Assistive Technologies and Children-Robot Interaction

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Introduction

Mobile robot technology can become useful tools to study and contribution in child development and rehabilitation. In this paper, we present our latest work in two of our projects in this area: adapting the robot's behavior based on perceived interaction using proprioceptive sensors, and studying if a mobile robot could, by being more predictable, attractive and simple, facilitate reciprocal interaction such as imitation. These projects started with robotic objectives but revealed to be rich sources of interesting problems to resolve and interdisciplinary collaborations.

Behavioral Adaptation Using Proprioceptive Perception

Adapting the robot's behavioral responses according to children' responses shall create and sustain more meaningful and broader range of interactions. However, natural communication or interaction with robots can be somewhat of an arduous task. While video and audio are typically used for communication and interaction between humans and robots, other sensors such as contact, infrared, proprioceptive and temperature sensors can provide additional means of communication related to touch (Kerpa, Weiss, & Worn 2003; Miyashita *et al.* 2005). But we believe that touch can be indirectly captured through proprioceptive sensors on-board the robot, usually exploited for its guidance and control. By looking at sensory data patterns coming from these sensors, our objective is to identify the types of interaction the robot is having with people and the environment, and ultimately use this information for achieving behavioral adaptation.

Our experiment consisted in using Roball (Michaud & Caron 2002; Michaud *et al.* 2005), a spherical robot shown in Figure 1, and study how sensory data patterns could be used to characterize the interactions experienced by the robot. Roball' proprioceptive sensors consist of three accelerometers, one for each axis (X, Y and Z), and three tilt sensors, one for left tilt, one for right and one for forward/backward tilt. The configuration of the tilt sensors allows the detection of either left or right tilt with both sensors giving the same value, and also allows detection of rotation with readings from the sensors giving opposite left/right tilt values due to centrifugal acceleration.

We first conducted a set of trials which involved a series of laboratory experiments, followed by a series of trials held at both a playgroup and a school setting. The laboratory experiments were used to investigate whether measurements from these two different types of proprioceptive sensors could record things such as jolts to the robot, the robot receiving general interaction, the robot being carried or the robot being spun. Trials in a playgroup and school setting were used to confirm laboratory sensor readings were also found in real life environments. These trials showed that it is possible to detect different environmental conditions through the analysis of proprioceptive sensors (accelerometers and tilt) (Salter *et al.* 2005).

More specifically, the accelerometer and tilt readings can be zoned into four different environmental conditions: Alone, Interaction, Carrying and Spinning. Another condition, named No Condition, is necessary for situations that can not be classified. We then derive an algorithm based on five heuristic rules derived from this analysis (Salter, Michaud, & Letourneau 2006).

- A) If the average difference between the X and Z accelerometers readings is above 0.05, set current condition to 'ALONE'.
- B) If the average difference between the X and Z accelerometers readings is below 0.03 and above zero, set current condition to 'INTERACTION'.
- C) If the average difference between the X and Z accelerometers readings is negative, set current condition to 'CARRYING'.
- D) If the tilt sensors show different readings, set condition to 'SPINNING'. Another way to detect spinning is if the average reading for the Z axis is positive and coupled with an average Y axis reading of above 0.05.
- E) If the sensor readings do not fall into one of the above categories, set the condition to 'NO CONDITION'.

Figure 1: Roball (Ieft) and Tito (right).

A first set of trials (3 per conditions, 4 minutes each) were conducted at the laboratory under four conditions: 1) the robot is alone in the pen; 2) the experimenter stimulates general interaction; 3) the experimenter carries the robot; 4) the experimenter spins the robot. This resulted in 2360 interaction classifications, with the objective of maximizing valid identification and minimizing false detection. Roball was able to identify Alone (97%), Carrying (92%) and Spinning (77%) with reasonable accuracy. However, identifying Interaction (10%) was more difficult. The probable causes for this are that firstly at times the robot is in fact spinning or alone during the Interactions trials. Such conditions would therefore be identified under the corresponding categories, (D) 45% and (A) 19% of the time. Therefore, adding the results for conditions A, B and D, a total of 74% classifications that were correctly identified by the algorithm during the Interaction experiment. Also, the experimenters simulation of general interaction that would be made by children was fairly vigorous.

We then experimented with the algorithm implemented on-board Roball with children in real life settings. With two of the four children involved in the trials, Roball responded appropriately to the interaction experienced. However, with the others, Roball did not always react correctly. In particular, the robot often thought it was being carried when it hit the wall of the pen, causing the robot to stop and asked to be put down. We noted that compared to all preceding trials, there was an increased level of interest and engagement from the children. We are currently trying to investigate the cause of these incorrect reactions, whether it is because of a hardware failure, environmental configuration (e.g., when the robot hits a wall, it records the same readings as being carried), adapted responses of the robot (e.g., creating an interaction pattern from its autonomous actions), a change in the way children interacted with Roball, or the inability of the algorithm to identify the correct interaction type.

Learning to Imitate Using a Robot

Unpredictability and complexity of social interactions are important challenges for a low functioning autistic child. Compared to 8-9 months old regular development children, 5 years old low-functioning autistic children present the same sensory interests. However, their sensory plays are more repetitive, their imitation is selective and used with an aim of increasing the stimuli (Lemay 2004). They also present unexploited abilities (e.g., attribute intentions to the imitator; plan and induce imitative behaviors and understand incitation to imitate) (Nadel 2002) and deficits in sharing attention (avoids eye contact, does not smile) and conventions (poor imitation of facial expressions and gestures) for communicating common interests (Lemay 2004). Also noted is the quasi-absence of verbal language and pretend play. These deficits are explained by a difficulty in perceiving and treating stimuli from their environment, affecting comprehension of social signals (gestures, words and intentions of others).

Thus, low-functioning autistic children need interventions which take into account their particular interests and their decoding deficits by a predictable and simple medium, able to catch their attention. Mobile robots show potential in that regard and because they can be designed in accordance with particular interests and decoding deficits of children with autism. They generate more interest and a wide variety of interplay situations compared to static objects, and bring into play social interactions skills (visual contact, imitation) (Michaud *et al.* 2006; Michaud, Duquette, & Nadeau 2003; Robins *et al.* 2004).

Our motivating research hypothesis is to verify that an animated object, more predictable and less complex than interacting with humans, would make the autistic child demonstrate reciprocal communication, observed by: 1) the reduction of avoidance mechanisms, namely repetitive and stereotyped plays with inanimate objects; 2) the increase in shared attention and shared conventions; and 3) the manifestation of symbolic mode of communication like verbal language.

We conducted an exploratory study following a single case protocol (Kazdin 1976) (22 exposures, 5 min cases, 3 times/week over 7 weeks). We evaluated shared attention and shared conventions with four 5 years old low-functioning autistic children (3 boys and 1 girl) selected in the Centre de réadaptation le Florès of Laurentides, Québec, Canada. The experimental procedure exposes a pair of children in interaction with a robotized mobile mediator (animated object with human-like appearance) and the other pair in interaction with a human mediator (the experimenter). The two mediators execute the same imitation plays of facial expressions, body movements and familiar actions with or without objects.

The robot mediator, named Tito, is shown in Figure 1. Tito has two arms that can move up and down rapidly, a head that can rotate (to indicate 'no') and rise up (to express surprise), a mouth (for smiling), two eyes, a nose and hair (made from fiber optic cable to illuminate). Also, a small wireless microphone-camera device was installed in one eye of the robot. Different parts of Tito's body can be illuminated. Tito generates vocal requests through prerecorded messages. A wireless remote control (using a video game controller) was designed for teleoperation, and an onboard microcontroller enables pre-programmed sequences of behaviors (motion and vocal messages). Tito records and stores internally the timing between the interactions of the child (from sensory data and according to the experimental scenarios). Tito also emits a sound when it starts the execution of an experimental scenario, allowing synchronization of video data recorded with an external camera. The activation button of Tito is hidden at the bottom of the robot so that the child is not tempted to play with it.

Three variables were observed in our trials: shared attention (visual contact / eye gaze directed toward the mediator for more than 3 sec; physical proximity; imitation of facial expression or gesture, but not directed toward the mediator); shared conventions (facial expression, gesture, actions and words, all directed toward the mediator); absence of sharing (no visual contact, leave the communication area, avoid the mediator, sensorimotor play, mannerisms, ritual, aggression). These variables were coded over 12 sec windowing, by two coders (98% fidelity) analyzing video footage of the trials (Camaioni & Aureli 2002).

We observed that children paired with the robot mediator show better shared attention (visual contact, physical proximity) than the children paired with the human mediator in all types of imitation plays including facial expressions, body movements, familiar actions with objects or without objects. This validates the hypothesis that the robot has appealing characteristics for interacting with autistic children. However, we observed that forms of shared conventions such as imitation of body movements and of familiar actions are higher with the two children paired with the human. This may be explained by working with low-functioning autistic children having more difficulty understanding communication intent from the limited motion capabilities of the robot. A robot having arms with more degrees of freedom may perform better. On the other hand, the two children paired with the robot mediator imitate facial expressions more than the children paired with the human mediator. Imitation of words only appeared for one participant, paired with the human mediator. Children paired with the robot mediator were also observed imitating motor noise made when the robots articulations are moving.

Our study helps understand the processes for decreasing autistic children anguish and increasing their attention to learn certain forms of communication. Our results are very encouraging and support the continuation of work on this research question, repeating the trials with a greater number of subjects and consolidate these conclusions.

Conclusion

Socially assistive robots are a rich source of novelty in creating interplay and learning situations, allowing implicit or explicit (adaptation to children and the environment, helping keep children engaged. At the same time, conducting trials with children and mobile robots is highly challenging, with a great set of factors (hardware, software, human, environmental) influencing the process and results. Robot design and conducting rigorous experimentations with people are two very demanding tasks, critical in making solid scientific contributions with concrete benefits. For efficient and fulfilling efforts in doing such work, it is important to start small and increase the complexity of the experiments (e.g., test population size, robot's capabilities, experimental methodology).

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