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Using Small Humanoid Robots to Detect Autism in Toddlers

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Abstract

Autism Spectrum Disorder is a developmental disorder often characterized by limited social skills, repetitive behaviors, obsessions, and/or routines. Using the small humanoid robot NAO, we designed an interactive program to elicit common social cues from toddlers while in the presence of trained psychologists during standard toddler assessments. Our program will capture three different videos of the child-robot interaction and create algorithms to analyze the videos and flag autistic behavior to make diagnosis easier for clinicians. Our novel contributions will be automatic video processing and automatic behavior classification for clinicians to use with toddlers, validated on a large number of subjects and using a reproducible and portable robotic program for the NAO robot.

1 Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder defined by behavioral symptoms that include social communication deficits and restricted and repetitive behavior patterns. Trained therapists use the Autism Diagnostic Observation Schedule to assess individuals, which is a semi-structured assessment that includes imaginative play, social cues, and communication. Early identification allows for enrollment in intervention programs before atypical patterns of behavior and brain function become firmly established. The Center for Disease Control and Prevention estimates that one in 68 children has an ASD. Early intervention significantly improves long-term outcomes for toddlers identified in the 2nd year of life and is the gold-standard approach for affecting lasting positive change for children with ASD [Dawson *et al.*, 2012]. The cause of ASD is unknown, and interventions are primarily designed to treat exceptionally complex, established behaviors.

Robotics research in autism is over a decade old, yet does not currently meet standards of psychology and child development researchers [Diehl *et al.*, 2012]. Robotics research stems from the fact that children with autism especially enjoy robots [Dautenhahn and Werry, 2004]. While the reason for this is unknown, researchers clearly have the potential to leverage robotics for autism diagnosis or treatment [Scassellati, 2005]. Problems with existing research include lack of robot integration to established treatments, lack of study participant followup, small sample sizes, little scrutiny on the actual therapeutic protocol, and little detailed characterization of participants. Diehl's review [2012] recommends addressing the problems above as well as focusing on what child characterizations indicate the most individual benefit from robot interaction.

With these recommendations in mind, we are working closely with psychologists at the University of Minnesota as part of a three-year study. The primary objective of this study, which begins in Spring 2015, is to characterize individual differences in reciprocal social behavior in multiple samples of children and several levels of analysis. Long-term goals of this project are to 1) decrease the average age of ASD diagnosis in the state of Minnesota from the current 5 year average age, 2) decrease cost while increasing quality and efficiency of screening and diagnostic classification, and 3) improve characterization of dimensional symptom profiles for local agencies providing intervention services. The study's central hypothesis is that improved screening, coupled with innovative assessments that incorporate robotics and computer vision technologies, will augment the characterization of dimensional profiles of individuals with ASD, and facilitate early diagnosis of ASD.

We ask two important research questions in this work. First, can using a small humanoid robot with toddlers reveal symptoms of autism? Second, can we create video processing software to help clinicians diagnose toddlers with autism at earlier ages? Our investigation includes designing an interactive program on a small humanoid robot, taking videos of test subjects while they interact with the robot, and creating software to examine the video footage and give feedback to the clinicians based on symptoms detected in the videos. Our novel contributions will be video processing software for clinicians and automated behavior classification, validated on a large number of subjects (approx. 150), using a reproduceable and portable robotic program.

2 Experimental Setup

We use the small humanoid robot NAO from Aldebaran Robotics; the NAO is about two feet tall, has 25 degrees of freedom, and many sensors and colored LEDs (see Figure 1).

Figure 1: NAO in mid-dance

Each participant session will include a trained psychologist, a toddler and caregiver, a NAO robot, and a data collector controlling the NAO. The primary video will be a close shot of the robot-child interaction (facing the child from over the robot's shoulder); we will also include a wider view of the child and robot and a video/audio recording from the NAO's point of view. The room will be a study room used for children in the University of Minnesota's Center for Neurobehavioral Development (CNBD) or in the Institute of Child Development. Subjects will be drawn from children of families already in connection with the Institute of Child Development and children assessed at the university's Autism Spectrum and Neurodevelopmental Disorders (AS/NDD) clinic.

We programmed the NAO to perform several different behaviors, which include invitations to perform actions via games and dancing. After introducing itself, the NAO performs two games of "Simon Says," two games of "I spy," and three song and dance routines in a specific, static order. In each "Simon Says" round, the NAO demonstrates five simple actions that can be done sitting down, like arm flapping or hand clapping. In each "I spy" round, NAO looks around and states "I spy a..." before stating an object; four of the five objects will be present. Before each dance, NAO invites the child to dance with it, and plays a different song and dance. The NAO does not wait for the child to interact with him; each sequence is preprogrammed and begins with encouragement or ends with positive words like "that was fun!"

The current program was designed with feedback from clinicians in CNBD, such as including songs with verbal instructions on what actions to perform. Initial work suggests that the child needs time to acclimate to the robot, so the session explained above should not be the first child-robot interaction. Preliminary visits indicate 2 years of age may be too young for introducing the NAO; we may need simpler robotic toy interactions before using the NAO with this age group. This is one challenge we expect to face quickly, and we expect different children (or possibly different ages) will have preferences on the interaction type or feedback the robot gives (e.g., changing the robot LEDs to the child's favorite colors or adding chances to converse with the robot).

The current program is also static; it does not change based on input from the child. The next iteration of the NAO's program may need to include a chance for the child to modify the robot's appearance or behavior, for example by asking the child if s/he would like the robot's eye lights to change to a different color, or if the child wants to play some game again. Because we are dealing with toddlers from age 2 to 5, not all children may be verbally equipped to converse with the robots, so any program must include a default behavior if the child does not speak to the robot.

3 Timeline and Technical Challenges

The IRB proposal was approved in April 2015, and an estimated 30 participants from the AS/NDD clinic will begin soon after. Another estimated 120 participants should be available around Fall 2015. The longevity of the study additionally allows us to compare child-robot interaction months and years after initial toddler-robot contact.

Technical challenges will include processing the videos, flagging appropriate behaviors while minimizing false positives and false negatives, and alerting clinicians to relevant symptoms. Repetitive body movements like hand flapping, rocking, asymmetric gait, or eye contact avoidance are target symptoms to explore first. Suitable techniques are explored in [Hashemi *et al.*, 2012], which successfully classified symptoms of arm asymmetry, visual tracking, and attention disengagement using Object Cloud Models and Cloud System Models for body pose estimation; they also used face trackers with facial features represented by multiscale Histograms of Orientated Gradients classified using a Support Vector Machine. We expect to find challenges in introducing toddlers to the robot, and we expect to modify or tailor the program to individual preferences (in an offline fashion).

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