field. Traditional robotic kits and home made robots require a lot of time trying to put all the pieces together, learning the hardware and finally programming the robot to solve a specific task rather than focusing on, not allowing the students to concentrate on robotics. Closed robotic platforms that could let student focus on robotics do not allow them to modify and understand the hardware and software details in an easy way. PI2 robot solves these problems giving a scalable and modular platform easy to build and program. The robot, which can be assembled in few hours, is composed of: TC-EPI2 control board, mechanical structure, sensors and software libraries. PI2 has been successfully used in several university workshops. The robot is currently used in different research and student laboratories of Spanish universities.

Keywords: Mobile Robots, Robot programming, Educational Robotics.

1. INTRODUCTION

PI2 robot is designed to provide a basic robotic platform suitable for several robotic courses, ranging from short workshops to high school and undergraduate university courses. PI2 is an evolution of his predecessor PI robot [1]. PI robot was also designed with academic purposes and was used in workshops held at *Universidad Politécnica de Madrid,* Spain in 2001.

Previous experiences with robotic workshops, before the PI robot design, allowed identifying some of the problems that commonly are found in this kind of courses. Due to the multidisciplinary nature of robotics, which involves electronics, mechanics and software engineering, designing and building a robot from the ground up within a period of a short course is a difficult task. Students apply much effort in developing hardware and mechanics [2, 3], learning a lot about this topics but in the end there is no time left to learn the basics of mobile robotics. The use of a complete closed platform [4] is not recommended because it does not allow modifying the robot in an easy way to add or change sensors and actuators. Robot PI was designed to address the problems of this kind of courses.

PI is a cheap robot made of plastic, electronics based on TC-EPI [1], previous version of TC-EPI2 control board used in PI2, and modified servomotors as motors. In these firsts workshops students with hardly any experience had a robot up and running in one day, so the following days

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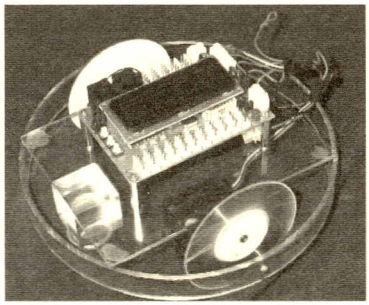
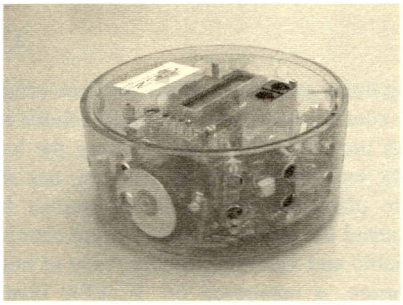
were dedicated to learning robotics, sensor conditioning and problem solving. Although the results where fine we found some problems. To achieve a low price the robot had to be built form components not designed for this task, the process of building the robot required modifying the servomotor, cable hand assembly and sticking parts with glue, most of the problems found were related to these tasks. PI robot used in the courses can be seeing on Figure 1a.

PI2 is designed as an evolution of PI but with parts designed to solve the problems found during the previous workshops. PI2 remains as an open platform that students must assemble and program during the courses. Lot of time is saved and students can learn robotics with the capability of exploring both the software and hardware deeply. As a drawback, the price of this kit is higher due to the specially machined parts.

PI2 consists in a stainless steel mechanical support, a plastic frame and cover, 2 commercial DC motors with wheels, mounting holes to place different electronics and sensors, TCEPI2 control board, sensors and cables. We can see an image of PI2 on Figure 1b.



a)



b)

Figure 1. a) PI, the antecessor b) PI2

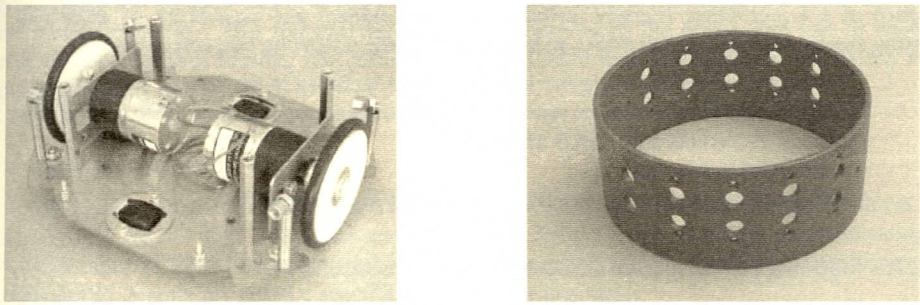
2. PI2 ROBOT

PI2 robot is divided into the mechanical platform, the control board TC-EPI2, sensors and software libraries. We will explain these items in the following sections.

2.1 MECHANICAL PLATFORM

The main part of the mechanical platform is a stainless steel support piece in which motors and electronics are attached (Figure 2a). A circular plastic ring is mounted over the central piece supported with four springs allowing this part to move freely letting the robot sense possible impacts (Figure 2b). Impacts are sensed with four switches placed on each corner of the support base. These switches are connected in a special bumper input built into TC-EPI2. The shape of the ring prevents the robot from getting stuck while navigating. The ring has two rows of holes where the sensors can be mounted from inside. On the top, a plastic cover protects the inside of the robot.

In order to move the robot two DC motors from McLennan Inc. ®. These motors require 6Volts, providing 1.25Kg/cm. Two wheels, made of aluminum and rubber, are attached to the axis of each motor.



a) b)

Figure 2. Mechanical structure

2.2 TC-EPI2

TC-EPI2 (Figure 3) is the main control board of the robot. With a size of just 70*90 mm, it contains almost all the electronics required for the operation of the robot. Only sensors, which must be placed in specific positions of the robot, are not placed in the board, these sensors are connected through a standard interface allowing an easy attachment of new electronics. The board can be divided in the following functional blocks:

- Controller: general purpose microcontroller, kernel of the control board.
- Input/Output: set of digital and analog input/output lines connected to the microcontroller.
- Power: voltage regulation system for the batteries.
- Communications: allow to communicate with a PC or other electronics.
- Motors: connection, power and control of up to two motors.
- LCD: screen of the system with two lines of 16 characters.
- Buttons: allow the user to interact directly with the board.

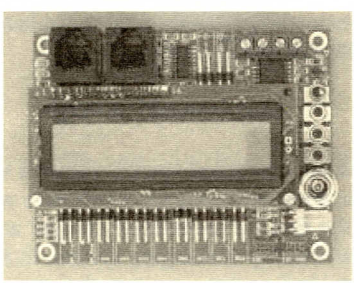


Figure 3. TC-EPI2

Controller

The microcontroller chosen was the general purpose PIC18F452 of Microchip Inc. ®. The reasons to choose it were wide availability, low price of the device, wide input/output capacity, the existence of a C compiler, friendly development environment and possibility of using real time operating system uC/OSII. It has RISC architecture with the following characteristics:

- Velocity of 10 MIPS, using the 10MHz crystal included in the board.
- Program and data memories separated: 32KB of program memory (16K instructions), 256 bytes of EEPROM and 1.5KB of RAM
- 16 bit word instructions.
- Self-programming and possibility of In Circuit Debugger (ICD).

The following peripherals are included in the microcontroller.

- 5 input/output ports, 3 pins for external interruptions and 8 channels of 10-bit Analog-to-Digital (A/D) converter
- 4 Timers of 8 and 16bits, 2 capture/compare/PWM functions and Watchdog timer
- Synchronous serial port as either 3-wire Serial Peripheral Interface (SPI™), 2-wire Inter-Integrated Circuit (I²C™) and Addressable Universal Asynchronous Receiver Transmitter (AUSART).
- Low voltage detection

Input/Output Interface

One of the principal properties of the TC-EPI2 is that the input/output interface is organized in 4 pins connectors in which just one ore two of them are signals of the microcontroller, while the others are used to deliver power. Sensors and actuators require in general a control signal and power to handle them. With the use of dedicated connectors for each sensor/actuator the task of plugging and unplugging is simplified, compared to the common approach of bus wiring, and modularity and scalability of the system are improved. The use of a standard wire reduces cost and complexity in the system.

The microcontroller includes 8 channels of 10-bit Analog-to-Digital (A/D) converter, and all of them but one can be accessed through the board connectors. The one not accessible is used as a pressed bumper sensor. The four bumpers are connected to this ADC through a resistor network designed to provide different analog values depending on the bumpers pressed, this way we can read four sensors simultaneously with just one input signal.

Power

The power module, based on a switched source, allows a wide range of input voltages (5.5 to 24V) with high conversion efficiency, powering the electronics with a nominal voltage of 5V and up to 1A. It has two connectors: the first for an external charger and the second for a set of batteries. Batteries can be charged with an intelligent charging system. In addition the board posses a red LED indicating power on and a resettable fuse that interrupts the power if the total current exceeds 1A.

One of the most important characteristics of the TC-EPI2 is the possibility of controlling the power of different peripherals through one of the pins of the microcontroller. Switching this pin allows powering on or off the following parts of the board: all the 4 pin connectors of the board, the special inputs for the four switches, the driver RS232 for serial communications with the PC and some pull-up resistors. This reduces the power consumption of the board, and can be especially useful when connecting sensors, like infrared ones, that have high consumption and do not require being permanently on.

Communications

The control board has the ability to communicate with other devices through different serial protocols: I2C, RS232 with TTL levels and RS232 with RS232 levels. It allows communicating with a PC, with other TCEPI2 and with peripherals. The connection of sensors and actuators through I2C is really useful, having the board a specific connector for this task.

Motor Control

The motor control is based in the integrated circuit L293DD consisting in an H-bridge configuration with one H-bridge per motor capable of give up to 1A. The velocity and direction (Figure 4)of each motor is controlled through a PWM signal, in which 0% duty means full velocity in one direction, 100% in the other direction and 50% motor stopped. A second signal controls the activation of each motor. With a total of four pins the two motors can be controlled.

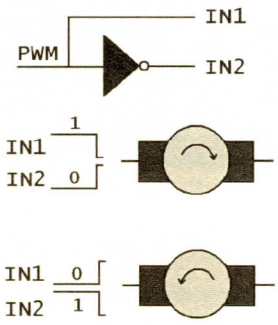


Figure 4. Direction control

Programming and Debugging

There are several C cross compilers in the market for the microcontroller that can be used to program the TC-EPI2, most of them with full use trial version. In addition the (mini) real time operating system uC/OSII has been tested and used on the board.

Once the program is compiled must be transferred to the controller for a later execution. Two methods exist to do it: programming through the serial port using a bootloader program resident in the controller or using external electronics that can in addition do debugging. Both methods have been successfully used in this board.

2.3 SENSORS

Several types of sensors are used in the PI2 basic robot, most of them can be integrated in the ring. The sensors used in the workshops are:

- Infrared sensor GP2D12 used to measure distance. It has a range between 10cm and 80cm.
- Ultrasonic sensor SRF04 used to measure distance. It has a range between 3cm and 3m.
- TS-70 sensor board that consists on a semicircular array of CNY70 sensors used to distinguish between the colors black and white that allows the robot following lines of these colors (Figure 5).
- Contact sensors mounted on the ring.
- Light sensors based on LDR used to measure light intensity.

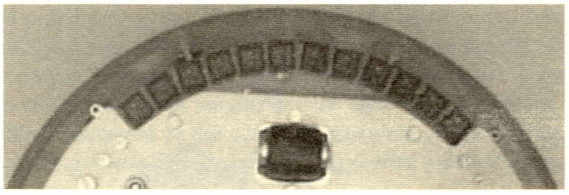


Figure 5. Bottom view of the TS-70 mounted on PI2

2.4 LIBRARIES

In order to make the robot more powerful some basic libraries were written. These libraries allow students to develop robotic projects faster without the need to go through every detail of the hardware. These libraries control the motors, sensors and some different basic behaviors that move the robot. The source code is provided to allow for improvements and new sensor programming.

4. EDUCATIONAL EXPERIENCE

During the years 2004 and 2005 four different workshop were held in different universities of Spain with the PI2 platform after the experience of the previous courses with the old PI platform. These

workshops took place in: *Universidad de Zaragoza*, with a total of 15 robots and 31 students; *Universidad Politécnica de Madrid* with 2 courses, of 8 robots and 22 students in the first one and 18 robots and 49 students in the second one; *Universidad Alfonso X El Sabio* with 24 robots and 58 students. Students came from different engineering and science fields and different educational levels, from first courses to last courses of university.

In the old PI robot workshops students used more than half time to build the robot, and the rest of the time went to understand the hardware and software, leaving not much time to build algorithms and behaviors. On the other hand, on the PI2 robot workshops few hours were used to build the robots and understand the hardware and libraries given, so students had much more time to learn robotics. They worked more than half time of the course on building algorithms and programming the robot, understanding robotic behaviors and learning some of the problems of mobile robots.

The use of the platform was a success both for teachers and students. PI2 allowed the teachers to spend the effort in teaching robotics and no so many time solving hardware and mechanical problems. The students had much more time to implement the robotic behaviors and discuss with the teachers about it.

In addition some PI2 robots are currently being used in several laboratories at university: At *University de Alcalá* working on fuzzy logic and behavior techniques and in the compulsory course "Neural and Fuzzy Control" [5]; at "Universidad Carlos III de Madrid" and at *Universidad Politécnica de Madrid* used in control laboratories. Feedback from the laboratories indicates that having an open design helps researchers to modify the robot to reach their goals, discarding other kind of platforms in some cases more powerful.

5. CONCLUSIONS

PI2 robot is a complete platform with desirable properties such as scalability and modularity that allows both expert and beginners users to build and develop mobile robotic projects oriented towards education. The robot is easy to mount, to understand and has enough powerful microcontroller and sensors that are controlled by some developed libraries. Several workshops had been held in different universities of Spain using the platform with excellent results. PI2 robots are currently been used in several research and undergraduate laboratories at different universities.

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