Artificial Intelligence for Human-Robot Interaction: Papers from the 2014 AAAI Fall Symposium

Socially Assistive Robotics for Personalized Education for Children

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Introduction

Socially assistive robotics (SAR) has the potential to combine the massive replication and standardization of computer technology with the benefits of learning in a social and tangible (hands-on) context. We are developing HRI methods for SAR systems designed to supplement the efforts of human teachers to personalize education in the classroom. This abstract defines and proposes solutions to the computational challenges inherent in accomplishing *differentiated and personalized education utilizing SAR in real-world classrooms*.

We aim to design robotic systems that are compelling, assist children in achieving educational goals, and mitigate developmental challenges in a classroom context. To do so, our approach must be deeply informed by the needs of our target users, children, at all stages of development, and must adapt to a variety of special needs. In this abstract, we discuss motivation and computational methods for personalized SAR systems for general, special needs, and mixed multi-child education contexts. We focus on the personalization and adaptation of curriculum, feedback, and robot character.

General Education Classroom

One process of developing systems for children with varying needs and/or developmental challenges is to begin by recruiting participants from a more general population, and to develop systems and tools that will work for those children before extending to the target population. In one of our preliminary studies, children drawn from a general education classroom learned about nutrition in a one-on-one interaction using the DragonBot robot (Short et al. 2014). During each of six bi-weekly, five-to-ten minute long interactions, the child could select various artificial foods, present them to the robot, and receive feedback on those choices. Even within the general classroom population, we have found interesting variations based on age and sex that indicate the importance of differentiated education.

We applied multidimensional scaling (MDS) to a select subset of features per interaction (mean response time, mean time to select food, and percentage of healthy food choices) for 16 participants over each of the three week interactions. We created a visualization of the participants' trajectories over the three weeks.

Figure 1 shows the change in participants' interaction patterns between the first and second weeks in black, and the second and third weeks in red. The direction and length of the visualized trajectories are proportional to the direction and magnitude, respectively, of the participants' change in interaction patterns from week to week. The trajectories of most participants are similar from week two to three. It can be hypothesized that participants whose movements are smaller than average from week two to three have minimal change in behavior; thus, a new or modified interaction strategy may be beneficial for these participants, supporting the need for personalized education even within a general classroom context.

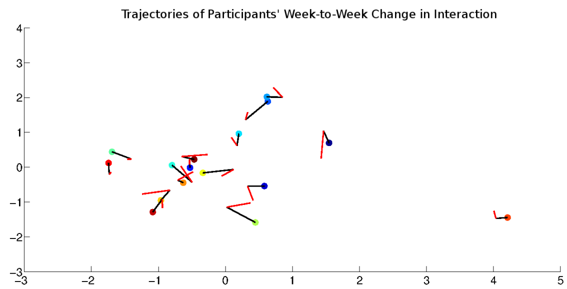

Figure 1: Visualization of change in interaction between weeks one and two (black) and weeks two and three (red).

Special Needs Education

Through the pilot study in nutrition education for children described above, we found that children had a wide variety of reactions to the robot (especially in terms of their speech) and level of ability to perform the task (Short et al. 2014). As our work moves towards meeting the needs of children with developmental challenges, we expect to find a significant increase in variation within any individual developmental area, typically split into social, cognitive, gross-motor and fine-motor development.

Children with Autism Spectrum Disorders

Children with autism spectrum disorders (ASDs) constitute a growing majority of special needs classrooms and have been one of our target beneficiary populations for over a decade (Feil-Seifer 2011). ASD symptoms can be nearly unique for each affected individual, and the recruitment of participants from such a sensitive population is often very challenging. Additionally, when working with special needs populations, it is often necessary to bring the experimental setup to a context they are familiar with (school, home, therapy room) rather than making accommodations to bring participants into the lab. Therefore, the sensing used in these studies must be robust to real-world noise but also portable and easy to set up. Computational challenges are found in expanding human-robot interactions to span longer, multiple sessions to allow for generalized behavior change and skill improvement to take place.

Robot-Mediated Social Skills Practice

A recent study we performed addressed SAR-mediated skill practice with school children with ASDs. We examined the benefits of autonomy-promoting graded feedback during an imitation game between a robot and a child with an ASD (Greczek et al. 2014). Graded cueing is an occupational therapy technique of giving the minimum required feedback when learning or practicing a task in order to promote patient autonomy and learning generalized skills. The implementation of the model was used to give feedback on imitation accuracy in a "copy-cat" game played between a Nao robot and a child (aged 7-10).

We sought to address the low-N, high-variance nature of this population with a Bayesian model of first prompt choice. Within four possible user prompts of increasing specificity, the graded cueing model selects the least specific feedback appropriate to the user's skill level based on previous observed user behavior. In this way, the model can reach a minimal level of feedback personalized to each user that changes along with the user's ability over time. Although the model was not fully exercised in the study, graded cueing style feedback was found to be at least as good as maximally specific feedback after every user mistake. These results encourage future work focusing on increasing user autonomy at a task without impacting performance.

Multi-Child Interaction

Computational research in adaptive user models for education is often limited to optimizing for individual users (Leyzberg, Spaulding, and Scassellati 2014; Han and Kim 2009; Schiaffino, Garcia, and Amandi 2008). Such research is motivated by the "two-sigma" phenomenon which shows that one-on-one tutoring leads to student performance that is two standard deviations above average (Corbett 2001). However, in many educational contexts, dyadic instruction between one robot and one user may not optimally accomplish educational goals. One intuitive instance is the development of social communication skills in children with ASDs as in the graded cueing study (Greczek et al. 2014). According to socio-constructivist theory, knowledge construction is socially mediated, and thus, it is important that both the teacher and the entire learning environment be social (Hickey 1997). The legal principle of Least Restrictive Environment (LRE) supports this approach by requiring that children with special needs are educated in as general a classroom as possible (Hasazi et al. 1994). In keeping with these ideas, we are inspired to develop a computational model of developmentally appropriate tasks that are optimal for a triadic and socially mediated interaction between two children with varying needs and a robot.

Each child in US special education receives an Individual Education Plan (IEP), detailing the individual child's challenges and educational goals and the specific steps that will be taken to meet the child's needs. We aim to leverage the information in IEPs to build computational models of educational tasks that allow a single task to be adapted to help address any combination of developmental challenges. An ideal SAR system will exist in an environment populated by both typically-developing children and children with developmental challenges. Towards this end, we are exploring computational methods to facilitate social interaction and educational goals by optimizing robotic instruction for any pair of children.

Future Work

Our future work in developing personalization algorithms for SAR systems centers on creating a method for selecting optimal educational tasks in multi-child robot interactions, expanding the graded cueing framework, and creating methods for customizing the robot's backstory.

In our preliminary nutrition education study using the DragonBot, we designed a backstory for the robot that connected the robot's character to its physical embodiment and the task (Short et al. 2014). Moving forward we are exploring the theme of developing aligned and consistent robot characters where the robots backstory, embodiment, and personality all form a cohesive task-relevant and interaction partner. Personality consistency between verbal and nonverbal modalities of a computer agent has been shown to increase liking (Isbister and Nass 2000). We plan to convey personality through these modalities as well as develop a method for creating a robot backstory that is consistent with the robot's personality.

Our future work in the context of graded cueing will expand the framework to include tasks with multiple steps and goals over many sessions with the robot. The key in this expansion will be the representation of each child's knowledge and abilities as part of a larger ontological structure of domain-specific skills. The larger goal is to create a personalized health education framework with autonomy-encouraging feedback from the SAR system.

Due to an increasing level of primary education standardization in the US, it is possible to find itemized curricula designed to address the wide but finite variety of developmental challenges that children experience. In the context of special education, we plan to leverage existing curricula to develop a method for selecting an optimal educational task in multi-child interactions with a SAR system. We plan to develop methods that will enable SAR systems to cater to multiple childrens' educational and developmental needs in a real-world classroom.

Acknowledgements

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