DESIGN AND REALIZATION OF A SOCIAL CARTOON-ROBOT FOR INTERACTION WITH CHILDREN WITH AUTISM SPECTRUM DISORDER

[1]BEHRAD MOZAFARI, [2]AZADEH SHARIATI

[1]Social & Cognitive Robotics Laboratory, Center of Excellence in Design, Robotics, and Automation (CEDRA), Sharif University of Technology, Tehran, Iran
[2]Department of Mechanical Engineering, Islamic Azad University, North Tehran Branch, Tehran, Iran.
E-mail: behrad.mozafari94@student.sharif.edu, azadeh.shariati@mail.kntu.ac.ir

Abstract - Design and realization of a social cartoon-robot for possible interaction with children with Autism Spectrum Disorder (ASD) is presented in this paper. Children with autism, usually enjoy playing with gadgets and autonomous devices such as robots. As a result, researchers utilize these devices in therapeutic sessions. They could be friends with children and make their therapy sessions more effective. The robot design parameters such as size, shape, and its social behaviors are very crucial to have a successful interaction with children with ASD. The robot we have constructed is based on the concept of WALL-E robot (the main character of the film WALL-E). This robot with two degrees of freedom, a camera on its head, and a Haar_Cascade vision system, is able to detect, track and interact with children.

Index Terms - Autism Spectrum Disorder (ASD), Haar_Cascade Vision system, Social Robot, WALL-E Cartoon-Robot.

I. INTRODUCTION

Based on the latest study in the United States, 1 in 59 children has been recognized with autism spectrum disorder (ASD) [1]. Studies indicate that social robots make the therapy sessions more effective [2]–[6]. Usually, children with ASD are in trouble with interacting and communicating with other people, on the other hand, they like to use some gadgets such as mobile phones, tablets[7], virtual reality [8], and robots [7], [9]. Robots have some advantages over other tools. For instance, a humanoid robot as a physical buddy can be in a shape of a real friend for a child with ASD and the child could generalize this friendship to another human partner [10]. In one of the early studies, Dautenhah et al. showed that a minimally expressive robot (KASPAR) could cause some important interactive behaviors; and children appear to generalize these behaviors in their everyday life [11].



Figure 1 _ Final shape of the constructed robot inspired from WALL-E cartoon-robot

Social robots can appear in different shapes, they can be in the form of humans, animals, or they can be system-like [10]. Some experiments have been conducted to examine the effect of robot appearance on the children's behavior [10]. Also, some researchers tried to elicit a specific behavior from the children [12] or teach them music or foreign language [6], [13].

In this research, a simple cartoon-like robot inspired from WALL-E robot [14] is designed and constructed (see Fig. 1). Besides its simple appearance, this robot is expected to interact with children and provide an appropriate platform for future studies. One of our possible future studies will be to investigate how this robot can affect the quality of gaze direction and joint attention of children with ASD.

In the upcoming sections, the design and construction processes of the robot will be discussed. An ARM processor controls all robot activities independently. A Haar-Cascade vision system [15], based on Python program detects and tracks children's face in the space.

II. THE ROBOT SPECIFICATIONS

The robot is lightweight and small in size. Being lightweight and small make the robot a safe tool to interact with children. It can be packed in a 268mm*176mm*153mm rectangular cube. Some specifications of the robot are presented in table 1

Table 1 _ The robot specifications

Main Board	Raspberry Pi 3 Model B
Operating System	Raspbian
Programing Language	Python
Vision System	Haar-Cascade
Camera	HD Webcam Logitech C270
Servo Motors	GOTECK GS-9025MG
Body Size	153mm*153mm*153mm
Package Size	268mm*176mm*153mm
Battery packs	2*4400 mAh
Total Weight (including two battery packs)	0.9 kg

III. PHYSICAL STRUCTURE

A. Design

The robot appearance and its design are inspired from the WALL-E cartoon-robot (the main character of the film WALL-E). For interacting with children with ASD, it is necessary for the robot to have a simple appearance and behavior. The size and color of the robot are also important. Its design and color are in accordance with the needs of children with ASD. At the present study, there are only two actuators in the neck of the robot; however, some space for adding future modules is considered. Some design properties are as follow;

-In Fused decomposition modeling (FDM) 3D printing, the shell thickness of the parts should not be less than the diameter of the nozzle of the printer (Fig. 2), otherwise, the printer will ignore the printing of that area.
-The robot must be lightweight to be safe for children.
-It should be robust enough, if kids suddenly hit the robot when they are playing with it.
-Design simplicity is very important when the robot is going to interact with children with ASD. If they intimidate with the complexities of verbal and nonverbal communications, this makes the whole communication process much harder [16].
-Sharp edges must be avoided to increase the safety of interactions.

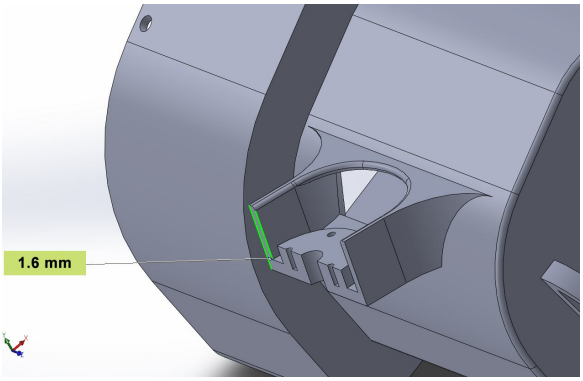


Figure 2 _ Designing robot parts, restrictions

Two servomotors actuate tilt and pan angles of the neck of the robot (Fig. 3). The tilt angle is actuated by the lower servomotor, and the pan angle is actuated by the upper servomotor. The tilt angle is more critical, since, the maximum load is applied to the lower servomotor.

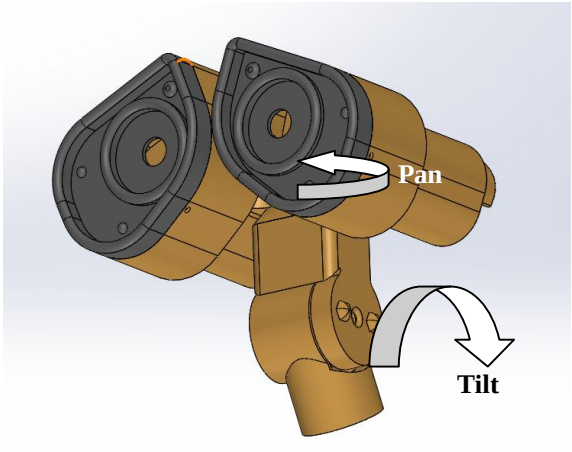


Figure 3 _ The tilt and the pan angles of the robot

B. Construction

The neck and the head of the robot are made using a 3D printer and the body is made of Acrylic laser cutting. The method which is used for the 3D printing of the robot head is the FDM method. For this project, a nozzle of size 0.4 mm has been used. Two actuators (2.3 kg.cm torque at 4.8 V.) are embedded in the neck of the robot, which performs the tracking action. The mass of the head of the robot (including the upper servomotor and the camera) is 0.3 kg (m = 0.3 kg) and the center of mass is 6 cm away from the lower servomotor rotational axis (r = 6 cm). Thus, the maximum applied torque on the lower servomotor for holding the head is as follows;

$$Torque_{max}=m*r=1.8\ kg.cm \quad (1)$$

The main board and two battery packs are located at the bottom of the body, and they are accessible from a door under the body of the robot. Two battery packs are considered to provide the energy. One battery pack is dedicated to the processor and the other one is dedicated to actuators

IV. SOFTWARE STRUCTURE

A. Processor

We selected the main processor from three nominated boards: BeagleBone Black, Raspberry Pi 3, and ASUS Tinker Board. Their main specifications are presented in table 2. For the human-robot interaction, it is imperative to have real-time responses. On the other hand, the processor should be able to detect the children's face, calculate the desired position of the motors, and send them the proper control signal to track the face. The BeagleBone Black processor is not able to perform the necessary calculations for real-time face detection The ASUS Tinker processor,

despite having the proper processing power, doesn't have appropriate libraries; however, the Raspberry Pi 3 besides has good processing ability, and appropriate libraries. So, among these candidates, the Raspberry Pi 3 was selected.

Table 2 _ Nominated boards processing power

	CPU	RAM
BeagleBone Black	Cortex-A8 1 GHz 32-bit	512 MB
Raspberry Pi 3	Cortex-A53 1.2 GHz 64-bit	1 GB
ASUS Tinker Board	Cortex-A17 1.8 GHz 32-bit	2 GB

B. Vision System

Due to the processing power of the board, it is very important that the visual system has a low computational cost. Therefore, the Haar-Cascade visual system is used for face detection. This method operates with a region of pixels (Integral Image), instead of whole pixels of an image [15]. Thus, this method has a fast computation and decision algorithm. The integral image for a specific pixel is defined as the sum of the intensity of all pixels at the up-left region of that pixel (see Fig. 4). At the specific point of (x,y), this summation (integral image) is as follows;

$$ii(x, y) = \sum_{x' \le x, y' \le y} i(x', y') \qquad (2)$$

where ii(x,y) and i(x',y') are integral image and the intensity of the pixel, respectively.

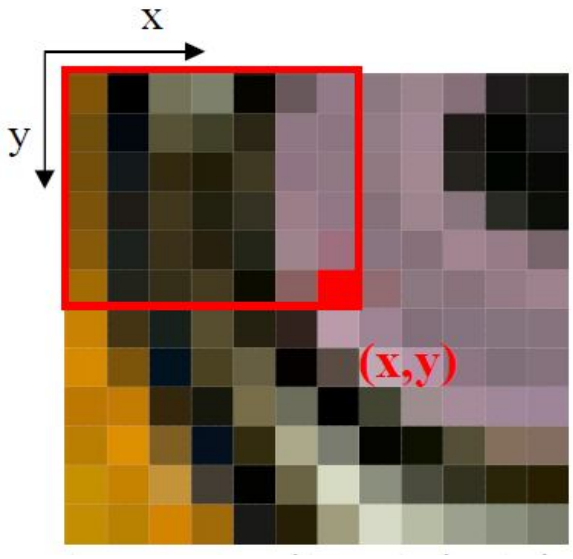


Figure 4 _ Integral image in the pixel

In this method, three types of features are generated and used (two, three, and four rectangle features) [15]. These features simply could be calculated by some lookups in the integral image table. So this method presents a low volume of calculations and seems to fit the processing power.

C. Control System

The robot control system is shown in the Fig. 5.

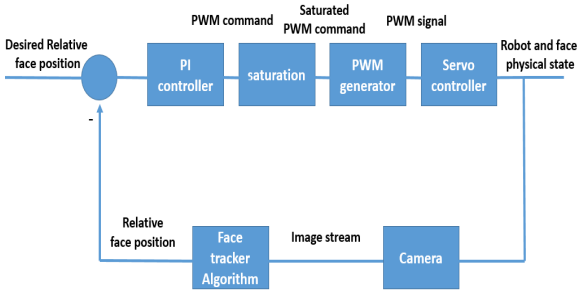


Figure 5 _ Control system of the robot

First, using the image stream of the camera, the position of the human face is calculated by a face tracker algorithm (the first program). Then, the position is sent to another program to control and create a desired PWM signal for the servo motors. Socket programming is used for communicating between these programs.

V. ROBOT INTERACTIONS

One of the robot interaction modules is the face recognition and tracking module (Fig. 6). Another interaction module is the sound module, which is able to play attractive sounds. These modules could increase the level of involvement of the children. While a child faces the robot, it will detect and track the child's face. This can be the basis of some future therapeutic games. This robot is expected to be able to increase the level of engagement of children with ASD in therapeutic sessions. Children with ASD usually avoid looking at the human face. The therapist could design some practical scenarios in the form of child-robot games. The games could improve the gaze direction and joint attention of the children with ASD.



Figure 6 _ Robot tracks the face of a human

VI. FUTURE WORKS

A future plan will be assessing the level of robot acceptability among the children with ASD. Then a number of robot-child games will be run to examine the impact of the constructed robot on improving the children's gaze direction and joint attention. Several sessions of therapeutic intervention will be conducted for this purpose. Another plan will be the combination of robot-tablet for achieving new results through novel scenarios.

CONCLUSION

In this paper, the design and construction of a social robot for possible interaction with children with ASD have been described. The robot is designed based on the WALL-E concept, which is a cartoon-robot. The authors assume that a cartoon-robot may increase the level of children's engagement in the therapy sessions. With the help of a camera and two actuators, the robot can recognize and track the user's face. The Haar-Cascade vision system is utilized for this purpose. The robot has an internal processor and operates in real-time. The processor is chosen from a practical test among three small single-board computers: a Beagle Bone Black, a Raspberry Pi 3, and an ASUS Tinker Board. The Raspberry Pi 3 is selected because it presents a good processing power besides richer libraries than the other two. The robot looks ideal for implementation in some game-based therapeutic scenarios. Also, it is equipped with a sound player, which could increase the level of children's involvement. Being lightweight and small in size, make the robot safe to interact with children. All the above make this robot an appropriate tool for our future therapeutic sessions for children with ASD, and based on the design characteristics of the robot, some games could be designed to evaluate gaze direction and joint attention of children.

ACKNOWLEDGMENT

We sincerely thank E. Ahmadi for developing the robot software. We also appreciate the support of our friends for the aesthetic design of the robot.

REFERENCES

[1] Autism Speaks. (2012, July 25). Retrieved from https://www.autismspeaks.org/what-autism/prevalence

[2] Robins, B., Dautenhahn, K., & Dickerson, P. (2009). From Isolation to Communication: A Case Study Evaluation of Robot Assisted Play for Children with Autism with a Minimally Expressive Humanoid Robot. 2009 Second International Conferences on Advances in Computer-Human Interactions. doi:10.1109/achi.2009.32

[3] Wainer, J., Dautenhahn, K., Robins, B., & Amirabdollahian, F. (2010). Collaborating with Kaspar: Using an autonomous humanoid robot to foster cooperative dyadic play among children with autism. 2010 10th IEEE-RAS International Conference on Humanoid Robots. doi:10.1109/ichr.2010.5686346

[4] Taheri, A., Alemi, M., Meghdari, A., Pouretemad, H., & Basiri, N. M. (2014). Social robots as assistants for autism therapy in Iran: Research in progress. 2014 Second RSI/ISM International Conference on Robotics and Mechatronics (ICRoM). doi:10.1109/icrom.2014.6990995

[5] Taheri, A., Alemi, M., Meghdari, A., Pouretemad, H., & Holderread, S. (2015). Clinical Application of Humanoid Robots in Playing Imitation Games for Autistic Children in Iran. Procedia - Social and Behavioral Sciences, 176, 898-906. doi:10.1016/j.sbspro.2015.01.556

[6] Taheri, A., Meghdari, A., Alemi, M., Pouretemad, H., Poorgoldooz, P., & Roohbakhsh, M. (2016). Social Robots and Teaching Music to Autistic Children: Myth or Reality? Social Robotics Lecture Notes in Computer Science, 541-550. doi:10.1007/978-3-319-47437-3_53

[7] Elahi, M. T., Korayem, A. H., Shariati, A., Meghdari, A., Alemi, M., Ahmadi, E., Taheri, A., Heidari, R. (2017). "Xylotism": A Tablet-Based Application to Teach Music to Children with Autism. Social Robotics Lecture Notes in Computer Science, 728-738. doi:10.1007/978-3-319-70022-9_72

[8] Shahab, M., Taheri, A. R., Hosseini, S. R., Mokhtari, M., Meghdari, A., Alemi, M., . . . Ghorbandaei Pour, A. (n.d.). Social Virtual Reality Robot (V2R): A Novel Concept for Education and Rehabilitation of Children with Autism. Tehran, Iran: The 5 th RSI/IEEE International Conference on Robotics and Mechatronics, ICRoM 2017, Amirkabir U.,Tehran, Iran, October 25 th -27 th 201.

[9] Scassellati, B. (n.d.). How Social Robots Will Help Us to Diagnose, Treat, and Understand Autism. Springer Tracts in Advanced Robotics Robotics Research, 552-563. doi:10.1007/978-3-540-48113-3_47

[10] Scassellati, B., Henny Admoni and Matarić, M. (2012). Robots for Use in Autism Research. Annual Review of Biomedical Engineering, 14(1), pp.275-294.

[11] Robins, B., Dautenhahn, K., & Dickerson, P. (2009). From Isolation to Communication: A Case Study Evaluation of Robot Assisted Play for Children with Autism with a Minimally Expressive Humanoid Robot. 2009 Second International Conferences on Advances in Computer-Human Interactions. doi:10.1109/achi.2009.32

[12] Kozima, H., Nakagawa, C., & Yasuda, Y. (2007). Children–robot interaction: A pilot study in autism therapy. Progress in Brain Research From Action to Cognition, 385-400. doi:10.1016/s0079-6123(07)64021-7

[13] Taheri, A., Alemi, M., Meghdari, A., Pouretemad, H., Basiri, N. M., & Poorgoldooz, P. (2015). Impact of Humanoid Social Robots on Treatment of a Pair of Iranian Autistic Twins. Social Robotics Lecture Notes in Computer Science,623-632. doi:10.1007/978-3-319-25554-5_62

[14] WALL-E. (n.d.). Retrieved from https://www.pixar.com/feature-films/walle/#walle-main

[15] Viola, P., & Jones, M. (n.d.). Robust real-time face detection. Proceedings Eighth IEEE International Conference on Computer Vision. ICCV 2001. doi:10.1109/iccv.2001.937709

[16] Cabibihan, J., Javed, H., Ang, M., & Aljunied, S. M. (2013). Why Robots? A Survey on the Roles and Benefits of Social Robots in the Therapy of Children with Autism. International Journal of Social Robotics, 5(4), 593-618. doi:10.1007/s12369-013-0202-2

★★★