Interactive Consoles for Adjustable Autonomy in Assistive Robots: a Case Study with ASD Children

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***Abstract*— In this paper we present the interactive consoles deployed on an assistive scenario with children diagnosed with Autism Spectrum Disorders (ASD). These interfaces were developed in order to provide support to the therapists during the therapy sessions in a hospital allowing the operators to better analyze the procedure from outside and intervene when it becomes necessary. Also it helped the development team to adapt the robot to its final configuration, fully autonomous.**

I. INTRODUCTION

The use of service robots in different contexts and environments has raised quickly in the last few years. Nowadays it is common to find robots operating with humans in industrial settings [1], interacting with kids in hospitals [2] and even reaching areas that are not safe to be explored by human beings [3]. In all those complex and different applications, some level of interaction between humans and robots is necessary.

Human-Robot Interaction (HRI) can be established using different approaches, for instance via communication, where the robot can use a pre-designed natural language to interact with an operator [4], or even using an interactive interface [5]. The benefits of the interactions have been discussed in an wide variety of applications, from industrial to non-industrial settings, such as home, urban areas, and schools. Salvine et al. describe some important benefits of HRI [6]. For example, assistive and health-care robotics can improve the quality of life of the elderly and physically impaired people; military robots can be used in search and rescue missions; and service robots can increase the efficiency of people work, providing new services.

Wu et al. demonstrate the importance of assistive robots in a scenario where independent elderly people live alone [7], a wearable emergency analysis module and a remote control module. The first module is responsible for detecting a help request; the wearable device can recognize the person's activities and predict a health condition; and the remote module is capable of tele-operating the robot on emergency situations. In critical scenarios involving human beings, it is common to use remote modules able to control the robot in order to fix or improve its behavior when specific conditions are detected.

Similar to the remote module described above, two different types of interfaces were developed in a project to avoid undesired behaviors from an assistive robot (ASTRO) during therapies sessions in a hospital with children diagnosed with autism spectrum disorders (ASD) [8], [9]. This project, called INSIDE[5] (Intelligent Networked Robot Systems for Symbiotic Interaction with Children with Impaired Development), developed new hardware and software solutions to support a real-world interaction with ASD children in a joint cooperative task with therapeutic purposes. A picture of one such interaction session is shown in Figure 1. In this scenario, the interfaces had also a novel approach supporting the development team to adapt the system until it becomes fully autonomous.

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Fig. 1. A therapy session with an ASD child at the Hospital Garcia da Orta in Lisbon, Portugal. Upon detecting an obstacle, ASTRO makes a sad face and tries to find a way around, before asking the child for assistance.

II. INSIDE PROJECT

The core concept that underlies much of the research in INSIDE is the concept of Symbiotic Autonomy. In order to develop an autonomous robot platform, capable of interacting with human agents in the context of a given task, the robot must be able to act in situations in which neither the robot nor the human are able to fully complete such task by themselves without the assistance of the other, due to inevitable limitations of the agents or the design of the task. This concept of Symbiotic Autonomy lends itself quite naturally to the scenario of therapy with children with ASD of the INSIDE project. Indeed, many of the activities employed in traditional therapy already take into account the scheme of symbiotic autonomy and are developed in order to focus on the behavior deficiencies of children with ASD, such as the difficulty in addressing help requests or in asking for help. To create robot-mediated therapy sessions we used a set of activities that have therapeutic goals (i.e., goals that train skills that are commonly impaired in ASD children);

and could be arranged in such a manner that allows the robot to have an active role in the session, as an alternative to being just a fun toy.

In order to address the different challenges posed to the system, it was necessary to develop a hardware infrastructure that supports the different types of interaction planned for the therapy sessions. Additionally, it was also necessary to design a software architecture that is able to seamlessly integrate the different functionalities required on such a system. Both hardware and software were designed following an adjustable autonomy approach, departing from initial mock-up studies, aimed at identifying key requirements for the system, until the final deployment.

The adjustable autonomy approach ensured a smooth transition from an initial Wizard-of-Oz (WoZ) paradigm in which a human operator is fully in charge of perception and robot operation, until the final setup, where perception is automated and the robot is fully autonomous. The high-level interaction between the different modules (Perception, Decision, Execution and Supervision) ensures that the robot is able to go through the therapy session autonomously and robustly, while still allowing anytime human intervention, if the circumstances so dictate.

The supervision module (Figure 2) is a central element in the INSIDE software architecture, as it provides a mandatory backdoor to the perceptual and behavioral elements of the robot, allowing human supervisor to take control of the interaction at any time, should circumstances so demand. In particular, if a problem is detected in the robot or the network, the supervision module allows a human operator to intervene and mitigate the potential impact of such problem. If no intervention is required, the supervision module has no impact on the system.

Popular web technologies (*HTML, CSS and JavaScript*) integrated with *ROS* were used to develop the Supervision Module. A bridge to exchange data between the robot and our platform was also necessary. The package known as *rosbridge* [10] was used for this purpose which allowed the robot to transmit its perception to the console and the users to override the robot's actions.

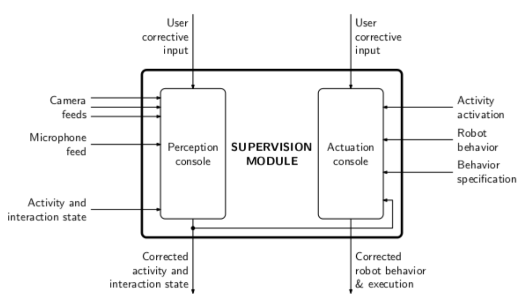

Fig. 2. Supervision Module: Wizard-of-Oz

III. Wizard-of-Oz

Over time the team developed two types of interfaces, one for the actions taken by the robot and another to handle

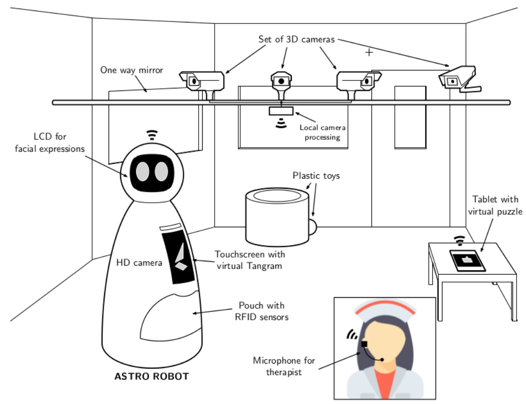

Fig. 3. Diagram illustrating the main components of the hardware setup used in INSIDE.

its perceptions. The interaction between the children and the robot was set up in a room already used for a similar type of social/game stimulation, where the parents and the therapist join the child and the robot. In that room (Figure 1, schematically depicted in Figure 3), cameras were used to video record the humans (with consent) and help estimating their current location.

While the team of researchers are in another room, accompanied by a second therapist, where the parents and the child do not see them, they are able to follow the interface (Figures 4 and 5) and remotely watch what the robot is doing. The interface will show, for instance, that the robot detected an open door, which could, for instance, be an indicator to greet a child that is coming in. One difficult issue, for robotics in general, but in this situation in particular, is speech recognition. In this situation, we had a therapist with a microphone headset to say certain keywords that the robot more easily recognizes so that it can react by changing its operational context, e.g. switching to another game. But if the voice command is not detected by the robot the interface is capable to override this functionality allowing the user to send the right command to the robot avoiding an undesired interruption during the therapy session.

These interfaces are very informative and easy to use, which allowed the researchers to realize how much they had to intervene or not and through a process of constant correction and improvement gradually reduce the number of interventions so that the robot could act more autonomously. If the operator decides to end a session or even stop the robot those options can be found in top of both consoles.

The functionalities for both consoles were developed based on modules called widgets. A new widget can be easily added if new information to be displayed becomes necessary. This feature allows the developer team to better adapt the interfaces during the project's phases. Also, the supervision module can be rapidly deployed for different applications.

A. Action Console

In terms of the action component of the interface (Figure 4), the decisions of the robot are shown, in real time, on a

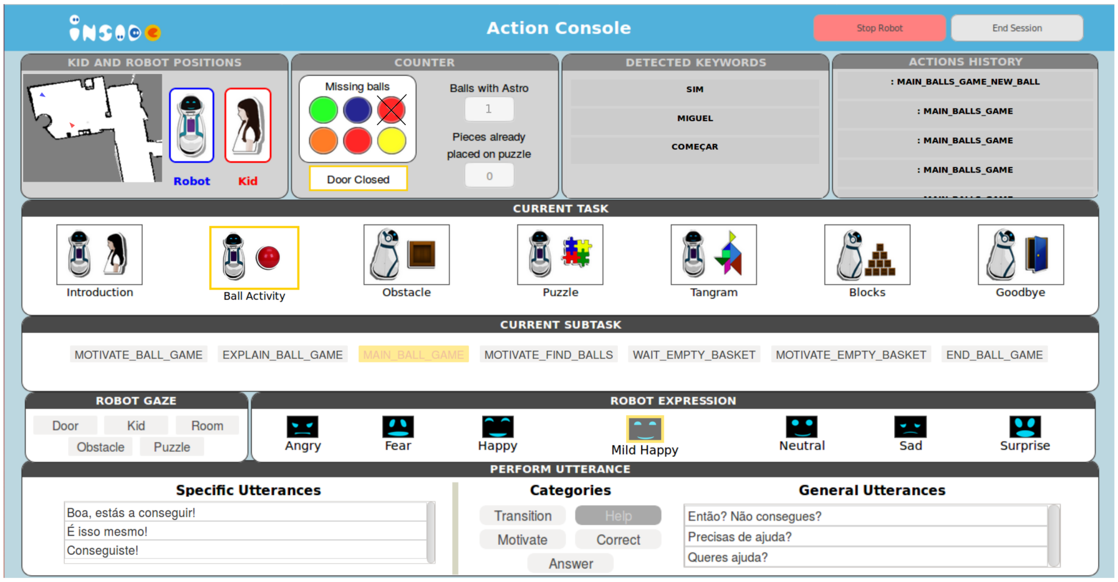

Fig. 4. Wizard-of-Oz: action console during the ball activity. The child found one of the balls and started looking for the others.

screen. When the robot takes a decision it is still possible to override that decision based on indicators from the therapist. While at the beginning the therapists had to provide several indications and the researchers were very busy controlling and overriding the robot actions and teleoperating it, the process became more and more optimized.

The interface is divided in two main parts that are represented on gray and white boxes. The gray part exhibits the information which the user is not able to interact. This information is continuously updated by the robot. In this part, the user is able to check the kid's and robot's position on map, the number of balls and pieces of puzzles related to some specific activities, the state of the door, the keywords detected by the robot and the history of the robot's actions. On the white part, there are different functionalities. The current task and subtask help the user to understand the robot's behavior. It can be overridden if the therapist notices the kid is not reacting properly to the activity. The robot's expression and the direction where the robot faces can be also fixed if the autonomous system fails. And at the bottom of the interface, the user can select some utterances to be spoken by the robot. The utterances are divided in two groups: the specific utterances, related to the subtask, and the general group, which is split in different categories to help the user to rapidly select an appropriate sentence.

During the therapy sessions, the current states are highlighted in yellow, as it can be seen on the console image. When some information gets updated it blinks twice to indicate the new changes.

B. *Perception Console*

The perception interface is also divided in those two groups (Figure 5), informative-only and interactive. The main idea of this console is to understand the perception of the robot during the therapy sessions.

In this way, the operator is able to rapidly detect the task that the robot is performing, the robot's expressions, and also visualize the images captured by the robot's camera and the camera placed inside the therapy room. The interface exhibits also the latest utterance and the states of some elements (balls, puzzle and door) that can be used during the Ball and Puzzle Games. This information is crucial for the outside therapist because the visual and acoustic feedback from within the therapy room can sometimes be unsatisfactory.

An intervention can be necessary in order to keep the therapy running properly if the network system unexpectedly fails during the sessions. The ASD child should not perceive this issue and the session needs to be finished without major changes on the robot's behavior. For example, it is important to have the robot constantly responding to the child's actions and looking to the child when utterances are performed.

IV. Results and Conclusion

The supervision module was tested during the final phase of the studies with the children diagnosed with ASD. A group of ten children participated in the studies where each one attended ten sessions. Based on their behavior on previous sessions, some children had an increase on the difficulty level of their activities. For example, new challenges were incorporated in the games in order to make the sessions more attractive for the children. Our goal was to promote relationships between autistic individuals and other people. Bonding with a robot was just an intermediate step that past clinical evidence suggests will have high impact in their life.

The interface was crucial in different moments of the studies. For example, we could change the activity when the inside therapist was not having any progress with a child. Some of them did not respond well to the robot during specific tasks. The kid's location could be fixed when the cameras system failed to detect the child. This feature helped to avoid undesired behaviors from the robot, like calling the

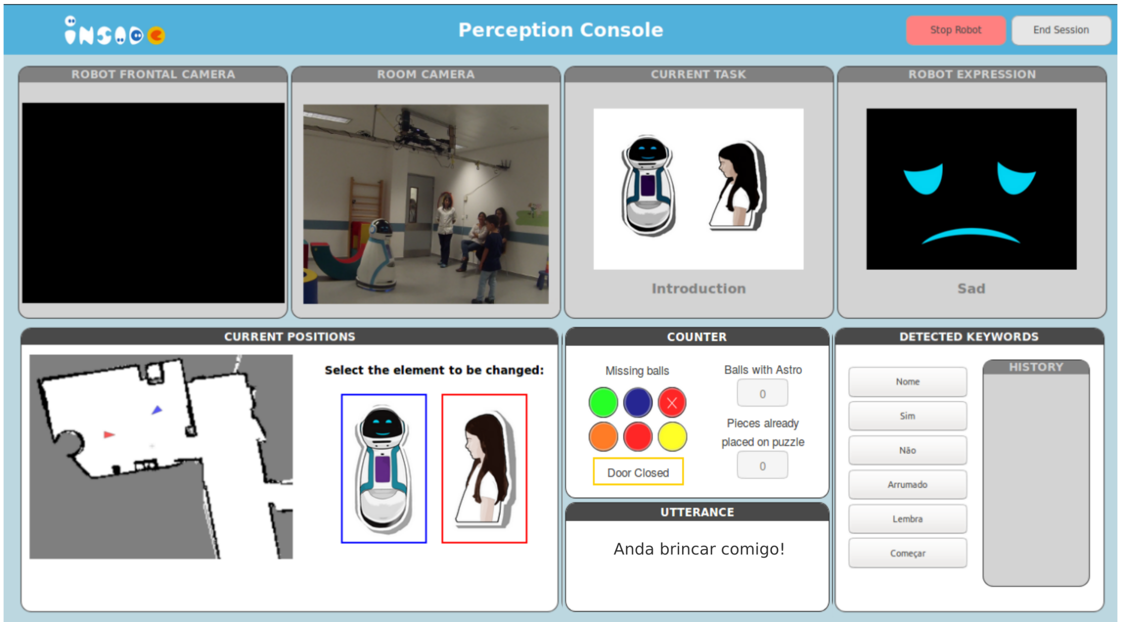

Fig. 5. Wizard-of-Oz: perception console during the introduction activity. The child did not respond to the robot's first call to play and it started the motivational behavior.

child to interact with him but facing to an opposite direction. And it also helped to send the keywords to the robot when the therapist had forgotten to turn the microphone system on or when the speech recognition system could not be able to detect the commands.

Also the interface was an important support for the outside therapist that was following the sessions and taking notes. In order to avoid the high number of people inside the therapy room, usually an issue for ASD children, some therapists and even part of the child's family could see the progress of the sessions from outside. Despite of the good visibility from must of the one way mirrors, sometimes it was not possible to visualize the robot's and child's expression and also the interaction of the child with the robot's touchscreen. Besides the visual issue, it was not always possible to understand the sounds from within the room but the interface helped showing the utterances, the images and the current tasks. In this way, it became easy to the therapist to assist the progression of all sessions.

The impact of the interface during the development of the system helped the team to increasingly improve the autonomous behavior of the robot. Consequently, during the final studies, it was noticed a significant reduction on the use of the consoles for intervention purpose. Also it had a notable impact during the studies with the ASD children for the therapist. It was an important tool used to support the analyses.

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