Developing the Capabilities of Blind and Visually Impaired Youth to Build and Program Robots

Rayshun Dorsey

WizKidz Science and Technology Centers

rdorsey@wizkidztech.org

Chung Hyuk Park

New York Institute of Technology, School of Engineering and Computing Sciences

chung.park@nyit.edu

Ayanna M. Howard

Georgia Institute of Technology, School of Electrical and Computer Engineering

ayanna.howard@ece.gatech.edu

Abstract

In this paper, we discuss the use of accessible technologies for exposing visually impaired students to the science of robotics using real world, hands-on activities. The purpose of the initiative stemmed from the current lack of engineering and robotics related extracurricular programs, activities, and resources offered to blind and visually impaired youth. Discussion of the technologies and our approach is presented in this paper and validated through a national outreach effort with visually impaired student populations.

Keywords

Visually Impaired Youth, Robotics, Accessibility

Introduction

Students living with various disabilities need exposure to real world situations and should be given such opportunities early in their education to stay competitive in the world arena of science, technology, engineering, and math (STEM). Educators that work with students with disabilities need new and exciting, accessible learning models that bring these students closer to real world learning scenarios to expose students with disabilities to careers in science and technology. Despite a student's particular disability, all students should have exposure to hands-on science and technology environments that prepare them for real world applications.

Currently, there are only a small number of efforts that are deployed to engage students with disabilities in the fields of computing and robotics, including the National Center for Blind Youth in Science, the AccessComputing Alliance and Project ACE which provides resources to prepare youth with visual impairments for higher-education and computing career opportunities (Bech-Winchatz and Riccobono; Access Computing; Ludi and Reichlmayr). In addition, there are a few individual efforts that have utilized robots to facilitate learning for students with physical impairments (Howell, Chipman, and Stanger; Cook et al.). Our efforts differ from other related projects in its attempt to engage students with disabilities by focusing on accessible interfaces for robot programming. We aim to deliver computing and engineering content via robotics as a delivery mechanism while providing infrastructure to engage pre-college level students in the classroom environment.

This approach requires several subprojects. The first subproject is to provide hands-on robot building activities that engage youth in the engineering design necessary to accomplish a given objective. The second subproject is the investigation and augmentation of current interfaces that will enable access to robot programming activities for the students. Accessibility is a strong requirement for these interfaces to be effective. The last subproject is the planning, execution, evaluation, and refinement of robotics institutes in conjunction with the Center for the Visually Impaired, the National Federation of the Blind of Georgia, Cleveland Sight Center, and the Colorado School for the Blind. In this paper, we discuss these subprojects for developing the capabilities of blind and visually impaired youth to build and program robots, which has been validated through a number of workshops and summer camps over a 5 year period.

Subproject 1: Hands-On Building of Robotic Platforms

Evaluation of Robot Platforms for Building

In 2007, we began hosting summer robotic workshops for the Center for the Visually Impaired STARS Program (Figure 1). These first workshop series were designed to understand what robot kits could be utilized to help develop skills in building and design for visually impaired students. The students, whose ages ranged from 9 to 17, were exposed to real-world situations using various robotic platforms. Our goal was to evaluate which robot building kits were better suited for engaging this target demographic. Using a team of mentors from the Center for the Visually Impaired, each student was paired with a sighted buddy who helped the blind student by reading directions, handing the student parts, and assisting with putting together the different parts of the system.

Fig. 1. Pictures of Robot-Building Activities

Taken from Computing and Robotics Workshops 2008-2012

Various robotic platforms were tested including Parallax, Tamiya, LEGO Mindstorm NXT, and LEGO Mindstorm RCX. We found that with the help of the sighted buddy, the students were able to successfully complete the build out of all the various robot kits, however, with great difficulty. Many of the students using the Parallax and the Tamiya kits had difficulty and complained the parts were too small and difficult to handle. Student teams also designed, built, and programmed robotic structures using the LEGO Mindstorm NXT and RCX Robotic Platforms. We found that the students using the LEGO kits needed less intervention from their sighted buddy and found the LEGO parts easier to handle, identify, and place in their proper location to complete their robot. Out of the two LEGO Robotic kits used, the RCX provided an easier interface for the students to locate and identify the parts. The LEGO RCX building components consist of classic LEGO pieces with raised studs. We found that this feature, in conjunction with the odd shapes, made it easier for the students to identify the part and complete his/her robot design (Figure 2). Based on our observation through these student interactions, we determined that the LEGO Mindstorm platforms were the most suited for designing interactive robot building activities for blind and visually impaired students.

Fig. 2. The LEGO RCX kits Showing Classic LEGO pieces with Raised Studs

Objective of the Robot Building Activity--Sumo Challenges

To provide a focused objective for the robot building activity, we initiated a curriculum that centered on competition through a Sumo-Bot Challenge, which featured two LEGO robots trying to push each other out of a ring. The challenges were non-destructive, kid-friendly, and a great learning experience for the students. Students were instructed to build a basic two-motor vehicle using the LEGO RCX or NXT robotic system. Once completed, the students were encouraged to build and add attachments that would give each robot a winning advantage. The two self-controlled robots were then placed in a challenge ring where the robots tried to push the opposing robot out of the ring. The first robot that touched the outside of the ring lost the round. The first robot to win two rounds won the match. Each of the LEGO Sumo-Bots was pre-programmed to move in a forward direction at a constant speed. After positioning and starting the robot, no remote control, power, positioning, or other external help could be provided. The robot had to autonomously push forward by itself until the round ended. A typical build session ranged from 30 minutes to 1 hour, depending on the complexity of the platform desired. Figure 3 shows highlights of two Sumo-Bot Challenges in 2009 and 2011.

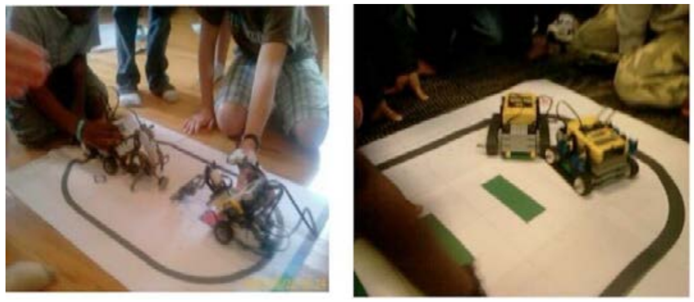

Fig. 3. Snapshots of the Sumo-Robot Challenge in which Students Competed Using Their Individually Built Robot Platforms

The excitement of the Sumo-Robot Challenge had a direct computing influence in that students began to express a desire to not only build the best robot platform, but program their robot to perform different functions in order to give their platform a competitive advantage. This naturally led to the next subproject in which we taught students how to program their robot platforms using various accessible programming interfaces.

Subproject 2: Robot Programming Activities

One of the major technical innovations found in the next subproject was the utilization of accessible interfaces to enable the programming of robots by blind and visually impaired youth. Accessible interfaces consist of a collection of multi-modal interfaces that rely on the integration of text-to-speech translators, audio feedback, and haptic interfaces to engage students with visual impairments in robot-educational activities (Howard et al.). Although there were a number of available programming interfaces available for the LEGO Mindstorms, we selected the Bricx Command Center (BricxCC) as a programming interface due to its accessibility attributes. We then integrated the JAWS screen reader and MAGIC screen magnification software to provide access to the programming environment (Freedom). The screen reader enables a direct text-to-voice conversion of the text within the programming console whereas the magnifier provides expansion of the text for those designated as legally blind (i.e. a central visual acuity of 20/200 or less). Using this platform, a teaching protocol was developed that utilized screen readers to relay visually displayed information on the computer console and a lesson plan that provided step-by-step instruction on the basic programming environment and syntax, such as compiling and downloading robot instructions, introduction of the robot command library, calling a function from the provided library, and figuring out how to call functions with input parameters. This self-explanatory teaching protocol was used to teach basic knowledge for programming the robot.

To provide sufficient feedback so that students could "see" what their robot accomplishes after it was programmed, we utilized two types of feedback--vibration-based haptic feedback and auditory feedback (Park et al.). For haptic feedback, a Wii remote controller (Wiimote) was used as the primary interface between the robot and the user. In this instance, combinations of differences in timing and forces of the Wiimote vibrations reflected different actions of the robot. In the case of auditory feedback, various sounds associated with different piano notes were recorded, and the saved sound file was associated with different robot behaviors. A full suite of auditory and haptic feedback was created to provide the student:

1. Sense of distance for how far the robot had traveled or in which direction the robot was turning
2. Sense of distance to an object located in front of the robot
3. Sense of whether the robot had reached a goal or not
4. Sense of whether the robot had bumped into a wall or an obstacle

As an example, Figure 4 depicts the auditory notes used to provide information about robot actions.

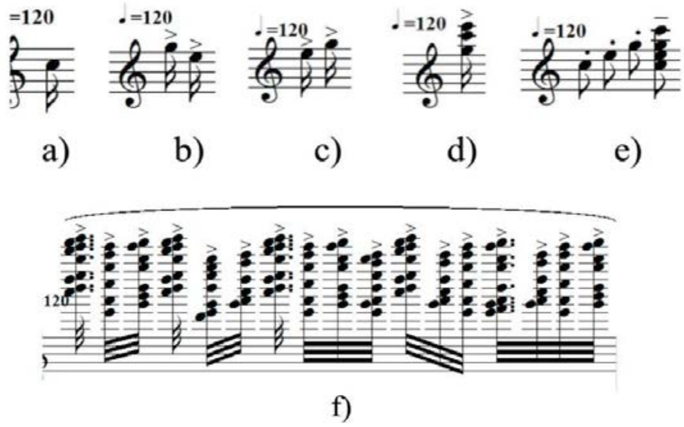

Fig. 4. Piano notes for auditory feedback: a) travel forward, b) turn left, c) turn right, d) object detected, e) goal achieved, and f) bump (crash).

Objective of the Robot Programming Activity--Maze Challenges

To provide a focused objective for the robot programming activity, the students were given a task to program their robots to navigate through a maze. For this task, we first provided students with a preprogrammed robot that was capable of successfully navigating the maze. While the robot navigated though the environment, the students were provided haptic/audio feedback. During each run, each student would report what they felt their robot was doing (i.e. moving forward 10cm, turning 45 degrees, etc.). This information was recorded and then provided to the students in order to enable them to program their robot to solve the maze (Figure 5).

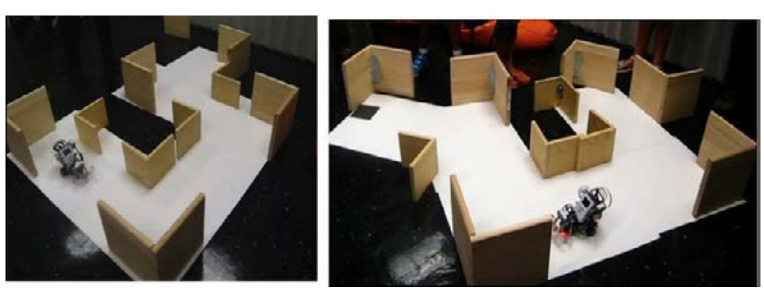

Fig. 5. Different configurations for the robot maze challenge.

Subproject 3: National Robotic Institutes

Over the past five years, we have run a number of robotic institutes nationally in the US, in conjunction with the Cleveland Sight Center, Center for the Visually Impaired, the National Federation of the Blind of Georgia, and Colorado School for the Blind. The institutes were targeted at middle and high school students with visual impairments and have had over 60 student participants. For assessment, we evaluated both the robot building activities and the robot programming activities. This was accomplished through pre- and post-surveys (Figure 6) as well as evaluation of the learning curve associated with how well students achieved their programming objectives.

Robotics Workshop

1. How helpful were the Wiimote vibrations in letting you know what the robot was doing?
a. very helpful b. helpful c. slightly helpful d. not helpful

2. How helpful were the sounds in letting you know what the robot was doing?
a. very helpful b. helpful c. slightly helpful d. not helpful

3. Which do you think was most helpful?
a. Vibrations b. Sounds c. both d. none

4. Which do you think was most confusing?
a. Vibrations b. Sounds c. both d. none

5. How much do you think this workshop helped show you that you are capable of working with computers or robotics?
a. a lot b. some c. a little d. none

6. How much has this workshop encouraged you to consider working with computers or robotics when you grow up?
a. a lot b. some c. a little d. none

Fig. 6. Partial Survey Used to Evaluate Robotics Activities

with Blind and Visually Impaired Youth

The learning assessment showed that, by providing sufficient haptic and auditory feedback, students could learn how to perform even highly visual tasks, such as programming a robot to solve a maze. In addition, based on the subjective assessment metrics we have validated after participating in the robot sessions, students have a stronger desire to consider working with computers/robotics as a career possibility.

Discussion and Future Work

Future work focuses on the development and dissemination of training kits based on learned practices using the accessible robot building and programming interface tools. A strong benefit of this effort is the investigation and augmentation of alternative interfaces that can be shared with others such that educators can engage students with visual impairments in the classroom environment. Teachers should be able to utilize the training kits and the associated robotic institute infrastructure to encourage participation of students with visual impairments in computer-related activities. Students themselves should also be able to use the provided infrastructure to enable independent exploration of other programming activities. To support this effort, we are currently creating a website that will allow easy access to documentation, learned practices, and modules. The website will be self-contained and conform to accessible design. We are also working on augmenting the curriculum to engage students with motor impairments in educational robotic activities.

Acknowledgements

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