Using Tablet Devices to Engage Children with Disabilities in Robotic Educational Activities

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Abstract

In a number of prior efforts, robotics-based activities has been shown to encourage K-12 students to consider careers in science, technology, engineering, and math (STEM) and has been incorporated into a number of engineering and computer science disciplines at a number of universities. Unfortunately, for children with disabilities, there are still inadequate opportunities for teaching basic science and engineering concepts using robotics-based curriculum. This outcome is generally due to the scarcity of accessible interfaces to educational robots. On the other hand, the widespread availability and ease-of-use of tablet computers have given rise to opportunities to engage children with visual, cognitive, and learning disabilities through various Apps. Due to their pervasive characteristics, these mobile platforms provide an ideal opportunity to integrate robots into the learning environment for children with disabilities. As such, in this paper, we discuss the integration of tablet computing platforms with alternative interface modalities to engage children with disabilities in robotics-based educational activities. We provide an overview of the interaction system and results on pilot studies that engaged nine children with disabilities in a number of Saturday robotics camps.

Keywords

Accessible Robots, Switch-to-Tablet Interface, Programming, K-12 Education, Assistive Technologies

Introduction

The percentage of entering college freshman reporting disabilities continues to increase in the academic environment [1, 2]. Among those undergraduate students with reported disabilities, only 8.7% majored in engineering or computer science [1]. Differences in precollege math and science education, which provides a foundation for pursuing a technical degree, are a large contributing factor to this disparity. At the pre-college level, approximately 11% of children between the ages of 6 to 14 have a reported disability [3, 4], and yet these students took fewer science and mathematics courses than those without disabilities. These differences are generally due to the unavailability of information in accessible formats [3]. However, many students with disabilities, like most students in K-12, are naturally interested in robotics [5]. Educational robotics has been shown to encourage non-traditional students to consider careers in engineering and science and has been incorporated into a number of engineering and computer science disciplines at a number of universities [6]. Robotics has even been used as a mechanism to teach mathematics [7] and science [8] to K-12 students. As such, as long as these robotic systems can be made accessible, robotics-based curriculum could provide a motivating factor to encourage children with disabilities to consider careers in engineering and science.

Currently, due to the pervasiveness of tablet devices and their ease-of-use, the emergence of tablet-based applications (Apps) for providing educational opportunities for children with disabilities is fast growing. With advances in Augmentative and Alternative (AAC) communication Apps [9] to cognitive memory Apps [10], resulting studies indicate that the use of Apps can provide effective therapeutic solutions for children with disabilities. And yet, the few efforts that are currently deployed to engage students with disabilities using robotics [11-14] are not utilizing these tablet devices as a delivery mechanism. As such, our efforts differ from other related projects in its attempt to engage pre-college level students with disabilities by integrating accessible interfaces with tablet-based robotic applications. In this paper, we discuss our interaction interface for making robotic platforms accessible and provide results from conducting a number of Saturday robotics camps that engaged nine children with disabilities, including those with Cerebral Palsy, Spina Bifida, Spinal Muscular Atrophy, Traumatic Brain Injury, and Autism.

Methodology

To enable delivery of accessible robotic educational activities, we require a platform that is adaptable to children with diverse needs. Due to the ease-of-use and portability of tablet devices, we developed such a platform by combining accessible interfaces and switch-accessible Apps for robot interaction. This interface was then integrated with multiple robotic platforms for engaging children with disabilities into the robot activities.

Accessible Interfaces and Apps

Although the current assistive technology market has provided speech, hearing, and visual aids using tablet devices, the market has overlooked the large populace that has difficulties using the touchscreen interface. Unfortunately, these interfaces are developed assuming a child is capable of 'touching' a specific small region with appropriate intensity and timing (i.e. effecting press and swipe gestures). This assumption does not generally hold true when considering children who possess limited upper-body motor control, such as observed in children living with cerebral palsy or recovering from traumatic brain injury. Given that over 200,000 children with disabilities being served in the public school system have an orthopedic impairment [4], there is a large demographic of children that are now being overlooked by the introduction of the tablet device into mainstream society. For such children with motor impairments, general access to computing platforms is currently accomplished using a physical device, such as a switch. Switch types of devices range from hand switches, head switches, foot switches, mouth switches, and even switches that can detect muscle movement. To enable use of software applications with switches, an application should enable scanning, a technique that enables movement through a pre-set list of elements that can be selected. Step scanning (or single-switch scanning) allows transitioning through the elements in a pre-set order whereas two-switch scanning enables a range of scanning options that include row and column navigation. The speed and pattern of scanning, as well as the way items are selected, must be individualized to the physical, visual and cognitive capabilities of the user. Although there are a variety of switches that can translate consistent and voluntary movement from any body part, the switch, itself, cannot be directly plugged into a computer or tablet device. In order to use a switch, a switch interface must be used to connect the switch to the computer. Thus, in order to provide children access to robotic platforms, we utilized a wireless controller called TabAccess™, which increases accessibility to tablet-based Apps that are used to interact with the robotic platforms (Figure 1). This alternative interface is designed to engage children that have difficulties affecting the common pinch and swipe gestures required for touchscreen-based interaction.

To enable direct command of the robot, we also designed switch-accessible robot interaction Apps that integrated step-scanning and two-step scanning options (Figure 2). The robot interaction Apps provide various robot control commands - typically forward, back, left, and right, as well as options to store a logical sequence of commands, which enables replay of a child’s stored program. Images (e.g. directional arrows) are used to identify the robot commands and, during the scanning operations, the commands are also highlighted with sufficient contract to reduce cognitive load. The switch-accessible robot interaction Apps, coupled with the accessible interface, allowed the development of an accessible robot interaction system that could be individualized to the capabilities of the child and engage a wider demographic of children with disabilities.

Fig. 1. Accessible Interface for Tablet Interaction

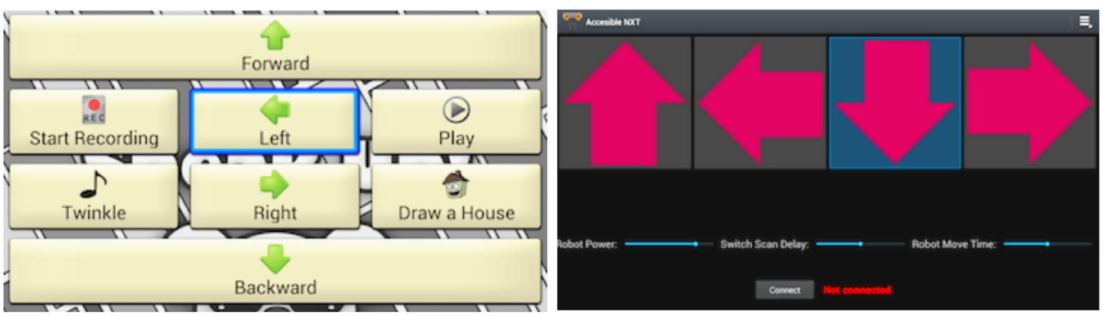

Fig. 2. Switch-Accessible Robot Interaction Apps

Robotic Platforms and Challenges

To address the unavailability of accessible interfaces for interacting with robotic platforms, we developed switch-accessible tablet Apps to interact with three Bluetooth-enabled commercial robots – the Lego Mindstorms, the Scribbler robot, and the Romibo. Lego

Mindstorms (http://mindstorms.lego.com) is a popular robotics kit that contains software and hardware parts (microprocessor, sensors, motors, and Lego parts) for creating customizable, programmable robots. The Scribbler robot (http://www.parallax.com/product/28136) is a small, low-cost fully programmable robot that also provides a pen port to enable the robot to physically draw as it drives. The Romibo platform (http://www.romibo.org) is an open-source do-it-yourself social robot that is designed for autism-based research. To provide a focused objective for the robot educational activities, we initiated a curriculum that centered on different challenges using these three different platforms, depending on the needs of the child. One competition focuses on the use of Lego robots in a Kick-the-Can competition (Figure 3a). In this challenge, the Lego robot was equipped with a wide base that allowed the robot to knock down objects. Children used their App to directly command, or program, their robot to knock down small blocks in a given time period. Another challenge focused on the use of the Scribbler robot in a drawing challenge (Figure 3b). In this challenge, the robot was equipped with a drawing pen of their color choice. Children used their robot App to draw different shapes, with the ultimate goal of having their robot draw a picture of their own choosing. The remaining challenge was focused on the use of the Romibo robot in a Maze-Solving challenge (Figure 3c). The Romibo, a DIY platform assembled at Georgia Tech, was used to navigate a maze from a start to a goal position, by controlling it with the tablet App. These challenges were non-destructive, kid-friendly, and a great learning experience for the students.

Fig. 3. (a) Lego robot and the Kick-the-Can Challenge (left), (b) Scribbler robot and the Drawing Challenge (center), and (c) Romibo robot and the Maze-Solving Challenge (right)

Pilot Study and Evaluation

To evaluate the effectiveness of the accessible interfaces for engaging children with disabilities in robotic educational activities, we ran a number of Saturday robotics camps. A total of 9 children with disabilities participated, each having various technical experience levels (Table I). Primary diagnosis of these children ranged from those with Cerebral Palsy, Spina Bifida, Spinal Muscular Atrophy, TBI, and Autism (Table II). Children ranged in age from 8 years old to 14 years old, with an average age of 10.2 years of age, and standard deviation of 2.2. Of particular interest was to evaluate the change in perspective of the children based on their experience interfacing with the robots (Table III). Based on pre-camp perception, on average, the students only considered working with computer/robotics a little when older. After participating in the robot camp, it can be noted there was strong agreement that they were capable of working with computers/robotics as a career possibility.

Table 1. Statistical Measures on Experience (A lot = 4; Some = 3; A little = 2; None = 1)

Experience	**Average**
Experience with a Computer	3.3
Experience using a switch or button to control a computer	3.4
Experience with programming	1.7
Consideration of working with computers or robotics when older	2.4

Table 2. Demographic profile of children

Number of Children	**Primary Diagnosis**	**Age (Avg ± Stdv)**
3	Cerebral Palsy	11.3 ± 3.1
3	TBI, Spinal Muscular Atrophy, Spina Bifida	10 ± 2
3	Autism	9.3 ± 1.5

Table 3. Measures on Perception

	Mean	**Stdv**
Pre-Session: How much have you considered working with computers or robotics when you grow up?	2.4	1.1
Post-Session: How much do you think this workshop helped show you that you are capable of working with computers or robotics?	3.6	1.0
How much has this workshop encouraged you to consider working with computers or robotics when you grow up?	3.1	0.6

Discussion and Conclusions

The field of robotics is extremely popular across generations of students. The use of robotics to teach Science, Technology, Engineering, and Math (STEM) concepts flourish in the literature and cover the entire educational spectrum from K-12 through graduate school. Unfortunately, the scarcity of accessible interfaces to educational robots can lead to children with disabilities not having equal participation with peers in these robot-based educational activities. In this paper, we have discussed how robotic educational platforms can be made accessible to children with disabilities by integrating tablet computing platforms with alternative interface modalities. The results from integrating these accessible interfaces into a number of educational modules was highlighted in a series of Saturday robotics camps that show the possibilities of utilizing this interaction system to engage children with disabilities.

Future work in this domain will focus on the dissemination of learned practices and the accessible robotic platform kits. A strong benefit of this effort is the development of alternative interfaces that can be shared with others such that educators can engage students with disabilities in the classroom environment. Teachers should be able to utilize the accessible infrastructure to encourage participation of students with disabilities in robotic educational activities. Students themselves should also be able to use the provided infrastructure to enable independent exploration of other activities.

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