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An Undergraduate Service Learning Research Project using a Humanoid Robot to Enhance Treatment for Children with Autism Spectrum Disorder

Ms. Jennifer Leaf, Eastern Washington University

Jennifer Leaf is a student in the Mechanical Engineering department at Eastern Washington University. She previously received a Bachelor of Science in Computer Science from Pacific Lutheran University and a Master of Science in Computing and Software Systems from the University of Washington, and worked as a software engineer and program manager in private industry. She intends to pursue graduate studies in robotics.

Mr. Arin Seth Preston, Eastern Washington University

Arin S. Preston is a mechanical engineering student at Eastern Washington University, specializing in robotics and automation. Prior to pursuing his degree, Arin spent 8 years in the United States Marine Corps, where he served as an artillery fire direction controller, a counter-battery RADAR team leader, and a firing member of the USMC rifle team.

Dr. Donald C. Richter P.E., Eastern Washington University

DONALD C. RICHTER obtained his B. Sc. in Aeronautical and Astronautical Engineering from The Ohio State University, M.S. and Ph.D. in Engineering from the University of Arkansas. He holds a Professional Engineer certification and worked as an Engineer and Engineering Manger in industry for 20 years before teaching. His interests include project management, robotics /automation, Student Learning and Air Pollution Dispersion Modeling.

Dr. Robert E. Gerlick, Eastern Washington University

Dr. Gerlick is Assistant Professor of Mechanical Engineering and Mechanical Engineering Technology at Eastern Washington University. He teaches courses in the areas of Robotics, Mechanics, Thermodynamics, Fluids, CAD, and Capstone Design.

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Abstract

This service learning undergraduate research project focuses on the use of humanoid robots to increase the effectiveness of therapy of children with autism spectrum disorder (ASD). Engineers often focus on industrial applications for robotics and automation. This project allows the engineering student to learn that the skills they are learning in industrial robotics can also be applied to societal problems in the community and provide ways to give back to the community. One in sixty-eight children are diagnosed with some level of autism, with the most common treatment being Applied Behavior Analysis (ABA). While ABA is an evidence-based approach, the learning process is time consuming, and it is not uncommon for an objective to take months, if not years, for a child to master. Two important consequences of this are the financial costs and the closing "window of opportunity," as therapy is often most effective in the younger, formative years. As an aid in improving ASD therapy, robots have been developed over the past decade, with noted potential for their use as "co-therapists." However, two major barriers to wider adoption of robots in therapy are the intensive programming requirements of the robots and the limited "off-the-shelf" programs available to clinicians. This paper describes a pilot project with the aim of enabling therapists to use the advanced technology of robots by eliminating these barriers through (1) the adoption of an intuitive and adaptable programming platform (NAO humanoid robot) and (2) development of an initial template program for the area of early language-communication.

Introduction

Eastern Washington University is a mid-size regional university with a primary emphasis in undergraduate education. Our Mechanical Engineering program has recently changed to include three track options: Thermal Sciences; Materials and Computational Mechanics; and Robotics and Automation. Faculty in the engineering program often work with students on research projects for scholarly work. This paper presents the effort from one research project in our Mechanical Engineering–Robotics program.

The EWU robotics program is applied in nature, where students learn to implement robotics and automation systems to solve real and simulated industrial challenges. Currently our robotics lab has four types of robots for students to gain experience with, including four articulated, four SCARA, and three delta robots, as well as Allen Bradley and Siemens PLCs for automation instruction. Recently we have obtained one humanoid robot, with the goal of delving into other emerging areas, such as collaborative and service applications. This robot, the NAO, is 23 inches tall, has 25 degrees of freedom, and several interactive inputs, such as tactile sensors, vision, hearing, and speaking abilities (detail sheet given in appendix). As our first experience with NAO, we are working with students on a service learning project in the area of autism, in which the robot is used as a “co-therapist” for therapy sessions with small children. The project goal is to develop a book reading program to assist autistic children in learning to read. For this project, undergraduate students are working with engineering faculty at EWU to design, build, and test this program.

Background on Autism and Project Need

Autism spectrum disorder is a neurological disorder effecting nearly 1 out of every 68 people [1]. Children with autism have various behavioral and cognitive challenges that impact their lives. Notably, these children often have difficulty communicating with peers and adults (both receiving and expressing), developing meaningful relationships, integrating in their community, and others. As autism is described as a spectrum, those on the lower functioning end have more severe disabilities, such as being completely non-verbal or completely dependent on care givers. Those on the higher functioning end may have only mild characteristics, such as difficulty communicating or relating to others. The treatment of autism has progressed over the past several decades and today the approach of Applied Behavior Analysis Therapy (ABA) is most common [2]. This method uses an operant conditioning approach, in which the therapist prompts the child to perform a task, followed by a reward if the child completes the task successfully, or a prompt to retry if not [2].

While ABA does lead to improvements with the child, there are some notable challenges; namely, progression is quite slow. Even small gains, such as teaching a child what pointing means (a neuro-typical child will naturally look in the direction of where someone is pointing, those with autism must be taught to do so) or teaching them the meaning of different facial expressions, or even how to say basic words, all take considerable time, often several weeks to months to master a single learning objective. While this learning pace has clear financial implications, the most important issue is the “window of opportunity.” That is, children with autism are typically more susceptible to therapy, and hence likely to benefit most, during their early years – before around age 8. Consensus from the literature is that the more intense the early intervention in, the greater the gains are [3], with 25-40 hours of therapy per week showing significant efficacy [4]. As a result, it becomes crucial for autistic children to receive very intensive therapy early on and that the therapy is effective and efficient. Therefore, a current need in autism therapy is for methods that will help children master their cognitive and behavioral learning objectives quickly.

Project Objectives

To address this need, behavioral therapists have recently begun to work with engineers to develop robots that are used in autism therapy. The premise is that autistic children are very interested in robots and gadgets, and therapists are seeking to leverage this interest to facilitate learning [5]. Research into robotic-assisted autism therapy has been ongoing for nearly a decade, and various physical robot forms have been studied. Numerous studies have led to the optimal attributes for this type of robot. For instance, children were found to benefit most from robots that are approximately the size of a small child and had physical features that were somewhat human-like, but not entirely [6]. Based on this research, and with the explicit goal of assisting in autism therapy, Aldebaran, Inc. has developed the humanoid robot NAO, as shown in Fig. 1.

Fig. 1. NAO Robot
(source: https://www.ald.softbankrobotics.com/en/cool-robots/nao)

In order to use this robot in clinical therapies, it must be programmed explicitly per the therapist's requests, based on the specific needs of a child. Due partly to this requirement, the robot has seen little use outside of research settings, with little to no use in practical autism clinics. Clinicians have stated that a major barrier to its use is in the high cost (time and money) of developing these programs, as they have little to no background in computer programming. For these robots to be feasible, a therapist with only basic programming skill and aptitude must be able to quickly and intuitively setup, program, and implement the robot in a therapy session. The robot must also be easily integrated into the existing therapy framework and agenda (objectives, setting, timing, etc.).

A second challenge relates to the characteristics of autism itself. Each child with autism is unique, with their own set of cognitive and behavioral skills and challenges that are often quite different than other children. This presents another barrier to robot use in therapy in that the time invested in programming a robot for one child would likely not be usable as-is with another child; it would likely need modifying to some degree based on the child's unique skills and needs. Therefore, for this technology to be more viable for clinicians, programs developed must be efficient in terms of the time invested in programming.

To address these needs, our goal is to design and build a template program for the NAO that is easy to program by novice users, flexible in use throughout a therapy session, and generalizable among children and therapists. The program will be focused in the area of reading and comprehension for children just learning to read, as this is often an area of therapy for many newly diagnosed autistic children.

Engineering Student Involvement

Two undergraduate students in the EWU engineering robotics program worked throughout the project. Both students were seniors, one male and one female. One student had a background in computer science and the other in mechanical engineering. Both were teaching assistants in the upper level robotics courses and, therefore, were very knowledgeable in programming industrial robots and utilizing sensors common to robotics and automation.

The major phases of this project include (1) the initial problem scoping phase, to understand the problem and goals, (2) the concept generation phase, and (3) the final detailed design phase. During the first phase, the engineering faculty gathered the general needs and requirements from clinical therapists. During the remainder of the project, the students were heavily involved, taking the lead on the both developing the concept and final details. To begin, the students were tasked to learn the programming language of the NAO robot, its abilities and limitations (e.g., voice recognition, speech clarity and speed), and explore various means of interfacing with the robot. Following this exploration phase and final concept selection with the faculty, the students then designed and completed the final programming and implementation details.

Students were given much autonomy throughout the project, as one priority was for this to serve as a service learning project for them.

Project Details

This section provides the details of the design requirements for the robot program, the overall design concept, and details of the final programming design.

Requirements. Our approach to designing a robot-assisted reading and comprehension program follows that of the usual methods: a therapist reads to or with a child and follows up with pertinent questions from passages in the book. In our project, the robot will read the book with the child while the therapist observes the situation and directs the robot through a wireless tablet device, based on the child's progression and needs. Some of the challenges and requirements for this project include the following:

- The robot must be easily programmable for any entry-level book chosen.

- The therapist must be able to control the length of passages read by the robot within a therapy session as the child reads (e.g., 1 sentence, paragraph, or page), due to the ability of child, as well as the daily variations of a particular child (motivation, focus, progress, etc.).

- The therapist must have the ability to direct the robot to re-read any passage on-demand.

- The therapists must have the ability to direct the progression of the follow up questions on-demand (e.g., proceed as child is ready, repeat question(s) as needed).

- In responding to the questions, the child's response must be fed back to the system. Ideally this would be logical input (decisively correct or incorrect) and automatically received and processed by the robot. However, while the NAO robot has the ability to recognize audible responses and can be programmed to respond accordingly, an autistic child's communication may oftentimes be incomprehensible. The program must therefore be able to evaluate the correct response *as intended* by the child, even if not properly or completely communicated.

Design Concept. Our concept is for the NAO robot to read a book along with a child while the therapist monitors the child's progression and directs the robot accordingly behind the scene (Fig. 2). The therapist programs the robot by inserting the book's text into the software, using our template program. Passages are read by the robot followed by pauses that allow the child time to view the book pictures, turn the page, get oriented, etc. Once the child is ready for the next passage, the therapist directs the robot's next actions through input via a hand-held tablet. The tablet provides the user the following options: choices for the desired passage to read, *Start, Read Next*, *Read Again, Correct, and Try Again* (Fig. 3).

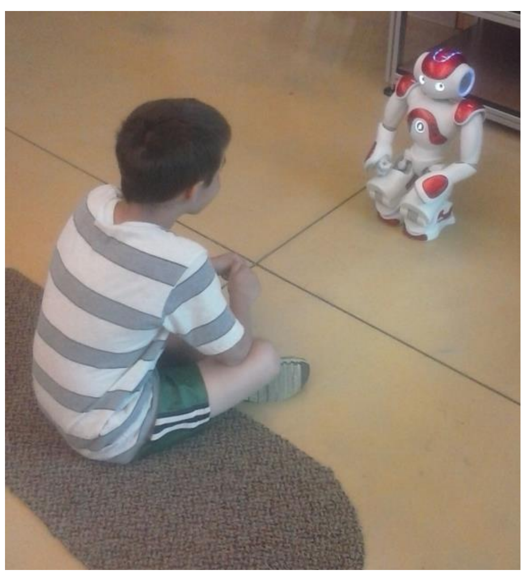

Fig. 2. Implementation of robot as co-therapists (actual therapist behind child with tablet)

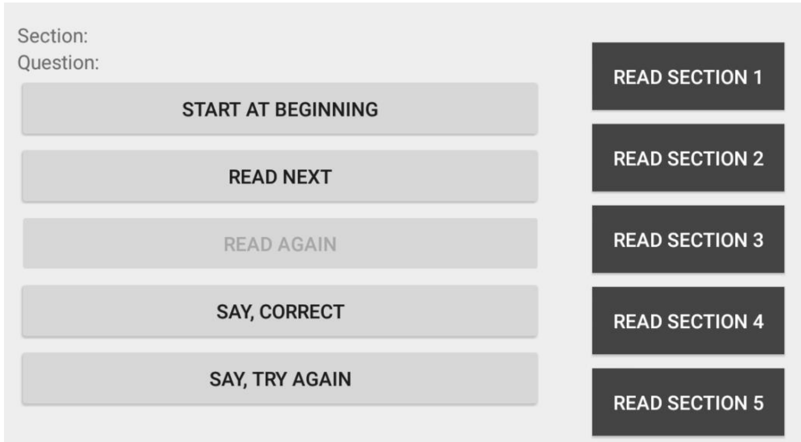

Fig. 3. User interface on tablet

After a passage is finished, the therapist prompts the robot through the tablet to ask the child questions. Following the child's response, the therapist, evaluating the response, will then select either *Correct* or *Try Again* on the tablet, after which the robot responds accordingly. A *Correct* response results in the robot praising the child, while *Try Again* will have the robot direct the child to try to answer the question again. The goal is for the therapist to have sufficient control of the robot and therapy session in order to adapt to the child's particular needs. The tablet is a key feature in that it can be out of sight of the child (and not distracting the child) while allowing control of the robot as needed with only minimal attention by the therapist.

Design Details. Early attempts for programming the NAO involved us making voice recordings of the book passages that the NAO could reference by filename. When the book reading program was initiated, NAO would find and play the recordings at the appropriate times, followed by a set of questions. This limited our flexibility, as the passages were of fixed length, and could not easily be segmented. Each audio file would need to be played through to completion, which also mandated a pause command in the NAO dialog, to accommodate the length of a segment. This proved cumbersome, as not all segments naturally lasted the same amount of time. Additionally, the reading would be in a different voice than the standard NAO speech. It was determined that this could be distracting, and the concept was discarded. It was eventually decided that the book text could be loaded into a program, and NAO's "text to speech" ability could perform the reading directly. This allowed for greater flexibility, as well as continuity in the presentation (NAO's voice).

Our first attempts also relied on NAO's speech recognition for response processing. A dialog routine was created to control the book reading, followed by the question and answer portion. NAO could operate completely autonomously to advance through the sections, based on correct responses to the questions. However, this was found to be somewhat unreliable due to various situations; ambient noise, unclear speech combined with similar response options, or un-programmed responses. This obstacle prompted the use of a therapist controlled override device (a tablet program) to keep everything flowing smoothly. Use of the tablet also provides potential therapists with the ability to proceed reading the book, if they determine that the response to the question is good enough.

The software development kit (SDK) provided with the NAO does not contain libraries for running NAO apps on tablet devices, so we needed to find a way to communicate between the NAO and the tablet. After evaluating several alternatives, we chose to use the WebSocket protocol as our basis for communication. Libraries that use WebSockets are available for many programming languages and operating systems, so we were not bound to using a single language or tablet device family.

The reading program consists of two parts, a set of Python scripts that run directly on the NAO to listen for the connection request from the tablet and call the NAO's APIs, and a native Android tablet app written in Java for the therapist to use. The books are loaded onto the NAO as specially formatted plain text files. These files contain the text of the book with reading comprehension questions interspersed as desired. When the tablet app is started and connects to the NAO, the list of books is downloaded to the tablet, so it is possible to load more books without changing any code. Once the therapist selects a book, separate buttons for the pages and the questions are added to the screen so the therapist has complete control over how the NAO interacts with the child.

Results

This section presents results with respect to the two goals for this project: (1) as a service learning research project with engineering undergraduate students and (2) as an early-reader template program with the NAO robot in autism therapies.

Student Perspectives. As students, this was a tremendous opportunity to engage in an exploratory research project that expanded on our coursework in engineering and robotics. Given only the requirements described earlier in this paper, we had a lot of freedom to explore the capabilities of the NAO and to determine a productive direction for the project. As students nearing the end of our undergraduate studies, we were able to demonstrate our ability to apply our engineering education to a real-world problem, and independently formulate and deliver a solution.

Knowing that this project may go on to aid the university, our robotics program, and people in the autism community has made it more meaningful than other projects we've been involved with in our regular engineering coursework. Our lab regularly hosts local school groups and prospective student visits, and when we demonstrate our project we invariably receive a positive reaction from the students and their parents. Seeing the robot in action inspires the student visitors to consider engineering as a future career path, while the parents appreciate the application of our engineering knowledge to address a real-world problem that has no clear-cut solution. We have been able to see first hand how our engineering work can impact and improve people's lives in a very direct way.

Book Program Pilot Test Results. This pilot project is our first attempt at designing programs with the NAO robot, as well as working in the area of autism. Therefore, the goal for testing the book program was to test the mechanics and general acceptability by a child (feedback by clinicians was not a goal at this point, but is intended as the next phase of the project). The NAO program was used with an 8 year old autistic boy with two level 1 books. Level 1 books typically have 10-15 words per page, and therefore approximately 20 words for the child to read between page turns. Each of the two pages between page turns was programmed as a “passage,” where the robot would read continuously and then stop.

With respect to mechanics, the tablet was found to work well for directing the progression of the program. As the child read the book along with the robot, he would pause often to look at pictures, and sometimes get distracted. Having the robot stop reading at each page turn worked well in this case. Once the child turned the page and got oriented and ready to read again, the *Read Next* button on the tablet was selected and the robot continued. For this particular child and book chosen, all of the follow up questions were programmed at the end of the book, as it was expected the child could retain this amount of material. Each question was prompted via the tablet. When the child responded correctly, the robot was given the *Correct* signal, again via the tablet, and gave an audible such as “That was correct. Good job!” The robot program and tablet interface worked as intended for this first test per the following aspects:

- the range of reading speed by the robot was found to be appropriate (reading speed can be varied as needed per child; current limits on the robot were adequate),

- the level of interactions on the tablet by the therapist was acceptable, not requiring so much attention as to distract the therapist from observing the child reading, and

- the ability to replay some questions for the child worked nicely.

With respect to acceptability of the robot, the child certainly enjoyed interacting with it, and as expected, it seemed to provide motivation for the child to maintain focus on the book.

Conclusions and Next Steps

The NAO robot program developed through this project is intended to serve as a template for programming and using level 1 reading books in autism therapy. The idea and general direction of the project was partly directed by practicing autism therapists, who provided to us the basic needs and requirements, based on their experience and expected client needs. The program we’ve designed with the NAO gives users the ability to easily upload level 1 book text, organize its passages as desired, and direct therapy sessions with a tablet interface that is discrete, intuitive, and with minimal distraction effects. Our first test of the program with a child was to evaluate the mechanics of the program (not the efficacy or acceptability by intended users). Based on our evaluation, the program worked as intended and the child appeared to engage well with the robot and maintain focus while reading – considered to be the primary criterion. With completion of this first test, our next step is to expand the evaluation with clinicians. Currently our perceived goal is to test the program for the following (however, this may change based on future input from clinicians):

- Acceptability: Are therapists inclined to support this technology in therapy sessions?

- Practicality: Is the robot and program practical in therapy sessions? Does is work – mechanically and logistically? Is it intuitive enough? Are there any unforeseen barriers?

- Usefulness: Is the robot and program effective in helping autistic children reach their reading objectives? Is it efficient, in terms of time for a child meeting objectives; i.e., does it offer any improvements relative to current achievement results?

References

[1] Centers for Disease Control. “Prevalence of Autism Spectrum Disorder among Children Aged 8 Years – Autism and Developmental Disabilities Monitoring Network, 2010.” https://www.cdc.gov/media/releases/2014/p0327-autism-spectrum-disorder.html. Accessed Jan. 2017.

[2] Sturmey, P. (Ed.). (2011). Functional analysis in clinical treatment. New York: Elsevier.

[3] Symes, M. D., Remington, B., Brown, T. Early intensive intervention for children with autism: Therapists’ perspective on achieving procedural fidelity. Research in Developmental Disabilities, 27 (2006), pp. 30–42.

[4] Howard, J., Sparkman, C., Cohen, H., Green, G., & Stanislaw, H. (2005). A comparison of intensive behavior analytic and eclectic treatments for young children with autism. Research in Developmental Disabilities, 26, 359-383.

[5] Barakova, E., Gillesen, J., Huskens, B., & Lourens, T. (2013). End-user programming architecture facilitates the uptake of robots in social therapies. Robotics and Autonomous Systems, 61(7), 704-713.

[6] Goodrich, M. A., Colton, M., Brinton, B., Fujiki, M., Atherton, J. A., Robinson, L., . . . Acerson, A. (2010). Incorporating a robot into an autism therapy team. Intelligent Systems, 27(2), 52-59.

Appendix

Overview of NAO robot sensors and capabilities