Robotic Toys for Autistic Children:Innovative tools for teaching and treatment.

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***Abstract*—This paper presents an initial study related to the use of robotic toys as teaching and therapeutic aid tools for teachers and care-givers as well as parents of children with various levels of autism spectrum disorder (ASD). Some of the most common features related to the behavior of a child with ASD are his/her social isolation, living in their own world, not being physically active, and not willing to learn new things. While the teachers, parents, and all other related care-givers do their best to improve the condition of these kids, it is usually quite an uphill task. However, one remarkable observation that has been reported by several teachers dealing with ASD children is the fact that the same children do get attracted to toys with lights and sounds. Hence, this project targets the development/modifications of such existing toys into appropriate behavior training tools which the care-givers can use as they would desire. Initially, the remote control is in hand of the trainer, but after some time, the child is entrusted with the control of the robotic toy to test for the level of interest. It has been found during the course of this study that children with quite low learning activity got extremely interested in the robot and even advanced to controlling the robot with the PS2 type joystick. It has been observed that the children did show some hesitation in the beginning 5 minutes of the very first sessions of such interaction but were very comfortable afterwards which has been considered as a very strong indicator of the potential of this technique in teaching and rehabilitation of children with ASD or similar brain disorders.**

Keywords— Autism Spectrum Disorder (ASD); Robotic Toys; IR Control; LabVIEW based remote control

I. Introduction

In this paper, the intended objective presented is to build/modify small robotic toys with several interactive and assertive capabilities. The purpose is to make these robots in the form of toys for autistic children. These kids can use this toy as a normal toy but the instructor and parents can use the robotic platform to maneuver the child more with the movements, lights, and sounds features with the remote-operation with video feedback in order to understand better the learning behavior of the child.

The proposed platform is also a very useful research tool since it can enhance the study of the behavior of the autistic children who are otherwise not so open in front of strangers. Once they have crossed the initial familiarization boundary, then anyone can use the robot remotely to help them learn, play, and interact with newer things and more advanced behaviors.

Autism is a disorder of neural development characterized by impaired social interaction and communication, and by restricted and repetitive behavior. Autism cannot be detected at the natal or early stage of development and, unlike other diseases; the symptoms vary from child to child. The presented work is aimed at helping the families, therapist, and teachers in schools of such children to better understand and interact with them. It is intended here to combine the features of already existing hobby robots with speech generation and remote control features. The robot is capable of motion as well as controlled by a remote device. It is capable of generating lighting patterns and sounds as desired by the care-giver using remote PC to make the robot more interactive with the autistic children. These features are designed to encourage the development of shared emotions and physical contact between young children with ASD.

For an autistic child, a robot may be less intimidating and more predictable than a human [1, 2]. At the same time, having a human override feature in the form of a remote control will enable the parents, teachers, and therapists to interject newer routines and actions slowly and gradually so that the child adjusts to the new objectives. This flexibility allows robotic toys to evolve from simple machines to systems that demonstrate more complex behavior patterns.

Similar developments were made previously and a toy named Kaspar (developed by Scientists at the University of Hertfordshire [3]) is believed to be the most advanced in this line so far. But still, it can perform only a handful of functions, limited to a few phrases, laughing at the touch of sides and feet, raising and lowering of the arms, or hiding his face with his hands and crying out "Ouch. This hurts," when it is slapped too hard and that is enough to keep autistic children captivated. Other similar solutions are Keepon [4], Rubi [5], and Popchilla [6] robots which were all designed with specific objectives of communication and verbal interactions with the autistic children. Recently, the NAO robot [7] has been gaining a lot of popularity among the humanoid robots community with a variety of applications including the interactions with autistic children. Almost all of these solutions are research based and are quite expensive when it comes to the affordability for an average school or parents.

II. Proposed Solution

In this work, Robosapien [8] robot has been utilized. Although some previous trials were done using custom-built humanoid or crawler robots but due to the easily available Robosapien robots with lower cost and ease of use made it the choice for this study. Robosapien is essentially a humanoid robot which is designed like a toy-gorilla shape with restricted movements and various mobile and dexterous movements. This biomorphic robot was designed by Mark Tilden and produced by WowWee toys and has been in circulation all over the world. The robot is preprogrammed and controlled for various actions and moves by an IR remote control with 21 different keys for various actions, an approximate total of 67 different robot-executable functions are possible with this remote controller. These include walking actions using the feet, grasping objects with either of the tri-finger hands, and making pre-programmed sound effects with its small loudspeaker unit. In addition, two LEDs are also provided that make up the eyes of the robot. As can be seen that the features are all very much desirable for the objectives stated above and hence the selection for using this robot for this purpose was made.

However, the main variation in the design for making it really user-friendly was the fact that the remote control unit is too complicated for the autistic children and must be changed. After many visits and discussions with the teachers of schools for autistic children, the Play Station 2 (PS2) joystick was found to be quite easy to use for these kids and that they were already using these joysticks to play video games. Hence the original 21 function joystick was mapped into the 8 digital and 2 analog keys of the joystick. Since there is a reduced mapping possible in this manner, the actual numbers of functionalities were also short-listed and only those of interest to the study were programmed into the software. These include the following:

1. Moving Forward
2. Moving Backwards
3. Turning Right
4. Turning Left
5. Stop moving
6. Swing Right
7. Swing Left
8. Arm Control (Analog keys)

Except for the last functionality, all others are simple digital switches that initiate an action in the software and appropriate robot command is transmitted. These functionalities are shown in Figure 1.

Fig. 1. PS Joystick with basic key mappings

One can rightly argue that the selection of bi-pedal robot was made without a sound justification. The reason behind that is the fact that this is an eye-catcher for the autistic children and something that resembles their own shape which can facilitate the process of becoming friends with the toy by the kids. Further add-ons are also resorted to including a Bluetooth speaker and some flashing lights. The sounds are transmitted to the speaker through the PC and the lights are a mean of catching the attraction of the children.

The main component used in first mapping and then in controlling the robot was a USB-UIRT device, which is essentially a USB-connected Universal IR Transmitter and Receiver module. A commercially available module [9] was used and the overall high level structure for the design is shown in Figure 2 utilizing all the above components.

Fig. 2. Overall system architecture. The user commands are given through the joystick and the PC converts these into IR packets using USB-UIRT module that are finally received by the robot's IR sensor (fitted in the head).

III. SOFTWARE STRUCTURE

The software environment that generates the right type of IR packet values was completely designed in LabVIEW. The main reason for this selection was to make sure that a set of routines be developed such that a whole toolkit related to IR controlled devices can be developed as a standalone application with best hardware connectivity. The overall software essentially is composed of four main components:

A. USB UIRT Interface

This involves the three DLL files available from the vendor to be used with the Library Call functions of LabVIEW to activate, Transmit/Receive, and Dispose the interface with the module.

B. Robosapien Command File

This was developed manually by capturing the IR commands using the USB-UIRT module with another commercial application VECTIR [10]. Once read, the commands were saved as a row in a text file. A typical file is shown in Figure 3. While the values are not really important to be displayed at this point, the main point to be noted is the positional value of a row attached to a specific functionality.

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0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000    NO-OP
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0023 0023 0084 0023 0084 0023 0023 0023 46C9    FORWARD
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0023 0023 0085 0023 0084 0023 0085 0023 3C54    BACKWARDS
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 3E6C    RIGHT
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0085 0023 0023 0023 0023 0023 0023 0023 4092    LEFT
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0085 0023 0085 0023 0085 0023 0023 0023 3A41    STOP
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0084 0023 0084 0023 0023 0023 0084 0023 35EE    Right Arm UP
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0084 0023 0023 0023 0084 0023 0023 0023 3B2E    Right Arm Down
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0084 0023 0084 0023 0023 0023 0023 0023 4072    Right Arm In
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0085 0023 0023 0023 0023 0023 0085 0023 4092    Right Arm Out
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0084 0023 0023 0023 3D5E    Left Arm UP
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0023 0023 0085 0023 0023 0023 0085 0023 3E70    Left Arm Down
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0023 0023 0084 0023 0023 0023 0023 0023 4088    Left Arm In
0000 006D 0000 0009 0115 0085 0023 0023 0023 0023 0023 0023 0023 0024 0023 0023 0023 0024 0023 0085 0023 3E7C    Left Arm Out
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0023 0084 0023 0084 0023 3B38    Swing R'ght
0000 006D 0000 0009 0115 0084 0023 0023 0023 0023 0023 0023 0023 0084 0023 0023 0023 0084 0023 0084 0023 35F5    Swing Left
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Fig. 3. A typical Robosapien command file with the functionalities on the right-most column.

C. Joystick interface

This was a custom-built part where each key stroke from the joystick is mapped to a number which essentially corresponds to the row number in the Robosapien commands file. The LabVIEW VI is shown in Figure 4.

D. The Calling Program

This program is essentially the Main program of the whole software that initializes the USB-UIRT module, reads the Command file, reads the joystick input, and based on that decides which row of the command file should be picked and sent to the IR module. Figure 5 shows this VI.

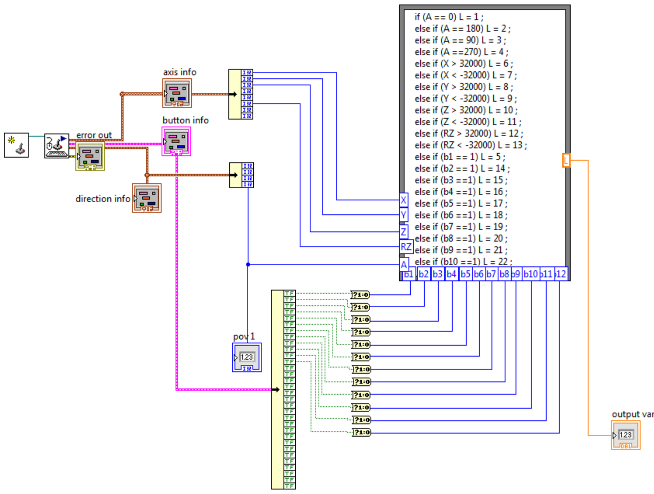

Fig. 4. The joystick mapping VI.

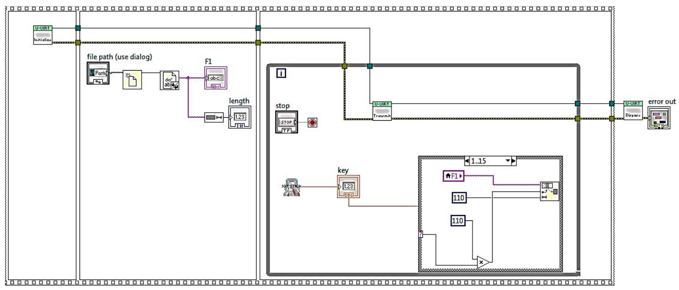

Fig. 5. Main Calling routine that performs the overall software integration.

IV. TESTING AND RESULTS

For testing the system with real subjects, a local school for special needs' children was contacted. In many sessions that were performed, following testing methodology was adapted:

With the collaboration with the Step-by-Step School for children with special needs, the arrangements for testing the robots have already been outlined. These include the following:

1. First, a workshop for the instructors was conducted in order to explain the procedure and usage of the designed system to them.

2. Permission from the parents, wherever necessary, was obtained for their children to participate in this 'game'.

3. Specific time slots were assigned to groups of children (not more than 4 students per group) in order to see their reactions and performance improvements.

4. In the beginning, low to mildly autistic children were tested with.

5. More severely autistic children were also brought in the study at random during various sessions.

6. During the testing period, the main teachers of these children were conducting the experiments with them. Rest of the team of the authors of this paper was asked to leave the room and watch the activity from the surveillance

cameras only since any strange face can affect the performance of children.

7. Trials were conducted including simple to more complex test procedures. Simple procedures such as voice base reactions or light based eye-catching routines to break the ice between the robot and the child. More complex routines involved mimicking actions such as greetings, dancing, waving, etc. or making the robot move in such a way that it forces the child to move and do physical activities like running, etc.

Figures 6 to 9 show some of these experimental procedures through the surveillance camera views. The selected views are based on preserving the anonymity of the people, especially the children, as a standard practice in such studies.

Fig. 6. Mimicing action testing. The child is asked to mimic the waving actions done by the robot. Subject is mild to medium autistic.

Fig. 7. Shaking the hands with the robot. The subject is severly autistic.

Fig. 8. A more curious child (from a severly autistic group) found the light son the eyes very attractive and is playing with the head.

Fig. 9. the most amazing reaction that was found during one of the sessions was the touching of head with the robots head (like a gesture of hugging) for almost 2 minutes. This showed how much the child like the toy. The subject is severly autistic.

The rubrics used in evaluating the tests were as follows:

1. Overcoming the Fear of the new toy.
2. Time needed to become friends with the toy.
3. Smoothness of coordination with various actions (technical)
4. Smoothness of coordination with various actions (by the child)
5. Ability of the child to mimic the robot.

In all of the above cases, tree levels of achievements were selected as the outcome of performance. Level 1 corresponds to 40% or less, Level 2 corresponds to 70% to 40%, and Level 3 corresponds to 70% and above. With about 10 children participating in these sessions (on average), the rough grading obtained was as follows:

1. Almost every child was surprised and got scared for 5 minutes but only in the beginning of the very first session of the study. Afterwards, they had no problem. Hence, most of the children scored in Level 3 with this aspect. This is a major success since for autistic children; it is not very easy

to remove the fear of anything from their mind once they catch it. But in case of Robosapien, they were only a bit startled in the beginning.

2. Again, majority of students fell in Level 3 with this rubric. Only severely autistic children took slightly longer to be able to go near, touch, and play with the robot.
3. This was also a Level 3 since there were no problems in controlling and making thing sharpen with the robot. Even with the remote controller given to the child, the performance of the robot was not affected.
4. In the smooth following of the robot and smoothness of interaction with the robot, the severely autistic children had some difficulty but were mostly in Level 2 or marginally in Level 3. Remaining children were in Level 3 of operation.
5. Almost every child mimicked the robot quite wonderfully when it was making dancing and swinging gestures. Some were quite interested to see the robot move and were following it around. But the most amazing display of ‘likeness’ was shown by a severely autistic child who touched his head with that of the robot and remained like that fr almost 2 minutes (Figure 9).
6. During one of the test sessions, the test was done with more than 1 robot present in the room simultaneously. The response was that the children were not so much focused with the robot. This inferred that the distraction may result in less response to the robot toy. This is probably true with any technological device even for normal people.
7. The children were quick in getting attached with the robot and with the robotic actions.
8. When the robot played its own default dance with built-in music, the children were very happy and this showed a positive feeling in the children.

V. Conclusion

In this study, it was clearly proven that the use of the Robosapien robot with more controlled usage with the presented system actually made the children with various degrees of ASD to interact better, imitate more smoothly, and un-knowingly, improved their social skills. While a more detailed study with hard statistics to support is being planned and will be carried out in subsequent months, the initial findings are really promising and put a lot of confidence in designing more challenging and more complex activities for these children to indulge into.

On the technical aspects, a couple of modifications are badly needed in the robot in order to make it into more users friendly. The sudden sounds that the robot makes are sometimes frightening to these kids. Firstly, removing or reducing the volume of these sounds can really benefit the usage for long-term study. Secondly, the IR line of sight did present some difficulty when a child or teacher cam in between the IR module and robot. Hence, changing this to a more radio controlled system will eliminate the problem.

The overall system costs less than any of the listed available solutions as listed in the Introduction section of this paper. Further cost reduction is being sought so that the whole system could become more affordable.

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