Autistic Child Friendly Robot

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Autistic child friendly robot

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Autistic child friendly robot

Abstract

The development of a humanoid robot system designed to enhance communication skills in children with autism. The system incorporates a camera-based emotion detection algorithm that analyzes facial expressions and identifies seven different emotions. Convolutional Neural Networks (CNNs) are employed for efficient emotion detection. Additionally, the system includes a manual mood selection feature, allowing children to freely choose between various activities such as learning, playing interactive games, and engaging in songs and storytelling. The graphical user interface (GUI) of the system, implemented using the tkinter library, provides an interactive platform for children. Hand tracking techniques enable control and interaction with the system's activities through hand movements captured by the camera. NEMA 17 stepper motors are utilized in the humanoid robot's structure, enabling precise movements synchronized with the GUI application.

The system aims to support children with autism by providing a customizable tool to enhance communication skills and facilitate engagement. By combining automatic emotion detection and manual mood selection, the system offers a range of activities tailored to individual preferences. The incorporation of interactive games, songs, and storytelling creates an engaging and personalized experience for children with autism, promoting communication and interaction

Chapter 1: Introduction

1.1. Background

One of the lifetime disorders that have a severe impact on communication skills is known as “Autism”. To clarify autism affects how people react when the contact to others. [1] what is more that understanding and learning in a logic or analytical way is considered an issue for people who suffer from autism [2]. Furthermore, autism spectrum disorder (ASD) individuals suffer from dealing with high voices and any unexpected conditions [3].

According to the National Autism Society of Malaysia (NASOM), in 2010, the minimum number of children diagnosed with ASD was one in every 150. .The most recent statistics from 2018 show an increase of up to 45%, or one in every 68 children. Autism is not curable and has no medication. Nevertheless, the number of therapist and treatments may help people to enhance the way they communicate. Through rehabilitation and intervention, the children can behave and react similarly to normal children [4].

Generally, ASD is classified into three groups: severe, average, and mild. ASD children in the mild group can still listen to therapist instructions. Nevertheless, each member of the severe group requires special attention from therapists. Most of the research prefer to conduct immediate treatment on the mild group rather than the severe as managing the mild group is way simpler than severe through the investigation [1].

The symptoms of autism differ from one person to other. To illustrate each person suffers from autism have their own challenges and obstacles. From that therapist can provide the needed support as each person will need different treatment [2]

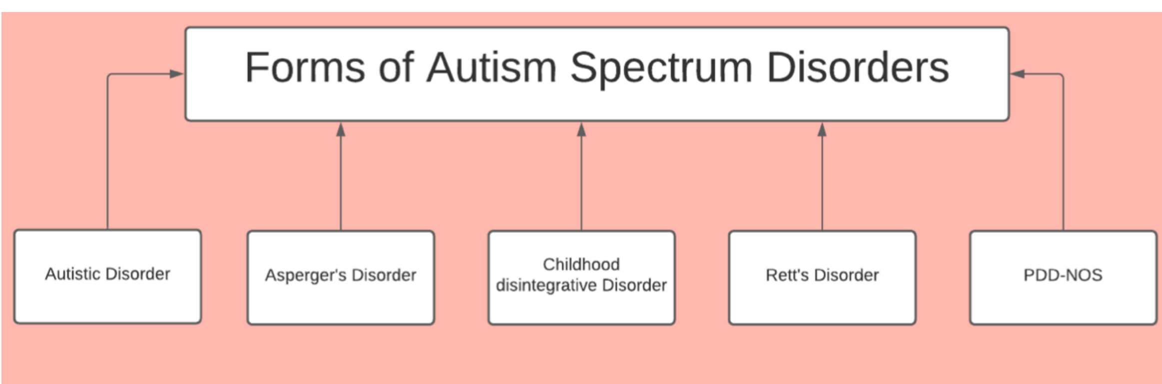

Figure 1 the types of autism spectrum disorders

Several ASD children may have decent language skills with only a slight speech difficulty. Even though communication skills significantly impaired, in contrast to other children may lack nonverbal skills as well as the desire to interact with others they are unfamiliar with.

Nowadays there is no ASD diagnostic assessment. Typically, a diagnosis is reached after careful evaluation and observation. Based on some family interviews and observation from clinic and one or more alternative autism diagnostic tests, including robotics, could be used. A child or adult with ASD is not permitted to play or pretend. [3]

Intervention methods for ASD have been developed in latest days; even so finding an approach to fit all cases of autism is so challenging. This is because the large heterogeneity of the autism spectrum, which means that many of these intervention approaches deficiency solid evidence of efficacy. Latest technological advances may be viewed as a promising opportunity for innovation in the intervention and diagnosis of autism spectrum disorder, particularly in the field of robotics, given that robots can be used as social communication collaborators.[4]

In the perspective of human communication skills robots have a great opportunity for innovation in this field. To reach a qualitative evaluation and concentrate on one phenomenon merely; utilizing controlled stimuli is the key. As well as utilizing the robot through therapist appointment for teaching and treatment purposes. Robot can assist children with autism who are attracted to them the most. Robot can support autism children in 3 different fields: a) behavior of child; b) The behavior of humans versus robots; c) providing feedback on performance and maintaining proof. Feedback is being provided by robot on the recent behavior of the child and learning level. Furthermore, the robot can assist therapists in achieving normal level of interactive with child, enhancing the ability of achieving natural environment during session. [4]

As a primary therapy for ASD children Human-Robot interaction is being utilized widely. The majority of robotic interventions produce improved results through therapy sessions, where children can engage in improving their communication skills.[2]

Children with autism can benefit from robotic-based rehabilitation by improving their communication skills. In order to investigate methods to improve ASD children practicing and learning levels past researchers manufactured their own prototype. Verbal skills, eye contact, imitation behavior, face expression, and robot motion are all part of the interaction between the robots and the children.[2]

1.1. Problem Statement

Children with autism spectrum disorder (ASD) often encounter challenges when it comes to expressing themselves and engaging in turn-taking activities. This difficulty becomes particularly pronounced when these children need to concentrate on multiple tasks simultaneously, such as imitating, playing, and interacting socially with their surroundings. These struggles can hinder their ability to effectively communicate and connect with others

Given the significance of early detection and treatment for ASD, it is imperative to develop appropriate interventions. However, due to the unique nature of each child with ASD, a one-size-fits-all approach is not feasible. Consequently, the utilization of a robot framework becomes relevant, as it can effectively fulfill specific tasks within predefined limits. To this end, the development of an expandable Human-Robot Interaction (HRI) framework, incorporating a range of communication modules, becomes essential.

The objective of this project is to design a robotic template that encompasses various components, including a learning module, entertainment features, and relaxation tools. By integrating these elements, the aim is to provide a comprehensive and adaptable platform that caters to the specific needs of children with ASD. This robotic template will serve as a valuable resource in facilitating their learning, providing engaging experiences, and promoting relaxation, thereby enhancing their overall development and well-being.

1.2. Design Objectives

The design objective of our project is to create a reasonably priced humanoid robot prototype that can serve as a human-robot assistant during therapist sessions for children with autism. The implementation will utilize the "Raspberry Pi" as the processing chip, providing a cost-effective and versatile platform for our robot. To enhance the interaction experience, we will incorporate the "Raspberry Pi camera module" for software applications and motion detection.

The primary focus of our robot is on facial emotion recognition, which will enable the robot to detect and respond to the emotions displayed by children. This feature will be valuable not only for therapists but also for parents and caregivers, as it can simplify the process of interacting with children with autism.

Furthermore, we aim to develop the robot to have teaching capabilities, allowing it to engage children in educational activities. By providing interactive and tailored teaching methods, the robot can assist in the learning process and support the child's development.

Additionally, the robot will incorporate features that promote play and relaxation. Creating a conducive environment for children to engage in recreational activities is important for their overall well-being. By integrating play functionalities, the robot can offer a range of games and activities that cater to the child's interests and help them relax.

Overall, our design objectives revolve around creating a versatile and affordable humanoid robot that serves as a human-robot assistant during therapy sessions. By focusing on facial emotion recognition, teaching capabilities, and promoting play and relaxation, our aim is to provide a comprehensive solution that benefits therapists, parents, caregivers, and most importantly, children with autism.

1.3 Design Questions

The aim of the study was to review previous research on robot-based interventions for children with autism to be implemented in our propose system

The study had four objectives:

- determining the skills that can be taught through robot interventions,
- exploring the emotions of interest to autism children,
- understanding the challenges in interaction with robots for autistic children and how to be able to solve them
- the proposed system will be had be developed to apply some movement such as the head and the arms and how to design this movement compatible with their situation

Chapter 2: literature review

2.1 Introduction

Studies have been conducted to improve the education and language skills of children with ASD using robots. The goal is to enhance communication and social abilities. Despite having similar objectives, these robots differ in design, appearance, behavior, and methods used to interact with children with ASD. They are often designed to be friendly and approachable so that the children feel comfortable and can easily connect with the robot.[4]

2.2 Related work

Aniketh M, Dr Jharna Majumdar (2018) [6] have proposed Human Interaction Robot Head that can teach children with autism to identify digits, alphabets, colors, and perform simple arithmetic operations using Convolution Neural Networks. The proposed system is composed of large displays and a humanoid robotic head that interacts with the child using voice gestures. The algorithms used in the system are optimized using Neural Networks and different Convolution Neural Networks architectures are used for different applications. The proposed system is designed with the aim of improving communication and interaction between the robot and the child.

K. D. Bartl Pokorny (2021)[7] provides a comprehensive overview of the current state-of-the-art in robot-based interventions for children with ASD, including the challenges and limitations of the studies, and highlights the potential benefits of such interventions. The authors also provide recommendations for the future development and robot application interventions for children with ASD.

X. Yang, M. L. Shyu, H. Q. Yu, S. M. Sun, N. S. Yin, and W. Chen,Chen (2018) [8] proposed framework for children with ASD A novel multi-modal picture book recommendation framework for children with autism. The framework integrates text and image information to improve accuracy and address inappropriate recommendations. An image neighbor discovery method and a friend NDK group detecting method have been developed to provide more relevant information. The AI robot, NAO, will assist in the recommendation process and will be introduced to the children for acceptance before use. Future research will focus on improving topic event mining and involving therapists, educators and parents. Manual corrections will be added to prevent false results.

Chapter 3: software System development process

3.1 Introduction

In the process of developing our system, we began by collecting a variety of educational videos, games, and awareness stories specifically tailored for children with autism. These resources were carefully curated to provide engaging and interactive content that promotes learning, skill development, and awareness.

The Python programming language was utilized for the design and implementation of the system, incorporating two distinct operation modes: manual and automatic. In the manual mode, users have the flexibility to personalize activity selection, providing tailored engagement. On the other hand, the automatic mode utilizes a facial emotion detection system to analyze the child's mood, identifying emotions such as happiness, sadness, or surprise. Based on the detected emotion, the system autonomously suggests suitable activities, including playing games, engaging with educational content, or enjoying music.

To enhance efficiency, a timer feature was integrated. If no user input or interaction is detected within a specified timeframe, the system automatically directs users to the "Semsem HUB," which functions as the main menu. This ensures continuous engagement and provides a central hub for easy access to various system features and functionalities.

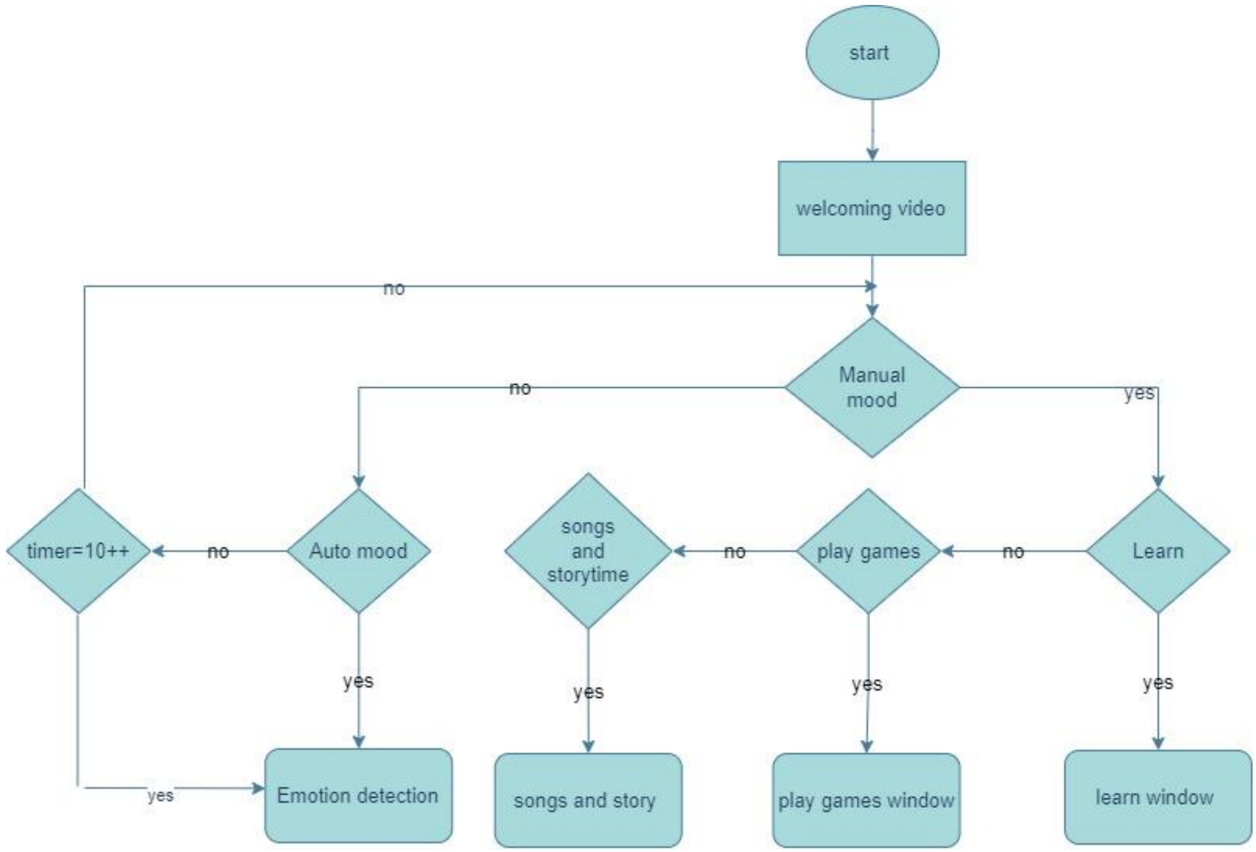

Figure 2.main system

3.2 Content Collection and Curation:

The process of content collection and curation involved comprehensive research and evaluation to procure a diverse range of resources catered specifically to the needs of children with autism. To ensure a comprehensive collection of games, we leveraged the OpenCV library, acquiring existing games that aligned with our objectives. In addition, we applied modifications to certain games, such as incorporating backgrounds or adjusting game speed, to enhance the overall gaming experience.

For learning videos, a meticulous search was conducted across educational channels, carefully assessing numerous videos to identify those that were most beneficial and engaging for children with autism. Factors considered during the selection process included content clarity, presentation style, and relevance to the learning objectives.

To complement the learning videos, educational games were meticulously chosen to provide practical reinforcement and practice. These games were thoughtfully selected to align with the concepts and topics covered in the learning videos, ensuring a cohesive and integrated learning experience.

In the realm of songs, particular attention was given to selecting tunes with repetitive melodies known to have a calming effect on children with autism. This deliberate choice aimed to create a relaxed and soothing atmosphere, fostering a sense of comfort and engagement.

The stories incorporated into the system were carefully curated to strike a balance between entertainment and education. Stories were chosen based on their ability to captivate and entertain while conveying important messages and raising awareness. The selected stories were designed to capture the children's attention, stimulate their imagination, and impart valuable life lessons.

Through the meticulous process of content collection and curation, our system offers a diverse array of engaging resources tailored specifically to the unique needs of children with autism. By integrating games, learning videos, songs, and stories, we have created a comprehensive and immersive experience that promotes learning, relaxation, and personal growth.

3.3 Designing User Engagement Implementation

Designing User Engagement Modes:

In the development of our system, we have meticulously designed two distinct modes to facilitate user engagement. These modes, namely the Emotion Scanner and the Semsem Hub, serve different purposes and cater to the specific requirements of our users.

- Emotion Scanner (Automatic Mode)

The Emotion Scanner mode employs advanced camera technology to detect and analyze the child's emotional state. By capturing facial expressions and interpreting emotions such as happiness, sadness, or surprise, the system autonomously selects appropriate activities for the child. These activities encompass a wide range of options, including interactive games, educational content, music, and storytelling. The Emotion Scanner mode provides a dynamic and personalized experience without necessitating manual intervention.

- Semsem Hub (Manual Mode)

The Semsem Hub acts as the central menu of our system and is accessible through the manual mode. This mode empowers parents, caregivers, and healthcare professionals to actively participate in selecting specific activities tailored to the child's needs. By offering manual control, the Semsem Hub ensures flexibility and customization in accordance with individual requirements and preferences.

To optimize user engagement and streamline the system's functionality, we have implemented a 10-second timer. If no user interaction is detected within this predefined timeframe, the system automatically transitions to the Emotion Scanner mode. This intelligent feature guarantees continuous engagement and adapts to the child's preferences even in the absence of manual input.

3.4 Semsem Hub (Manual Mode)

The Semsem Hub, also known as the manual mode, is a crucial aspect of our system that allows parents, caregivers, or guides to manually select activities for the child. It serves as the main menu, providing a user-friendly interface for personalized engagement.

In the Semsem Hub, users have the flexibility to choose from a range of activities and options. It aids in creating a tailored experience for the child's learning and development. Unlike the Emotion Scanner mode, which operates automatically based on facial emotion detection, the Semsem Hub puts the control in the hands of the caregiver.

By accessing the Semsem Hub, caregivers can select various options that align with the child's needs and interests. It simplifies the process of choosing activities, ensuring that the child engages in relevant and beneficial content.

The Semsem Hub serves as a central hub for activity selection, offering a streamlined approach to manual operation. It enables caregivers to guide the child's learning journey, supporting their educational, cognitive, and emotional growth.

3.5 Emotion Scanner (Automatic Mode)

3.5.1 Face Detection

Facial expressions play a crucial role in interpersonal communication, but individuals with autism spectrum disorder (ASD) often encounter challenges in effectively communicating and socializing. Communication difficulties with family members, instructors, and peers can arise, as individuals with ASD may struggle to express their emotions and have difficulty understanding the emotions of others. Recognizing the importance of strong human connection and the various forms of nonverbal communication, such as body language, facial expressions, attitude, and movement, researchers have developed a unique technology for real-time detection of facial emotions from captured face images.

Understanding a person's mood or mental state can often be achieved with a single glance at their face. However, children with ASD frequently face communication and social skills difficulties, making it challenging for them to interact with their parents, teachers, and classmates. Furthermore, they may have difficulty recognizing and expressing their own emotions, further complicating their social interactions. To address these challenges, a system equipped with a comprehensive dataset of people's emotions has been developed, allowing for real-time recognition of facial expressions in any individual. This chapter introduces a facial emotion recognition technique specifically designed for individuals with ASD. The application involves real-time scanning of facial images and prediction of emotional states. The software utilized includes advanced face detection and facial emotional recognition algorithms, enabling instantaneous capture of facial images and accurate recognition of children's facial emotions.

Recent advancements in deep learning have significantly contributed to the classification of facial expressions. The developed system employs automatic recognition of frontal faces in a video stream and labels each frame according to one of seven emotional dimensions: neutral, anger, disgust, fear, happy, sadness, or surprise. This real-time, automatic method achieves an accuracy rate of 71.16%, which is considered favorable considering the classification of seven different emotions. An important feature of this system is its ability to perform preprocessing tasks without explicitly detecting and aligning internal facial features. This characteristic is particularly valuable for real-time applications as it reduces processing time. Facial emotion recognition is accomplished through computer vision and neural networks, utilizing the design technique of Convolutional Neural Networks (CNNs) and Python libraries.

the development of facial emotion recognition technology offers a promising avenue for enhancing communication and socialization for individuals with ASD. By leveraging deep learning techniques and real-time analysis of facial expressions, this technology enables the understanding and expression of emotions, thereby facilitating more meaningful interactions and connections between individuals.

3.4.2 Face emotion recognition

Facial recognition technology, which uses specialized software to analyze facial features, has become widely integrated into various devices and technologies. Combining different techniques in facial recognition systems enhances their accuracy and success rates. One important technique involves the combination of conventional recognition, 3D-dimensional recognition, and skin surface pattern examination. This improves the system's ability to recognize and verify individuals.

Facial emotion recognition systems follow a typical process that includes identifying and drawing a rectangle around the face, extracting facial features, separating spatial and temporal properties of facial parts, and generating recognition results using feature extraction classifiers. By analyzing facial landmarks and utilizing pattern classifiers, these systems can measure and identify different facial expressions accurately.

facial recognition technology has expanded its applications, and combining different techniques enhances the system's performance. Facial emotion recognition systems follow a specific process to accurately identify and measure facial expressions.

Deep Learning-based Facial Emotion Recognition (FER) systems eliminate the requirement by allowing end-to-end learning directly from the input images, face-physics models and preprocessing techniques are enabled. The most widely used approach is through Convolutional Neural Networks (CNNs), which construct a feature map by applying filters to an input image through convolution layers. This mapping is then fed into fully connected layers, where the facial expression is classified based on the output produced by the Feature Extraction (FE) classifier.

3.4.5 Face detection and Face recognitions methods

face detection is a computer algorithm-based method used to identify and measure human faces in digital images. It employs machine learning or deep learning algorithms to locate and determine the presence of faces in still images or video frames. The Viola-Jones method is a commonly used technique for face detection. On the other hand, face recognition focuses on identifying individuals based on their facial features and involves preprocessing facial photos before analyzing the distinctive features for recognition. Convolutional Neural Networks (CNNs) are widely used for detecting emotions from faces and are known for their effectiveness in image and facial recognition tasks. CNNs utilize convolution operations to extract relevant information and typically consist of multiple layers, filters, and neurons.

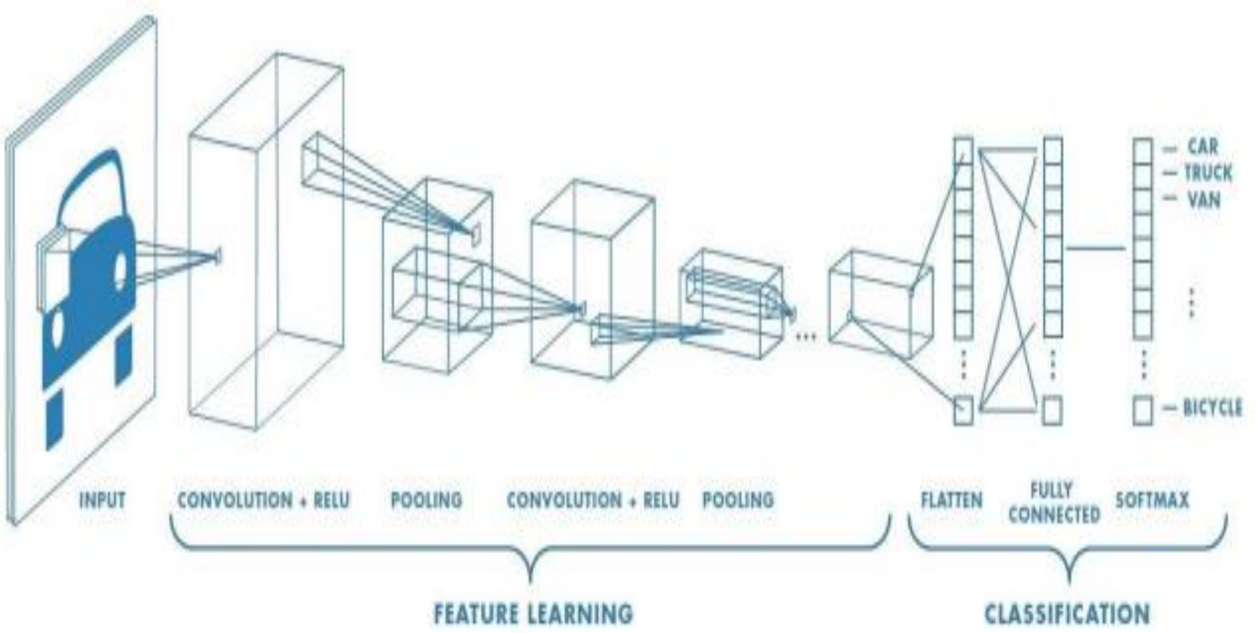

Figure 3 CONVENLUTION NEURAL NETWORK PROCESS

The convolution layer in a Convolutional Neural Network (CNN) serves several functions [13]. The pooling layer simplifies the complexity of each activation map by dividing the input into non-overlapping sections and applying either average or maximum non-linear functions [13]. The flattening layer compresses the input image from two or three dimensions into a one-dimensional array [11]. The connected layer (FCL) is responsible for connecting each filter in one layer to each filter in the next layer. This allows for the extraction of high-level features from the input image after the convolutional, pooling, and flattening layers [13].

3.4.6 Data Set

The data set used for training the CNN model in facial emotion recognition consists of 48x48 grayscale images sourced from Kaggle's FER dataset [14]. The dataset is divided into "test" and "train" categories, with each folder further categorized into 7 emotions. The steps involved in processing the dataset include identifying the dataset, generating train and validation batches, generating a CNN model, and training and assessing the model. The goal is to classify each face into one of seven emotions based on the facial expression, including anger, disgust, fear, happiness, sadness, surprise, or neutral. The images in the dataset are aligned to ensure a centered face in each picture. The focus is on face detection and emotion detection based on extracted features.

3.4.7. The Viola-Jones method

The Viola-Jones method, introduced by Paul Viola and Michael Jones in 2001, is a real-time image characteristic detection system. It has become prominent in face detection applications. For our implementation, we used Python and the OpenCV package to construct the algorithm. OpenCV is an open-source library that supports various programming languages, including Python and Java. It is commonly used in computer vision, image processing, and machine learning tasks. OpenCV provides functionalities for analyzing static and dynamic images, enabling tasks such as face and object recognition. It serves as a common interface for computer vision and machine learning applications, particularly for object detection and facial recognition. [13]

3.4.8 System Architecture

The major goal of the application is to capture the image instants and to check for the human face and then predict the Emotion of child.

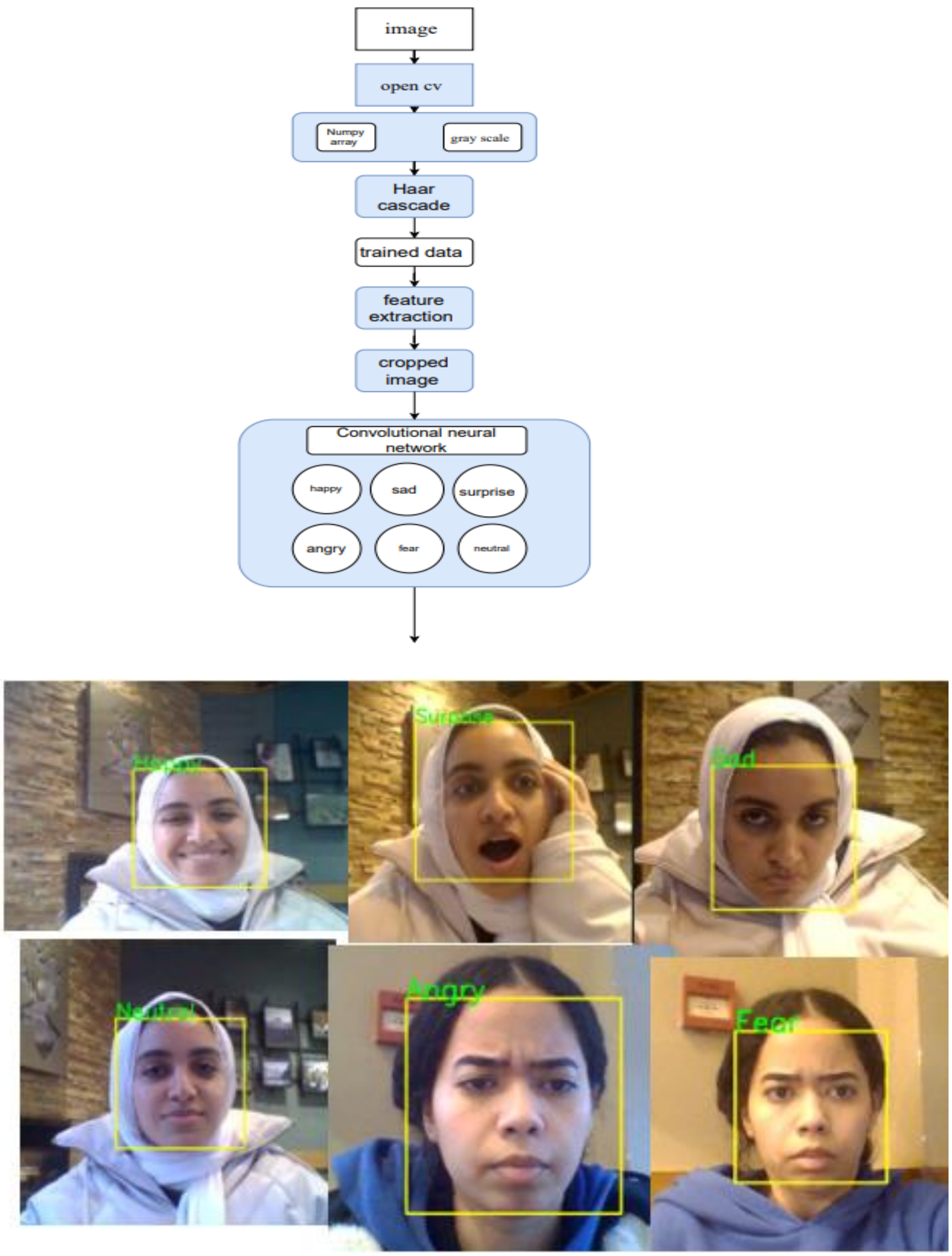

Figure 4 the face emotion detection diagram and results

Figure 5 architecture of emotion detection and results of system

3.4.8 Detection

The model architecture is designed to identify appearances and detect expressions in images. In the project, when an image is inputted, OpenCV preprocesses the image by converting it into a numerical array represented by a NumPy array. The image is then converted to grayscale. The Haar Cascade classifier, a machine learning-based method, is used to detect human faces by extracting Haar features from trained data and creating a rectangular box around the face. Once the face is cropped from the image, further operations are applied.

The Haar Cascade classifier, also known as the Viola-Jones algorithm, is a real-time object detection system pioneered by Paul Viola and Michael Jones in 2001. It uses the haarcascade frontal face default.xml to identify frontal faces, particularly in the context of this project, focusing on child faces with a high detection rate. This algorithm distinguishes between faces and non-faces.

The process of emotion detection using OpenCV

- Image Acquisition: The process starts with acquiring an image or a video frame that contains the face of the person whose emotion is to be detected. This can be done using a camera or by loading an image from storage.
- Converting to Grayscale: The acquired image is converted from its original color format to grayscale. This simplifies the subsequent image processing steps and reduces the computational complexity. The conversion can be done using the **cv2.cvtColor()** function with the appropriate color conversion code (**cv2.COLOR_BGR2GRAY**).
- Face Detection using Haar Cascades: Haar cascades are used for face detection, which involves identifying regions in the grayscale image that potentially contain faces. OpenCV provides pre-trained Haar cascade classifiers specifically designed for face detection. These classifiers can be loaded using the **cv2.CascadeClassifier()** class. The **detect Multiscale()** function of the cascade classifier is then applied to the grayscale image to detect faces, returning the coordinates and size of the detected face regions.

- Region of Interest (ROI) Extraction: Once the face regions are detected, they are considered as regions of interest (ROIs). These ROIs are extracted from the grayscale image to isolate the facial area for further processing and analysis.
- Feature Extraction: Feature extraction techniques are applied to the ROI to capture relevant facial information for emotion recognition. This can include various methods such as calculating facial landmarks (e.g., eyes, nose, mouth), extracting texture patterns, or computing statistical features. The choice of feature extraction method depends on the specific approach and model being used.
- Emotion Classification: The extracted features from the ROI are fed into an emotion classification model. This model can be a machine learning algorithm by using the Convolutional Neural Networks (CNN), trained on a labeled dataset of facial expressions. The model predicts the emotion or emotional state based on the input features.
- Emotion Visualization: Once the emotion is classified, the system can provide a visual representation of the detected emotion. This can be done by overlaying text or graphical elements on the original image, indicating the recognized emotion or by displaying corresponding emoticons.

The system utilizes a dataset to detect facial emotions of human faces. Facial Emotion Recognition (FER) is employed using Keras, TensorFlow, OpenCV, dlib, and NumPy. Convolutional Neural Networks (CNNs) are used to recognize emotions in child faces. The human face expresses emotions through facial expressions, and FER predicts emotions based on these expressions. The output represents the highest scoring emotion, which could be anger, happiness, surprise, neutral, fear, anger, or disgust. The result is displayed on the output screen.

3.5 Semsem Hub: Main menu and Functionality

The Semsem Hub serves as the primary interface of our system, offering users a central hub to access various features and functionalities. It provides a user-friendly interface that assists parents, caregivers, or guiding individuals in selecting specific activities tailored to the child's requirements.

The Semsem Hub comprises three distinct sub-windows, each dedicated to different aspects of the child's development and engagement:

1. Learn and Play: This sub-window provides a balanced blend of educational content and interactive games. It offers a wide range of educational videos, practice games, and engaging activities that enhance cognitive development, problem-solving abilities, and knowledge acquisition.
2. Interactive Gaming Zone: Utilizing hand tracking technology (OpenCV), this sub-window offers engaging games designed to promote physical activity, coordination, and the development of motor skills for children with autism.
3. Songs and Storytime: This sub-window provides a selection of calming songs with repetitive tunes and thoughtfully crafted stories that entertain, educate, and stimulate the imagination of children with autism.

3.5.1 Learn and Play

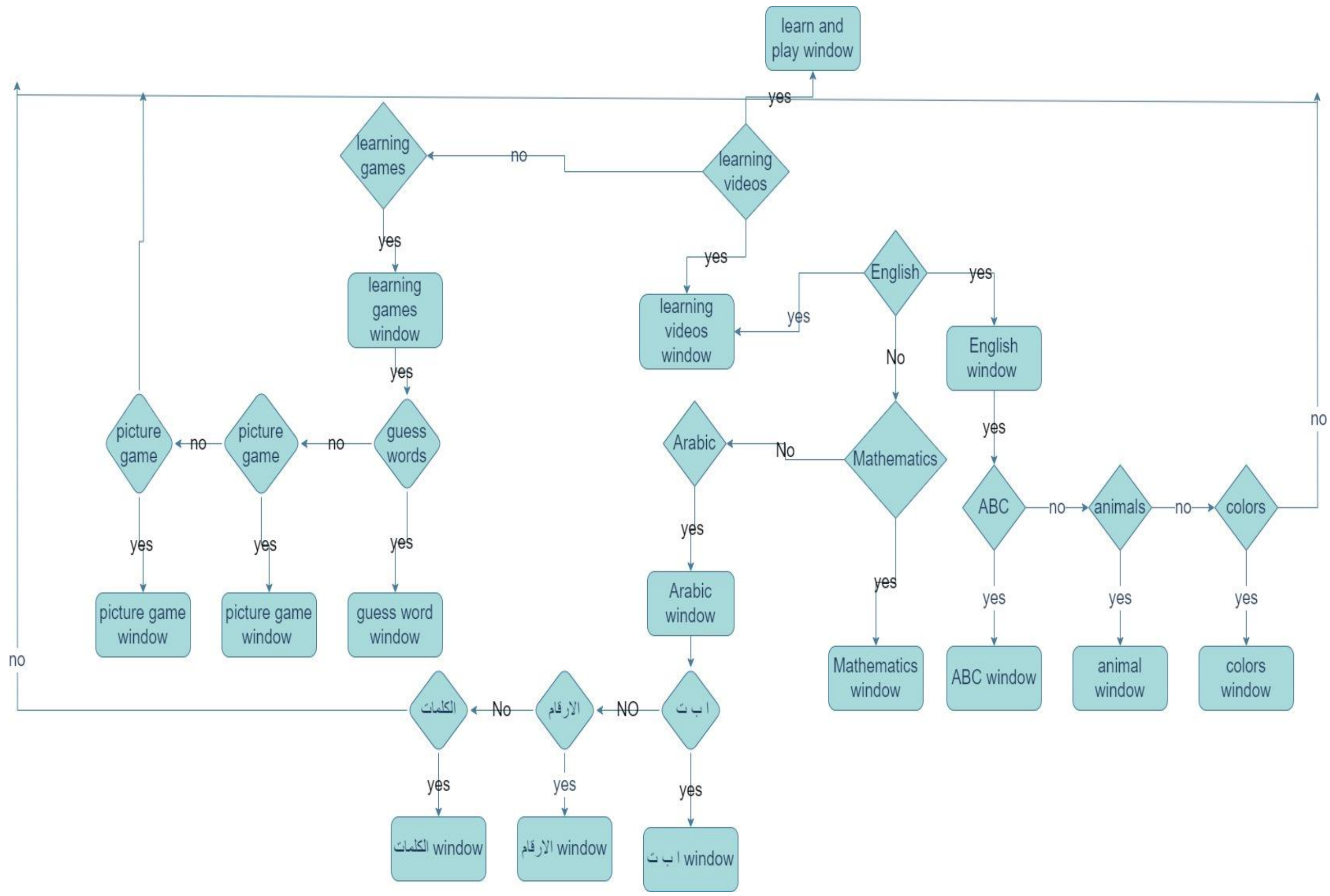

Figure 6 flow char t of learn and play window

3.5.2 *Learn and Play Window*

The Learn and Play window consists of two sub-windows: Learning Videos and Edu games:

1. Learning Videos sub-window: There are three buttons for English, Arabic, and Mathematics. The English sub-window is designed to teach children with autism the English language. It includes three buttons, each opening a video that focuses on teaching the alphabet, common words, and colors

- The mathematics sub-window provides educational videos to teach children basic math concepts. It includes videos on numbers, addition and subtraction, and telling time using a clock.
- The Arabic sub-window aims to teach children Arabic language skills. It includes videos on the Arabic alphabet, numbers, and useful words for daily life.

2-The second sub-window in the Learn and Play window is the Edugames sub-window. It features three different educational games that allow children to practice what they have learned from the videos.

- Guessing the Word: In this game, children are presented with separate alphabets and they try to guess the correct word. The game has a one-minute timer, and the score is displayed after guessing the word. Players can submit their answer, change the word if it's too difficult, or reveal the answer if they have enough points. They can also choose to exit the game.

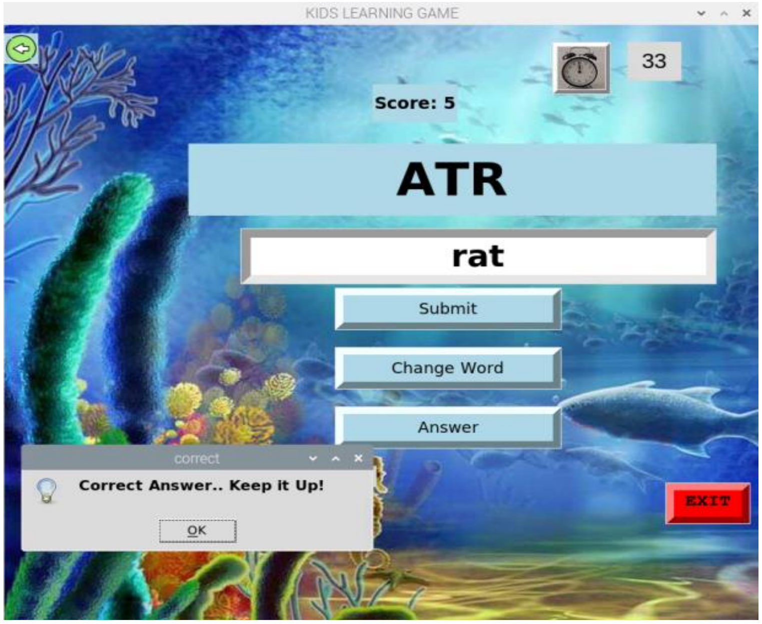

Figure 7:guessing word game

- Picture Game: In this game, children are given a text prompt such as "Choose the tiger from the given options." They are presented with four different photos and need to select the correct one. After answering, a small window appears to indicate whether the answer is correct or not. Players can continue playing or choose to exit the game at any time. The score is also displayed

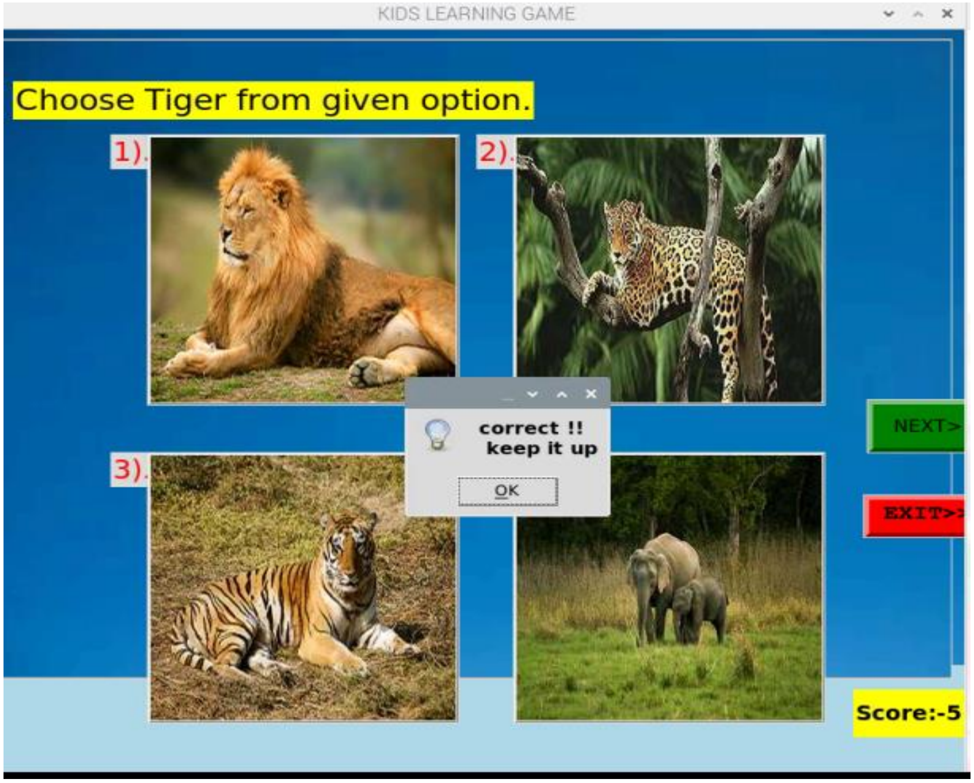

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Figure 8:picture game

- Mathematics Game: This game offers four choices: addition, subtraction, multiplication, and division. Players can select their preferred math operation and engage in solving related problems. The score is displayed during gameplay.

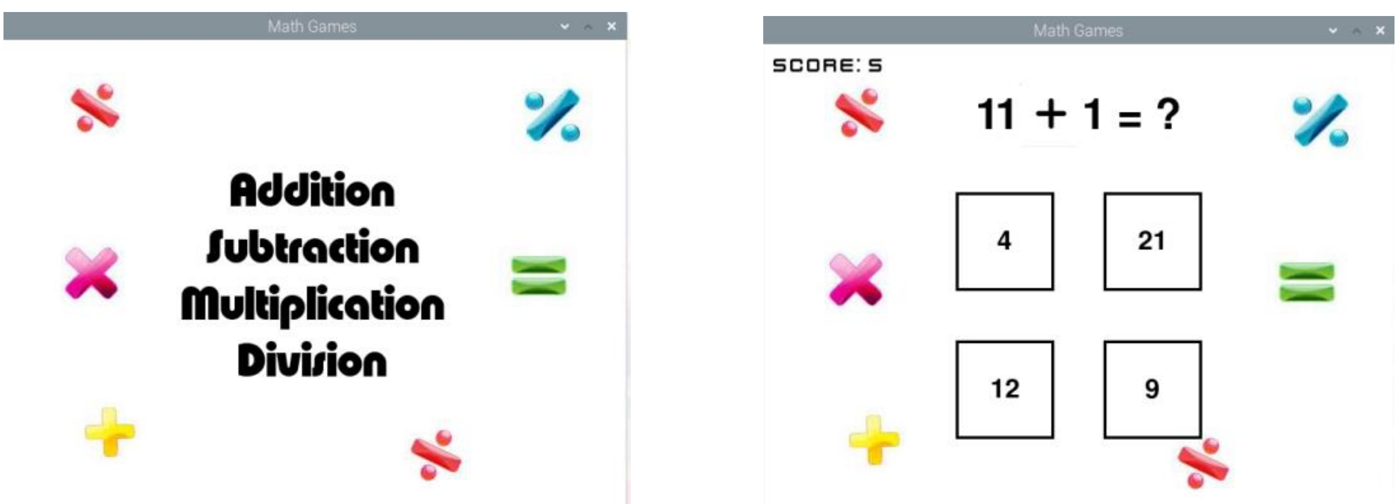


Figure 9 the main window of the game and the second picture represent example of the game

These educational games provide an interactive and engaging way for children with autism to reinforce their learning and practice important skills in a fun and enjoyable manner.

3.5.3 Interactive games zone

The Interactive Gaming Zone in our system offers three engaging games: Snake, Ping Pong, and Balloons. These games are specifically designed to provide interactive and immersive experiences for children with autism, promoting physical activity, coordination, and the development of motor skills.

Using advanced hand detection technology powered by OpenCV (Computer Vision), these games utilize the child's hand movements to control and interact with the virtual environment.

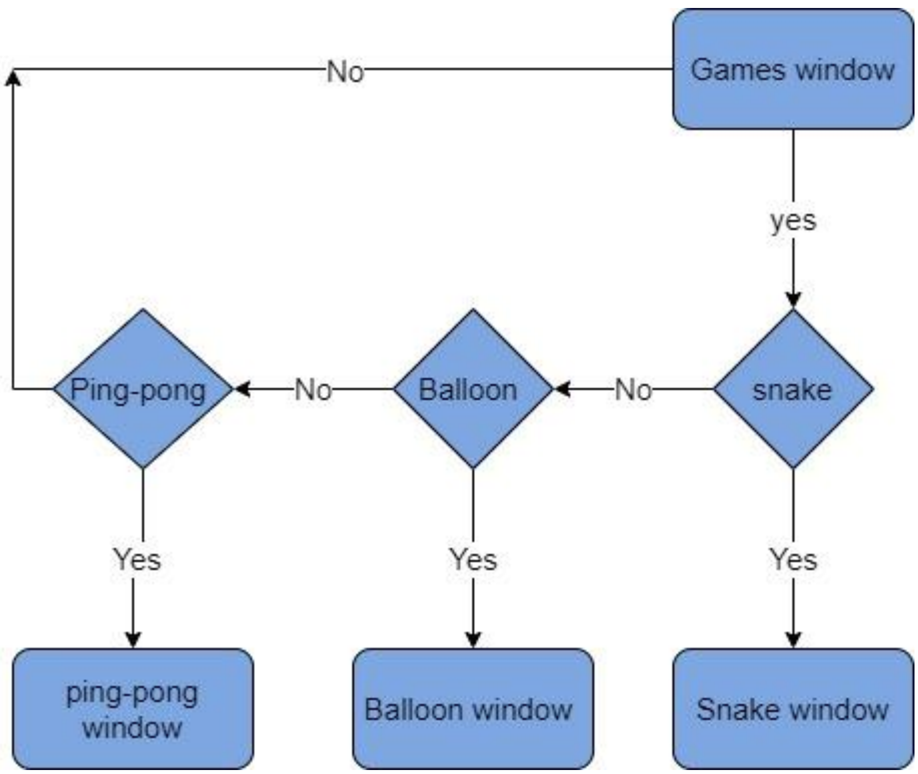


Figure 10:flow chart of games window

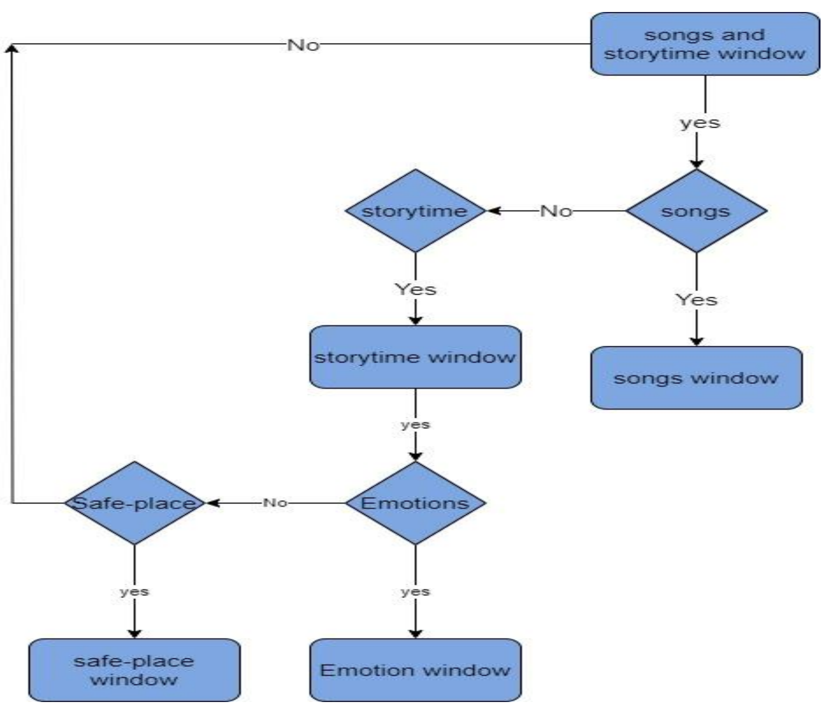
- Snake: The Snake game involves controlling a virtual snake using hand gestures. By moving their hands in different directions, children can navigate the snake to collect apples . This game enhances hand-eye coordination and fine motor skills as players strive to achieve high scores.

- Ping Pong: The Ping Pong game simulates a classic table tennis experience. Children can use their hand movements to control the virtual paddle and hit the ball. This game focuses on hand-eye coordination, timing, and motor control, providing an enjoyable and interactive way for children to engage in physical activity.
- Balloon: In the Balloons game, colorful balloons appear on the screen, and children can use their hand movements to pop them. This game encourages reaching and grasping movements, promoting gross motor skills and hand-eye coordination.

The incorporation of hand detection technology adds an extra level of interactivity and immersion to these games, allowing children to actively participate and have a personalized gaming experience. By combining fun and physical movement, the Interactive Gaming Zone provides an inclusive and engaging environment for children with autism to enjoy recreational activities while developing essential motor skills.

3.5.4 Songs and Storytime

The Songs and Storytime section of the system offers a curated collection of songs and stories specifically designed to engage and benefit children with autism. The songs feature repetitive tunes, chosen for their ability to induce relaxation and create a soothing atmosphere for the child.



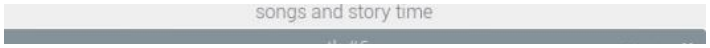


Figure 11:flow chart of songs and story time window

Figure 12:song main window

Within this section, the stories are carefully crafted to be both enjoyable and educational. One of the stories focuses on teaching children how to express their feelings effectively. It emphasizes the importance of understanding and communicating emotions in a healthy and constructive manner, promoting emotional intelligence and facilitating positive social interactions.

Another story aims to raise awareness among children about safe spaces in their bodies, specifically addressing the issue of harassment. It educates children about personal boundaries and the importance of consent, empowering them with knowledge and fostering a sense of self-protection and safety.

The Songs and Storytime section provides a valuable opportunity for children to engage with entertaining and meaningful content, promoting their emotional well-being and imparting important life lessons.

Chapter 4: Graphical User Interface (GUI)

4.1 Introduction

The graphical user interface (GUI) is an essential component of modern computer systems, providing users with a visually intuitive and interactive way to interact with software applications. GUIs have revolutionized the way humans interact with computers, enabling users to navigate through complex functionalities and perform tasks with ease. In this section, we will explore the significance of GUI in human-computer interaction, provide a brief history of its evolution, and discuss key principles that underpin effective GUI design.

4.2 Brief History of GUI

The development of GUI can be traced back to the 1960s when researchers began exploring novel ways to interact with computers beyond the traditional command-line interface. One notable milestone in the history of GUI is the pioneering work done at Xerox PARC (Palo Alto Research Center) in the 1970s. Xerox PARC introduced groundbreaking concepts such as the graphical desktop metaphor, windows, icons, and the use of a pointing device called a mouse.

The Xerox Alto, introduced in 1973, was one of the first computers to feature a GUI. Although the Alto was not a commercial success, it laid the foundation for future GUI-based systems. The concepts and technologies developed at Xerox PARC heavily influenced the subsequent development of GUIs, leading to innovations such as the Apple Macintosh in 1984 and Microsoft Windows in 1985.

Since then, GUIs have continued to evolve, becoming more sophisticated and visually appealing. Advances in hardware capabilities, such as increased processing power and graphical rendering capabilities, have enabled the creation of more immersive and feature-rich GUIs. Today, GUIs are pervasive in various domains, from desktop and mobile operating systems to web applications, gaming consoles, and embedded systems.

4.3 GUI and its Importance in Human-Computer Interaction:

The graphical user interface plays a crucial role in bridging the gap between users and computer systems. It enables users, regardless of their technical expertise, to interact with software applications using visual elements such as icons, menus, buttons, and windows. By presenting information in a visually appealing and structured manner, GUIs enhance usability, accessibility, and overall user experience.

GUIs have transformed the way we interact with computers, making complex tasks more accessible and intuitive. They have democratized technology, allowing users to leverage the power of software applications without extensive technical knowledge. Whether it is navigating through file directories, creating documents, editing images, or playing games, GUIs provide users with a familiar and user-friendly interface that facilitates their interaction with digital systems.

4.3.1 Key Principles of GUI Design

Effective GUI design is guided by several principles that aim to optimize usability and user satisfaction. These principles include:

- Consistency: GUI elements, such as icons, buttons, and menus, should be designed consistently throughout the system to provide users with a sense of familiarity and predictability. Consistent placement, behavior, and visual design help users navigate and interact with the interface more effectively.
- Simplicity: GUIs should strive for simplicity in design and functionality. Clutter-free interfaces with clear and concise visual elements reduce cognitive load and make it easier for users to understand and use the system. Avoiding unnecessary complexity promotes efficiency and enhances the overall user experience.
- Feedback and Responsiveness: GUIs should provide users with immediate feedback and responsive interactions. Visual cues, such as highlighting selected items or providing progress indicators, help users understand the system's state and their actions' impact. Responsive interfaces create a sense of control and engagement, improving user satisfaction.
- Visual Hierarchy: GUI design should establish a clear visual hierarchy to guide users' attention and prioritize important information. Effective use of typography, color, spacing,

and layout helps users quickly scan and comprehend the interface, facilitating efficient interaction.

- Flexibility and Customization: GUIs should allow users to personalize their experience and adapt the interface to their preferences. Customizable settings, such as font size, color themes, and layout options, empower users to tailor the system to their needs and enhance accessibility.

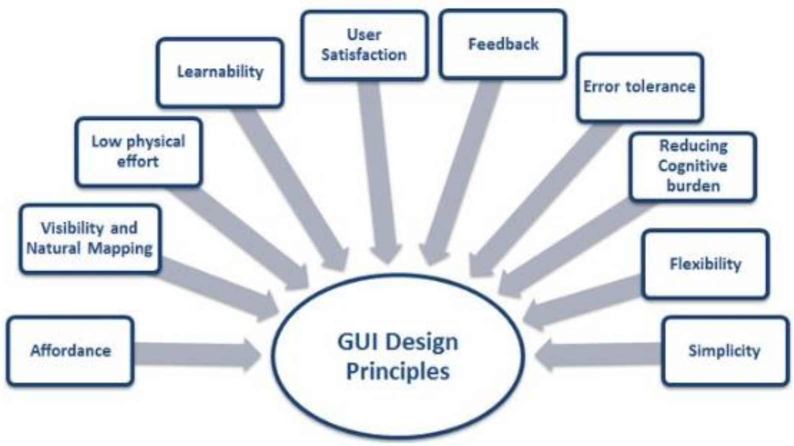


Figure 14 Graphical user interface Design principles

4.3.2 Considerations for Designing GUIs for Autism Children

Designing graphical user interfaces (GUIs) for children with autism requires careful consideration of their unique needs and challenges. Autism is a neurodevelopmental disorder characterized by difficulties in social interaction, communication, and sensory processing. When designing GUIs specifically for autism children, the following considerations should be considered:

- Visual Clarity and Simplicity: Prioritize clear and uncluttered designs with minimal distractions to avoid overwhelming visuals and sensory overload.
- Consistency and Predictability: Maintain a consistent layout and visual language throughout the GUI to promote predictability and familiarity.

- Visual Structure and Organization: Provide a clear visual structure and use cues such as headings and grouping to facilitate information processing and navigation.
- Visual Supports and Cues: Incorporate icons, symbols, and visual prompts to aid comprehension and independent navigation.
- Customization and Personalization: Allow for customization options to empower children with autism to tailor the interface to their specific needs and preferences.
- Sensory Considerations: Be mindful of sensory sensitivities and provide options to adjust sound, brightness, or animations to accommodate individual preferences.
- Clear Feedback and Response: Ensure that GUIs provide immediate and clear feedback for actions performed, reinforcing cause-effect relationships.
- Support for Multiple Modalities: Consider incorporating visual, auditory, and tactile elements to support different learning styles and provide alternative means of interaction.
- By considering these design aspects, GUIs can be made accessible, engaging, and tailored to the needs of children with autism.

4.4 Graphic User Interface Design and implementation

4.4.1 Introduction

Designing and implementing Graphical User Interfaces (GUIs) play a vital role in the development of systems, including those designed for autism children. GUIs serve as the primary means of interaction between users and the system, providing an intuitive and visually appealing interface that facilitates user engagement and enhances the overall user experience. In this chapter, we explore the design and implementation of GUIs for our system, specifically tailored to meet the unique needs of autism children. We will discuss the rationale behind our design choices, the technical aspects of GUI implementation using the Tkinter library in Python, and the integration of GUI with the underlying system functionality. Through this chapter, we aim to highlight the importance of GUIs in fostering effective communication and interaction with autism children, ultimately contributing to their learning, engagement, and well-being.

4.4.2 Graphic User Interface Design

The GUI design for our system considers the unique needs of autism children, aiming to create an intuitive and visually appealing interface. We carefully select colors, fonts, and layouts to provide a calm and simplified environment. Recognizable icons and symbols are used to aid understanding and navigation. The design focuses on accessibility, with clear labels, appropriately sized interactive elements, and visual feedback cues. Our GUI design aims to create a comfortable and engaging experience, promoting active participation and empowering autism children in their interactions with the system.

4.4.3 system Design

In the GUI design, special considerations were taken into account for designing a user-friendly and engaging interface specifically tailored for autism children. One key element is the inclusion of a welcoming video featuring Semsem, the robot character. The purpose of this video is to establish a connection and initiate interaction with the users. The video showcases Semsem introducing himself with the phrase "Hello, my name is Semsem."

To create the welcoming video, a multi-step process was followed. Initially, a suitable GIF representation of Semsem, including his appearance and animation, was downloaded. Next, a child-like voice-over was added to the GIF using the text-to-speech website Narakeet (https://www.narakeet.com/create/text-to-speech-child-voice-online.html). This allowed for the generation of a personalized greeting with an engaging and relatable voice. Finally, the voice-over and GIF were combined and converted into a single video using the online tool Clideo (https://clideo.com/video-maker).

Upon completion of the welcoming video, the system presents the start window, which serves as the entry point for users. The start window prominently displays the title "Semsem Helper," our custom-designed logo, and a clearly visible start button. The logo was carefully crafted using the online platform Free Logo Design (https://logo-maker.freelogodesign.org/), ensuring a unique and visually appealing representation of our system.

For the remaining elements of the GUI, a manual approach was adopted. Backgrounds, photos, and PNG files were downloaded, and their integration into the design was done manually using presentation software such as PowerPoint. This approach allowed for precise customization and arrangement of the graphical components, resulting in a visually cohesive and aesthetically pleasing interface.

By combining the use of online logo design tools and manual integration of graphics, we have successfully created a visually engaging and user-friendly GUI that captures the essence of the Semsem Helper system.

4.4.4 The GUI implementation using software python library

The graphical user interface (GUI) implementation for our system was achieved using the Python Tkinter library. Tkinter is a widely used library that provides a set of tools and functions for creating interactive GUIs in Python. By following a series of steps, we were able to generate the GUI for our system.

The first step involved importing the Tkinter library into our Python script, which allowed us to access the necessary classes and functions for GUI development. With Tkinter, we created the main window that served as the container for all the GUI components. This window provided the foundation for the overall layout and design of the interface.

Next, we carefully designed the layout of the GUI, considering factors such as the placement and alignment of widgets, the organization of information, and the overall visual hierarchy. Tkinter offers various geometry managers, including pack (), grid (), and place (), which helped us position and arrange the widgets within the main window according to our design specifications.

Once the layout was established, we proceeded to add the desired widgets to the GUI. Tkinter provides a wide range of pre-built widgets such as buttons, labels, text entry fields, and checkboxes. We instantiated these widgets and placed them within the main window, ensuring they were positioned according to the established layout.

To enhance the user experience and align with the system's objectives, we customized the appearance of the widgets. Tkinter allowed us to modify properties such as colors, fonts, sizes, and styles, enabling us to create a visually appealing and cohesive interface

Furthermore, we implemented the necessary functionality for each widget. This involved defining event handlers or callback functions that would be triggered when users interacted with the widgets. These functions were responsible for capturing user input, updating the system's state, and executing relevant actions based on the user's interactions.

Throughout the implementation process, we conducted thorough testing to ensure the GUI's functionality, usability, and responsiveness. Any issues or bugs discovered during testing were addressed promptly to ensure a smooth user experience.

The implementation of the GUI using Tkinter in Python provided us with a powerful toolset for creating a user-friendly and interactive interface for our system. By following these steps, we were able to design and generate a GUI that effectively presented the system's features and facilitated user interaction.

4.5 Graphical User Interface Overview and Key Windows

This section provides an overview of the GUI) implemented in the Semsem Helper system. The GUI plays a crucial role in facilitating interactions with autism children and enhancing their learning and engagement. This note outlines the key windows and components of the GUI, highlighting their significance in the overall user experience.

- *Welcoming Video Window*

The Welcoming Video Window serves as the initial interaction point, where the robot Semsem introduces himself with a personalized greeting. The video combines a visually appealing GIF with a child-like voice-over, creating an engaging and welcoming experience for the autism children.

Figure 15 welcoming video

- *Logo Window*

The Logo Window showcases the distinctive logo of the Semsem Helper system, designed to represent its identity and brand. The logo, created using the online platform Free Logo Design, captures the essence of the system and adds a visually appealing element to the GUI.

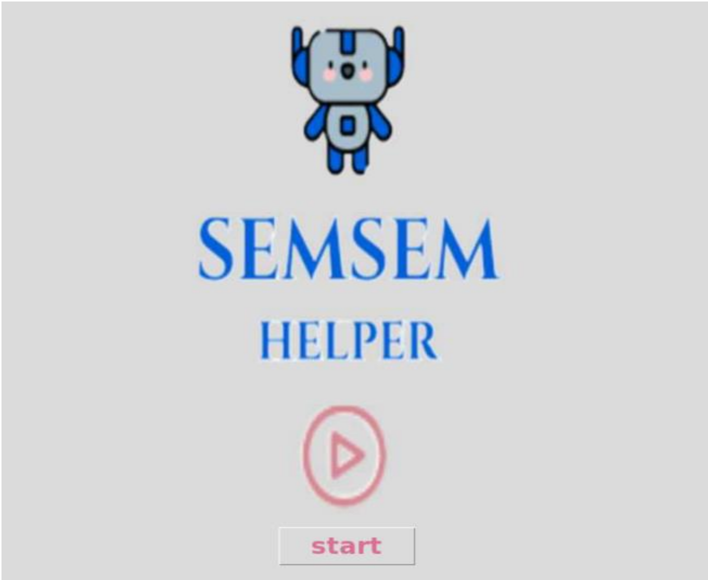


Figure 16:logo window

- *Modes of operation window*

This window features two distinct buttons: the Emotion Scanner and the Semsem Hub. The Emotion Scanner utilizes the camera to detect the child's mood in real-time. Depending on the detected mood, the system intelligently selects suitable activities and recommendations for the child. On the other hand, the Semsem Hub button acts as a direct pathway to the main menu, allowing effortless navigation to access the diverse range of features and functionalities offered by the system.

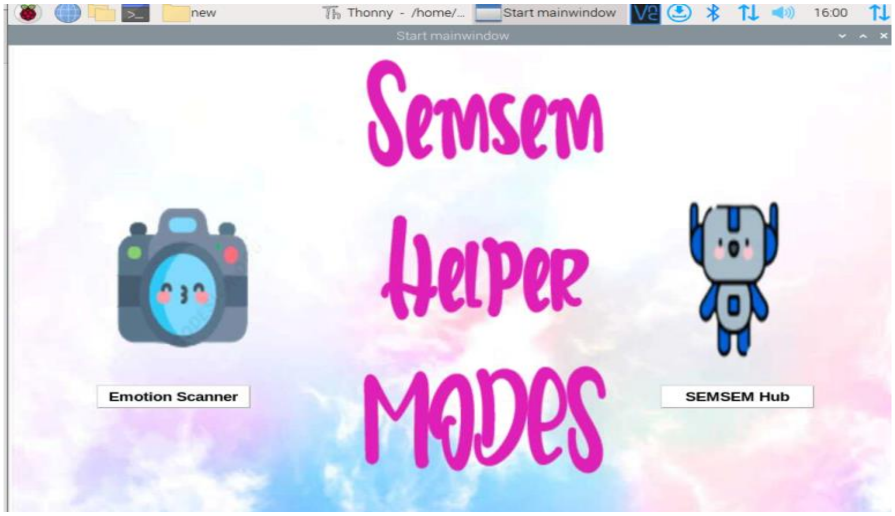


Figure 17:modes of operation window

- *Main Menu Window*

The Main Menu Window serves as the central hub of the GUI, presenting autism children with various options to choose from. It features prominently displayed buttons, including Learn, Play, and Songs and Storytime. These options provide access to different learning activities and interactive content.

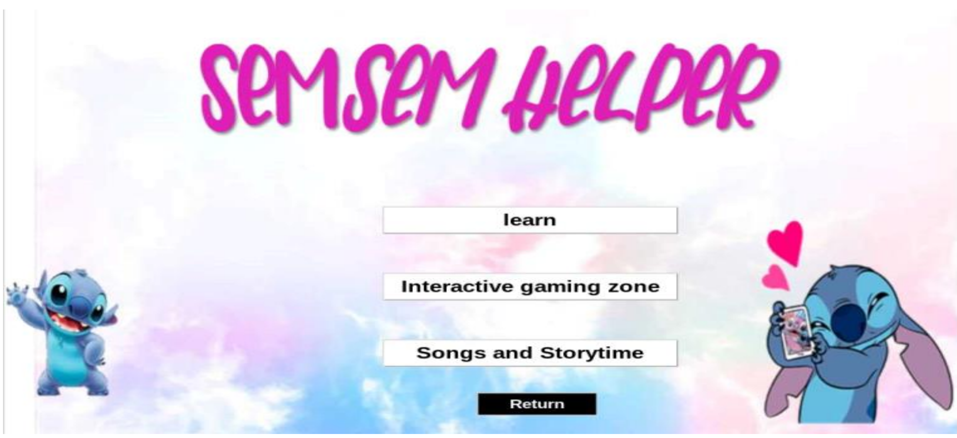


Figure 18:main menu window

- *Learn Button Sub-Window*

Within the Learn Button Sub-Window, autism children can further explore educational materials and resources. This sub-window includes two additional buttons; learning videos and educational games.

6.

Figure 19:learn sub-window

- *Interactive gaming zone Button Sub-Window*

Within the button sub-window, you'll find three games tailored to assist children with autism. By utilizing hand detection technology, these games encourage active participation and motor skill development through hand movements.

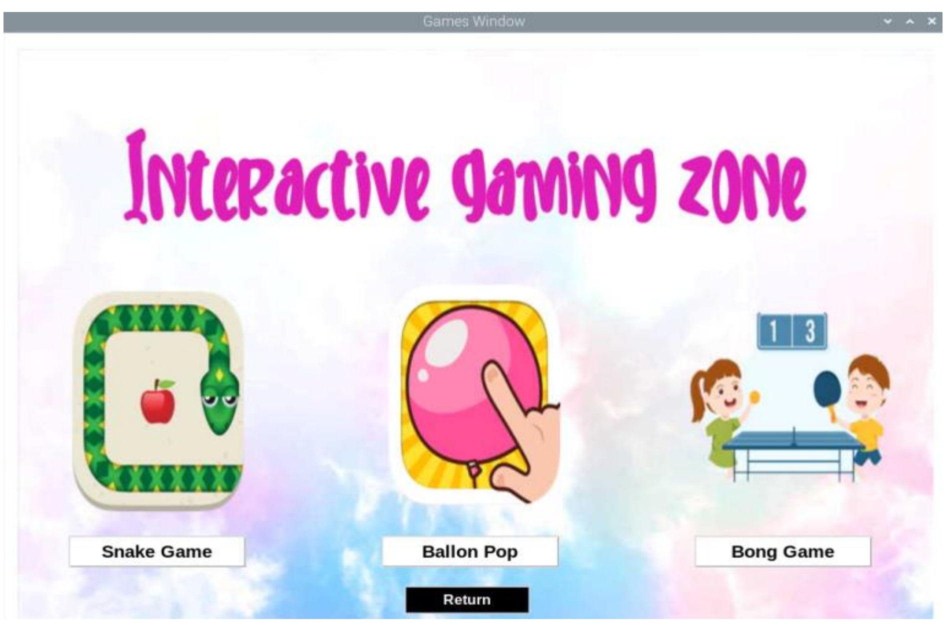


Figure 20:Interactive gaming zone Button Sub-

- *Songs and Storytime sub-window*

This button sub-window is dedicated to providing children with autism a range of engaging songs and stories. With a simple click, children can access a curated selection of captivating stories or enjoy their favorite songs, fostering an interactive and enjoyable experience.

Figure 21 the songs and story time

. In conclusion, The design and implementation of the graphical user interface (GUI) for our system has been carefully executed to create an engaging and user-friendly experience for children with autism. Through the use of the Tkinter library in Python, we have developed a visually appealing interface that caters to their unique needs. The GUI incorporates features such as a welcoming video, custom logo, and intuitive layout, providing a supportive environment for learning and play. With a focus on accessibility and inclusivity, the GUI enhances the overall usability of the system for children with autism.

Chapter 5: time plan

Semester	Task number	Task description
Semester one	1	Apply flow chart and block diagram of system
	2	Apply face emotion detection
	3	Collect games for children using computer vision • Apply videos for education • Music playlist for entertainment
	4	GUI application for the system
	5	Connect the face emotion with the GUI application as backend

Table 1. time plan of semester 1

Semester	Task number	Task description
Semester two	1	Implement the codes on of the raspberry Pi
	2	Motor choice and implementation
	3	Printing the 3D model of the robot

Table 2 the timeline of semester 2

Task number	**24/9/22**	**1/10/22**	**8/10/22**	**15/10/22**	**22/10/22**	**29/10/22**	**5/11/22**	**12/11/22**	**19/11/22**	**26/11/22**	**3/12/22**	**10/12/22**
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
1												
2												
3												
4												
5												

Table 3 the Gant chart of semester 1

Task number	4/2/23	11/2//23	18/2/23	25/2/23	4/3/23	11/3/23	18/3/23	25/3/23	1/4/23
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9
9									
10									
11									

Table 4 the Gant chart of semester 2

Chapter 6: Hardware System development process

The Raspberry Pi is a compact iteration of a contemporary computer that possesses efficient task execution capabilities. This device employs diverse types of processors, limiting its compatibility to open-source operating systems and applications exclusively. Additionally, the Pi empowers users to engage in activities like web browsing, email communication, document creation through word processing, and many other functionalities. Moreover, the Raspberry Pi supports an array of programming languages, including Python, C, C++, BASIC, Perl, and Ruby.

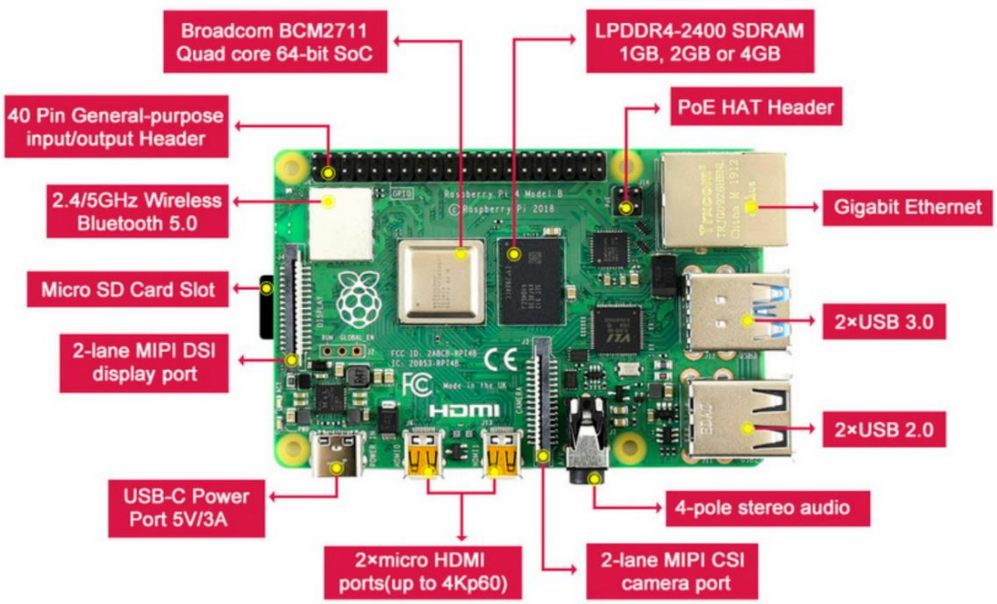


Figure 22: raspberry pi 4 model

The technical specifications of the latest Raspberry Pi 4 Model B can be an organized manner as follows:

- Processor: The Raspberry Pi 4 Model B features a Broadcom BCM2711 processor, which consists of a Quad-core Cortex-A72 (ARM v8) 64-bit System-on-Chip (SoC) running at a speed of 1.5GHz.
- RAM: It is equipped with 8GB of LPDDR4-3200 SDRAM, providing ample memory capacity for efficient data processing.

- Bluetooth: The Raspberry Pi 4 Model B supports Bluetooth 5.0 technology, including Bluetooth Low Energy (BLE) functionality, allowing seamless connectivity with compatible devices.
- Wi-Fi: It offers wireless connectivity on both the 2.4 GHz and 5.0 GHz IEEE 802.11ac frequency bands, enabling versatile network connections.
- USB: The board features two USB 3.0 ports for high-speed data transfer and an additional two USB 2.0 ports for connecting various peripherals.
- Ethernet: A Gigabit Ethernet port is included, ensuring fast and reliable wired network connectivity.
- HDMI: With two micro-HDMI ports, the Raspberry Pi 4 Model B supports video output of up to 4K resolution at 60 frames per second.
- Storage: The primary storage option is a microSD card slot, providing a convenient way to store the operating system and data.
- Power Supply: The recommended power supply for the Raspberry Pi 4 Model B is a 5.1V 3A USB Type-C power source, delivering stable and reliable power.
- Dimensions: The Raspberry Pi 4 Model B has compact dimensions measuring 85.6mm × 56.5mm, making it portable and suitable for various applications.

Initially, Raspberry Pi had its own Linux-based operating system called Raspbian. However, the software market now offers non-Linux-based operating system alternatives for the Raspberry Pi, providing users with a range of choices to suit their specific needs .

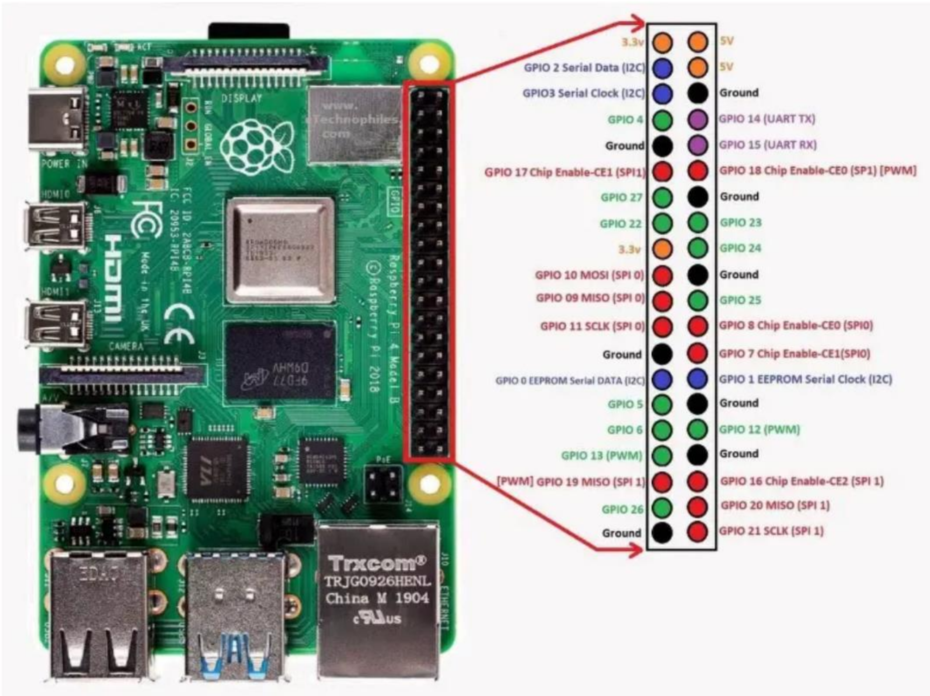


Figure 23 raspberry pi 4 GPIO pins

The GPIO (General Purpose Input/Output) pins of the Raspberry Pi 4 Model B serve as versatile interfaces for digital communication and interaction with external devices. With a total of 40 pins available, users can connect a variety of components and peripherals to expand the capabilities of the Raspberry Pi. These pins support digital communication protocols such as I2C, SPI, and UART, allowing for seamless integration with sensors, displays, motors, and other electronic devices. Some GPIO pins have specialized functions like PWM output and hardware interrupts, providing additional functionality. Accessible through programming languages like Python or C/C++, the GPIO pins offer flexibility in configuring, reading, and writing digital signals. This versatility enables users to create custom circuits, undertake interactive projects, and interface with the physical world, offering endless possibilities for makers and professionals in diverse fields.

- *Raspberry pi 4 camera V2*

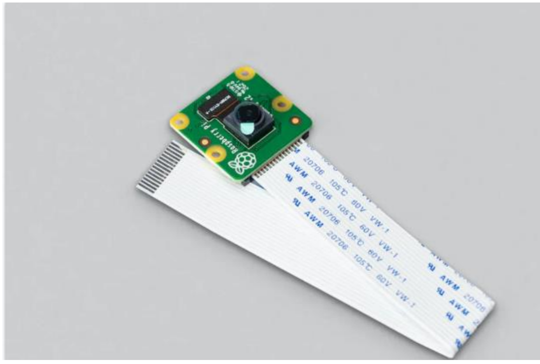


Figure 24 raspberry pi camera v2

The Raspberry Pi Camera V2 is a compact and versatile camera module designed specifically for the Raspberry Pi 4 Model B. It features an 8-megapixel Sony IMX219 sensor, ensuring high-quality image and video capture. With its small size, it can be easily attached to the Raspberry Pi board. The camera offers various resolutions and frame rates, providing flexibility for capturing different media types. It is commonly used in projects involving image and video processing, computer vision, and surveillance systems. Its integration with the Raspberry Pi ecosystem enhances its capabilities for visual data analysis and exploration.

- *The 7-inch Capacitive Touch Screen LCD HDMI*

Figure 25 the 7 inch of raspberry pi touch screen

It's a display module specifically designed for use with a Raspberry Pi. It features capacitive touch technology, ensuring precise and responsive touch input. With its 7-inch screen size, it provides a spacious viewing area for immersive visuals. The LCD supports high-resolution displays, delivering clear and vibrant images. It is widely utilized in various projects that require user interaction, including gaming, multimedia, and industrial applications. The touch screen module seamlessly integrates with the Raspberry Pi, making it an ideal choice for creating interactive and user-friendly interfaces.

- *The Stepper Motor NEMA 17HS4401S*

Figure 26 nema 17 stepper motor

The theory behind a stepper motor revolves around its ability to convert electrical pulses into precise mechanical motion. Stepper motors are synchronous motors, meaning they rotate in steps or increments, rather than continuously. They achieve this through a combination of electromagnets and a toothed rotor.

Stepper motors consist of a stator with multiple coils and a rotor with teeth. The stator coils are energized sequentially in a specific pattern, creating a magnetic field. By energizing the coils in a particular sequence, the magnetic field pulls the rotor teeth towards it, causing the rotor to move in discrete steps.

The sequence of energizing the coils determines the direction and speed of the motor. This sequence is controlled by a driver circuit that sends electrical pulses to the coils. The number of steps per revolution is determined by the motor's design and the number of teeth on the rotor.

Stepper motors are known for their precise positioning capabilities and the ability to hold a position without the need for external feedback. This makes them suitable for applications where accuracy and control *are crucial, such as robotics, 3D printers, CNC machines, and automated systems.*

Specification

- Number of Phase: 2
- Step Angle: 1.8°
- Phase Voltage: 2.6Vdc
- Phase Current: 1.7A
- Resistance/Phase: 1.5Ω ±10%
- Inductance: 2.8mH ±20% (1KHz)
- Number of Wire: 4 (100cm Length)
- Holding Torque: 43Ncm
- Shaft Diameter: Ø5mm
- Motor Length: 40mm
- Rotor Inertia: 54gcm^2
- Temperature rise: 80°C Max
- Insulation Class: B
- Dielectric Strength: 500VAC/1-minute
- Mass: 280g

- *Working Principles*

The stepper motor is a brushless DC motor renowned for its incremental rotation capability. An important advantage of this motor is its capacity for accurate positioning without relying on feedback sensors, operating as an open-loop controller. Its structure consists of a rotor, commonly a permanent magnet, encircled by stator windings. By systematically energizing the windings in a predetermined sequence and enabling current flow, the stator generates magnetic fields, resulting in the creation of electromagnetic poles that propel the motor. This fundamental working principle serves as the foundation for stepper motors.

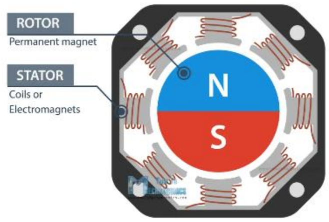


Figure 27 the motor primary element

By applying electrical current to the coils, specific magnetic fields are produced in the stator, resulting in either attraction or repulsion of the rotor. Through sequential activation of the coils in a specific sequence, we can achieve continuous motion of the rotor. Furthermore, we have the ability to halt the rotor at any desired position by appropriately controlling the coil activation.

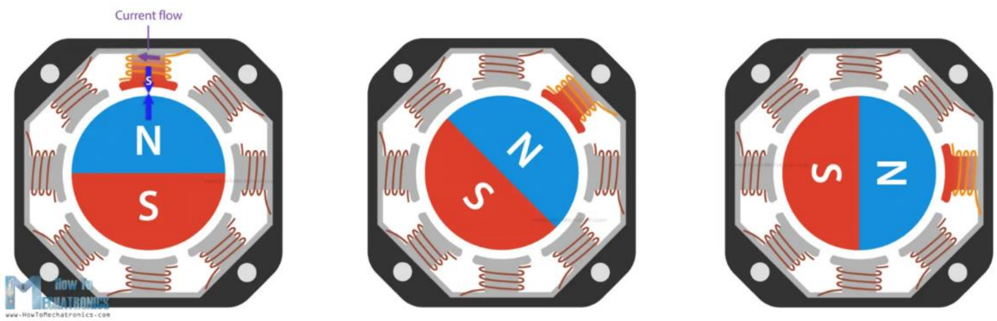


Figure 28 different views when the motor rotate

The step angle (β) refers to the rotation angle of the motor shaft in response to each command signal. By reducing the step angle, the number of steps per revolution increases, resulting in higher resolution and improved positioning accuracy.

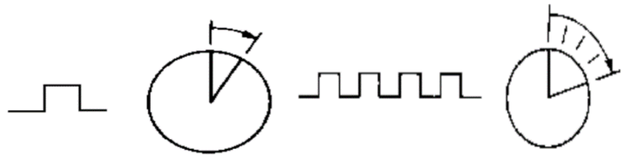


Figure 29 shows one step represent one count and two step represent tow count

A bipolar stepper motor typically consists of four wires, with each wire connecting to one coil inside the motor. The wiring diagram for a bipolar stepper motor typically follows one of two common configurations: the unipolar series or the unipolar parallel. A NEMA 17 bipolar stepper motor typically has four wires, which connect to the two coils inside the motor. These wires are used to control the motor's movement and rotation To operate a NEMA 17 bipolar stepper motor, a motor driver is required. The motor driver receives input signals, typically from a microcontroller which are the Raspberry Pi, and generates the necessary current and voltage levels to control the motor's movement. By energizing the coils in a specific sequence, the motor driver can achieve precise control over the motor's rotation and position.

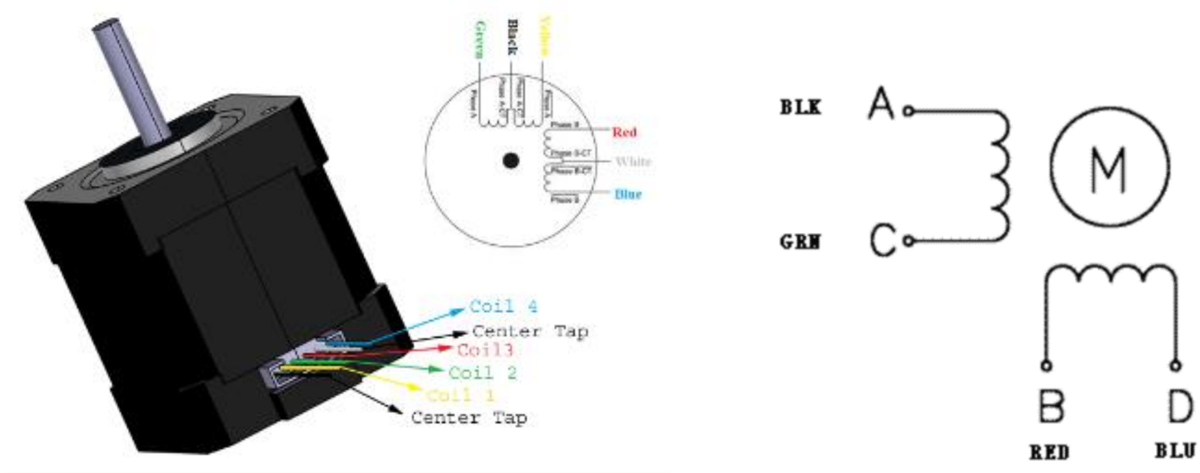


Figure 30 stepper motor coils

Driving Modes

There are two main driving modes for stepper motors: Wave Drive or Single-Coil Excitation and Half Step Drive.

- The wave drive or single-coil excitation mode involves activating one coil at a time, allowing the rotor to complete a full cycle in 4 steps. The sequence follows a specific pattern from step one to step four, and then repeats. This rotation causes the motor to move in a clockwise direction. Reversing the sequence from step four to step one will result in counterclockwise rotation of the motor.

Step	$\phi1$	$\phi2$	$\phi3$	$\phi4$
1	ON	OFF	OFF	OFF
2	OFF	ON	OFF	OFF
3	OFF	OFF	ON	OFF
4	OFF	OFF	OFF	ON

Step	$\phi1$	$\phi2$	$\phi3$	$\phi4$
1	OFF	OFF	OFF	ON
2	OFF	OFF	ON	OFF
3	OFF	ON	OFF	OFF
4	ON	OFF	OFF	OFF

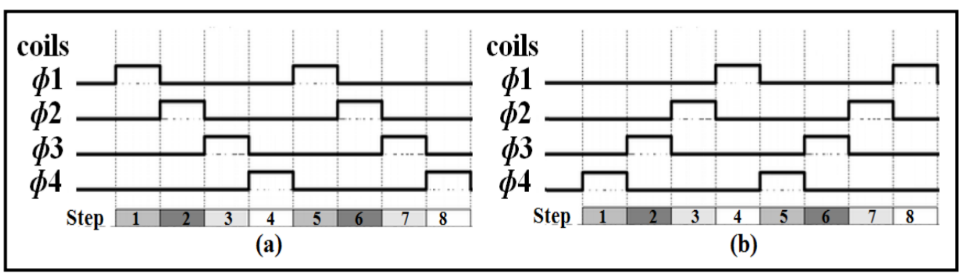


Figure 31 the Sequence of wave stepping excitation method: (a) Clockwise, (b) Anticlockwise

This excitation method generates smooth rotations and consumes the least amount of power compared to the other methods. However, it provides lower torque compared to other stepping methods and is less stable at higher speeds

- Half Step Drive: The Half Step Drive mode is a combination of the previous two modes and is used to enhance the resolution of the motor. It follows a pattern of activating one coil, then two active coils, and repeating this sequence. This mode effectively doubles the resolution without requiring any modifications to the motor. It offers the benefits of higher torque, increased stability at higher speeds, and improved resolution, making it a popular choice over other stepping methods.

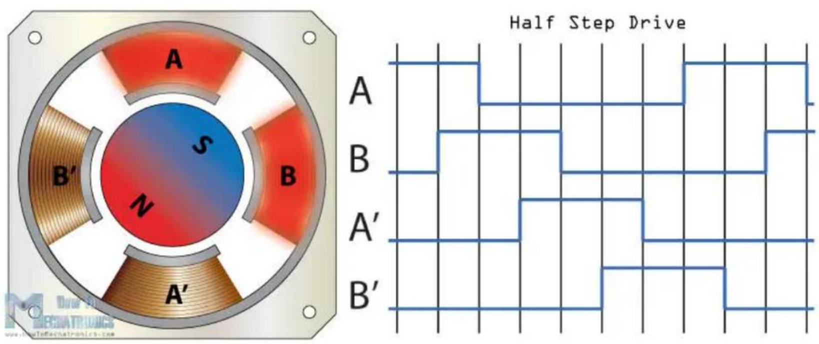


Figure 30: the half step drive

Micro stepping is currently the prevailing method for controlling stepper motors. It involves supplying the coils with a variable and controlled current in the form of a sinusoidal wave. This technique enables smooth and precise motion of the rotor, reducing stress on the motor

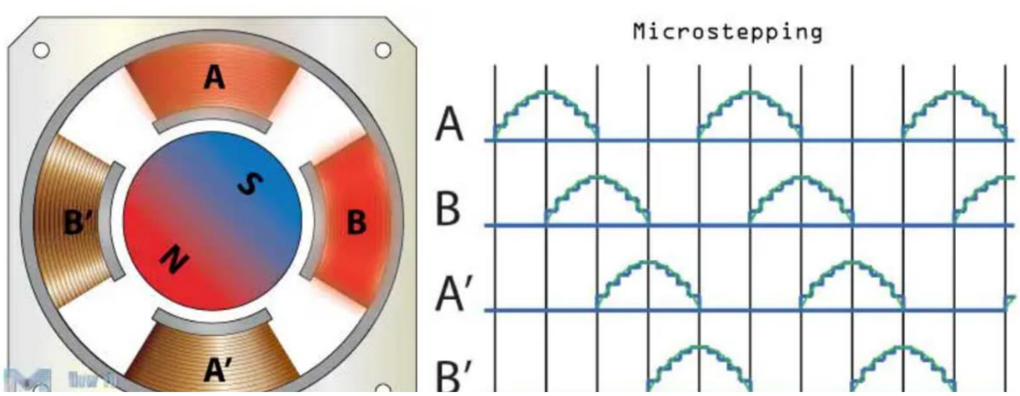


Figure 33 micro stepping approach

components. By utilizing micro stepping, the accuracy of the stepper motor is significantly increased.

Stepper motors are cost-effective, easy to integrate, and widely used due to their standardized designs and compatibility with microcontrollers and driver circuits. They offer a reliable and versatile solution for precise motion control in various industries.

- *A4988 DRIVER*

This driver is highly versatile and can function within a voltage range of up to 35 V while supporting a current of approximately ± 2A. It incorporates the allegro A4988 chip, which acts as a translator, eliminating the need for step signals. Instead, users only need to provide the desired step size and direction. As shown in figure 27 , display the A4988 stepper motor driver module and its corresponding pinout diagram. The driver allows for stepper motor rotation from a full step down to as small as one-sixteenth of a step. It includes a reset (RST)and a sleep (SLP) pin that need to be connected to initiate motor operation. When operating the motor in full-step mode, there is no requirement to connect any pins to (micro-step),To achieve fractional step rotation, the pins M1,M2, and M3 can be used according to the specifications outlined in TABLE 3

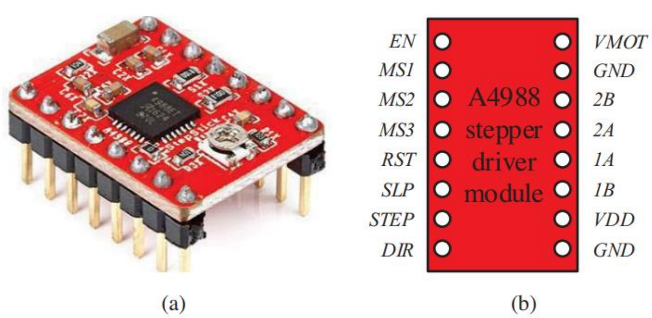


Figure 34 A4988 DRIVER BOARD and pins

Resolution	MS1	MS2	MS3
Full Step	0	0	0
Half Step	1	0	0
Quarter step	0	1	0
Eight step	1	1	0
Sixteenth step	1	1	1

Table 1 the input pins sequence for rotation

- *Power supply*

A power supply is a vital component within an electrical system, responsible for delivering electrical energy to power an electrical load. Its primary function is to convert one form of electrical energy into another, earning it the common designation of an electric power converter. Power supplies can exist as standalone devices or be integrated into larger systems alongside the loads they serve.

Comprising a power input and a power output, these devices receive energy from an energy source and distribute it to the connected load. By facilitating the transformation and distribution of electrical energy, power supplies play a critical role in enabling the operation of various electronic devices and systems.

In the implemented design, two power supplies will be utilized. One power supply is dedicated to supplying the motors, providing a voltage of 12V and a current rating of 3A. The other power supply is specifically for the controller and will deliver a voltage of 5V with a current rating of 2A. This configuration ensures that the motors receive the necessary power while the controller operates at its required voltage and current levels.

- *WYD66/3W speaker*

Figure 35 the 8ohms /3W speaker used

The WYD66/2 speaker is a speaker with a power rating of 3W and an impedance of 8 ohms. It is commonly utilized in audio systems and is well-suited for applications such as portable speakers, multimedia devices, and small audio projects. Its design aims to provide clear sound output, and its compatibility with audio amplifiers and output devices makes it easy to integrate into various setups. The speaker's power rating ensures sufficient volume levels, offering versatility for different audio requirements.

- *Mini Digital Amplifier Board Module (PAM8403)*

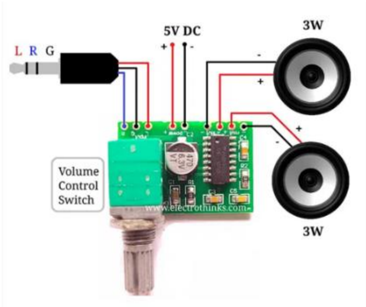


Figure 36 circuit amplifier

The Mini Digital Amplifier Board Module (PAM8403) with Switch Potentiometer is a small-sized audio amplification solution that offers convenience and versatility. It utilizes the reliable PAM8403 chip and incorporates a switch potentiometer for easy volume adjustment. Despite its compact design, this module provides excellent audio quality and is suitable for a wide range of applications. It is favored by audio enthusiasts and hobbyists for its dependable performance and space-saving features.

Chapter 7: Main Circuit Development and Programming Technique

7.1 system Structure

To create a humanoid robot that can seamlessly interact with children, the initial step involves carefully determining the robot's dimensions and configuring its workspace according to the specific requirements of the target users. By accurately defining the size and range of motion, the robot can be custom designed to effectively engage with children.

Once the dimensions and workspace configuration have been established, the subsequent critical stage entails determining the specifications for each actuator movement. These movements are simplified to ensure effortless interaction and control. For instance, the robot may be designed to have movable head and arms, allowing it to perform precise tasks like handling lightweight materials with exceptional accuracy.

By concentrating on these fundamental design aspects, the goal is to develop a humanoid robot that not only closely imitates human behaviors but also possesses the necessary agility and capabilities to effectively assist children with autism. Serving as a companion and helper, this robot will offer a range of interactive and educational experiences tailored to the unique needs and abilities of each individual child.

7.2 Block Diagram

The implementation of the humanoid robot involves a range of hardware components, such as NEMA 17 stepper motors, A4988 drivers, an extension board for additional A4988 drivers, Raspberry Pi 4, Camera V2 module, touch screen, power supplies, speaker, and circuit amplifier. These components enable motor control, sensory input, processing capabilities, user interaction, and audio output. Together, the hardware and software components form a comprehensive platform for the humanoid robot, providing capabilities for motion, perception, control, user interaction, and multimedia functionality.

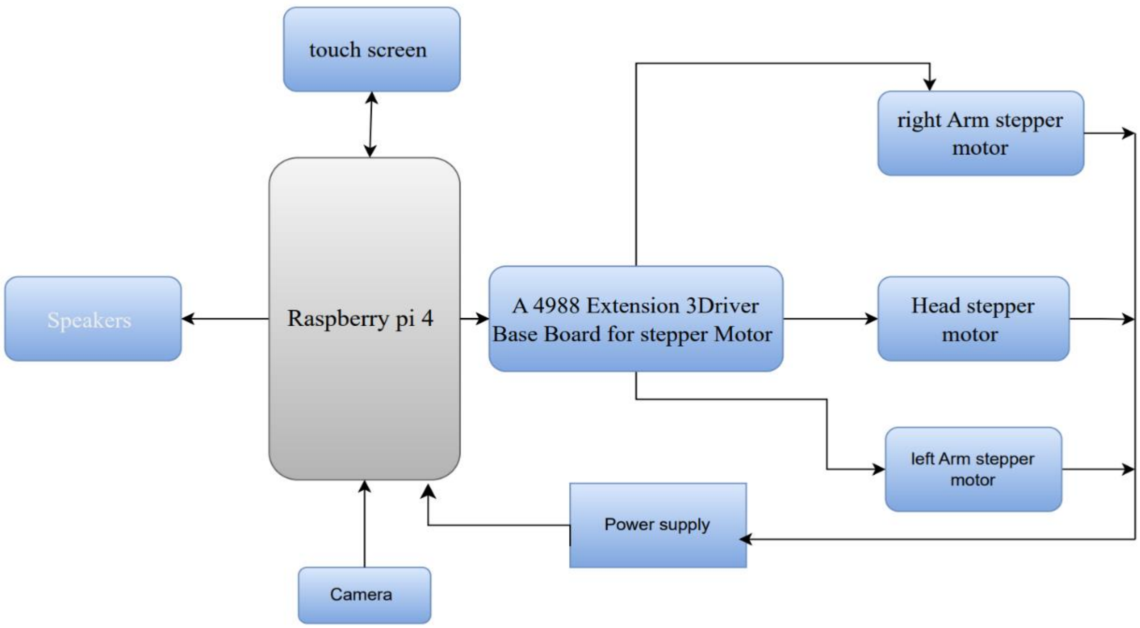


Figure 37: block diagram of the proposed system

7.3 control unit

The control unit of the robot operates by executing a program stored in the microcontroller's memory. This program is responsible for controlling each motor's steps and direction to achieve the desired movement of the robot's head and arms. By programming the microcontroller, the robot can perform precise movements and navigate its environment effectively.

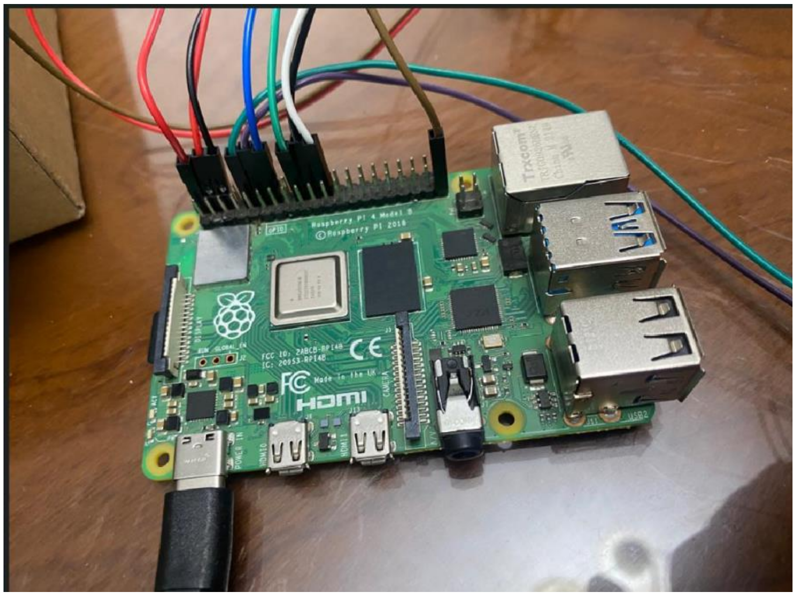


Figure 38: the control unit of the system

These connections enable the control and operation of the motor using the Raspberry Pi as the controller. The control system involves the head of the system that control the connections. Were the three motors, and the 3 drivers act between the controller and the motor , and the speaker which serves as the central operating unit. To establish a reliable connection, an Extensions board capable of supporting three A4988 drivers is utilized. The VDD and GND pins on the driver board power the internal logic circuitry, with a voltage range of 3V to 5.5V. These pins are connected to a power supply through a jack, where the black wire is connected to ground, and the red wine is connected to 5V. This power supply, in turn, connects to the controller pins (VCC and ground) on the driver board. A power supply with a range of 12V and 3A is connected to the VMOT pin, which accepts a voltage range from 8V to 35V, serving as the power source for the motor.

Each driver is equipped with step and direction inputs, which will be connected to the Raspberry Pi. The enable pin on the Extensions board, responsible for activating the driver, is connected to ground since the driver operates on an active-low configuration, ensuring its proper functionality.

To specify the connection between the drivers and the Raspberry Pi, the step and direction pins for each motor are detailed in the following table:

Motor	Step Pin	Direction Pin
Head	15	14
Left Arm	2	23
Right Arm	25	24

By establishing these connections, the Raspberry Pi will be able to control the movement of each driver individually. The step pins determine the stepping intervals for the motors, enabling precise control over their rotation. The direction pins determine the rotational direction of the motors, allowing them to move clockwise or counterclockwise as needed. Additionally, an 8-ohm/3W speaker is connected to an amplifier circuit to enhance the audio output. The amplifier circuit's ground and VCC pins are connected to the ground and VCC on the Raspberry Pi controller, respectively. This allows the Raspberry Pi to drive the speaker effectively and produce amplified sound.

On the other hand, the driver connected to the Raspberry Pi facilitates the communication between the Raspberry Pi and other external devices or components. It provides the necessary electrical isolation and protection for the Raspberry Pi's sensitive circuits while enabling the exchange of signals and data with other peripherals. This driver ensures that the signals from the Raspberry Pi are compatible with the motor, allowing for seamless integration and communication between the Raspberry Pi and the external components.

the connection of drivers to the motor and the Raspberry Pi establishes a reliable and efficient link for motor control and device communication. It enables the Raspberry Pi to command the motor's behavior and interact with other components

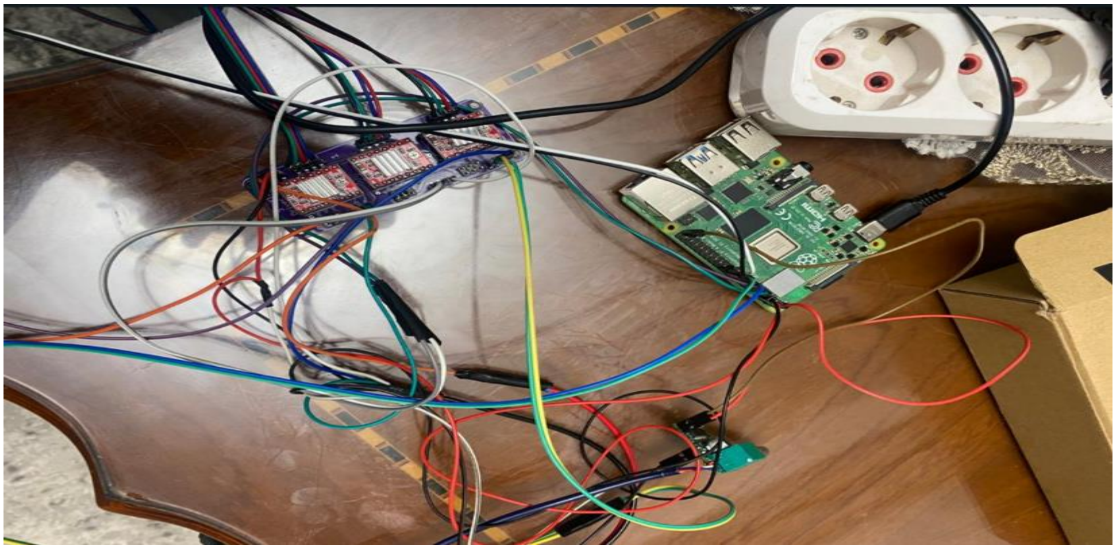


Figure 39 : the connection of the driver and the speaker to the control unit of the system

7.4 Circuit design

The system comprises a Raspberry Pi 4 microcontroller serving as the central processing unit, along with three Nema 17 stepper motors and an A4988 motor driver. The circuit is specifically designed for a robot application, with dedicated motors assigned to control the movements of the head and both hands.

The first motor governs the precise positioning and orientation of the robot's head. It enables the robot to adjust its viewpoint and focus on specific objects or directions as required. This controlled movement of the head enhances the robot's situational awareness and interaction capabilities.

The second and third motors are allocated to the robot's right hand and left hand, respectively. These motors provide the necessary actuation and control for the robotic hands to perform intricate tasks. The precise movements of the hands enable the robot to manipulate objects, grasp items with varying degrees of force, and execute delicate operations with accuracy.

To facilitate motor control, the A4988 motor driver acts as an intermediary between the Raspberry Pi and the Nema 17 stepper motors. It translates digital commands from the microcontroller into precise electrical signals, enabling the motors to move with the desired precision and accuracy. The A4988 motor driver's reputation for smooth and reliable control of stepper motors makes it an optimal choice for the robot's motor control system.

The Tiny A4988 Extension 3 Drivers Base Board plays a crucial role in the circuit design, providing a compact and efficient platform for motor connection and management. It offers the necessary pinouts and interfaces to seamlessly integrate the Raspberry Pi and the three Nema 17 motors. By utilizing this extension board, the circuit design ensures a simplified and error-free wiring process.

the circuit design incorporates a Raspberry Pi 4 microcontroller, Nema 17 stepper motors, and an A4988 motor driver. The motors dedicated to the head and arms enable the robot to perform precise movements and manipulations, enhancing its interaction capabilities. The inclusion of the Tiny A4988 Extension 3 Drivers Base Board streamlines the motor connections, contributing to an efficient and reliable design.

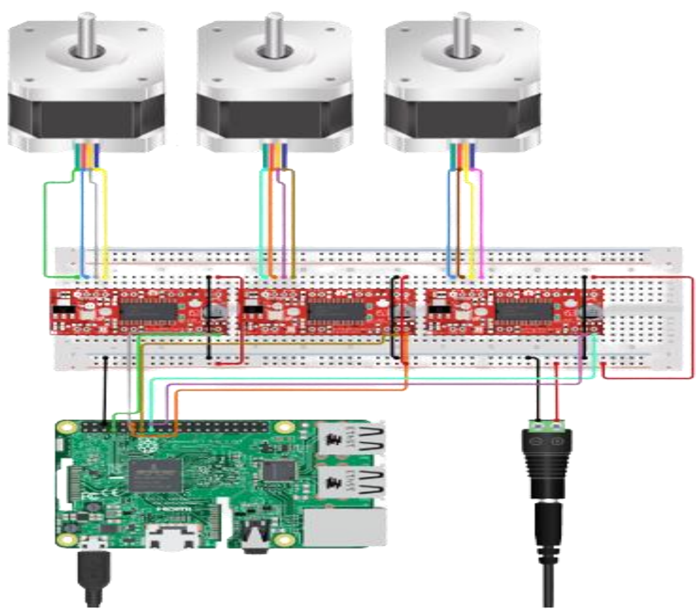


Figure 40: circuit diagram connections

7.5 Motor Control Algorithm

Micro stepping is a technique used to achieve finer resolution and smoother movement in stepper motors. It involves dividing each full step into smaller micro steps, allowing for more precise control over the motor's position. The Tiny A4988 Extension 3 Drivers Base Board, which is utilized for the Nema 17 stepper motors in this system, supports micro stepping modes through the M1, M2, and M3 pins.

The M1, M2, and M3 pins on the Tiny A4988 Extension 3 Drivers Base Board provide control over the microstepping mode for the connected stepper motors. These pins are typically connected to the corresponding pins on the A4988 motor driver, allowing the selection of different micro stepping resolutions.

The microstepping modes available on the A4988 motor driver, controlled by the M1, M2, and M3 pins, offer various levels of microstepping resolution. The most common modes include:

- Full Step (1x): In this mode, no microstepping is used, and the motor moves in full steps. The M1, M2, and M3 are low to achieve full-step mode which will be 200 step per revolution
- Half-Step (2x): In half-step mode, the motor moves in half-step increments, effectively doubling the resolution compared to full-step mode. This mode can be set by connecting M1 is high and M2 and M3 is pin low. The full cycle will be 400 step/revolution
- Quarter-Step (4x): Quarter-step mode divides each full step into four microsteps, providing four times the resolution compared to full-step mode. To enable this mode, the M1, M2 pin is high and M3 is low. The full cycle will be 800 step per revolution
- the A4988 motor driver may offer additional microstepping modes such as eighth-step (8x) or sixteenth-step (16x).

By appropriately configuring the M1, M2, and M3 pins on the Tiny A4988 Extension 3 Drivers Base Board, the motor control algorithm can select the desired microstepping mode for the Nema 17 stepper motors. This allows for smoother and more precise movement, minimizing the step size and providing greater control over the motor's position.

Utilizing microstepping can significantly enhance the overall performance of the system, especially when the robot requires accurate positioning or smooth motion for tasks such as delicate object manipulation or precise tool control.

7.6 Head and Arm Movement Control

In this section, we will explore the control and code implementation for the movement of the robot's head and arms using GPIO (General Purpose Input/Output). We will discuss how the head and arms are controlled, the logic behind their movement, and the code snippets involved in their operation.

7.6.1 Control Mechanism

The control mechanism implemented in the code utilizes the Raspberry Pi's GPIO pins to control the head movement. GPIO pin 15 is responsible for the step input, while GPIO pin 14 controls the direction input. The code pulses the step pin to incrementally rotate the head, introducing small delays for smooth motion. The use of microstepping technology enhances precision and reduces vibrations. This control mechanism enables accurate head positioning and is valuable for applications such as robotics and human-machine interaction.

In the provided code segments, the control mechanism for the robot's left and right arms relies on utilizing the GPIO pins of the Raspberry Pi to establish communication with their respective stepper motors. By manipulating these GPIO pins, precise control over the movement of the arms can be achieved.

The GPIO pins allocated for controlling the left arm are as follows:

- Step Pin: GPIO pin 2
- Direction Pin: GPIO pin 23

Similarly, the GPIO pins assigned for controlling the right arm are:

- Step Pin: GPIO pin 25
- Direction Pin: GPIO pin 24

By configuring the GPIO pins as outputs and apply the steps using the half mode and the direction (clockwise and antilock wise), the code enables the Raspberry Pi to send control signals to the stepper motors of the left and right arms.

7.6.2 Procedure of the whole system

The proposed system incorporates a camera-based emotion detection system to analyze the child's emotions. The system will utilize a dataset consisting of seven emotions, allowing it to accurately identify and classify emotional states. (CNNs) and Haar cascades are commonly employed in the system for the part of the emotion detection. Convolutional Neural Networks (CNNs) are deep learning algorithms renowned for their capability to learn hierarchical representations of visual data by utilizing interconnected layers. Through the integration of convolutional, pooling, and fully connected layers, CNNs autonomously extract relevant features from images. This system will be used for the This dataset will serve as a reference for the system to analyze facial expressions data obtained through the camera.

Haar cascades employ a machine learning-based strategy by employing pre-defined Haar-like features and a cascade structure to swiftly detect objects. Haar cascades are particularly adept at achieving real-time performance and computational efficiency, while CNNs demand larger datasets and greater computational resources. This fusion of CNNs and Haar cascades optimizes to get the best accurate outcome when the camera open in the real time to get the accurate estimation of the child's emotion. This dataset will serve as a reference for the system to analyze facial expressions data obtained through the camera.

The camera will capture real-time input from the child 's face, which will be processed by the emotion detection algorithm done by the GUI. The algorithm will analyze the captured data and determine the user's emotional state based on the dataset.

the system combines a camera-based emotion detection system, a dataset for seven emotions, and seamless integration with the GUI to enable real-time emotion recognition and control over the motor movements within the graphical user interface.

The proposed GUI system will be developed using the tkinter library, which is a popular Python library for creating graphical user interfaces. tkinter provides a rich set of functionalities and widgets that allow for the creation of interactive and visually appealing GUI applications.

The system main window contains these buttons which are Learn and Play, interactive games, songs and stories with will specifically windows upon pressing on this button the GUI cooperate the interactive games developed with hand tracking and OpenCV.

Hand tracking techniques will enable users to control and interact with the games using their hand movements captured by the camera. By incorporating this interactive gaming feature into the system, users will have an engaging and entertaining experience while simultaneously utilizing the emotion detection capabilities.

By combining these components and techniques, the proposed system will provide a GUI with emotion detection capabilities, synchronized movement of the motors, and enhanced stability and precision through microstepping. The user will be able to control the system's behavior and observe the corresponding motor movements in the welcoming window and the music window.

The system will utilize three motors, and their movements will be synchronized with the GUI. The motors use in the proposed system are nema 17 stepper motors. The chosen of this motor due their ability to their precise control and ability to move in discrete steps.

The movement of the three motors will use the a4988 driver to be connected between the controller and for each motor. stepper motor typically has a step resolution of 200 steps per revolution. This means that for each complete revolution of the motor shaft, it is divided into 200 discrete steps. To make the smoother in their movement will use the technique exist in the a4988 driver called microstepping a technique used to achieve finer control and reduce motor noise. By applying microstepping through appropriate driver configurations (such as setting M1, M2, and M3 to high, low, low), the system will be able to achieve 400 steps per revolution instead of the standard 200 steps per revolution for a NEMA 17 stepper motor. The part of the software that control system applied as MOTOR_CONTROL and the Main system code that applied all configuration of the pins and the configuration needed to complete the system as described before.

The proposed humanoid robot will be constructed using 3D printing technology, allowing for precise and customizable fabrication. The robot's specifications include a weight of 3kg, a height of 64cm, and a width of 45cm. These dimensions are carefully determined to achieve a balance between functionality, stability, and human-like proportions.

The Motors placement will be in the left and the right arm of the robot and the third motor will place in the head of the robot. The left and right motors will be controlled by specifying the direction (clockwise or anticlockwise) and the step size. The step size determines the angular displacement of the motors, and it will be 400 step per revolution instead of the normal step of the stepper motor nema 17 that specification is 1.8 degree /200 step per revolution which act as one cycle. the 400 step means that the arm will move one cycle, so the movement of hand will be set to 1/4 * 400 = 100 steps and another major to determine the movement is the time delay where it will be equal to 0.01 (in seconds) will be implemented to control the speed of the motor movement. This delay determines the interval between each step, allowing for smooth and controlled motion of the motors.

system will include an 8-ohm/3W circuit amplifier with a controller to enhance the audio features of the GUI application. This amplifier circuit will provide improved sound quality and power output, while the controller allows for fine-tuning of audio settings. The integration of these components will ensure a high-quality audio experience within the GUI application.

The whole system will in cooperate the system the three motors to be connected and apply the movement with the software system, these motors will be synchronized with the graphical user interface (GUI) application for ensuring coordinated movements in response to child.to implement this full system to work with each other the system done by using function called threading implemented in desired window that need to move the hands and the head.

Threading is a technique used in programming to enable concurrent execution of multiple tasks within a program. It allows different parts of the program to run simultaneously, improving performance and responsiveness. In a GUI application, threading is particularly useful for handling tasks that require continuous or background processing without blocking the user interface. By using threading with the motor control, while keeping the GUI responsive. This ensures a smooth user experience and efficient multitasking.

An example in Python that demonstrates the usage of threading in a GUI application:

```
import threading

import time

# Create a new thread for the background task

background thread = threading. Thread(target=move_right_left)

Start the background thread

background thread. start ()
```

To ensure the sensitivity and comfort of the child, the system takes into consideration the specific movements that are applied. The movement of the head will be limited to the welcoming window and the music window, which are the designated areas where the child can interact with the system. This focused movement of the head creates a more engaging and personalized experience for the child.

In other windows of the GUI, the system will prioritize the movement of the hands to facilitate communication and interaction with the child. By emphasizing hand movements, the system enhances the child's ability to engage with the graphical elements and control various features of the GUI. By carefully managing and coordinating the movements of the head and hands, the system aims to provide a child-friendly interface that optimizes communication and interaction while respecting the child's sensitivity and comfort.

7.7 Prototype

The prototyping phase was a critical aspect of developing the robot system, allowing for the translation of design concepts into tangible and functional components. The process began with careful planning and considerations, determining the dimensions and integration of essential parts. Design software are implemented that take a part of the design is SolidWorks aided in accurately modeling the mechanical structure, ensuring compatibility and optimal

performance. Through 3D printing technology, high-quality prototypes were rapidly produced, enabling efficient iterations and improvements.
The design needed to implemented according to the hardware components are used in the system for taking the precise dimensions of the robot needed to be designed. the robot dimension is taking to be 3kg, 64 cm Hight and 45 in width.

The calculation applied to see if the 17 nema stepper motor compatible with moving the head and the arms of the robot, firstly we need to know that the torque of motor = 3.2kg-cm. the arms' weight determine of the design each of them equal to 800 gm. and the head the head weight after calculating the weight of the speaker the camera and the touchscreen will be equal to 1.2 kg ,then this 3 parts are the important to take in consideration because this part related to the motors the rest will be air inside the 3d printing .
Firstly, to determine if a NEMA 17 stepper motor can handle a weight of 800 grams (0.8 kg) for each hand, need to consider the motor's torque specifications.

the torque specification provided for stepper motors is in terms of holding torque, which is the maximum torque the motor can generate to hold a stationary load without movement. To calculate whether the motor can handle a specific weight, you can use the following formula:

Torque = Weight x Distance

The distance of 1 cm (0.01 meters) from the motor shaft to the center of gravity of the 800-gram weight, we can calculate the required torque:

Torque = 0.8 kg x 0.01 m = 0.008 Nm (Newton-meters)

The holding torque of the NEMA 17 stepper motor is specified as 3.2 kg-cm. To convert it to Newton-meters (Nm), we need to multiply it by a conversion factor.

- 1 kg-cm is equal to 0.09807 Nm.
- The holding torque of the motor in Newton-meters is:
- 3.2 kg-cm x 0.09807 Nm/kg-cm = 0.3138 Nm

Comparing the calculated torque requirement of 0.008 Nm with the holding torque of the motor (0.3138 Nm), then that the NEMA 17 stepper motor is more than capable of handling the 800-gram weight for both of the hands.

To calculate the torque required to hold a head weight:

Torque (Nm) = Weight (kg) x Distance (m) x Acceleration due to gravity (m/s^2)

- Weight_head= 1.2 kg
- Distance = 0.1 meters
- Acceleration due to gravity = 9.8 m/s^2
- Torque = 1.2 kg x 0.1 m x 9.8 m/s^2
- Torque = 1.176 Nm

So, for a weight of 1.2 kg and a distance of 0.1 meters, the required torque is approximately 1.176 Nm. Comparing this torque requirement with the holding torque of the NEMA 17 stepper motor (0.3138 Nm), we can conclude that the motor is indeed capable of handling the weight of 1.2 kg.

The figures presented depict the implementation of the robot using SolidWorks software, which enables the design process for 3D printing. The utilization of this software facilitates the creation of precise and detailed designs that can be translated into physical objects using 3D printing technology. By employing SolidWorks, the design of the robot can be accurately modeled and optimized for manufacturing after making sure of all the dimension of the hardware and motors that will be added to the robot , ensuring compatibility and functionality in the final printed product This approach combines the advantages of digital design and additive manufacturing, allowing for the creation of intricate and customized components that contribute to the overall functionality and aesthetics of the robot.

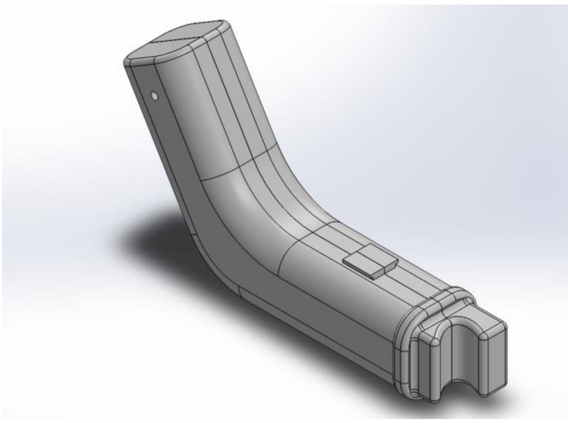


Figure 41 the right hand of robot

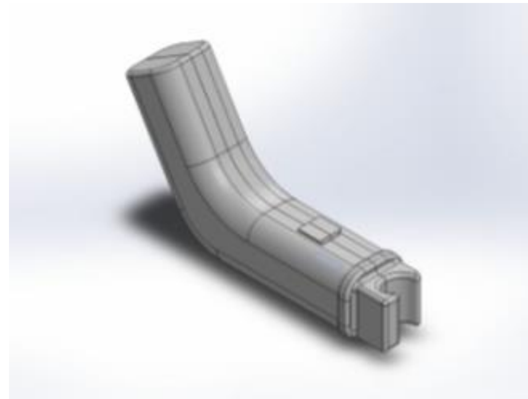


Figure 42 the right of the robot

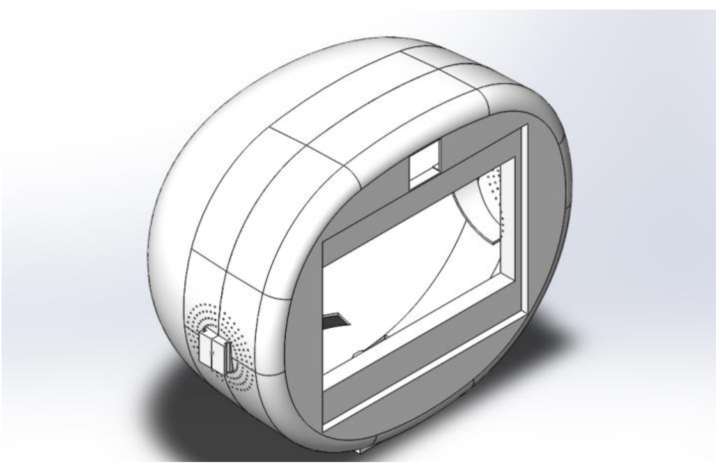


Figure 43 the head of the robot

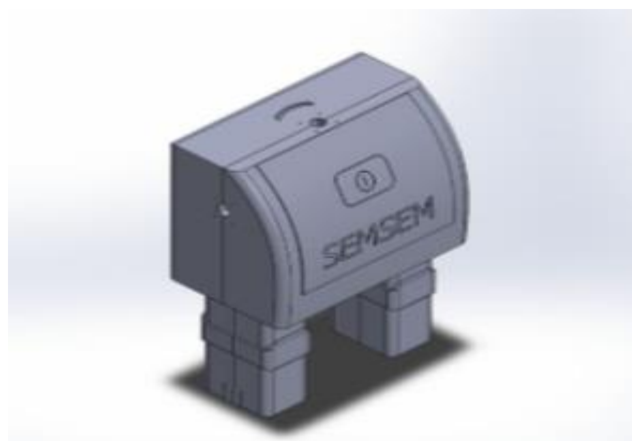


Figure 44 the body of the robot

As illustrated in the figure 43 presented showcase the outcome of our implemented system, where all the necessary components mentioned earlier have been incorporated to complete the design. Through careful planning and integration, the system has been equipped with the required elements to ensure its functionality and effectiveness. It represents a crucial aspect of the system, highlighting the integration of components such as the screen, camera, motors, and other essential elements. It demonstrates the successful realization of the system design, reflecting the comprehensive integration and inclusion of all necessary components to achieve the desired functionality and performance.

Figure 45 humanoid robot implementation and results

Chapter 8: Conclusion and future work

In conclusion, the robot system developed for children with autism has successfully incorporated various features to create an engaging and interactive experience. The system begins with a welcoming window, where the robot introduces itself to the user, setting the stage for interaction. The presence of a start button provides the user with control over the system's operation, allowing them to choose between two modes: automatic and manual.

One notable aspect of the system is the inclusion of a timer. If no action is taken within a specified time, the system automatically transitions to the emotion detection system. This feature ensures that the user's emotional state is taken into consideration, leading to a more personalized and tailored experience. The emotion detection system categorizes emotions into three main categories: happy/surprise, neutral, and sad/fear. Each category directs the user to a specific window, namely the Learn, Play, and Songs and Storytime windows, respectively.

The Learn window focuses on providing educational content and interactive learning activities for the user. It serves as a platform for acquiring new knowledge and skills in an engaging and stimulating manner. The Play window, on the other hand, offers interactive games and activities that encourage active participation and foster cognitive development. Finally, the Songs and Storytime window provides a collection of songs and stories, accompanied by synchronized movements, to create a captivating and enjoyable experience for the user.

Throughout the system, the robot's continuous movements, including head and arm motions, add a dynamic element and enhance the user's engagement. However, in certain windows, such as the Learn window, hand movements may be paused to promote concentration during educational content consumption.

The system's overall design and functionality aim to provide a holistic and tailored experience for children with autism. By incorporating elements of personalization, interactivity, and emotion detection, the system addresses the unique needs and preferences of each user. It offers a range of activities and content to support learning, cognitive development, and emotional well-being.

With further refinement and advancements, the robot system holds significant potential in assisting children with autism in their development, communication, and overall quality of life.

By creating a supportive and interactive environment, the system aims to promote engagement, learning, and emotional connection, contributing to the positive growth and well-being of children with autism.

8.2. Future work:

Moving forward, there are several areas of potential future work that can contribute to the continued improvement of our system. These include enhancing the accuracy and sensitivity of the emotion detection mechanism, expanding the content repertoire with additional educational materials, games, songs, and stories, and incorporating adaptive learning algorithms to personalize the experience for each child. Furthermore, promoting social interaction among children, implementing long-term monitoring and progress tracking, collaborating with therapists and healthcare professionals, and actively seeking user feedback through user studies and surveys are essential steps to refine and optimize the system. By focusing on these areas, we can ensure that our system remains at the forefront of providing a comprehensive, engaging, and tailored interaction for children with autism.

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Appendix A

Executive Summary: Autistic Child Friendly Robot

Abstract

The development of a humanoid robot system designed to enhance communication skills in children with autism. The system incorporates a camera-based emotion detection algorithm that analyzes facial expressions and identifies seven different emotions. Convolutional Neural Networks (CNNs) are employed for efficient emotion detection. Additionally, the system includes a manual mood selection feature, allowing children to freely choose between various activities such as learning, playing interactive games, and engaging in songs and storytelling. The graphical user interface (GUI) of the system, implemented using the tkinter library, provides an interactive platform for children. Hand tracking techniques enable control and interaction with the system's activities through hand movements captured by the camera. NEMA 17 stepper motors are utilized in the humanoid robot's structure, enabling precise movements synchronized with the GUI application.

The system aims to support children with autism by providing a customizable tool to enhance communication skills and facilitate engagement. By combining automatic emotion detection and manual mood selection, the system offers a range of activities tailored to individual preferences. The incorporation of interactive games, songs, and storytelling creates an engaging and personalized experience for children with autism, promoting communication and interaction.

Problem Statement

children with autism spectrum disorder (ASD) often encounter challenges when it comes to expressing themselves and engaging in turn-taking activities. This difficulty becomes particularly pronounced when these children need to concentrate on multiple tasks simultaneously, such as imitating, playing, and interacting socially with their surroundings. These struggles can hinder their ability to effectively communicate and connect with others.[2]

Given the significance of early detection and treatment for ASD, it is imperative to develop appropriate interventions. However, due to the unique nature of each child with ASD, a one-size-fits-all approach is not feasible. Consequently, the utilization of a robot framework becomes relevant, as it can effectively fulfill specific tasks within predefined limits. To this end, the development of an expandable Human-Robot Interaction (HRI) framework, incorporating a range of communication modules, becomes essential.

The objective of this project is to design a robotic template that encompasses various components, including a learning module, entertainment features, and relaxation tools. By integrating these elements, the aim is to provide a comprehensive and adaptable platform that caters to the specific needs of children with ASD. This robotic template will serve as a valuable resource in facilitating their learning, providing engaging experiences, and promoting relaxation, thereby enhancing their overall development and well-being.

Objective

Our objective is to create an affordable humanoid robot prototype as a human-robot assistant during therapist sessions for children with autism. The implementation will use the "Raspberry Pi" as a cost-effective and versatile processing chip, incorporating the "Raspberry Pi camera module" for software applications and motion detection.

The primary focus is on facial emotion recognition, enabling the robot to detect and respond to children's emotions, simplifying interactions for therapists, parents, and caregivers. Additionally, we aim to develop teaching capabilities to engage children in educational activities, supporting their learning and development.

Furthermore, the robot will include features for play and relaxation, creating an environment for recreational activities that promote well-being. By integrating tailored games and activities, the robot caters to the child's interests and aids relaxation.

Overall, our design objectives center around creating an affordable and versatile humanoid robot as a human-robot assistant during therapy sessions. By emphasizing facial emotion recognition, teaching capabilities, and promoting play and relaxation, our comprehensive solution benefits therapists, parents, caregivers, and most importantly, children with autism.

Brief Background

Autism, a lifelong disorder that affects communication and learning, presents unique challenges for individuals. The increasing prevalence of autism calls for effective interventions to enhance communication and behavior. As a spectrum disorder, autism manifests in different ways, requiring tailored approaches for therapy and support. Robotic technology has emerged as a promising tool in this regard, offering innovative solutions for assessment, intervention, and communication. By leveraging controlled stimuli and providing personalized feedback, robots can engage children with autism, helping them develop essential skills such as verbal communication, eye contact, and imitation behavior. Through human-robot interaction, therapists can create a natural and supportive environment, facilitating the progress of individuals with autism towards improved communication and social interaction. Ongoing research and development in robotics continue to pave the way for more effective and personalized interventions for individuals on the autism spectrum.

Software system procedure

The software system development process involved collecting and curating educational videos, games, and stories tailored for children with autism. The system was designed and implemented using the Python programming language, incorporating manual and automatic operation modes. In the manual mode, users can personalize activity selection, while the automatic mode utilizes facial emotion detection to suggest suitable activities based on the child's mood. A timer feature was integrated to ensure continuous engagement, redirecting users to the main menu if no interaction is detected.

The content collection and curation process involved comprehensive research and evaluation to procure diverse resources for children with autism. Existing games were acquired and modified, learning videos were carefully selected, and educational games were chosen to reinforce learning. Songs with calming melodies were included, and stories were curated to balance entertainment and education.

Two distinct modes were designed for user engagement: the Emotion Scanner (Automatic Mode) and the Semsem Hub (Manual Mode). The Emotion Scanner mode uses facial emotion detection to select activities automatically, while the Semsem Hub allows caregivers to manually choose activities tailored to the child's needs. A 10-second timer was implemented to transition from manual to automatic mode if no user interaction is detected.

The Emotion Scanner mode utilizes facial emotion recognition techniques based on deep learning and real-time analysis of facial expressions. It enhances communication and socialization for individuals with autism by understanding and expressing emotions. The Semsem Hub serves as the main menu, offering a user-friendly interface for activity selection by caregivers, supporting the child's learning and development.

Facial emotion recognition involves processes such as face detection and facial feature extraction using convolutional neural networks (CNNs). The Viola-Jones method is commonly used for face detection. The system's architecture captures facial images, detects faces, and predicts emotions using the collected dataset.

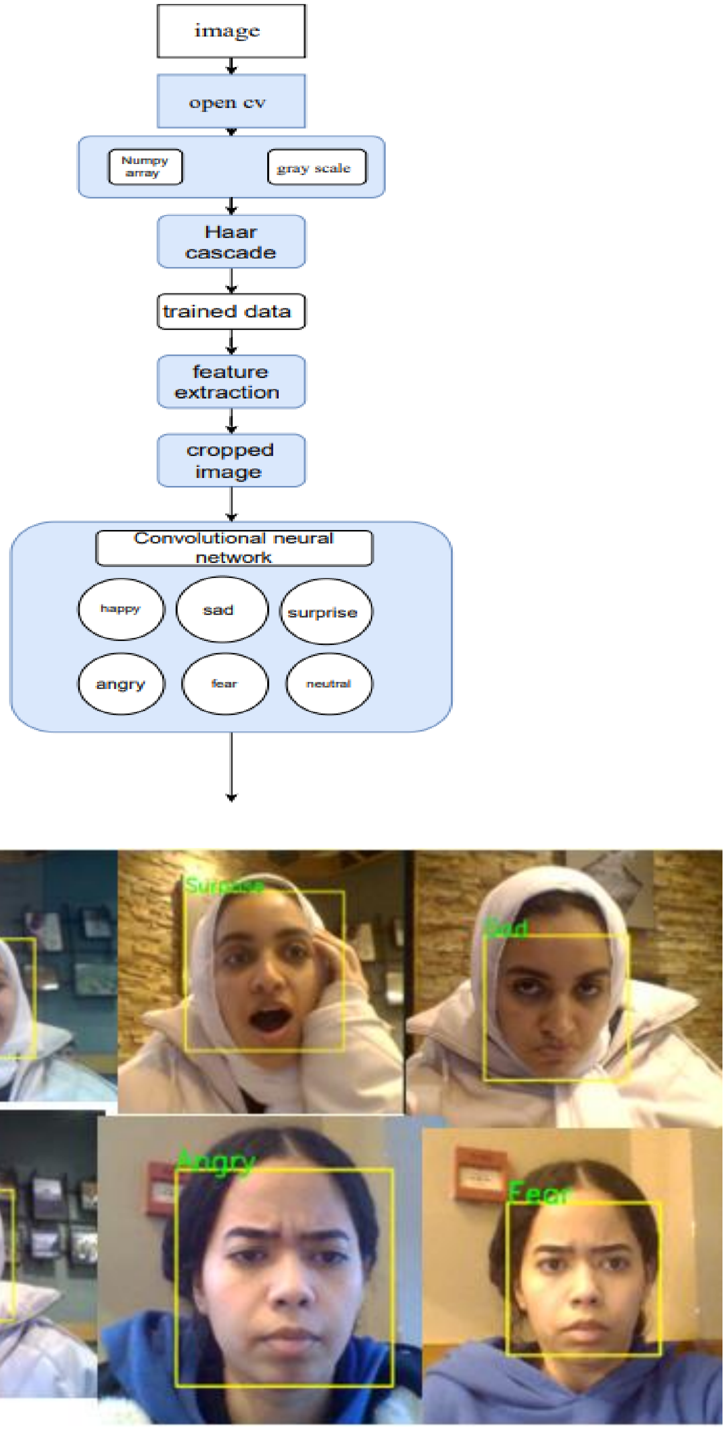

Figure 46:emotion detection

The detection process in OpenCV involves converting an image into a grayscale numerical array and applying the Haar Cascade classifier to detect human faces. The Haar Cascade classifier uses trained data to extract features and create a bounding box around the face. The detected face is then cropped and processed for emotion detection. Emotion detection involves acquiring an image or video frame, converting it to grayscale, detecting faces using Haar cascades, extracting regions of interest (ROIs), applying feature extraction techniques, and classifying emotions using a machine learning model. The system utilizes tools like OpenCV, NumPy, Keras, TensorFlow, and CNNs to detect facial emotions, with the results displayed on the output screen.

Semsem Hub: Main menu and Functionality:

The Semsem Hub is the central interface of the system, offering users access to various features and functionalities. It provides a user-friendly environment for parents, caregivers, or guiding individuals to select activities tailored to a child's needs. The Semsem Hub consists of three sub-windows, each focusing on different aspects of the child's development and engagement.

1. Learn and Play: This sub-window offers a balanced mix of educational content and interactive games. It includes educational videos, practice games, and engaging activities to enhance cognitive development, problem-solving skills, and knowledge acquisition.
2. Interactive Gaming Zone: Using hand tracking technology (OpenCV), this sub-window provides engaging games designed to promote physical activity, coordination, and motor skill development, specifically for children with autism.
3. Songs and Storytime: In this sub-window, users can access a selection of calming songs with repetitive tunes and carefully crafted stories. These resources aim to entertain, educate, and stimulate the imagination of children with autism.

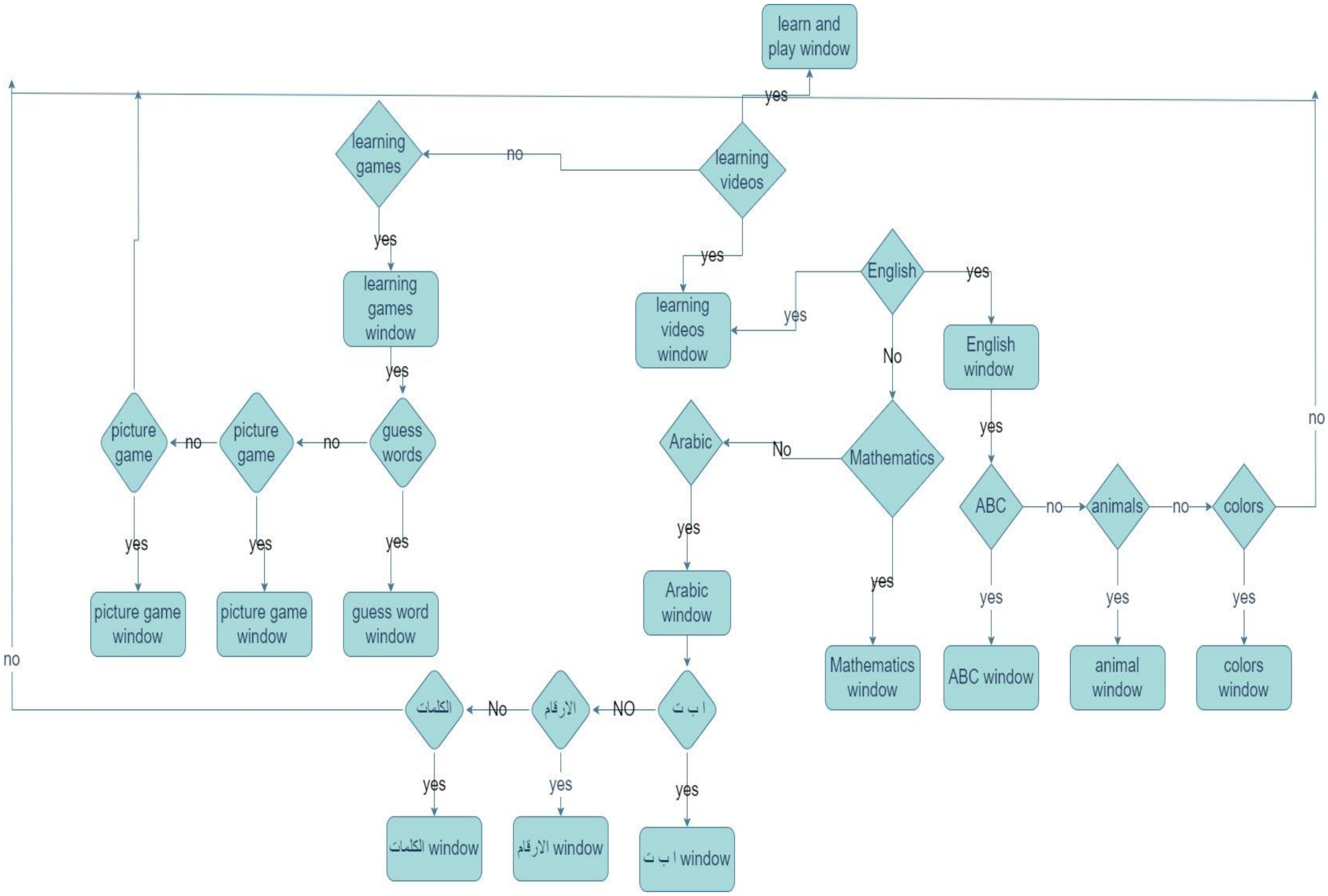

Figure 47:main system flowchart

The Interactive Gaming Zone offers three games (Snake, Ping Pong, and Balloons) designed for children with autism. These games use hand detection technology to control and interact with the virtual environment, promoting physical activity and motor skill development. Snake improves hand-eye coordination, Ping Pong focuses on timing and motor control, and Balloons encourages gross motor skills and hand-eye coordination. The Zone provides an inclusive and engaging environment for children to have fun while developing essential skills.

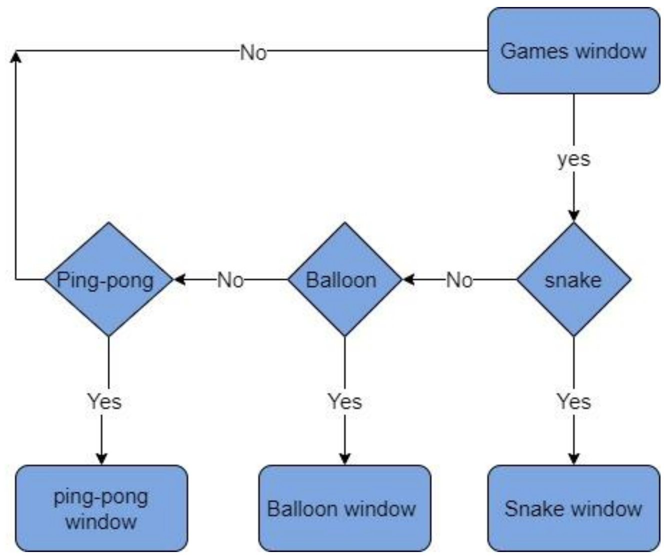

Figure 48: flowchart game windows

Graphical User Interfaces (GUIs):

The chapter focuses on the design and implementation of the Graphical User Interface (GUI) for a system aimed at children with autism. The GUI is essential for facilitating communication and interaction with the system. It is designed to be intuitive, visually appealing, and tailored to meet the specific needs of autism children. The GUI incorporates elements such as a welcoming video, a custom logo, and a well-organized layout. The Tkinter library in Python is used for GUI implementation, providing tools and functions for creating interactive interfaces. Thorough testing ensures functionality and usability. The GUI overview highlights key windows, including the Welcoming Video Window, Logo Window, Modes of Operation Window, and Main Menu Window, each offering specific features and content for an engaging user experience. Overall, the GUI design and implementation enhance the usability and effectiveness of the system for children with autism.

The careful design and implementation of the Graphical User Interface (GUI) in the Semsem Helper system contribute to creating a supportive and inclusive environment for children with autism. By considering their unique needs and preferences, the GUI fosters engagement, promotes learning, and enhances their overall well-being. The visually appealing interface, intuitive navigation, and personalized elements such as the welcoming video and custom logo establish a positive and welcoming experience. Using the Tkinter library in

Python, the GUI implementation successfully integrates the system's functionality with user-friendly interactions, ultimately empowering children with autism to actively participate in educational activities, interactive games, and engaging content offered by the system.

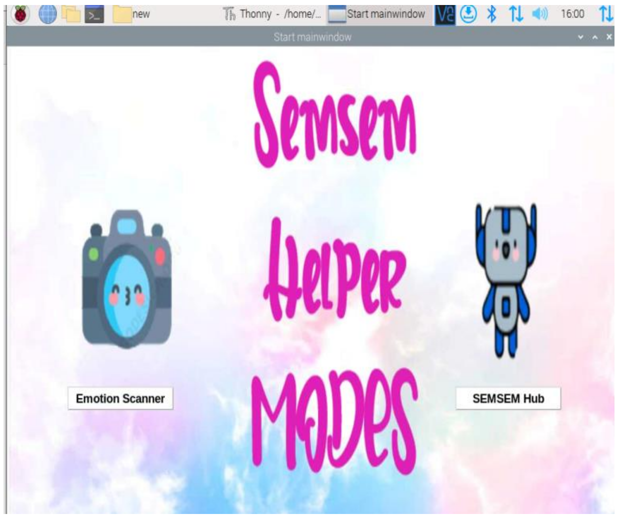

Figure 50:modes of operation window

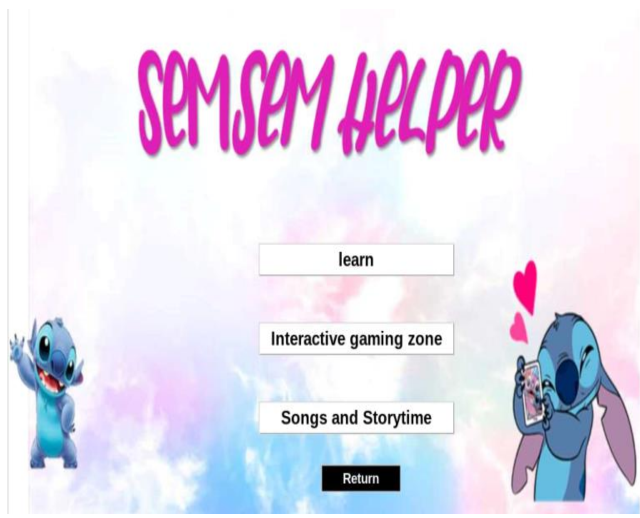

Figure 49:main menu window

Hardware implementation and prototype:

To create a humanoid robot that interacts with children, the initial step involves determining the robot's dimensions and configuring its workspace. The robot's size and range of motion are defined to engage effectively with children. The robot is custom designed to imitate human behaviors and assist children with autism.

The hardware components for the robot include NEMA 17 stepper motors, A4988 drivers, Raspberry Pi 4, Camera V2 module, touch screen, power supplies, speaker, and circuit amplifier. Software components include Text-to-Speech technology, Python Tkinter library, Python scripts for GUI design, and PowerPoint for visual representations.

The control unit of the robot uses a program stored in the microcontroller's memory to control each motor's movement. Connections are established between the drivers, motors, and Raspberry Pi for motor control and communication. The control system allows the Raspberry Pi to command the motor's behavior and interact with other components.

The circuit design incorporates a Raspberry Pi 4, NEMA 17 stepper motors, and an A4988 motor driver. The circuit is designed for precise head and arm movements. The Tiny A4988 Extension 3 Drivers Base Board simplifies motor connections.

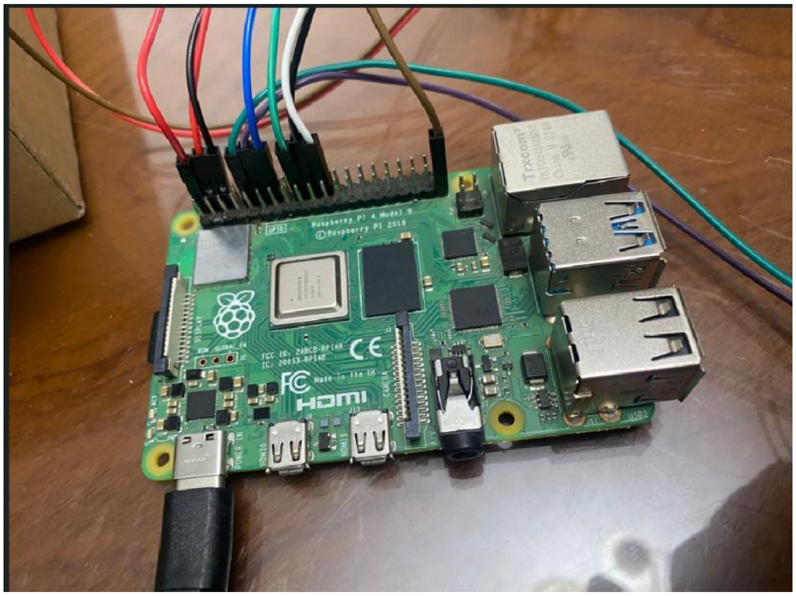

Figure 51:control unit

Microstepping is used to achieve finer resolution and smoother movement in the stepper motors. The motor control algorithm selects the desired microstepping mode for the motors, enhancing precision and control.

The control mechanism for the head and arms utilizes GPIO pins on the Raspberry Pi for step and direction control. The code pulses the step pin to rotate the head incrementally, and similar control is applied to the arms using respective GPIO pins.

The system incorporates a camera-based emotion detection system using CNNs and Haar cascades. The camera captures real-time input to analyze the child's emotions based on a dataset. The GUI, developed using tkinter, integrates the emotion detection system, motor movements, and interactive games.

The system includes three synchronized motors controlled through the GUI. NEMA 17 stepper motors are used with the A4988 driver for precise control and microstepping. The humanoid robot is constructed using 3D printing technology with specified dimensions.

Overall, the goal is to develop a humanoid robot that closely interacts with children, assists them, and provides tailored experiences based on their unique needs and abilities.

Conclusion

The developed robot system for children with autism offers an engaging and interactive experience. It includes features such as a welcoming window, automatic and manual modes, and an emotion detection system. The system provides educational content, interactive games, and songs/stories in different windows. Continuous robot movements enhance engagement, although hand movements may be paused during educational activities. The system aims to personalize the experience and support learning, cognitive development, and emotional well-being. Future work involves improving emotion detection, expanding content, incorporating adaptive learning, promoting social interaction, monitoring progress, collaborating with professionals, and seeking user feedback. The system strives to provide comprehensive and tailored interaction for children with autism.

Future work for the robot system designed for children with autism includes improving the accuracy and sensitivity of the emotion detection mechanism, expanding the content repertoire with additional educational materials and activities, integrating adaptive learning algorithms for personalized experiences, promoting social interaction among children, implementing long-term monitoring and progress tracking, collaborating with therapists and healthcare professionals, and actively seeking user feedback through studies and surveys. These efforts aim to enhance the system's effectiveness, engagement, and overall impact on the development and well-being of children with autism.

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