Designing Toy Robots to Help Autistic Children - An Open Design Project for Electrical and Computer Engineering Education

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Abstract

In our curricula, freshmen use an autonomous robotic platform to get introduced to fundamental concepts in Electrical and Computer Engineering. Using this platform, teams of students interested by the challenge are invited to apply knowledge acquired during their first year of studies by participating in a toy robot design contest. Initiated in 1999, the challenge is to design a mobile robot to help autistic children. The goal of this paper is to describe the contest, its organization, its pedagogic principles and its impacts in order to show how open design projects can create meaningful and exciting learning experiences for students in Electrical and Computer Engineering.

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. In 1998, we initiated a pedagogical project in which Electrical and Computer Engineering (ECE) were introduced simultaneously to a large group of first-year undergraduate students registered in these two distinct programs. The primary goal of this project was to confirm early on the career choice of these students by putting them close to the reality of the profession and making them work on projects involving design and analysis abilities, autonomous learning, teamwork, communication skills and social considerations. We also wanted to create a stimulating and motivating learning environment, with a reasonable workload that favored the integration and the application of the engineering knowledge and skills.

To accomplish this goal, we were looking for a project that could integrate these ideas in different courses with appropriate complexity, and also provide open challenges that push further the creativity and the ingenuity of the students. With that in mind, we developed an autonomous mobile robotic platform that we named ROBUS[10].

ROBUS was given to the students completely unassembled, and their first challenge was to build and test the robot by using the documentation provided[9]. This process revealed to be very exciting for many students who were introduced, for the first time in their life, to electronics and instrumentation. Then, ROBUS was used in projects from six of the ten courses given during the first year[10]. For instance during the first semester, in the *Logic Circuits* course, students first designed a combinational logic circuit to make the robot move freely in the environment and turn away when it collided with an object. They also learned to use a Xilinx CPLD board to control the robot. The assignment was to design a system that could memorize a series of commands given from a keyboard, and play back these commands at the appropriate time. The task required to memorize the commands that made the robot follow a path drawn on the floor, and also the commands that made the robot avoid an obstacle of known dimensions. Then, the robot was placed at the start of the path and had to try to repeat it by having to avoid the obstacle (detected by infrared proximity sensors) placed somewhere on its way. During the second semester, the *Introduction to Circuits and Microprocessors* course allowed students to use a simple analog circuit to again make the robot move freely in the environment[6]. They also worked on a light detection circuit using photoresistors and on a sound detection circuit that were used with the Handy Board[8], a microcontroller board programmed using a C multi-tasking environment named Interactive C. As the course project, students had to design the electrical and software mechanisms that allowed their robot to follow a flashlight, avoid obstacles and respond to sound commands. Other courses that used ROBUS in learning situations were *Introduction to Engineering and Teamwork*, *Technical Drawing*, *Software Design* and *Written and Oral Communication Skills*[9].

Overall, students showed enthusiasm in these course assignments that were set to demonstrate a progression in the technology and concepts used for their design with ROBUS. But as indicated earlier, we also wanted to challenge students to move beyond what was requested or taught in their courses, and apply their knowledge in an open design project. So, at the beginning of the second semester, we invited students to participate in a robot contest. Most robot competitions involve making robots accomplish a task like playing hockey, ping pong[12], blowing out a candle[15], etc. Robot performance is evaluated based on their abilities in performing the task and in competing with other teams, and these competitions are an excellent way to familiarize students with technical considerations in ECE design. However, instead of focusing on a task, we wanted to have a robot competition that had some sort of social impact, close 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, since the precision required in accomplishing tasks is traded for the abilities to deal with the contingencies and unpredictability of the real world, to give believability to the characters and to interact with the user.

The idea we came up with was to initiate a toy robot design contest. To increase the social aspect of the challenge, we added a requirement stating that the toy robots should be designed to help autistic children increase their ability to focus their attention and to be more opened to their surroundings. Autism is characterized by abnormalities in the development of social relationships and communication skills, as well as the presence of marked obsessive and repetitive behavior. Despite several decades of research, there is currently no cure for the condition. However education, care and therapeutic approaches can help people with autism maximize their potential, even though impairments in social and communication skills may persist throughout life. The idea is to see how robots could help autistic children open up to their surroundings, improve their imagination and try to break repetitive patterns.

II. Toy Robot Contest – First Edition

The contest was announced January 15, 1999, and was to take place April 15, 1999[i]. With only three months left, a team of three professors and four students were put in charge of organizing the event. Weekly meetings were conducted to manage the following aspects related to the contest: building and maintaining a web page, managing team registration, creating email aliases to contact the participants, designing a logo, gathering information on autism, preparing documents explaining the contest, finding sponsors, advertising the event, providing technical support, establishing the evaluation rules and finding the jury, publishing a document of the robots presented during the contest, preparing the exhibition hall and making a video of the event. Concerning the topic of autism, we carried the project a step further when we asked a teacher with a class of autistic children to become our consultant. Information about the pedagogical tools used with these children (like the TEACCH program implemented in this class and based on the use of pictograms and geometrical shapes) was provided. Because it was impossible to get all of our students to meet the teacher's children, four members of the

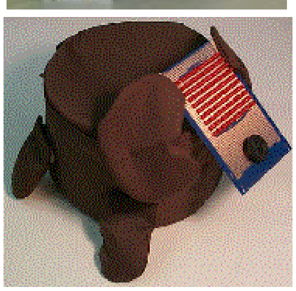
[i] This date was chosen because it was the last day of the semester before the exams. But incidentally, April was also Autism Awareness Month here in Québec.

organizing committee went to meet her classroom. The teacher also provided eight profiles of children, each with specific characteristics from which it would be possible to identify and align certain features for the robots. The Department of Specialized Education at the Université de Sherbrooke also provided videotapes related to autism.

Students registered in teams of 3 to 7 and used their ROBUS platform, up to 200$CAN of electronic components for their design and a sound generating device that allowed the robot to play messages recorded on a ISD ChipCorder (a single chip device for voice recording and playback). This last component allowed a robot to address a child using vocal messages. The day of the contest, sixty-six students grouped in twelve teams presented their robots. The following paragraphs present a brief description of each of these robots. Note that while the designs of a clapping detection circuit, a light following device and the program to make the robot move around while avoiding obstacles were done in the *Introduction to Circuits and Microprocessors* course, everything else indicated in these descriptions were made by the students.

CARI. This robot-clown asks the child to play to three different games: to dance, to press on the round, the triangular or the square shape push buttons, or to pursue the robot. The head of the robot is mounted on a servo-motor and eyes are made with green LEDs. The legs of the robot are attached to the wheels to go up and down when the robot moves.

Diskcat. This robot has a special fur exterior and looks like a cat. Games like 'Simon says', dancing and visual effects using LEDs as eyes and on the back of the robot have been implemented. Resistive bend sensors are used as whiskers.



Dream-Bot. This robot-dog has the particularity of using a LED display to generate five different faces according to the situation. It can also be guided using a leash attached to a joystick located on the back of the robot.

FLIP. This robot is designed to portray a rabbit in a car. It has a LED panel on its back to communicate different things to the child. The robot also has a memory game, music and can be tickled.

Kiss. This robot-turtle offers different games based on shape recognition and dances when the child succeed. It also uses small motors and a mechanism[ii] to make the shell move.

M³. This clown is programmed to call the name of the child as it moves. It can dance and play with the child using its nose and ears to interact. It smiles or shows signs of sadness depending on the situations. At the end the robot can give some candy to the child by opening its mouth, made using a CD-ROM reader.

Paradigmes Proactifs. This turtle uses LEDs to illuminate its eyes and mouth, and photoresistors to detect that the child is touching its shell at the appropriate places, generating distinct sounds. The robot can dance, play music and race with the child. Special care is made to make the robot robust to hard interplay conditions.

Robosorus. This dinosaur has very elaborate LED displays built in the eyes and the mouth. The head and tail move using servo-motors. It is also equipped with a bone (an ultrasonic device) that can be used to guide the robot.

Robus-T. This robot-dog has a pyroelectric sensor in its nose to move toward people. Touch buttons are also installed on its back to interact with the child. The head and the tail move using servo-motors, and are used to express the mood of the robot.

[ii] This mechanism was very original since it was made of deodorant sticks.

SuperG. This Garfield robot can talk and sing. Its special face built using LEDs is mounted on a servo-motor, along with its moving tail. Both are used to express the mood of the robot. Contact switches are used to pet the robot. When happy, SuperG also starts to purr. A keyboard placed under the cape is used to select different behavioral configurations. By clapping, the robot could also be directed to move or to stop.

TOBY. This penguin can follow a light source and when it detects a loud noise, the propeller on top of its hat starts to turn. Clapping is used to start the robot. The robot also comes equipped with a console used in a game where the robot asks the child to correctly identify an object. Students in this team also found a way to improve the sound generation device.

TOM. This robot is designed to portray a hockey player robot, build to resist hard usage, because one profile indicated that a child had special interest in hockey. It also has a face made of LEDs and two arms mounted on servo-motors. The robot can play music, dance, move around and say the name of some hockey players when the child pushes some buttons in the proper sequence.

Each team had a presentation stand with posters describing their work. The jury composed of two people working with autistic children and two people with technical knowledge on ECE, evaluated each team based on an oral presentation of 5 minutes and a demo. The demo was held in the center of the exhibit hall, on a wooden platform. Using a microphone, students commented the behavior of their robots and also made it possible to hear the messages their robots were saying in different situations. Kindergarten children were invited to play with the robots during this demo. Media coverage was also important: television stations, radio stations and local papers found the topic interesting enough to present reports of the event.

Robot designs were evaluated based on their ability to interact with children and their characteristics in regard to autism, originality and their presentation to the public. The first three prizes were books provided by one sponsor, ROBUS platforms and multimeters (for the winner). All others received a book as a participation prize. An Iomega Zip Drive, sponsored by a computer company, was also drawn between the participants.

It was not possible to bring autistic children during the event because a public setup would not have been appropriate for them to interact with the robots. So in October 1999, we went back to the class of autistic children with four robots to see what could result from having mobile robots interplay with autistic children. In the experiments, the robots were presented one by one to each child. All of them had his or her own distinct way of interacting with the robots. Some remained seated on the floor, looking at the robot and touching it when it came close to them (if the robot move to a certain distance, the child just stop looking at the robot). Others moved around the robots, sometime showing signs of excitation. One little girl showed clear indications that having the robot moved in the environment helped her become aware of its surroundings:

she started to move around the room in a routinely fashion and, as time went by, she started to break the pattern by going to the robot and interacting with it. She even once dragged the robot by the tail to bring it back were it was supposed too (based on what she was used to see when she looked at the robot). While it may be difficult to generalize the results of this first experiment, we can say that the robots surely caught the attention of the children, even making them smile. While all of this has more to do with scientific research than with ECE education, freshman students involved in these tests enjoyed and grew from their experience with these children.

III. Observations

Surely, like other robotic contests, the fact of working on mobile robots or on a technologically challenging project may be stimulating for many students. But analyzing afterwards what we have experienced with this first edition of the Toy Robot Contest, we believe that the success of the event can be explained by additional factors.

Designing a robotic toy for autistic children is a very interesting design problem for many reasons. Autistic children cannot express their preferences to guide the design of a robotic toy. Also, autism disorder is not well known by ECE professors and students, as robotics to educators working with autistic children. Design specifications cannot then be given by the professors but must instead be elaborated by students, putting them in a real engineering situation. By having a concrete collaboration with a class of autistic children, we created a project that was in fact a real-life situation, where the students were to give life to a product that was to meet certain needs. People that we contacted to get information and collaboration in regard to autism were certainly surprised about the project, and quickly welcomed the initiative. This real-life connection is seen by certain authors in the pedagogic field as a powerful way to make what is called *authentic learning*[4]: “Authentic learning demands that students actively solve problems. Life involves an ongoing series of problems to solve, decisions to make, concepts to understand, and products to produce.” This gives a firm ground to the learning experience that we, as a team of teachers, have to follow in order to extract the learning connections, whether to be at an abstract level and/or at a skill development level. In fact, the project by itself was based on the motivation to give a solution to a real problem, not only for the students but for the professors as well! It was no surprise that many of our students (and teachers) were engaged in a personal reflection about their own values and attitudes in regard to these children displaying what is called abnormal behaviors. The profiles provided of autistic children helped established some design guidelines, but certainly not all and without certitude. For example, it was considered more appropriate to put big buttons instead of sounds to interest a child to engage into a concrete action with the robot. In fact, it gave the opportunity for all the teams to experiment the difficulty of making choices and explaining them in relation to a “quasi-therapeutic goal”, instead of putting all sort of devices just in case or because it was appropriate for them. Students were then not only motivated by the engineering challenge of the project but also by the social implications of their work.

Another key point here is that, in addition to the real-life situation, the contest creates by itself interest, hands-on experience and, moreover, motivation and engagement from the students. The “calibration” of the goals and the determination of the level of complexity have been done in accordance to the principles of the *Flow Experience*[1,2]. It was important to have a project that had 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). All of this increased the chances to obtain an optimal learning experience very rewarding by itself. Using the material covered in the courses, the challenge of the team of teachers was to take advantage of the students’ open attitude and to invite them to go further in their learning and 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. This follows principles of *experiential learning* as developed by Kolb[7]: "Learning is the process whereby knowledge is created through the transformation of experience" (p. 38). Finally, we can see some connections between the contest and ideas related to *project-based learning*, *problem-based learning* and *cooperative learning* principles. Project-based learning and problem-based learning as two new models of teaching and learning that emphasize curricula that provide opportunities for sustained thinking. “Project-based learning (…) starts with a problem, called a «driving question», (…) focuses on the construction of intermediate and final artifacts that serve as foci for discussion and reflection. In both cases, the authenticity (i.e., how much the problem is like real problems) of the problem or project is important to help situate and motivate learning. These approaches emphasize «doing with understanding», that is having students learn as they solve the problem or complete a project”[5].

Also, since the contest was oriented toward building an interesting product and creating meaningful interactions with children instead of competing with other teams, intra and inter-team collaboration was able to take place. The night before the contest, most students worked in the lab all night to complete their designs, helping each other out. Contrarily to the situations in the courses were the choice of teammates were imposed, having the students build their own teams help create good working conditions. We also observed that teamwork projects work best when the challenge cannot be accomplished by the work of a small set of individuals, aspect that was valid for the contest to guarantee original, creative and ingenious designs. In addition, since robotic toys are not commonly available yet on the market, students had a lot of latitude in proposing creative and innovative solutions. It was all up to the students to develop the capabilities they believe to be appropriate for the robot. As you could see from Section II, this led to a great variety of interesting and distinct 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 the designs.

However, having a real-life problem as a contest objective also created additional stress, especially for this first edition organized in such a short period. More specifically, we were not able to know what to expect. Since this was a public event that would contribute to the visibility of our programs, failing to present an interesting contest would have had bad repercussions on the department. Initially, 18 teams representing about half of the freshmen students registered to participate to the contest. But as the semester progressed, the workload of students started to increase, even though we tried to maintain it at a reasonable level. The contest was an extra-curricula activity, and rumors started to circulate in mid-March that many wanted to drop the contest. A special meeting was held right away to clarify the situation and to clearly establish which teams were going to present their design at the contest. The principal cause of this situation was that many students were aiming too high in their designs, wanting to integrate too many ways of interacting with the child. Some of them were also hesitant in presenting something that would not make them proud. After the meeting and without pressuring anybody, 70% of the students decided to go all the way and participate.

For those who participated, we believe that the event was a success. In a general meeting held after the contest, we asked them to comment their experience. They indicated that they did not participated for the prizes but because they enjoyed the challenge and to work on such an open design project. Acquiring the experience of working on a real project also contributed to their curriculum vitae and portfolio, helping them find a summer coop training experience. An official letter was given to each team, indicating their participation to the contest and how their designs were original. However, the participants complained that the course loads were not appropriate, especially for those who volunteered to participate to the contest. They also regretted that the third prize winner was given to one of the two robots which were not able to perform in the demo part of the presentation. This confusion occurred because two members of the jury put more importance on the relevance of the design in regard to autism than on the proper working of the robot. Nevertheless, the majority manifested their interest in participating again if the contest was opened to all students and not just for freshmen.

Finally, this Toy robot Contest activity is also part of curriculum reforms in our department. While this activity was not built with accreditation criteria like ABET 2000 in mind nor did it was evaluated based on them, we believe that the Toy Robot Contest is done in accordance with the fundamental spirit of such guidelines. For instance, ABET recognizes the need for meaningful engineering design experiences and that "the engineering design component of a curriculum must include most of the following features: development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, concurrent engineering design, and detailed system descriptions. Further, it is essential to include a variety of realistic constraints, such as economic factors, safety reliability, aesthetics, ethics, and social impact"[13]. The Toy Robot Contest creates a good learning environment that draws upon previous course work to address most of these features early on in the student's academic development. Since design cannot be taught in one course, this activity should help students develop even more this ability and be better prepared to tackle other major engineering design experiences. In regards to the Engineering Criteria 2000[13], the contest addresses more specifically (a) an ability to apply knowledge of mathematics, science, and engineering, (c) an ability to design a system, component, or process to meet desired needs, (g) an ability to communicate effectively, (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context, (j) a knowledge of contemporary issues, and (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

IV. Orientations for Future Robotics Contest Events

Some people say that risky projects are also the most fulfilling, and in our case its revealed to be true. For this first edition of the Toy Robot Contest, with only 3 months and no experience in organizing such an event, the risks were enormous: we wanted to have an event that would give our department lots of visibility, but we did not know what to expect from the students. Everything turned out great, but it took lots of energy and efforts to make it all happened.
In this short period of time, we were also able to find eight sponsors that provided the prizes and a total of 1700$CAN that was used to pay for the exhibition hall, the electronic components, the publication of the document presenting the robots of this first event, and other operational costs.

Now that the first edition is completed, we are better equipped to organize the second edition of the event, scheduled in April 2000. The organizing committee, composed of six students from the first event, two freshmen students and two professors, has started to work on the second edition in October 1999, and an official presentation of the event to freshmen was done at the beginning of November. Participation is still voluntary, but the technical aspects of the designs will now be evaluated in the *Introduction to Circuits and Microprocessors* course, which should help balanced student workload. Students build their own teams for the contest and for the course as well. The contest is also opened to all students of the Department of Electrical and Computer Engineering, as from other departments (to get multidisciplinary teams to participate) and other universities. Contacts have been established to publicize the event outside the department, and the contest is also advertised on RoboHoo![14] web site and IEEE Spectrum. As of December 1999, solicitation of sponsors has just begun and we have more than triple the budget of the first edition. A special budget has been established to purchase sensors, actuators and electronic components that will be the property of the Toy Robot Contest and that could be used in the following editions. The Interactive Science Museum that opens in May 2000 in Montréal will present some of the robots designed by students for the contest. The Québec Society for Autism is supporting the project, and one member of the organization should participate as a member of the jury for the second edition. The Québec Society for Autism will also have a presentation stand to explain autism syndrome to the public. Research collaboration with Prof. Dautenhahn[3,11], who also started a project involving the use of robots as a rehabilitation tool for autistic children, is underway. Experimental results with the robots used by autistic children will be presented to the participants to refine their designs. The long-term goal is to eventually converge toward a complete mobile robot adapted to the problematic of autism. When this goal is reached, other topics of toy robot for sick children or for children with learning or physical disorders could be organized.

V. Conclusion

As more and more of our new students come from the "Nintendo and Play Station era", the problem of designing activities where they are not only exposed to concepts but also have to grasp these concepts in a very practical way is becoming more and more important and urgent to address. ROBUS, our autonomous robotic platform used in courses and activities, tries to accomplish this by putting students close to the reality of the profession. The Toy Robot Contest also pushes further the creativity and the ingenuity of freshmen students by providing a fun, open (for students as well as for the teachers) design project that creates an optimal learning experience in engineering and social sciences, design skills, teamwork and communication, preparing them well for their academic development and a successful engineering career.
At the same time, in addition to increase awareness of Autism syndrome, it also contributes to the visibility of our department and our university, and on an innovative manner in which the fields of Electrical and Computer Engineering can help society. Overall, the activity reveals to be beneficial for everybody, the students, the professors, the collaborators and the university.

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