Designing and Evaluating a Mobile Social Robot as an Intervention Tool for Autism Spectrum Disorder

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***Abstract*— Socially assistive robotics (SAR) research has showed significant promise for supplementing and augmenting therapy for children with autism spectrum disorders (ASD). Still, the great bulk of SAR research has been restricted to brief investigations in extremely controlled settings. Engineering and computer hurdles abound in the design and implementation of a SAR system that can interact autonomously in situ for extended periods of time. The creation of a completely autonomous SAR system for long-term in-home usage with children diagnosed with ASD is presented in this work. This paper designs and evaluates the embedded system for Autism Spectrum Disorder children. These children face difficulties from the communication barrier, mood swings, hyperactivity, and learning basics. A mobile social Robot for autistic children detects emotions. According to their sentiment, it teaches when the child is happy, and if the child is sad, it entertains the child. The robot detects motion and teaches social skills. The Robot includes a safety feature.**

Keywords— Autistic Children, Emotion Detection, Motion Detection, Teaches Social skills, Feedback system, Robot Safety by avoiding and following children.

I. INTRODUCTION

The autistic spectrum is a developmental condition that affects three primary abilities in everyone: To communicate, socialize, and think flexibly. Children with ASD (Autism Spectrum Disorder) have problems observing and imagining or understanding things. They want more attention than normal children, but the mentors/parents are not always available to give proper time or attention to a specific child. [1] ASD-suffering children need more politeness and repetitive answers because they do not get the point at one time. Most of the time, these children are neglected by children in classes/homes.[2] The therapist can treat ASD, but the session with the therapist is worth hundreds of dollars, and it's a long process for curing the child and making them able to compete with an average child. According to a report, Autism spectrum condition affects many children. [3] The illness is characterized by reduced social functioning in nonverbal behaviors, difficulty developing respectable peer relationships, and a lack of social and emotional interactions. Children with autism who receive early intervention have better behavioral and social outcomes thanks to play therapy.[4] When interacting with humanoid robots that provide simple emotional responses and engagement, it has been found that children with autism have better communication skills. [5] By creating a customized and adaptable robot-mediated technology for kids with ASD, our present research aims to close this gap. The system consists of a humanoid robot with real-time head-tracking capabilities provided by a distributed network of cameras [6] A range of permanent problems known as autism spectrum diseases damage people's capacity for social interaction and communication. Robots appear to boost engagement and inspire unique social behaviors in individuals with autism, especially children and teenagers, according to research into using robots as therapy tools.[7] As one of the first application fields in socially assistive robotics, robot therapy for autism has been investigated (SAR). [8] It was educating kids with autism spectrum disorders in producing and recognizing gestures using a social robot. Assistive technology for people with disabilities. 2018 Aug 18. [9] Although it has been asserted that kids with autism spectrum disorders respond to toys that look like robots, a microscopic study has looked at how robot-based intervention affects gesticulation. These kids' gestural development is delayed. [10] A review of the humanoid robot's implementation and evaluation for autistic kids. The 2019 issue of the International Journal of Computation and Applied Sciences Autism is a disease that impairs a child's capacity to form relationships with others around them and interact with them; [11] it requires a speedy and effective treatment method. This effort aims to examine the use of robots as interactive education tools for autistic children. [12] A humanoid robot named Yousif J. is an assistant tutor for autistic kids. International Journal of Computational and Applied Sciences, April 25, 2020. This essay aims to provide an interactive tutoring environment for autistic youngsters based on humanoid robots. [13] According to statistics, more than 5,000 robots are now being used in more than 50 nations for teaching and learning. Humanoid robot improving social and communication abilities in autistic children, Yousif M. Journal for the Development of Artificial Intelligence and Robotics, 2 June 2021.[14] Autism is a neurological condition that impairs a person's social, communicative, and cognitive skills. They find it challenging to express themselves and blend in with others and society easily.[15] Finding a teaching method to aid in the therapy and education of autistic children is a global effort being made by researchers and caregivers alike as the number of autism cases increases. [16] It has been researched that autistic children are more likely to be attracted to robots than humans. Mobile Social Robots for Autistic Children can teach children basic English, detect their swing moods, and treat them accordingly.[17] It also teaches social skills and manners by seeing their actions. The Robot develops communication skills in them by taking feedback from them.

II. SOCIAL ROBOTICS AND AUTISTIC CHILDREN

Social robots may interact and communicate with people by mimicking human social characteristics, including speaking, hearing, sight, and movement, and responding audibly and dynamically to commands. A humanoid robot is a class of social robots that can take on numerous forms and sizes, interact with people daily, and maybe a fundamental part of human society. Human-robot interaction (HRI) describes the interaction between humans and humanoid robots regarding communication. With the most minor innovation, HRI has expanded its capabilities to help kids with autism spectrum disorder (ASD). Through robot-based mediation, these functions integrate various areas, including sociability, communication, and social conduct. Those with autism face a slew of issues, the most serious of which is a social connection with others. In today's frantic environment, parents are too preoccupied to provide their full attention to a child with autism, and teachers are unprepared to teach them. According to studies, these children are more prone than others to be drawn to technology. Our motivation for developing a mobile social robot for autistic children stems from the need to give them a full-time mentor who can teach them social skills.

III. SYSTEM MODEL

This section contains a presentation of the system model. Many hardware and software components are included in the system model. The following subsection of this section talks about the hardware parts.

A. Hardware Components

The prototype of the system was created using several hardware components. The following details the hardware and its features:

• The Raspberry Pi is a minicomputer and embedded board used to make a mini/pocket computer. It is compatible with machine learning and real-time detection use by using open-cv and TensorFlow lite.

• A pi-camera module is used for video capturing, image capturing, and real-time detection. The Pi camera has five 5-megapixel Omni Version 5647 camera modules, a photo resolution of 2594 x 1944 pixels, and a video quality 1080p @ 30fps or low. The size of the camera is 25mm x 23mm x 8mm with a weight of 3 grams

• A 7-inch touch LCD the output from Raspberry Pi 4. The touch LCD is fitted on the chest of the robot. LCD is for displaying the graphical user interface (GUI) for interacting with the child, learning the alphabet, and playing the piano.

• This is a tiny USB microphone with high-definition voice input. It is easy to interface with Raspberry Pi 4. There is no need for any driver to plug this small microphone into a USB port. The Raspbian Linux operating system automatically detects the microphone. Now, you can use a tiny microphone with an application like (python ides, Voice recording, and feedback).

• Arduino nano to control the mobility of the robot/movement of the robot, interfacing two sensors with Arduino nano to save the robot from irregular paths, avoiding and following the children.

• An ultrasonic sensor is a technology that uses ultrasonic sound waves to measure an object's distance. Here are two pins used for this process: echo and trigger pins. The trigger pin emits a high frequency, and the ultrasound receiver echo pin receives the reflected sound. The ultrasonic sensor in the robot avoids children's attacks and follows the children if they go away from the robot while the robot is teaching the children.

• An infrared sensor is used to secure the robot. Two IR sensors are used. One is on the backside, and the second is on the downside. The back IR sensor protects the robot from the backside walls when the robot moves backward, and the downside IR sensor detects the space and irregular paths. If any of them is detected, the robot won't move forward. It will return or turn right/left. they are unavoidable.

B. Software Components

- Use. Kali Linux Raspbian Bullseye 11 is used as the operating system.
- Python 3.9.2 is used for programming the functionalities.
- The input is taken from the pi-camera for detection of the motion and emotion of the children for further processing and giving commands according to the situation.
- All the input is taken continuously and fed into a queue data structure. The feedback of the children is taken from the microphone for further processing.

IV. SYSTEM DESIGN

The project is divided into three parts. The first part is designing the CAD model and selecting sensors and actuators for the robot. The second part is implementing the CAD model into the real-world model and assembling all the sensor actuators for real-time detection, display, feedback system, and loudspeakers for audio output with the microcontroller. It is hard to design the microcontroller. We use the built-in microcontroller, Raspberry Pi 4 model b, with 8 GB RAM. Furthermore, the third part is a programming language. We are working with machine learning to develop the model for our robot. We use Python language to create the required model and use the different Python libraries and built-in packages for implementation.

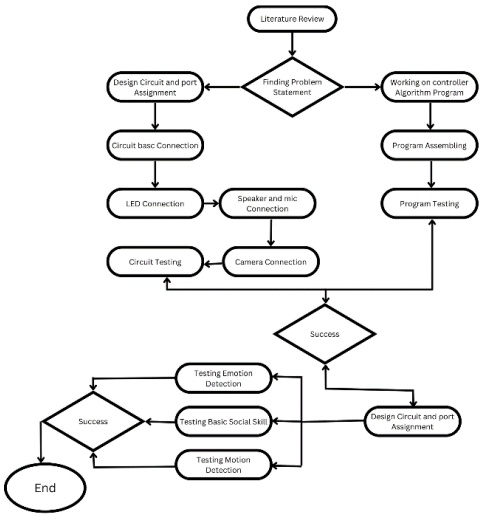

Fig. 1. Flow chart for Autism Spectrum Disorder tool.

The 3D model of the mobile social robot is designed on the software "Solid Works." The idea is taken from research papers discussed in the second chapter. We must design a robot-like human structure because we must make a humanoid robot, so we researched and finally got the idea of robot design. After finalizing the robot's CAD software design, it was converted into physical parts and assembled to develop a complete robotic structure. The method for detection the ASD use the deep learning framework for detection the emotions and motion i.e. CNN (Convolutional Neural Network) and Background Subtraction (for Simple Motion Detection).

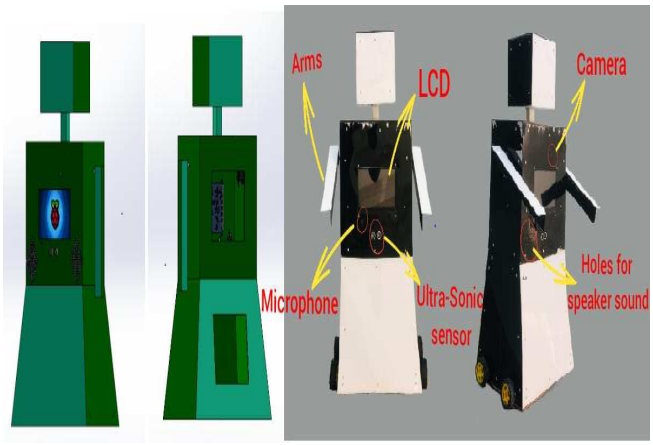

Fig. 2. CAD Model and Physical Structure of Mobile Social Robot.

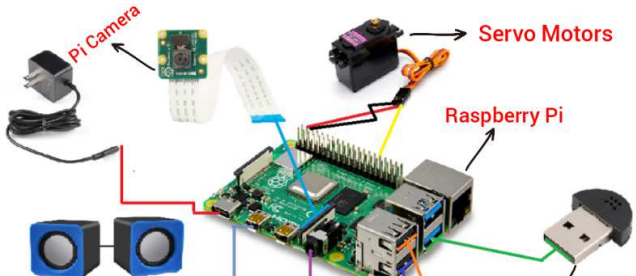

Fig. 3. Circuit Design. (*Main Circuit of Robot*)

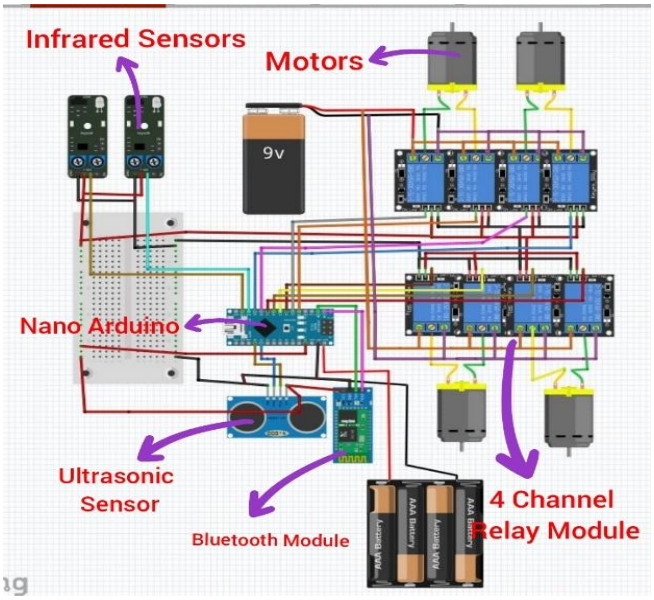

Fig. 4. Mobility Circuit of Robot.

V. RESULTS AND DISCUSSION

A mobile social robot for Autistic Children is the substitute for a therapist who gives full attention to a specific child without any tiredness or revolt from the child, unlike the therapist. It can help children with Autistic Spectrum Disorder interact with people, observe things, and think flexibly by giving some tasks.

This endeavor aims to provide a comprehensive learning system for children with autism using technology. Additionally, provide interactive resources that benefit special needs kids' communication and thought processes—for example, teaching essential learning and social skills like sitting quietly, greetings, and manners. It detects a child's moods and hyper-activities and gives commands to engage a child in a different task.

A microprocessor is embedded in the system, and various special equipment like a camera to get real-time data to detect the emotions and movements of the child and speakers to give commands. Mic to get feedback from the child, LCD for display pictures to engage the child, and ultrasonic sensors are used to protect themselves from the child.

Hardware testing ensures that each component operates according to its intended functionality while the assembly procedure explains which part goes in which position. The results show that they are doing it correctly. From capturing input using a camera and microphone on a Raspberry Pi to generating outputs using an LCD and speakers, software testing ensures that the robot operates as expected. The results show that they are working as intended.

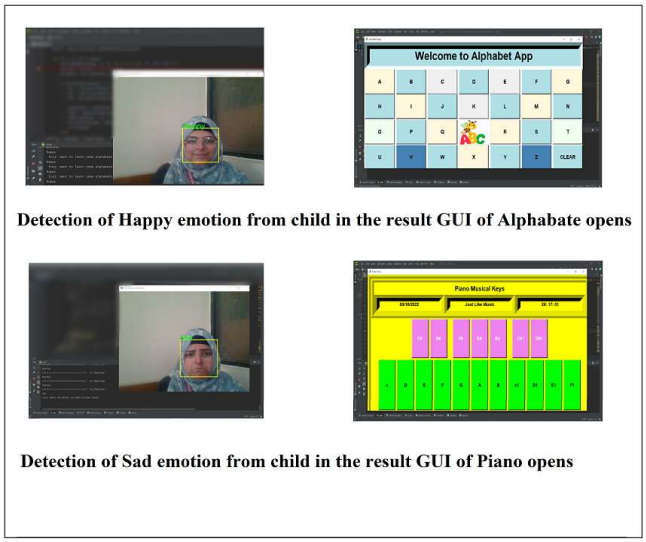

Fig. 5. Detection of Emotions e.g. Happy and Sad.

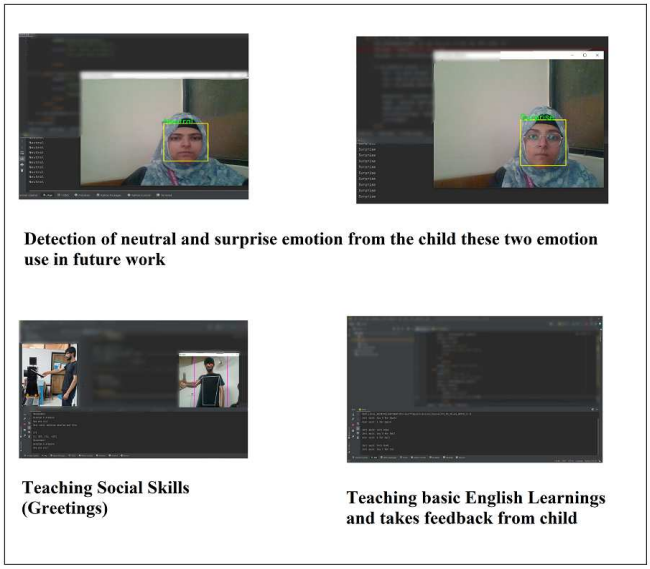

Fig. 6. Detection of Emotions e.g. Neutral and Surprise and Teaching Basic English and Social Skills (*Handshake*).

Fig. 7. Detection of Hyperactivity e.g. Jumping, Runing, Putting finger in Nose and Mouth.

A. Child Mood Detection and Proving Corresponding Feedback

The real-time emotion detection is done through a camera connected to a Raspberry Pi. The way a child is treated and instructed depends on their feelings. To detect emotions In figure 5, we gather datasets, train a model, and implement it using built-in Python libraries. If the robot sees sad emotion, then the robot cheers up a child by playing piano GUI. If a child is happy, it teaches basic English by displaying GUI.

B. Teaching Basic English with a feedback system

In the figure 6(d), the robot teaches a child basic English with feedback from the child. The Robot interacts with children and trains them repeatedly until they get it ideal and give feedback. We use built-in Python libraries and conditions for frequently learning children for teaching purposes.

C. Teaching Social Skills (Greeting)

In figure 6(c) the Robot teaches a child social skill like greeting and shaking hands with people. The body's posture is detected through camera and serial communication with Python IDE fermata.

D. To Detect The Motion Of The Child And Pacify The Motion By Command

The camera detects real-time activity, and commands are issued by the activities, as depicted in figure 7. We gathered datasets, trained the model, and put it into use using built-in Python modules.

E. The Safety of the Robot

For safety purposes, we use a couple of sensors (Infrared sensor and Ultrasonic sensors) and the microcontroller (Nano Arduino) attached to servo

motors. The robot dodges the child's sudden attack for damaging the robot, and it also prevents irregular surface dangers by taking a turn right/left or returning.

VI. CONCLUSION

This project attempts to provide an extensive learning system for autistic children using technology. Create interactive resources that aid youngsters with special needs to communicate and think more clearly, for example, teaching essential learning and social skills like sitting quietly greetings, and manners. It detects a child's moods and hyper-activities and gives commands to engage a child in a different task. This robot interacts with children in a friendly way and gives them repetitive answers until the child gets the word. This project successfully operates on the Raspberry Pi by using Python language. The speakers give commands, and the robot takes feedback from the child through a mic. An onboard Camera is used for real-time detection of a child's Facial expression and activity. A robot treats the child according to their mood. If the child is happy and neutral, it teaches basic English. If the child is sad, it cheers up the child by displaying the GUI of the piano on the LCD. This robot teaches social skills by detecting the movements of the child. If the child picks a nose, puts a finger in the mouth, and runs, it commands the child not to do it. Also, it teaches greetings like shaking hands and saying the greeting word. Ultrasonic and IR Sensors are also implemented on the robot's body to protect itself from uneven surfaces and children's attacks. The main goal of this project is for the child with autism to move forward and achieve everything like an average child.

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