ARTY: Fueling Creativity through Art, Robotics and Technology for Youth

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Abstract

ARTY is a week-long program for middle school students to teach them programming of robots and allow them to express themselves artistically. It was started in 2013 and ran its fourth edition in 2016. We describe the ideas behind the inception of this program, its curriculum, our experiences during the 2016 workshop and challenges/future directions for the program. Our primary intent in this paper is to convey the program curriculum and its design, including the way in which robots can be viewed as vehicles for artistic expression. Some results from a brief attitudinal survey that was administered before and after the workshop are also included along with a discussion of outcomes assessment and issues.

Introduction

ARTY (Art, Robotics, and Technology for Youth) is a workshop for 9-12 year olds that introduces students to robotics and computation in the context of visual and performance art. The program was developed and first offered in 2013. The focus of this paper is on the 2016 edition of the workshop.

ARTY is free of charge to participants with the goal of engaging as many underserved students as possible. The workshop location is easily accessed by public transportation and is centrally located in an urban area. The 2016 edition had 16 students and ran for a week. Previous editions took in between 15 and 20 students per week and were conducted for two weeks during summer.

ARTY was developed collaboratively by faculty from the University at Buffalo (Theater and Dance/Techne Institute) and Canisius College (Computer Science). The program has focused on the idea of robots as a vehicle for artistic expression. In this context, behaviors are construed as performative acts, and students are encouraged to appreciate the visual and entertainment aspects of robot movement and sound production while engaging in solving traditional problems such as line following. In addition, activities present robots as artists through the use of a drawing pen; as performers through student choreographed performances; and as moving displays for artistic creations through the use of robot-carried wooden platforms that serve as parade floats.

Support for the program, including funding for staff, supplies, food, as well as use of laboratory facilities, robots and computer equipment, has been provided by both institutions.

Participants build Lego Mindstorms NXT robots and program them using NXT-G. Art projects are created on top of the float platform and employ a wide variety of art and craft supplies. There is a structured curriculum, yet flexibility provides students with the freedom to express their individual creativity. The staff is multidisciplinary, drawn from science/engineering and the arts.

History

The collaboration that led to the creation of ARTY emerged from a unique theater production: WoyUbu (Pape et al. 2015). This performance involved a mash-up of two plays: Woyzek, by Georg Buchner, and Ubu Roi, by Alfred Jarry, juxtaposed with computer gaming, electronic music, video projection and creation, and a robot war. The event included audience participation, with the opportunity to engage in activities such as firing Nerf guns, dressing up, participating in the Ubu play, and playing video games.

WoyUbu involved faculty and students (graduate and undergraduate) from computer science, media studies, theater, and art, as well as professional actors, musicians, and artists. We developed our technology outreach activities within a similarly rich interdisciplinary context. In ARTY, we wanted students to engage in robotics with the goal of developing a performance piece for a robot they built themselves. In terms of visual art, students would create something that would be part of their robot's performance. It might provide additional insight about the robot as a component of the performance; it could transform a robot visually into a novel creature; or it might be an entirely unrelated creation to view alongside the robot performance. The robot is specifically designed to carry a wooden platform that serves as a float for carrying the art. In most years, the robots have participated in a robot parade followed by individual performances and demonstrations by the participants.

The following description, from our first year flyer, captures our excitement and ideas:

> The Art, Robotics & Technology for Youth summer robot workshop will provide elementary school children (9-12 years old) with an amazing opportunity to learn and experiment with robot art

projects! Students will work in teams to create and build a unique working robot and will create performances and presentations for their creations. Students will be supervised by engineers and artists to encourage wonder and creativity.

Related Work

There are many noteworthy programs in the US that focus on STEM education at the middle school and high school levels. A number of them use robotics as a means to teach various topics in STEM as well as STEAM, which adds an art component to the STEM endeavor.

(Burgsteiner, Kandlhofer, and Steinbauer 2016) created a program teaching several aspects of AI to high school students. The program was two hours every week over seven weeks and involved nine students. Topics included automata, intelligent agents, graphs and data structures, classic planning and machine learning. (Anderson and Baltes 2007) and (Baltes and Anderson 2010) designed an educational curriculum around an inexpensive robotics lab as well as a mixed reality approach to introduce robotics ideas in a controlled fashion. They also describe detailed robotics labs involving multiple robots and friendly competition among the students. Perhaps the closest in spirit to our effort is the Artbotics program (Yanco et al. 2007) out of U-Mass Lowell. It is a collaboration between artists and computer scientists to teach computer science to students from elementary school through college and includes training for teachers. For this, they developed the *SuperCricket*, an embedded controller board and a custom language called *Cricket Logo*. They use multiple robot platforms including the NXT and the EV3 from Lego. The first pilot had seven students, three from computer science and four from the arts. The program has computer science objectives, art-related objectives as well as service learning objectives. There were four projects and a final paper as part of the initial curriculum. It was supported by the NSF Broadening Participation in Computing program, and continues to form the basis for ongoing outreach activities.

Curriculum

We have several intended objectives for the ARTY program. We would like the students to build a Lego robot themselves, with help, as needed, from staff members and their peers.We also want students to learn basic programming concepts and design. We want students to be able to program their robot to move around in the world, and to learn to use sensors to inform robot behaviors. We are also interested in robots as vehicles for artistic expression. Finally, we are interested in engaging the students in discussions on use of robots in ways that are generally unfamiliar to them. This includes robot art and performance as well as applications such as assisting the handicapped, emulating biological creatures, and engaging in group behaviors and communications.These objectives are realized in our curriculum which can be divided into three components:

- Robot design: building; moving; sensing; behaviors; performance/display

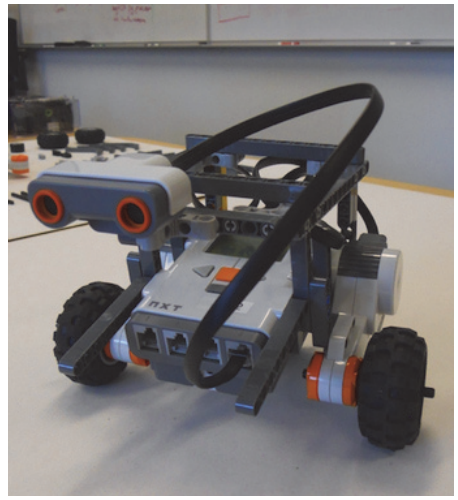

Figure 1: Basic ARTY build

- Artistic expression: planning and creating visual art; writing and playing music; choreographing dances
- Learning from Experts: What do people who actually work with robots do with them?

Robot Design

We use the Lego NXT robot platform. Following introductions and a welcome session, students receive a bin containing all the parts for the robot build. The basic robot is a rover with two front wheels, a castor wheel in back, and a frame for holding sensors and other Lego pieces (Figure 1). The build instructions comprise a 50-page file with high-resolution images and detailed step-by step instructions. The building instructions have been improved over the course of the program and can be found at:
http://www-cs.canisius.edu/~burhans/ARTYbuild.pdf
The act of building a robot from start to finish enables students to engage with the robot as a creation of their own; they feel a real sense of achievement in going from a bin of parts to a complete, working autonomous robot.

Most students in the workshop are able to follow the instructions fairly well. The frame is designed to hold a wooden platform, serving as a parade float, upon which art is constructed. A battery pack containing four AA batteries is affixed to the bottom of the platform with Velcro so that it can be easily removed. The batteries are used to power LED lights and/or circuits, which students can create with staff help and include in the art project. The platform can be snatched easily off the robot in case things go awry with movement since it is not actually fastened to the robot structure, but held in place due to the way the battery fits into the frame opening. In addition, the frame is very sturdy and provides an easy way for students to grab their robots if need be. The battery pack provides weight and stability to the robot in addition to fitting neatly inside the confines of the frame.

Students are generally able to build the robot the first day. Staff provide additional help where needed. The next task is moving the robot with simple programs. Lines, circles, and basic shapes are first programs. Once robots can trace simple shapes, students turn their robots into artists by attaching drawing pens to them that we have pre-built. On a large paper area taped the floor (10ft. x 20 ft approx.), students can immediately observe their robot's movement by watching the trace of a colored pen. Students program a design for their robot to draw and create an individual piece of robot art to take home.

The next learning task is about sensing. We employ light/color sensors, touch, ultrasonic, and sound sensors. Students learn to avoid running into an object in front of the robot with touch and with ultrasonic sensors. They use sensors to follow lines and curves, with a large range of student outcomes. At this point, students have built a robot that can create in the world (draw) and behave in response to sensor input. By the end of the second day students have all achieved these milestones, with some just sensing a wall and finishing up a drawing, and others having developed quite sophisticated line or light followers.

From this point onwards, students plan and develop a robot performance, which could range from the theatrical to creating a sumo competitor. We also offer them a variety of robot challenge problems to complete, including complex pattern tracing, various following activities, obstacle course navigation, and generation of sounds and music.

In past years, we have had a robot parade with all of the robots followed by individual student presentations and performances. This year we hosted a *Gallery of Robots* that also featured individual presentations. We hope to incorporate some group behaviors next year that involve all robots together. We briefly experimented this year with a drum and sound sensors: students programmed a little turning or dancing behavior in response to sound, which was made using the drum. By incorporating the behavior in a loop, the robots would all move when the drum was played, and stop when it was quiet.

In addition to the shift from a parade to a gallery, the 2016 teaching team involved two faculty from UB who do research in robotics along with a number of their students. The goal was for them to offer more advanced activities for students ready to pursue them, such as the development of more sophisticated algorithms for sensing and coordination, and other bio-inspired behaviors such as foraging.

Artistic Expression

The art component provides students with purchased and scavenged materials from paper and fabric to cardboard, beads, drawing supplies and materials, small circuit boards with LED lights and other components for display. Over the years, student projects have ranged from a unicorn in a forest to chainsaw cat (a purple feline), the tower of terror (topped with a flower), and many others. Generally closer to 3-d sculpture and craft than 2-d art, it engages students deeply and enables them to imagine and play. Even students who are initially reluctant to participate in art activities get caught up in the creative process. A student-designed robot float can be seen in Figure 2. This year, as well as in the first year, we also provide students with a chance to build and remodel their robots using additional Lego pieces. This may be no less artistic and allows for greater creativity over the standard build.

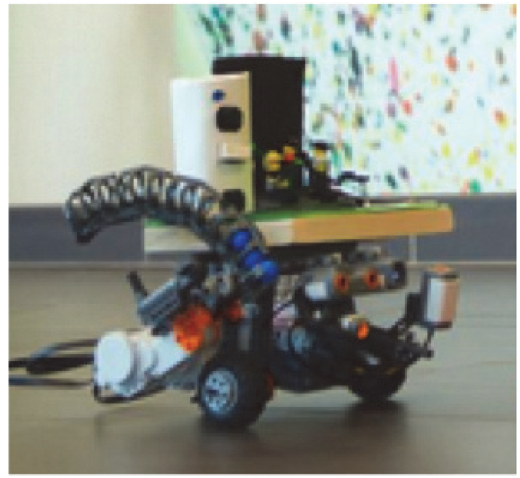

Figure 2: Robot platform and art

For this, our teaching team also included an artist whose interests are in using motion in her artistic expression. She introduced students to pieces from art history that prominently used motion in art.

Robots with extra Lego pieces are generally not able to support the platform, in which case the constructed art component is a side accompaniment to the robot performance.

Learning From Experts

This component of the curriculum includes talks from people who work with robots. Their experiences range from dramatic performance with robots to art, sculpture, communication, and research robotics. The purpose of this component is to show the students some real-world uses of robots/programming that are generally not what they might expect based on popular culture. We invite faculty from local colleges as well as visual and musical artists employing electronics and robotics from the local community for this segment. They present for 20 minutes during snack time followed by a 10 minute discussion with the students. Topics ranged from bio-inspired robotics, observations from sensing, actuation, and coordination in nature, use of motion in artistic expression and others.

ARTY 2016

As has been the practice, we conducted the ARTY program in the robotics laboratory at Canisius College. The staff included Profs. Karthik Dantu and Nils Napp from UB CSE along with Prof. Debra Burhans from Canisius College. Due to limited support this cycle, our recruitment window was quite small and our outreach to city students was limited. In previous years, we have partnered with specific local schools and recruited students with more diverse backgrounds. Due to the success of previous editions of the program, we had considerable interest and the seats filled up within days of opening. We had a total of sixteen participants - ten male and six female. Participants included a small group of returning home-schooled students. Since the start of ARTY there have been home-schooled students enrolled in every edition of the program. Four students were exchange students from Korea visiting for the summer. There were four sibling pairs which made for interesting group dynamics.

It was important to us that students had staff to look up to from both genders as well as diverse backgrounds. For all middle school students we see great value in providing strong teachers and experts who represent diversity: it helps to dispel stereotypes about not only who can learn to work with technology but also who can attain a level of achievement in a STEM field that enables them to teach and do research. Our 2016 staff included three African American women, two of whom worked in 2015 as high school interns with ARTY. There were three graduate students, including two women (Brazilian and Asian) and one man (Indian). There were two additional Caucasian women on the staff. There were three supervising faculty members, including one Caucasian woman, one Caucasian man, and one Indian man. Overall, there were 8 females and 3 males.

Shown in Table 1 was our 2016 schedule. The program, like previous years, was a week long with classes going from 9:30-12:30pm. To ensure a high level of student engagement, we limited the sessions to 1.5 hrs each with a snack break in between. We also use the break for a short talk from an expert to introduce ideas from nature and art as well as to engage in a discussion about STEAM. This routine kept the students engaged and gave them opportunities to express themselves.

Day 1: The first day was the robot build. This build was previously designed, and is shown in Figure 1. As can be expected, the pace of students varied significantly. A few students finished them in the first period, while some others could not finish until the end of Day 1. The build was an exercise in being able to follow instructions, visually match various pieces, and compare their design to the pictures in the guide. After the build, students were introduced to the NXT-G programming environment. Simple movements such as going forward for a given distance, going in circles, and tracing out other regular shapes were introduced.

Finally, the students were given a set of five challenges to create regular shapes that were checked by one of the staff members. We then gave the students pre-built arms with colored markers attached. They could actuate this arm up and down using a third motor such that the pen drew discontinuous patterns as the robots moved along, or they could choose to leave the pen stationary and just drag it to create a single line pattern. When students watched the robot try to draw a square without lifting the pen it illustrated the turning radius associated with the pen attachment and showed them that making clean figures with the given pen attachment required some careful thinking and planning. Students were asked to write programs to have their robot create a design using what they had learned. The drawing activity can be seen in Figure 3.

Figure 3: Robot art made with drawing arms

One of the interesting events on Day 1 was that a student was not happy with his robot design. He looked up different designs online and settled on a picture that he liked. He then reconfigured his robot looking at the picture which impressed the staff. His robot is shown in Figure 4. One of the avenues to pursue in future ARTY editions is to present custom robot design as an option to allow students to be creative in the physical build as well as in performance and actual creation of 3-d art. The Day 1 presentation, "What is a robot?", involved asking the students what they thought robots were and showing them pictures and video of a spectrum of robots that did not conform to their expectations.

Day 2: The second day introduced the students to sensors and sensing. Several sensors were presented to the students including an ultrasonic sensor that can sense obstacles (how far away they are), sound sensors that allow the robot to react to sound, light sensors that sense the luminescence of light and color sensors that can differentiate various colors. During the first session on Day 2, the staff helped many students in understanding the basics of sensing. Similar to Day 1, students were given a set of challenges to complete using the sensors. The first one was to use the ultrasonic sensor and perform obstacle avoidance while executing the behaviors designed on Day 1.

There is a speaker on the NXT robot brick for sound production, and students were introduced to its usage as well. Students immediately started creating programs that combined these modalities and used a parallel track for sound production. Some students had the robot say "obstacle" whenever the robot came to an obstacle, starting and stopping the robot as a response to a sound, and others composed tunes using the built-in NXT keyboard. During the second session, students were asked to perform more complex sensor behavior such as line following using a color sensor that is looking down. This introduced the students to control logic and challenges of programming on a real robot as such programs require a lot of tuning. The Day 2 presentation, "Robot Behaviors - Communication, Foraging", described examples from biology of insects communication and collaboration. This gave the students ideas on how robots could emulate behaviors found in nature and in doing so could act like actual living creatures.

Day 3: On the third day, we had students start building their art projects. We provided them with a wooden platform that was mountable on their robot as well as an array

Day	9:00-10:30	10:30-11:00 Snack	11:00-12:30
Monday	Intro to ARTY	"What is a robot?" - Deb Burhans, PhD	NXT-G robot movement Robot drawing - robot as artist
Tuesday	Robots move and draw Sounds and sensors Robot songs and music	"Robots as creatures foraging and communication" - Nils Nap, PhD	Sensor input and behaviors Introduction to art supplies and possibilities
Wednesday	Art: making a float Robot as performer	"Robots and swarm behavior" - Karthik Dantu, PhD	Art or Robot challenges Variables, complex control structures
Thursday	Art or Robot challenges Robot interaction	"History of motion/robotics in art" - Liz Lessner, MFA	Art activities Robot performance behaviors
Friday	Finalize robot structures, behaviors, art	Set up robot gallery	Gallery of Robots ! Robot performances for visitors !

Table 1: ARTY week schedule

of supplies. These included color paper, felt, foam, other materials and patterned papers, markers, gems, and a large and varied collection of found and purchased objects allowing the students to design and build many different creations. The art room was separate from the robotics lab. We let the students choose between continuing to work on their robot behaviors and creating art for each subsequent session. The outcomes were very interesting. Five of the seven girls chose to mostly create art while only one of the boys chose this. Two of the visiting students from Korea chose to collaborate in their artwork, and create a country-flag themed art. One other female student created a horse-head, and other students created nature-inspired art such as a garden.

Students also continued to improve on their robot behaviors. Several boys created robot appendages that were used for a robot wrestling match. They incorporated aspects of behaviors from before such as line following to stay inside a fighting circle. These students spent day 4 refining their designs after repeated wrestling matches where the arms fell off or the sensing did not perform adequately. One other student who had some musical training created tunes that the robot played on some sensory input such as a clap. We felt that Day 3 was really when the students started expressing themselves creatively based on their interests. The Day 3 presentation, "Robots and Swarm Behavior" introduced the students to coordination both from nature (such as ants and bees) and in robotics. Again, they were shown ways in which robots could embody themes from the natural world.

Day 4: Day 4 was similar to Day 3 where we let the students either create art or improve their robot programs. Several students who did not participate in art on Day 3 were inspired by the others who did, and went and created art of their own. The two visiting students from Korea continued to work collaboratively and created robot behaviors that were synchronized to accompany their Korean flag art, including playing the Korean national anthem while they performed the behavior. Some students also joined the wrestling league with their art. The student who chose to re-design his robot on Day 1 figured out how to use multiple sensors to detect different colors (red/green pieces of construction paper) that he scattered around the lab. As his robot "foraged" around the lab it called out the color of a piece of paper when it was detected. Most students moved on to using nested control structures such as if-then statements and loops for continuous behavior. For example, a doubly-nested loop is used to transition between two states that are controlled with sensor input, and nested if structures can be used to distinguish between more than two possibilities. In both cases, mediating behaviors using sensor input is usually the reason for employing the control structures. Unfortunately, going beyond a couple layers of nesting in NXT-G is quite awkward in terms of visualizing the code.

The presentation on Day 4, "History of motion/robotics in art", was given by a returning ARTY staff member who is a practicing artist and media designer. She works on using motion and sensing in her own creations, which are often 3-d interactive sculptures. Her presentation showcased historic instances of motion and sensing in unexpected art contexts. This led to the most vigorous discussion with the students. In a certain sense this is not surprising: while students may easily make connections between robot design and behavior and biology, they have probably never seen a dress that can sense and change as it is worn. In addition, by the fourth day of ARTY students have become more comfortable in the environment and with one another, making them more likely to participate in discussions.

Day 5: Day 5 was the final day of the workshop. In the first seesion we administered a post-workshop questionnaire after which students worked to finalize their art and set it up on their respective robots. There was a lot of last-minute testing and fixing.

For the second half of the day we hosted families and visitors in a robot gallery where they looked at the robots and engage with the displays and their creators. They were genuinely interested in all of the students robots, not just those of their own children. After visitors had a chance to look at the robot displays, we watched the performances created by students: each student or group introduced their robot(s), which had been named by students earlier in the week, and ran their performance programs. One of the students created a musical robot named *Bot-thoven* and had it play *Ode To Joy*, which he had incorporated into a program by figuring out the melody on the NXT-G built-in keyboard. Others incorporated a variety of sounds and behaviors. The foraging robot performed very well, finding red and green paper squares and yelling out "red" or "green" with complete accuracy. In

Figure 4: Custom robot design by a student for a foraging task

addition to these performances, one of the students set up a sumo robot league competition for those who were interested. One student programmed his robot to patrol outside the ring and act as the ”referee”.

Discussion and Future Directions

Challenges

There are many challenges to running a program such as this, not the least of which is support. We are thankful to the Techne Institute at University at Buffalo whose mandate is to support arts and emerging technologies. Robotics requires a high staff-to-student ratio, and we have typically required one staff member for every two students. In addition, there have been at least a couple of students in every cohort who require significant one-on-one mentoring. This level of engagement makes it extremely difficult to scale up a program such as this. One of the directions we would like to explore in the future is ways to scale up such a program.

Evaluation

Assessing the impact of the program is itself a challenge. We administered a brief pre- and post-workshop survey this year to gauge student attitudes. There were two interesting findings from the survey, evinced by questions or statements where the student responses shifted markedly. The first concerns the question, ”In your opinion, is robotics an easy or difficult topic?” On the pre-survey three students indicated easier than average, eight indicated average difficulty, and five above average difficulty. The post-survey showed seven ratings easier than average, five average, and four above average difficulty. The workshop clearly had an impact here: the number of students who felt that robotics was easier than average more than doubled after a week of working with robots. The second item of interest was responses to the statement, ”Robotics skills will be useful for non-science projects.” Initially seven students were unsure about this, two thought probably yes, and seven indicated definitely yes. The post-survey showed only three students unsure, five said probably yes, and eight indicated definitely yes. This seems to show that the message that robotics is something that has broad application has been received, being, affirmed by 13 of the 16 participants. The rest of the survey showed little difference between the pre- and post-surveys: designing and administering a good survey instrument is challenging and has been an issue since we started ARTY in 2013. The post-survey asked an open ended question about what students enjoyed most about the workshop: seven students specifically referenced programming and getting a robot to do what they wanted it to, including creating a performance; five indicated the art or music aspects of robotics; and a couple preferred building.

Future Directions

We would also like to be able to send students home with the robot they build, and not just their artwork as well as a small breadboard with an LED circuit on it. This would allow them to continue their engagement beyond the week-long program and will likely have more sustained impact. It would also help us keep engaging with students who are graduates of this program. We are in the process of seeking support for this.

We hope to explore ways in which we can increase the engagement in terms of numbers of students as well as bringing back students from previous editions as mentors. We would like to reach out to a broader range of ages, including high school students.

Conclusions

Our intent was to offer a program that engaged students in technology in a non-traditional fashion. We provided enough structure in the program to complete common tasks while providing enough freedom for their individual artistic expression. This was by design allowing the students to learn from the creation of others, feedback from experts and their own creative play.

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