Artbotics: Combining Art and Robotics to Broaden Participation in Computing

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Abstract

The Artbotics program is a collaboration between artists and computer scientists which uses robotics technologies to teach computer science to undergraduates and high school students. Project-based courses culminate in public exhibitions at a local museum. This paper describes the curriculum developed for the course, the technology used and lessons learned.

Introduction

The Artbotics program is a collaboration between the University of Massachusetts Lowell (UML), The Revolving Museum and Lowell High School, all located in Lowell, Massachusetts. Our program uses project-based learning to introduce students to computing through the development of technological art projects for public exhibit. Student projects leverage existing technologies, including the Super Cricket, a small processing board for building robots and moving objects.

Team projects are an implicit but key component of theme-based education. While theme-based education in general has had numerous successes in K-12 education [National Academic Press 2003], there have also been many studies that show the benefits, in terms of lower attrition rates and higher material retention, of team-based endeavors such as pair programming [Williams and Kessler 2000a; Williams and Kessler 2000b] at the undergraduate level. We focus on team projects involving art and robotics to provide a collaborative learning environment. In this collaborative context, we hope to dispel the notion of the asocial programmer, and provide positive, realistic experiences in teamwork, design, and programming.

The goals of the Artbotics program are to (1) increase the participation of women and minorities in computing through the use of innovative and interactive technologies, (2) broaden student understanding of the field of computing, teaching them that computing can be a part of many disciplines and used in a variety of ways, (3) introduce computing to the public through art exhibitions of the projects, and (4) build community with mentoring opportunities for students.

Related Work

There has been much work done in the design of robotics-based course for K-12 education (e.g., [Miller and Stein 2001]). Nourbakhsh et al. [2005a, 2005b] designed a seven-week robotics course for high school seniors, taught to 20 boys and 8 girls. Single-sex teams were formed for building and programming the robots. The evaluation of the course found that while girls were less confident than boys with the technology at first, their confidence levels improved more rapidly than the boys throughout the course. Additionally, a survey given at the start of the course asking what the students expected to learn found that they rated teamwork, problem solving and self-identification with science and technology the lowest. However, at the end of the course, teamwork was ranked as the skill that they felt they had most learned. Together with teamwork, problem solving and self-identification with technology showed the largest increase between the initial and final surveys.

In the Artbotics program, we wish to broaden participation in computing not only by reaching out to women and minorities, but by also reaching out to all people who have never considered trying computer science before. We believe that the use of art as a project medium will garner the interest of students who might be reluctant to try a course that focuses solely on mobile robotics. Another unique feature of the Artbotics program is the outreach to the community at-large through public exhibits. Exhibits have information about the computing elements provided with the pieces created by the students.

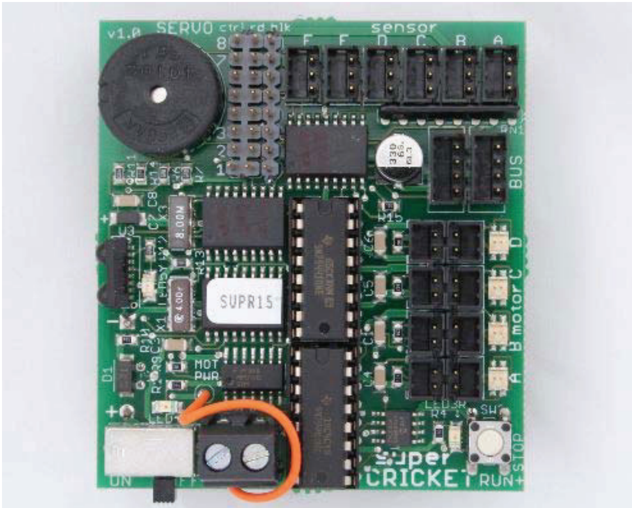

Figure 1: The Super Cricket.

Materials

To develop their projects, students are given a Super Cricket, servo and DC motors, and a variety of sensor types, including touch, infrared ranging, and light. Art materials are available in the lab space

The Super Cricket, shown in figure 1, is an embedded controller co-developed by Martin [Martin 2000]. The palm-sized Cricket device combines processing, sensor data collection and actuator control. The Super Cricket allows students to directly control 4 DC motors and 8 servo motors and to process input from 6 analog sensors.

The Cricket is programmed using Cricket Logo, a procedural text-based language. Cricket Logo allows students to easily create imperative programs (e.g., turn on this motor, wait until this sensor value changes) and download them into the Cricket device.

Piloting Artbotics

To date, two pilot programs have been held. The first was an eight-week, full time summer project for seven undergraduate students. The second was an eight-week after school program for high school students. Students worked in a lab space designed for the program at the Revolving Museum.

Summer Pilot

Artbotics began in the summer of 2006 with an eight-week pilot that included seven undergraduate students (four incoming freshmen and three upperclassmen; four art majors and three computer science majors; two women and five men). Students were tasked with creating two projects over the summer; the theme for the first was puppetry and for the second was water and light. The students developed The Evolution of Puppetry (see figure 2) and The Flow of Creation (see figure 3).

In "The Evolution of Puppetry," the students created four pieces, symbolizing the use of no computation and sensing in puppets and moving up through using greater amounts of each. The simplest piece was a sock puppet, involving no computation. The next piece was a monkey puppet on a rotating bar. In the piece's base was an infrared ranging sensor, allowing the puppet to "see" people as they looked at the exhibit. When someone was close to the sensor, it would make the bar spin, flipping the monkey over. The third piece was a marionette that also included infrared ranging sensor to allow people to make it move.

The final piece was "F.R.E.D.," the Fantastic Electronic Robotic Dancer. For this piece the students designed a sensor board with a human outline drawn on it; infrared ranging sensors were placed at the joints. Moving in front of the sensors would cause F.R.E.D. to move the corresponding joint, actuated using servo motors. F.R.E.D.'s body was made of colored Plexiglas. A laser cutter was used to make the pieces as well as etch some of the pieces with "tattoos."

The puppetry exhibit was displayed in the museum during the Lowell Folk Festival. Hundreds of people interacted with the pieces, allowing the students to watch how people tried to interact and learn from the experience. Students were at the exhibit throughout the weekend to discuss the work with visitors.

The second project, "The Flow of Creation," was designed to incorporate the themes of water and light. The students utilized an outdoor pool area to create an interactive fountain. The fountain included a large welded hand with lenses as knuckles, a heart built with chicken wire, and a cascade of metallic ivy leaves. The sound of water cascading down the ivy leaves was amplified from microphones placed on the back of a couple of the leaves. Around the pool's edge were placed infrared distance sensors that would note when people moved near the fountain and change the pattern of servo-actuated spray nozzles based upon the sensors that were triggered. After a period of no interaction, the fountain would transition to a default spray pattern.

Both projects were on display at an Artbotics gallery opening at the end of the summer. Again, students were able to watch people interact with their projects and learn from the experience.

In the summer pilot, we learned that building necessary to create the "art" part of the project consumed much of the students' time; those who have used LEGO robots in courses may have observed a similar phenomenon.

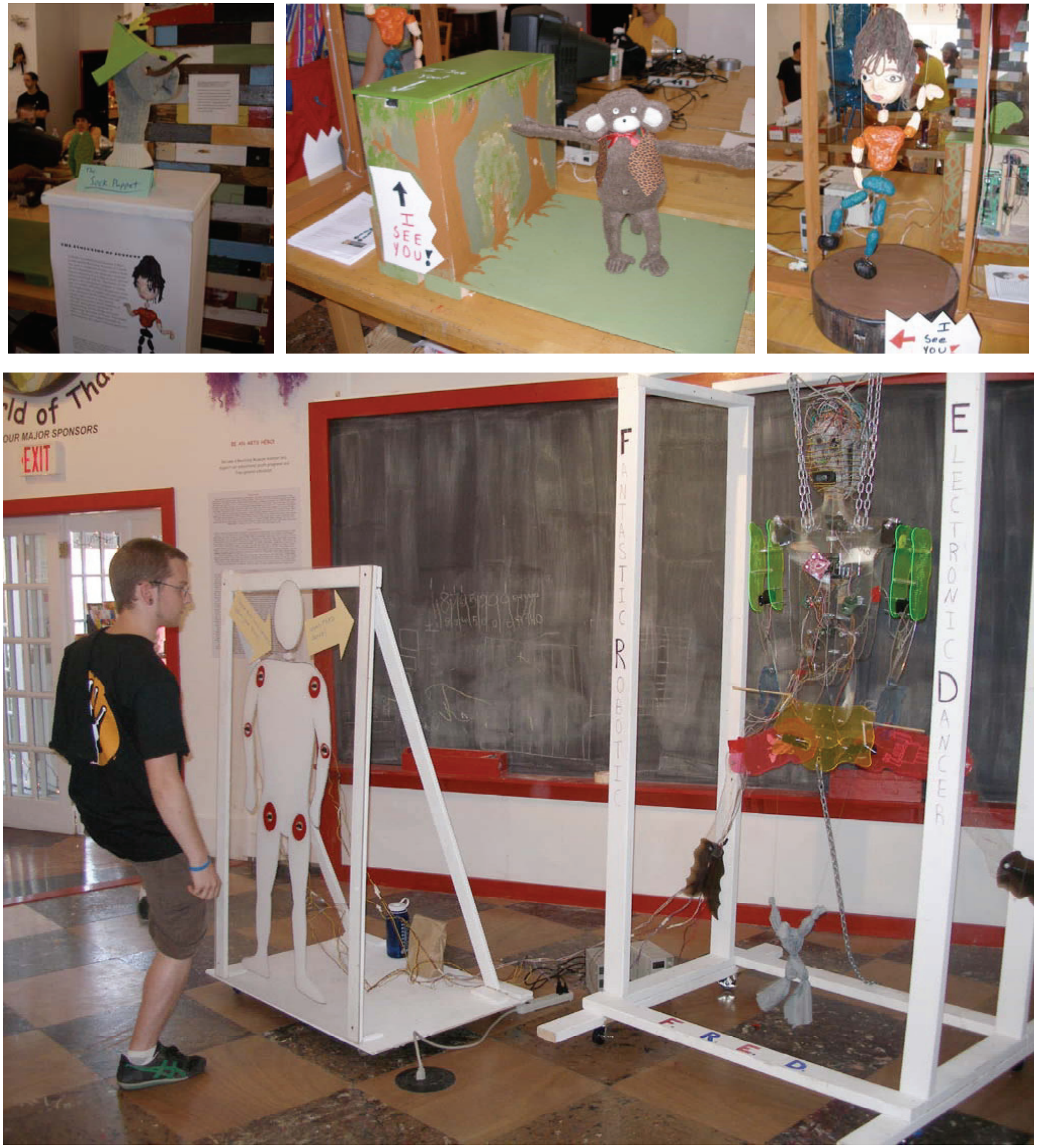

Figure 2: The four pieces comprising the first exhibit in the summer pilot, entitled "The Evolution of Puppetry." On the top left is a sock puppet, with no sensors or computation. To its right is a bar puppet of a monkey, which spun when someone walked in front of its ranging sensor. Next in the evolution is the marionette, which would move when people interacted with its sensor. The last piece in the "evolution" is F.R.E.D., the Fantastic Robotic Electronic Dancer; interacting with the sensor board on the left would make the puppet on the right move. Note that F.R.E.D. itself has a puppet that it is controlling.

Figure 3: The fountain, entitled "The Flow of Creation," which combined the themes of water and light.

After School Pilot

To combat the issue of topic imbalance, the project scope was limited during the after school program for high school students that we piloted in the fall of 2006. Sessions were divided between teaching robotics technologies and programming, brainstorming and building projects. Despite efforts to even out the balance of art and CS, the balance still swung in the favor of making the art, although not as much as in the summer pilot.

The summer pilot's gallery opening functioned as an effective recruiting event for the after school program; the museum is located two blocks from Lowell High School, so many high school students attended the end of summer Artbotics event (timed so that the Lowell High School students were already back in session). From the pool of applicants, twelve local high school students (7 female, 5 male) were selected for the program. They were mentored by five UML undergraduates (three were returning students from the summer pilot; two females, three males). The group met twice each week for a total of three hours each week in the museum's lab space.

Given the theme of "light," the students designed a project called Eclecticity, combining the words "eclectic," "electricity" and "city." The project had a globe at its center; emanating from this center were representations of world landmarks, including the Great Wall of China, the Tower of Pisa and an Egyptian Pyramid. A spaceship is also part of the exhibit. The piece is shown in figure 4.

The plan had been to have visitors interact with the piece by shining flashlights on different portions of the art to trigger light sensors, but a last minute design change led to LEDs on the globe being used to trigger the light sensors to turn on the piece's parts. An unexpected outcome of this change was the failure of several of the servo motors on the piece after one week. Without the interaction to turn on the servo motors only when people were watching, LEDs were programmed to cycle on around the globe to activate the light sensors, resulting in the motors running almost constantly during museum hours. Our Artbotics pieces need to achieve what has only rarely been achieved in robotics to date; long running times with no failures.

Curriculum

In Spring 2007, the Artbotics course for UML undergraduates will be offered for the first time. The course will be co-taught by two CS professors and an Art professor. The course is co-numbered, with General Education credits in technology given to arts students and arts credit given to science students.

Our Artbotics course is designed to allow students in a variety of majors to explore the intersection between Art and Computer Science, especially Robotics, through community-based public exhibitions and service-learning experience. In this project-driven class, students will learn founding principles in both the fields of Art and Computer Science, and put them into practice by creating interactive, tangible exhibits that are displayed in public settings. The knowledge and experience gained during the class will be further deepened by the service learning experience of mentoring high school students in the community through an after school program. The course will include guest lectures from practitioners in Art and Computer Science.

Topics

The course is interdisciplinary, covering both Art and Computer Science as well as integrating these two disciplines. The hybrid core includes:

- Contemporary art practices of the collaboration with science and technology.
- Problem-solving process of engineering and art—its commonality and differences.
- Sustainable community through art, science and technology, and education.

The computer science and robotics core includes:

- Introduction to imperative programming: functions, arguments and return values.

Figure 4: The Eclecticity piece created by the twelve high school students in the Fall 2006 after school program.

- Introduction to real-time systems including sensors, actuators and control loops.
- Agent-based models of computing (sense-act loops).
- Elements of robotics systems and how to physically create them (e.g. wiring and construction techniques).
- Uses of computing in a variety of fields.

The art core includes:

- Examination of form and content—use of visual language to support communicative issues such as concept, content and subject matter; the interplay between media and idea.
- Traditional visual language—aesthetics in color, composition, value, texture and material.
- New media language—aesthetics in time, motion, space, interactivity and hybrid media.

Objectives

The objectives of the course are many, falling into three areas: those that are related to CS and Robotics, to Art and to service learning.

CS and Robotics related objectives include:

- Have hands-on experience with embedded computing and digital technology.
- Gained the ability to formulate structured algorithms and program them.
- Understand use of sensors and interactive algorithms.
- Carry out a project from inception to public exhibition that incorporates computing.
- Understand how computing is used in a variety of fields and applications.

Art related objectives include:

- Have examined principles of aesthetic and conceptual elements in visual art.
- Be able to find strategies for a successful and engaging art expression.
- Have investigated examples of art and technology collaboration especially in public domain.
- Evaluate interactive art works in various context including gallery or public installation.

Service Learning related objectives include:

- Design a project-in-a-box for the after-school program for high school students
- Deepen the knowledge in the subject matter by teaching and mentoring high school students.
- Recognize art and science education as a way of supporting sustainable community.

Projects

Students in the course will complete several projects. The first project is a two-week research and writing assignment on the applications of art and technology collaborations.

This project is intended to get students to learn about existing artworks made throughout the world and to start thinking about the projects that they could create. During this initial project, students will be engaged in weekly labs to begin learning the technology to be used in the Artbotics projects.

In the second project, lasting four weeks, students will design and implement a themed exhibit for display at the museum. In Spring 2007, the theme will be "light," as the museum's spring opening in March will have this as its theme. This project phase will be quite similar to the two pilot programs we have already run.

In the third project, the students will spend two weeks working collaboratively with the instructors to design the curriculum and project theme for the spring's after school program. We will also discuss how to teach the high school students as well as discuss methods for effective mentoring. We piloted this type of design with the mentors who participated in the summer pilot, allowing the students to suggest how to teach the materials and structure the after school program. We found this collaboration to be quite effective and empowering for the student mentors, who were able to shape the after school program based upon what they liked and disliked from their summer experience.

The final project will be the result of the collaboration between the undergraduates and the high school students in the after school program. (Labs for the undergraduate course have been scheduled at the same time as the after school program, to ensure that the undergraduates will be able to work collaboratively with the high school students.) The theme for this final project will have been determined in the third project.

At the conclusion of the final projects, students will write a final paper reflecting upon the final exhibition and the after school program.

Conclusions

In this early stage of the Artbotics program, we have already found the combination of Art and CS to be an engaging medium for students. Our two pilot groups have formed strong bonds and worked well as both small teams and in the larger whole.

We are still working to find the proper balance between art and computer science. The issue is not art as a topic, but the amount of time required to build the structures that are part of the piece. For example, the hand in the fountain required two students to spend three full days constructing it. The hand was integral to the piece, but this type of work takes students away from learning more about programming and other types of sensors that could be used in the work. As we continue with our pilot year, we hope to discover whether we need to be concerned with this imbalance. As one of our goals is to encourage students to understand computing and its many uses, perhaps it is enough for them to be exposed at an introductory level. Longitudinal studies will allow us to assess if the program is successful in attracting students to take additional computing courses.

Acknowledgments

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