Using ROBUS in Electrical and Computer Engineering Education

François Michaud, Gérard Lachiver, Mario Lucas, André Clavet, Jean-Marie Dirand, Noël Boutin, Philippe Mabilleau, Jacques Descôteaux

Université de Sherbrooke (Québec Canada)

Abstract

ROBUS (ROBot University of Sherbrooke) is an autonomous mobile robot designed to facilitate interdisciplinary engineering design in Electrical Engineering (EE) and Computer Engineering (CE). Its primary purpose is to serve as an integrated platform for a project called INGÉNIUS that introduces electrical and computer engineering simultaneously to a large group of first-year undergraduate students registered in these two distinct programs. Divided in thirty-five teams of six or seven, these students are being initiated to various aspects of electrical and computer engineering such as electric circuits, electronics, sensors and actuators, logic circuits and CPLD, microprocessors, real-time C programming, robotics, technical drawing and communication. This way, ROBUS gives hands-on technical and teamwork experiences early in the curriculum. The robot is used in six different courses, and an interdisciplinary team of professors also work together to coordinate these activities. At the end of the second semester, teams participate in a robot competition where the objective is to design an entertainment robot for children with learning disorders. For fourth-year students in EE and CE, ROBUS is used in more advanced undergraduate courses such as Microprocessor Interfaces, Real-Time Systems, Robotics Projects and also in one graduate course on Artificial Intelligence. The projects done in these courses are oriented toward giving more advanced capabilities to ROBUS, help developed complete autonomous robots and to teach specific concepts. This paper gives a description of ROBUS and how it is used in all of these activities.

I. Introduction

The Department of Electrical and Computer Engineering at the Université de Sherbrooke offers two distinct bachelor engineering degrees, one in Electrical Engineering and one in Computer Engineering (which has been initiated six years ago). Even though both programs share some activities and that students are placed in an environment that involves electrical and software considerations, students are still having difficulties integrating and applying the engineering knowledge and skills that they learned in the curricula. To avoid this problem, we thought that more could be done in the curricula to develop this as soon as possible. We also wanted to put students in situations closer to the reality of the profession by making them work on projects that involves multidisciplinary considerations, design and analysis abilities, autonomous learning, teamwork and communication skills.

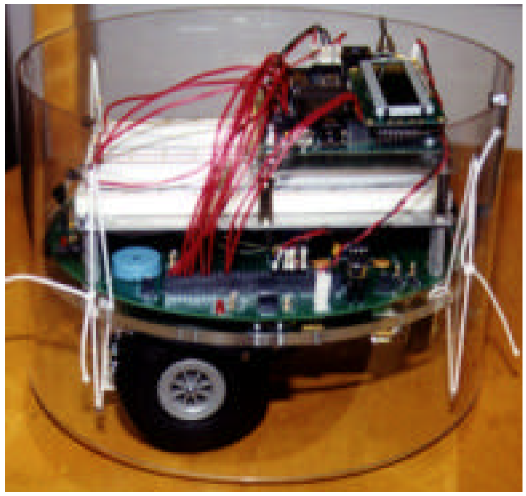


Figure 1. ROBUS (RObot Université de Sherbrooke)

To accomplish these goals, we decided to develop an autonomous mobile robot that could be easily expanded and used in various activities of both curricula, that could adequately reflect the challenges in electrical and computer projects, and that could be supported by good development tools and documentation. This paper describes the mobile robot developed and named ROBUS, shown in Figure 1, and explains how it is used in various activities. After having described the characteristics of ROBUS in Section II, Section III explains how it is used to introduce electrical and computer engineering to teams of first-year undergraduate students in a project called INGÉNIUS. Section IV describes how ROBUS is used in projects with more advanced students in other courses in our curricula. Finally, Section V concludes the paper by presenting the various impacts this platform is having on electrical and computer engineering education in our department.

II. Characteristics of ROBUS

There are a growing number of universities that get involved in using mobile robotic platforms in their curricula[14]. Between Legos or other reconfigurable robot kits and complete mobile robot platforms, we wanted to have a robot that would give us the best of both worlds, i.e., the ability to add structural features to the robot and also have a variety of properties and engineering tools to work with, at the lowest cost possible.

Figure 2. *Electro-Mechanical Base* and *Interface Circuit Board* of ROBUS

To reach these objectives, our mobile robot ROBUS is composed of the following parts:

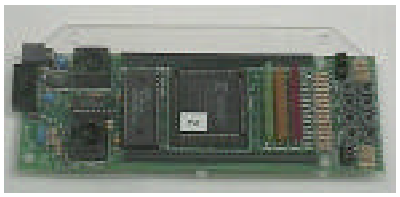
-*Electro-Mechanical Base*. The mechanical structure of the robot was inspired from the RugWarrior robot[6], which is circular and surrounded by a protecting surface, allowing the robot to detect when it collides with an object. ROBUS' base, shown in Figure 2, is made of one Plexiglas chassis plate, one motor support, two DC motors, two drive wheels with shaft encoder patterns, two photoreflectors, one caster, four bump switches, two 4x1 battery holders with rechargeable batteries, one flexible Plexiglas surface and elastic bands to attach it to the robot. These elastic bands allow the user to take the robot directly by the surrounding Plexiglas, and can also be used to lift the wheels of the robot, allowing driving the motors without having the robot move. Structural additions or modifications to the robot can be easily done on the Plexiglas chassis plate or on the protecting surface.

-*Interface Circuit Board*. The purpose of this board is to serve as an interface between sensors, actuators and power circuitry of the robot and a control device (like the ones described in the next paragraph). This board was designed to give as much flexibility as possible to the robot by providing a variety of signals and circuits, summarized in Table 1.

Table 1 – Components of the *Interface Circuit Board*

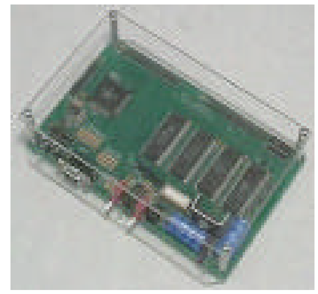
Circuit	Purpose
Power system	-Provide the energy from the batteries to the circuits and control devices of the robot (9.6 Vdc, 5 Vdc regulated and a regulated variable power source for the motors) -Recharge the batteries when an external power source is provided to the robot
Motors	-H-bridge interface to the two driving motors -Direct access to the driving motors and to possibly two additional motors
Shaft encoders	-Measures the position or rotation rate of the wheels
Bumpers	-Detect collision all around the robot using four bump switches and the protecting surface surrounding the robot
Piezo beeper	-Generate sounds at different frequencies
Near-infrared proximity detectors	-Detect objects in proximity with the robot, using one detector and two near-infrared LEDs on each side (if required)
Microphones	-Two amplifying circuits for microphones
Expansion connectors	-Pull-up/pull-downs circuits for connecting various sensors (photoresistors, pyroelectric sensors, bend sensors, etc.) -Circuitry for two servo-motors -Circuitry for one sonar

-*Control Devices*. Figure 3 shows different control devices that can be used on ROBUS. In the standard configuration ROBUS is controlled by the Handy Board[10,11], designed by Fred Martin[9]. The Handy Board is based on the Motorola 68HC11 microprocessor and includes a 32K of battery-backed static RAM, built-in recharging circuit, outputs for four DC motors, a 16x2 LCD screen, a piezo beeper, two user-programmable buttons, one knob, IR transmitter/receiver, SPI circuit, and inputs for a variety of analog and digital sensors. It also uses Interactive C[4,17], a cross-platform multi-tasking version of the C programming language. The simplicity of this development environment, the quality of the documentation and the amount of information available on the Internet or shared between users make the Handy Board an excellent tool to get familiarize with robotics.

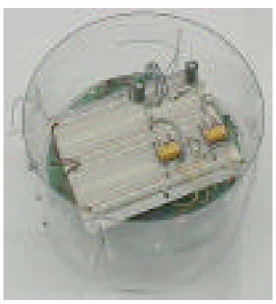


Xilinx CPLD board

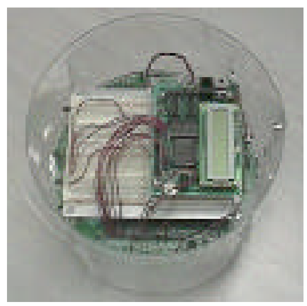
Handy Board and equipment



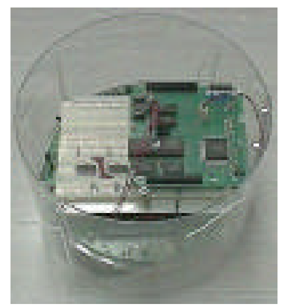
68331 board



Analog control circuit



ROBUS with a Handy Board



ROBUS with a 68332 board

Figure 3. Control devices for ROBUS

We also had at our disposal 68331/68332 microprocessors that could give more processing power to ROBUS. These boards are equipped with 256K of ROM, 256K of RAM, and are programmed in C++/C using Motorola's SDS development environment. Finally, to teach concepts related to programmable logic circuit design, a Xilinx CPLD board was developed to control ROBUS.

Overall, with this first version of ROBUS, material to build up to 60 robots were prepared at a cost of approximately 300$CAN (around 200$US) per robot (which includes the electro-mechanical base, the interface circuit board and the parts required to assemble the Handy Board).

III. INGÉNIUS – Introduction of Electrical and Computer Engineering to First-Year Undergraduate Students

The general goal of the project INGÉNIUS is to introduce electrical and computer engineering simultaneously to a large group of first-year undergraduate students registered in these two distinct programs. Divided in thirty-five teams of six or seven, more than 200 students are being initiated to various aspects of electrical and computer engineering such as electric circuits, electronics, sensors and actuators, logic circuits and CPLD (Complex Programmable Logic

Design), microprocessors, real-time C programming, technical drawing, written and oral communication skills and contemporary issues related to engineering. This project is built on the concept of collaborative learning[1,5], in which students work together to distribute the responsibilities of learning by sharing expertise, questions and ideas. Team representatives are also used in specific activities to receive particular instructions from and to give feedback to the professors. Web pages are also used to broadcast all pertinent information (schedule, assignments) concerning the activities, and "news pages" are also available to let teams exchange information.

In INGÉNIUS, collaboration is also apply at the teaching level: an interdisciplinary team of professors (with backgrounds in electrical engineering, computer engineering, civil engineering, mathematics, psychology, technical communication and business) work together to coordinate the activities related to INGÉNIUS. Professors meet each week to plan these activities and to resolve issues related to student teams. In addition to the professors directly involved in teaching to these students, other professors are implicated in activities related to INGÉNIUS such as team formation, robot assemblage, familiarization with the Handy Board, robot programming and organization of the robot competition.

Similarly to problem-based learning[8], ROBUS is used in INGÉNIUS as a general platform to give students hands-on technical and teamwork experiences early in the curriculum. ROBUS is given to the students completely unassembled, and their first project is to build the robot by using the documentation provided so that they can use it in projects to come. By literally "putting pieces together", students are engaged in an integrative learning experience where they are invited to see how concepts learned from different courses go together in ROBUS. A key point here is that ROBUS creates by itself interest, hands-on experience and, moreover, motivation and engagement from the students. This is done in accordance to the principles of the *Flow Experience*[2,3]: having a project that has 1) a clarity of goals (to build a robot that accomplishes a certain number of specific functions); 2) immediacy of feedback (you know rapidly if the robot works or not) and 3) a good match between the task and the skills of the students (different levels of challenge can be adjusted according to the evolution of the learners), increases the chances to obtain an optimal learning experience very rewarding by itself.

From this basis, the challenge of the team of teachers is to take advantage of the students' open attitude and to invite them to go further in their learning. The task is to engage them in a process where they will deepen their comprehension of the principles underlying the problem at hand. In other words, when people are engaged in an activity that is motivating by itself, chances are good that they will be interested in learning things if they see that they will serve them in regard to the accomplishment of their project. In the challenge to "extract" a learning opportunity from ROBUS, we follow principles of experiential learning as developed by Kolb[7]: "Learning is the process whereby knowledge is created through the transformation of experience" (p. 38). One purpose of ROBUS is to create a project that brings a rewarding experience by itself during the process of assembly of pieces. From this, we want to create knowledge. When the students then come to ask how to do such and such a thing, the opportunity is there to generate more knowledge with them. The same is true inside a team when a student explains a concept that other colleagues have to know in order to accomplish his or her part of the job! The material covered in the courses constitutes conceptual building blocks ready to serve when the students are ready to use them in order to solve the difficulties met in the process of building their robot and using it in projects.

ROBUS is essentially used in six of the ten courses given during the first year:

Introduction to Engineering and Teamwork (Fall). Students are introduced to teamwork methodologies, and ROBUS is one of the problems on which these techniques are applied. Conferences are also given in this course on issues related to the engineering profession, and two of these conferences are based on robotics: the first explains how ROBUS was designed, and the second is on artificial intelligence and mobile robotics.

Technical Drawing (Fall). While learning the basic skills of technical drawing in engineering, the students learn to use AutoCAD by drawing the mechanical design of the robot's caster. They also learn some of the basics in electrical circuit drawing. Finally, they also have to illustrate the behavior scenario they plan to design for the robot competition.

Logic Circuits (Fall). In this course, students learn about contemporary logic design. Using ROBUS, students design a combinational logic circuit to control the robot, making it move backward and turning when it collides with an object or move forward otherwise. They also learn to use the Xilinx CPLD board to control the robot. The assignment is to design a system that can memorize a series of commands given from a keyboard and playback these commands. The task is to memorize the commands that make the robot follow a path drawn on the floor, and the commands that make the robot avoid an obstacle of known dimensions. Then, the robot is placed at the start of the path and has to try to reproduce it and avoid the obstacle placed on its way. Figure 4 shows pictures of the system designed and of this assignment that can be viewed as a small task-oriented robot competition.

Figure 4. ROBUS used with the Xilinx CPLD board in the Logic Circuits course

Introduction to Circuits and Microprocessors (Winter). The goal of this course is to introduce the fundamentals of the analysis and design of basic analog and digital circuits. Among the assignments, students have to work on a simple analog circuit to control the robot, again by making it move backward and turning when it collides with an object or move forward otherwise. They also work on a light detection circuit using photoresistors and on a microphone circuit with simple amplifier, to be used with the Handy Board on the robot. Notions about real-time programming are also introduced to help students prepare for the robot competition (described in the following subsection).

Software Design (Winter). Principles of modular programming and multi-layer robotic software architectures are explored in this course with the objective of producing a good software design for the robot competition.

Written and Oral Communication Skills (Winter). Some of the activities in this course are oriented in helping students prepare for the presentation of their robot at the robot competition.

A. Robot Competition in INGÉNIUS

The final objective at the end of the second semester is to participate in a robot competition. Most robot competitions involve making robots accomplish a task like playing hockey, ping pong[16], blowing out a candle, etc. These competitions are an excellent way to familiarize students to the limitations in sensing, acting and processing, difficulties in programming and the need to make a compromise between it all. Robot performance is evaluated based on their abilities in performing the task and in competing with other teams.

At the end of the second semester, we also ask teams to participate in a robot competition. However, instead of focusing on a task, we want to have a robot competition that has some sort of social impact, that relates to the kind of work engineers are asked to do and that contributes to the development of such devices in their use in real-life situations. Developing entertaining robots is actually a good context to do that: the precision required in accomplishing tasks described in the previous paragraph is traded for the abilities to deal with the contingencies and unpredictability of the real world, for the believability of the characters[13] and the interactivity with the user.

The idea we came up with is to ask students to design an intelligent toy robot to be used by children with learning and physical disorders. Based on the idea of having a robot that reproduces some interesting functionalities of a pet or a small animal[4], the goal is to see how interacting with robots could help autistic children, suffering from communication disorders, short attention span and inability to treat others as people, increase their ability to focus their attention and to be more opened to the surroundings. This is a very open problem where teams have a lot of latitude to develop creative and innovative solutions. For example, they can add a device that generate sounds (see Section IV) and use it to communicate with the child; they can program the robot to play some music or to play games; they can add pyroelectric sensors and develop a people-following behavior; they can make the robot look more like a small animal by adding a tail on a servo-motor or a disguise; they can add a leach to guide the robot; etc. It is up to the students to develop the capabilities they believe to be appropriate for the robot in accomplishing the goal of the competition. This should lead to a great variety of interesting solutions, making the best of the sensors and the actuators available, the processing capabilities of the microprocessor board and what can be done in practice, while still consider the social impacts of their designs. In accordance to cooperative learning principles[5], the competition is then much more oriented toward the challenge of building an interesting product for this task instead of competing with other teams.

The first competition is going to be held in April 1999, and results of this experience will be reported at the conference. Evaluation of the performance of the robots will be based on the characteristics and the originality of their design, the behavior implemented, the interaction between the robot and children, the demonstration and the presentation of the abilities of their robot.

IV. Other Activities Involving ROBUS

ROBUS revealed to be a great platform to generate a variety of design projects for more advanced students. One type of project is to add new features to the robot, like the design of an autonomous charging station for the robot, the design of a sound generating device that allow the robot to play messages recorded on a ISD ChipCorder (a single chip device for voice recording and playback), the design of a sonar positioned by a servo-motor to build a map of the surroundings of the robot, the addition of a compass, etc. Figure 5 shows two design projects done using ROBUS. The basic goal in these projects is that these new features can be of some use for the competition held in INGÉNIUS. This way, more experienced students can learn new things and put their knowledge to good use by improving the capabilities of the robot and documenting them so that they can benefit first-year students in their projects.

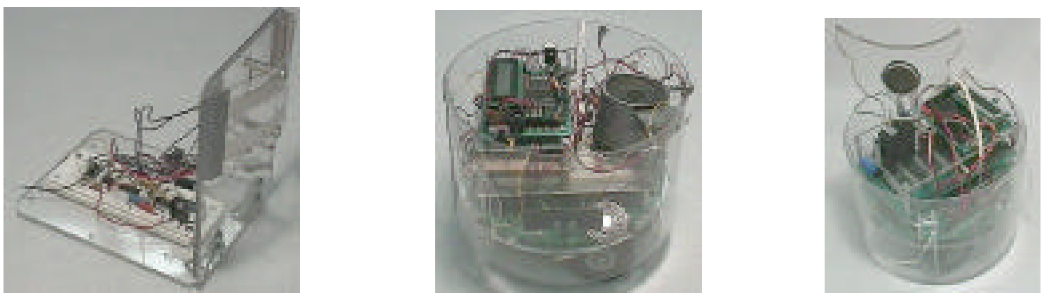


Figure 5. ROBUS equipped with a ISD ChipCorder (center) near a charging station (left), and with a sonar mounted on top of a servo-motor (right)

A second type of projects is to build complete autonomous robot. ROBUS is then used to help students understand the issues related in building robots so that they can build their own more efficiently. For example, one team got to build a micro-mouse robot, shown in Figure 6, made of four arms equipped with infrared sensors to sense the walls of a maze. The robot uses a 68332 board and some of its circuitry and parts were inspired from ROBUS.

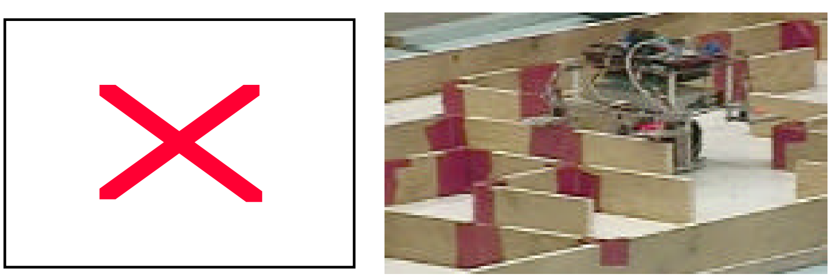


Figure 6. Micro-mouse project

These two types of projects are taking place in a fourth-year design project course, and students involved have to present their work and do a demo opened to the public at the end of the semester. These projects are also extremely beneficial for these students since they have to integrate mechanical, electrical, electronics and computational aspects into one project, giving them a real understanding of building complete systems. They also give a good example to first-year students of what they should be able to accomplish at the end of the curricula.

Finally, ROBUS is also used in more specialized courses to teach specific concepts. For example, the course on Microprocessor Interfaces uses ROBUS and the 68331 board to teach how to design hardware/software interfaces with sensors and actuators; the course on Real-Time Systems uses it to make students learn how to design a kernel for embedded systems; and one graduate course on Artificial Intelligence allows students to validate techniques like fuzzy logic, reinforcement learning and intelligent control architecture on ROBUS. Students can learn to apply a variety of concepts, methodologies and skills from Electrical Engineering and Computer Engineering using the same platform.

V. Conclusion

ROBUS has a lot of positive impacts on our curricula in Electrical Engineering and in Computer Engineering. In INGÉNIUS, it allows students to get familiarize quickly with basic skills and knowledge in electrical and computer engineering (such as soldering technique, measuring instruments, electronic components and programming). Even though the robotic platform is already designed and only assembled by these students, lots of addition (sensors, actuators, shape, software) to the robot can be made, allowing students to engineer creative and innovative solutions in developing new capabilities for the robot competition that involves building an intelligent toy robot for autistic children. At the same time, ROBUS revealed to be an excellent platform to integrate hands-on experience, teamwork, real-life considerations, communication skills and interdisciplinary issues related to electrical and computer engineering, at different levels in our two curricula and close to the reality of the engineering profession. Students are very enthusiastic and motivated by these projects, and other students not involved in activities with the robot also manifest their interest in participating in such projects. As ROBUS continues to evolve in the next few years, we plan to broaden the scope of interdisciplinary projects to include more mechanical, electrical and computer features, complex tasks and other aspects such as the marketing of such robots.

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FRANÇOIS MICHAUD
François Michaud is an assistant professor in the Department of Electrical and Computer Engineering at the Université de Sherbrooke, in Québec Canada. He received B.Ing. (1992), M.Sc.A. (1993) and Ph.D. (1996) degrees in Electrical Engineering from the Université de Sherbrooke. He also did postdoctoral research in mobile robotics at the Interaction Lab, located at the time at the Volen Center for Complex Systems of Brandeis University, under the supervision of Pr. Maja J. Mataric. He is now the principal investigator of LABORIUS, a research group working on software/hardware design of mobile robots and intelligent systems, funded by the Natural Sciences and Engineering Research Council (NSERC) and the Canadian Foundation for Innovation (CFI). His research interests include mobile robotics, machine learning, fuzzy logic and applied artificial intelligence.

GÉRARD LACHIVER
Gérard Lachiver is a professor and the Department Head of the Department of Electrical and Computer Engineering at the Université de Sherbrooke (Québec). His expertise includes logic design, automatic control and fuzzy logic. His research interests are in intelligent control of systems.

MARIO LUCAS
Mario Lucas teaches human relation in working environments at the School of Engineering of the Université de Sherbrooke. He has a Master's in Psychology – Human Relations (1980) and he is currently completing his Ph.D. in adult education on the topic of leadership in action. He is associated to a firm specialized in team building, working relations in small and medium size companies. He has 20 years of experience working as a consultant for companies, and he also participates as an expert in teamwork methodologies applied in University's curricula reforms.

ANDRÉ CLAVET
André Clavet is an associate professor in the Department of Electrical and Computer Engineering at the Université de Sherbrooke, in Québec Canada. He received B.Ing. (1973) and M.Sc.A. (1975) degrees in Electrical Engineering from the Université de Sherbrooke. His technical interests include DSP systems, mobile robotics and control systems. He is now mainly involved in pedagogic experiments on cooperative and autonomous learning.

JEAN-MARIE DIRAND
Jean-Marie Dirand is a professor at the Department of Electrical and Computer Engineering at the Université de Sherbrooke (Québec). He received a Ph.D. (1969) degree in applied mathematics from Université de Nancy (France). His research interests include Artificial Intelligence (expert systems with the multi agent approach), Intelligent Learning Environments. He develops a WEB based shell to create tutorials, in particular a C++ programming course.

NOËL BOUTIN
Noël Boutin is a professor at the Department of Electrical and Computer Engineering at the Université de Sherbrooke (Québec). His expertise includes analog and numerical communication, systems and circuits design.

PHILIPPE MABILLEAU
Philippe Mabilleau is a professor at the Department of Electrical and Computer Engineering at the Université de Sherbrooke (Québec). His expertise includes telecommunications, embedded and real-time systems, and human-machine interfaces.

JACQUES DESCOTEAUX
Jacques Descôteaux is a professional civil engineer teaching technical drawing at the School of Engineering of the Université de Sherbrooke.