ALIZA: SMART MIRROR AS AUTISTIC EDUCATION ASSISTANT

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Dissertation submitted in partial fulfillment of the requirements for BSc (Hons) in Information Technology

Department of Software Engineering

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DECLARATION

We declare that this is our own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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(Jesuthasan Alosius)

ABSTRACT

Autism is a neurodevelopmental disorder that causes difficulties in communication, emotional responsiveness and social skills. There has been a global increase rate in autism and lack of resources locally to educate ASD children. This condition affects children at an early stage and prolongs through their lifetime. It is clinically proven that ASD can vastly improve when treatment started at an early age [1]. “Aliza” Gamified smart mirror introduced to help autistic children in their basic education needs comprising components: writing mentor for pre-writing, math tutor for mathematics, verbal trainer for speech, attentiveness tracker emotion detection to enhance their competency in education. Aliza is a multi-user, self-learning platform to cater individual and enterprises.

Keywords— Aliza, autism, smart mirror, writing mentor, basic math tutor, verbal trainer, attentiveness tracker, pre-writing, emotion detection, Autism Spectrum Disorder(ASD)

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LIST OF ABBREVIATIONS

ASD	Autism spectrum disorder
CNN	Convolutional Neural Network
AAC	Alternative and Augmentative Communication
ABA	Applied Behavior Analysis

1. INTRODUCTION

1.1. Background

ASD or else commonly known as Autism spectrum disorder. "One in 160 children has an autism spectrum disorder" (ASD) [2]. This is a common issue in the globe that affects all children. These children should be taken care as they have special needs and should be assisted in daily activities. These children have strength and weaknesses that are common as well as unique to each individual. Mainly there are 3 levels of ASD [3]. Level 1 – commonly has issues with socializing with peers and others, Level 2 – lack of verbal and nonverbal communication and need assistance for tasks, Level 3 – severe communication skills, have distracting behaviors and need constant assistance. Even though they have weaknesses as such they tend to be very organized and work according to a routine. Guided with simple actions and commands helps them easy to complete a given task.

Educating ASD children has to be done in a methodical way that they could understand and level up. They deviate from the methods that is used for non-autistic kids and therapies are given for all basic education. Considering writing skills first they need to be prepped with pre-writing skills. Such as drawing shapes with lines and curves. It is also done in a step by method starting by connecting dots to complete shapes, lines, curves and patterns. Gradually then based on the shapes, lines and curves letters are taught to be written.

Same as Alphabets the numeric are also initially started with prewriting skills as mentioned above. However, when it comes to math skills there are many symbols that makes children critical to learn. And solving math problem always doesn't occur in the same left to right order. Thus, basic training begins with counting numbers with flash cards, count sequentially, find the missing number etc. Since ASD children have a great way of understanding things visually their problem-solving are different compared to a non-autistic individual.2

The surrounding is the key element when educating ASD children because they tend to get distract very easily since they are very sensitive to the background environment and

reacts for even small changes. Due to this factor gestures are uses when teaching them. Pointing at an object and describing it or illustrating a shape and teaching it are some common teaching techniques. When using gestures, it is common that they repeat the same action and learn by themselves.

Sound is a major factor for ASD children as mentioned above sound does distract ASD children but even use of sound can be utilized for their learning. Clapping hands makes them cherish and enthusiastic that make them want it more. So, mentors use this technique to encourage them in completing activities, to encourage them when they perform well and importantly as an achievement award when they engage in good habits. Moreover, positive reinforcement by words also helps them to learn better.

These therapies are succeeded when an ASD individual reacts upon it and has a continuing improvement. This is measured by their reaction towards these therapies. When an autistic child enjoys the activity they are involved even though they are unable to verbally communicate it they express it by emotions. Emotions play a great deal of importance in them. Sensory Integration Therapy (SIT) [4] explains how to teach ASD students based on their reactions.

Reflecting all factors above this study proposes a smart mirror which caters aspects and provides a smart solution based on machine learning technology. This is an interactive device for ASD children for fun learning

1.2. Literature Review

Technology usage has prominently risen in intervention and researches of ASD. People with autism are often overwhelmed by the demands of human interaction. To beat this problem, number of researches have started to explore ways to use AI to teach Autism children [5].

Acapela group have invented a robot with facial expressions and a screen to display the instruction. MILO's functionalities are turn-on emotions, join attentions, speaking activities, improve social behaviors and imitations. MILO is more like a peer who will always keep interacting with the ASD child. Only humans will get bored or feel lazy to do things repetitively, however milo is a robot that doesn't have any feelings such as laziness or tired. It will always keep interacting with the student with recurring positive

enforcement [6]. The objective of the robot is to develop social and behavior skills by continuously encouraging positivity for the ASD student.

Humanoid robot NAO, created by Softbank Robotics has its capability to blink its eyes, speak and play music which can entice the children's interest to engage in communication [7] .Both humanoid robot Milo and NAO especially focus on training the social and communication skills.

Moreover, there are wide ranges of applications which are game oriented to develop their different skills. Finkelstein et al [8] designed a game "CMotion" that will use virtual humans to teach emotion recognition and programming concepts to Autism children. This is designed to teach the intended users how to recognize facial expressions and manipulate an interactive virtual character using a visual drag-and-drop programming interface. They found that the system of virtual human teaching has increased learning capacity and learning interest than a system of regular classroom teaching to Autism children. Ould Mohamed [9] developed an educational personalized games activity with behavior tracker during the game session. It helps to Autism children to focus their attention on a specific task.

Alvaro Fernandez-Lopez [10] devised a mobile platform based on iPad and iPod touch devices called Picaa for people with special needs. Picaa is a platform to design educational activities such as Exploration, Association, Puzzle and Sorting activities. Its aim is to help special needs children to learn basic education. Otsimo [11] is a mobile application that helps the ASD students to learn numbers, colors and shapes. Autism Read & Write [12] is an app with simple activities like finding given object's name. Even though these applications provide activities and games like Aliza, it fails to provide an integrated solution to develop multiple skills. Table 1-1 illustrates the features that are missing in those existing applications while Aliza includes as its functionalities.

1.3. Research Gap

Even though there are many hands-on applications it only contains few of the aspects of ASD and having all the skill development in one device is rare indeed. Aliza is not a robot or mobile application its smart mirror that have the features which is more advanced than the devices that are being used nowadays. Popular example is the "Milo"

humanoid robot [no] engages with students as their peer and assist them in education and it teaches the social skills. But doesn't evaluate the student or doesn't take users emotions as an input into the system. Similarly, a mobile application named "Otsimo" [no] was developed to facilitate ASD children with fun activities. Even though Otsimo contains activities for pre-writing skills, numeric skills and speech and language skills, it neither evaluates the progress with AI based system nor tracks the emotion.

Table 1-1: Existing Research/ Products

Features	Existing Research/Products					Aliza
	CMotion	Attention Analysis in Interactive	Picaa	Otsimo	Autism Read & Write	
Game based education approach	✓	✓	✓	✓		✓
Pre-writing activities				✓	✓	✓
Math activities				✓		✓
Speech activities				✓		✓
Emotion tracker		✓				✓
Progress tracking	✓			✓		✓
Evaluation report						✓

Picca [no] which is another mobile application that is specifically built for iOs devices, provides education activities for exploration, sorting, puzzle and association. This app can be personalized by the therapist based on the student's requirement which is its unique feature comparing to other apps. However, this application has an evaluation system that checks the usage of activities rather than the performance of the child in the activities. There are more other applications such as cMotion to teach emotions, Austism Read & Write to teach pre-writing skills and attention analysis system for focus games. Aliza provides the feature that tracks the motion of the user and swap activities to keep them more engaged whereas the other applications doesn't contain this feature except the

attention analysis system [no]. Moreover, comparing all the other applications Aliza uniquely has its evaluation system that uses modern technologies to track their progress and generates report based on it. The Table 1.1 depicts the comparison of related works.

1.4. Research Problem

As far as it has been stated as a statistic by world health organization that "One in 160 children has an autism spectrum disorder (ASD) [13]. ASDs begin in childhood and tend to persist into adolescence and adulthood. While some people with ASD can live independently, others have severe disabilities and require life-long care and support"[14]. This is a major cause in our future generation. Existing tools and mechanisms are insufficient since these methods doesn't cater all the ASD children's educational needs. Parents of these kids hunts for the affordable and efficient therapies, strategies and apps to provide their kids with the ideal solution. However, in the academia and industry new trending technologies such as robotics, Artificial Intelligence, Internet Of Things are introduced but not greatly used for Autism education.

Adolescent age is the greatest age to of learning where [15] 85% of the brain development occurs by the age of 5. So, it is a greatly important to handle all autistic children with proper material and learning application. More innovative solutions must be given to them with diverged technology. When looking back in the improvement in this sector mobile apps were introduced after manual therapies. Mobile applications had a huge range of activities for children that facilitates autism education but was not much of an impact on them. Since the screen engagement time was not as much as effective as interacting with a real mentor or with their same aged peers. Therefore, when robots came into play it had a significant impact on children other than the mobile app. But as a massive drawback these equipment's where too expensive to afford. So, the technological advancement was barely a benefit in above scenario.

As the world is more emerging with the concept of making everything "SMART". Smart phones, smart homes, smart cities, smart transportation are a hit currently. Below Figure 1.1 show the overall impact of smart concept

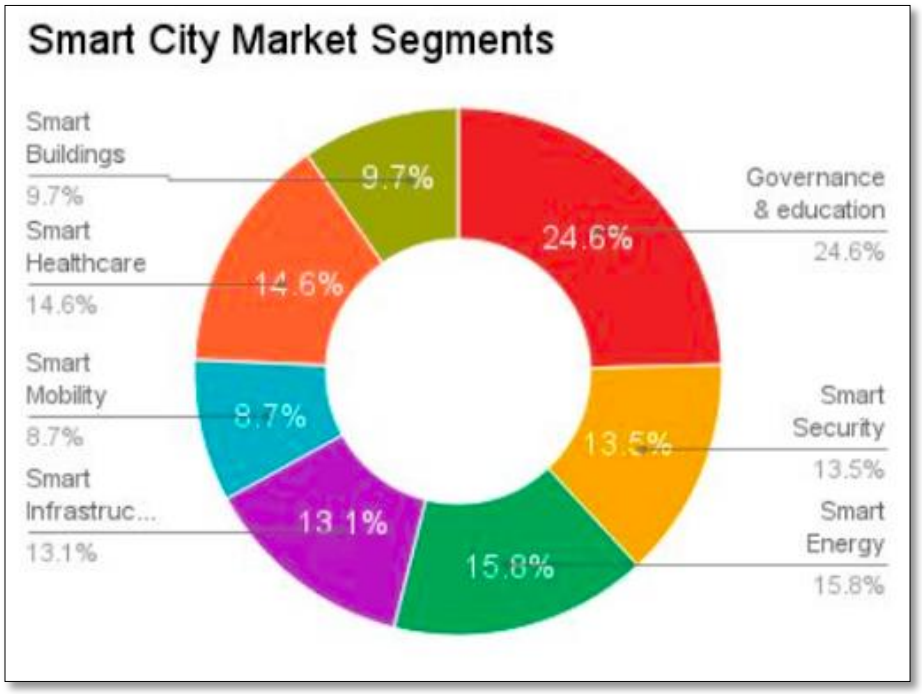


Figure 1-1: An Overview of the Technology Trends Driving Smart Cities [6]

Above Figure1.1 illustrates 24% of the education is adapting "smart" concept. So, this is a great phase to introduce smart equipment's to the ASD children. This research study proposes an innovative approach for autistic children; a smart mirror "Aliza" as an educational companion to ASD individuals for better learning based on their emotion.

1.5. Research Objectives

1.5.1 Main Objective

The main objective is to implement a smart mirror that helps to improving the writing kills, basic mathematical skills, verbal skills and focusing skills of ASD children. Also, accustoming modern technology learning system among the ASD children.

1.5.2 Specific objectives

Writing Mentor

- Identifying digital drawing images according to variations of the size which are drawn by autism children.

- Identifying digital drawing images according to any area which is drawn by autism children on the smart mirror display.
- Identifying digital drawing images according to any area which is drawn by autism children on the smart mirror display.
- Increasing the overall quality and knowledge of the ASD children's pre-writing skills through using Aliza-Writing Mentor system.
- Improving few peer socialization among the ASD children' after using the Aliza Writing Mentor system.
- Accustoming modern technology learning system among the ASD children.

Math Tutor

- Able to count numbers from 1 to 10.
- Identify numbers from 1 to 10.
- Write numbers on their own.
- Improving IQ level.

Verbal Trainer

- To identify the spoken word accurately regardless of noisy environment.
- To prompt reinforcers after completing task successfully.
- To ask for swapping another activity when kid seems less engaged.
- To design the game based on the characteristics of Autism.
- To generate a progress report based on how many words they succeeded to pronounce or how many objects they have identified during the game.

Attentiveness Tracker

- To build an emotion recognition teaching model
- Real-time emotion recognition of the user.
- Analyze the emotions though-out the activities.
- If negative emotions received, suggest activity switch.
- Maze game to boost focus level of user.
- Increasing difficulty level by introducing new obstacles in focus game.

2. METHODOLOGY

2.1. Data Collection

This study gathered primary data from randomly selected 100 ASD children between the ages of 5 to 12 from 5 selected schools in Jaffna districts. The data was collected in the form of document, audio from selected ASD children's routine lessons. These collected data will be kept confidential and secure due to privacy concern of the children. In addition, publicly available data was used to train some of the models.

2.2. Design

Hardware and Software components of the Aliza

As shown in Figure 2-1, Two-way mirror with 70% reflection on top of LED monitor, covered with a wooden frame to hold them together. The LED monitor is to display the program. These two aesthetic components are 20 inches. A speaker and web camera in-built with microphone is connected to the Raspberry Pi for voice recognition and emotion recognition. Raspberry Pi is the brain of smart mirror which has the processing capability with low processing power. It is booted up with Linux 64-bit OS which is configured to run Magic mirror module during the startup. Inside the Magic mirror module, our application resides as a game that could be played by the user.

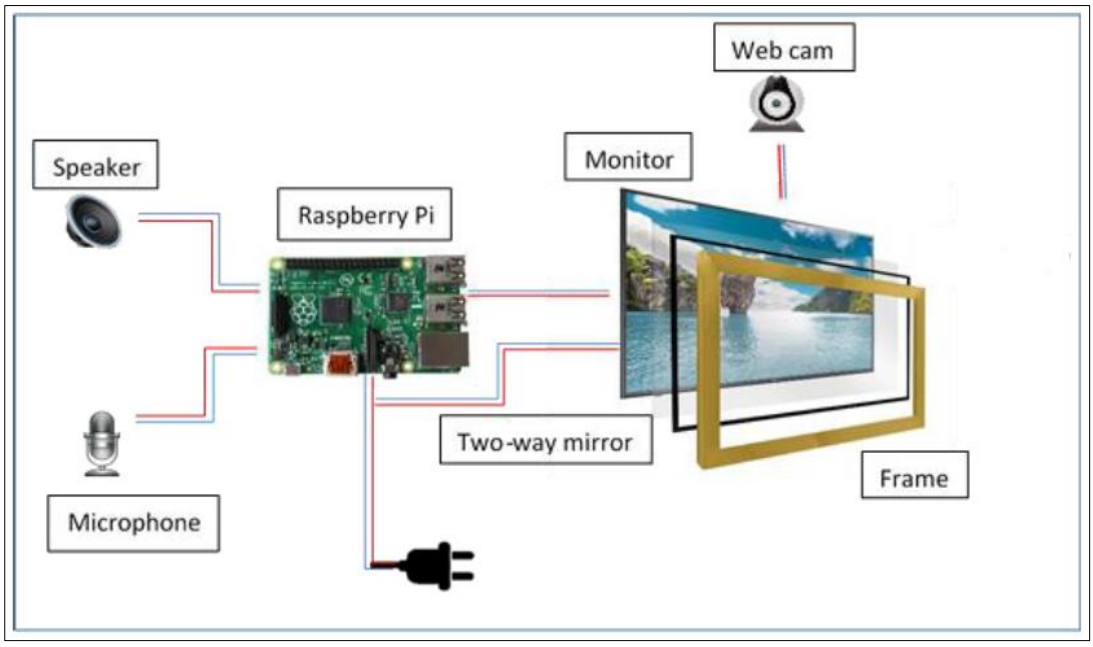


Figure 2-1: .Hardware Components

Writing Mentor

Writing skill is used for self-expression, communication, and recording of thoughts and experiences. Informal reports acknowledge that children with autistic spectrum disorder (ASD) have higher levels of writing disability. Also, learning pre-writing skills through game, can further enhance the sense of presence and engage even more deeply with ASD children. Therefore it's consequently, further foster motivation to learn pre-writing skills [17].

In this research, an advanced self-teaching system is introduced with the help of a smart mirror (Aliza). This writing mentor activity games are based on tracing and connecting dots strategy. Through this, ASD children are easily able to develop their pre-writing skills [18].

In the first step before starting, system will pre-evaluate the writing skills of ASD children with the help of CNN model. After the pre-evaluation process, the system will provide some pre-writing skill training activities such as lines, curve and shapes drawing games to ASD children. The system continuously evaluates those children when they are practicing and prepare a progress report.

Pre-writing activity's levels will be levelled up through every evaluation report. For example, after the 1st level of activity completion, the system will give a task to a user based on 1st level activities. If the evaluation report shows the progress level above 80%, then the activity level is levelled-up, if not the same level activities will continue until the user achieve the progress level 80%.

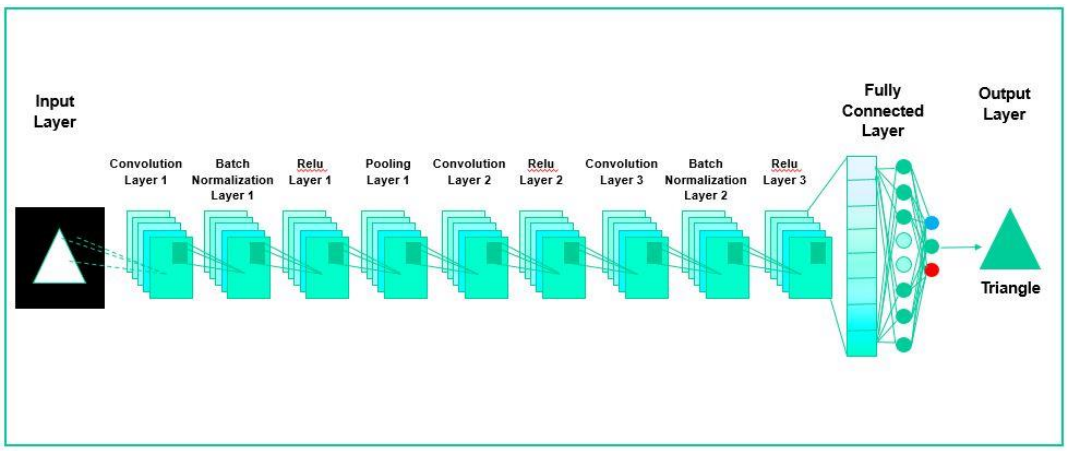


Figure 2-2: The overall architecture of the Convolutional Neural Network

To evaluate user's pre-writing skills and prepare a progress report, an eleven-layered convolutional neural network with one input layer followed by five hidden layers and one output layer is tried out. It's illustrated in Figure 2-2.

The input layer consists of 28 by 28 pixel images which mean that the network contains 784 neurons as input data. The input pixels are grayscale with a value 0 for a white pixel and 1 for a black pixel.

In this model of CNN has nine hidden layers. The first hidden layer is the Convolution Layer 1 which is responsible for feature extraction from an input data. The next hidden layer is Batch Normalization Layer 1. It speeds up the training of CNN and reduces the sensitivity to network initialization. Relu Layer 1 is the next hidden layer, then the pooling layer 1 is next hidden layer it reduces the output information from the convolution layer and reduces the number of parameters and computational complexity of the model.

Convolution Layer 2, 3 and Batch Normalization Layer 2, Relu Layer 2, 3 which has the same function as Convolution Layer 1, Batch Normalization Layer 1 and Relu Layer 1 and operates in the same way except for their feature maps and kernel size varies. A fully connected layer is another hidden layer also known as the dense layer. It is similar to the hidden layer of Artificial Neural Networks (ANNs) but here it is fully connected and connects every neuron from the previous layer to the next layer. In order to reduce over-fitting, dropout regularization method is used at a fully connected layer.

The output layer of the network Input classifies the output as the lines, curve, and shapes types. Through this seven-layer CNN, the strategy can identify the input image, as well as we can get the output of percentage which is consistent with the ideal image.

Basic Math Tutor

Math mentor for Aliza has four games basics, counting, identifying and writing. Initially math mentor begins from the basic game, its displays a number with text and audio to train them identification of digits. Next the counting game, the user is given objects to identify and count the objects to predict the number. The 3rd game Identification of missing numbers. These games are in a level basis that gear towards difficult levels and are given to prep up the students for the main goal of self-written numbers.

A CNN model is used in the final game, where the canvas is displayed to write a number and then evaluated the precision of the number. The number written in the canvas passes through out 5 convolution neural network where the image is resized and processed to generate the output shown in Figure 2-3 given below.

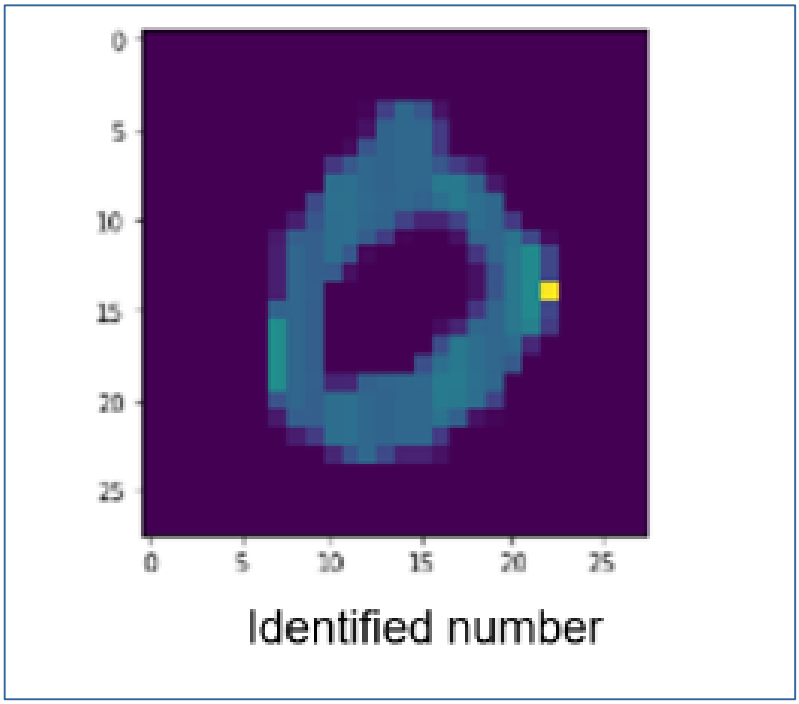


Figure 2-3: Output of Math Tutor game's CNN model

Then system flattens and dense the image to train the model more accurately. Each captured picture has its own pixel, considering the edges of the written number every edge will have a pixel weight, each pixel gets assigned to a neuron in the CNN layer initially. In the upcoming layers the weight of the neuron is being multiplied by a constant. At the end, algorithm outputs a probability distribution, according to the percentage that match with the sum of weights the number will be determined. It simplifies the probability distribution using NumPy library into a simple number.

At the end of the process, a report will be auto generated with the progress of the ASD student comparing with a non ASD student. Rather than the traditional teaching method this will be a new dimension of autism education.

Verbal Trainer

Speech therapy plays key part in early intervention programs. Aliza provides games which are designed based on Augmentative and alternative communication (AAC)

technique for speech development skills. There are three different games to learn alphabets, identify alphabets and objects and spell word. A Child has to identify the object or the alphabet shown on the screen and pronounce the word. The aim of this activity is to evaluate based on the number of words they managed to pronounce in a given time. Spell word game uses visual drag and drop interface to form the word by arranging the letters. Level increases up to five letter words based on the points. Speech to text model is integrated with the game to evaluate the user during the speech activities.

For the microphone input, the model computes the Mel spectrogram in its non-trainable layer and two convolutional layers extract the local relations in the audio and two set of bidirectional LSTM that captures the two-way dependencies and the output is projected as a dense layer and utilized as query vector and finally the weighted output is fed into three fully connected layers.

Attentiveness Tracker

Emotions are the major key of this component. Based on facial emotions the module tracks the user's attentiveness and responds in the game. Teaching according to the emotions of student has been proven very effective that applied behavior analysis recommends teaching according to autism children's emotions. Sensory Integration Therapy (SIT) entirely describes this teaching method [20].

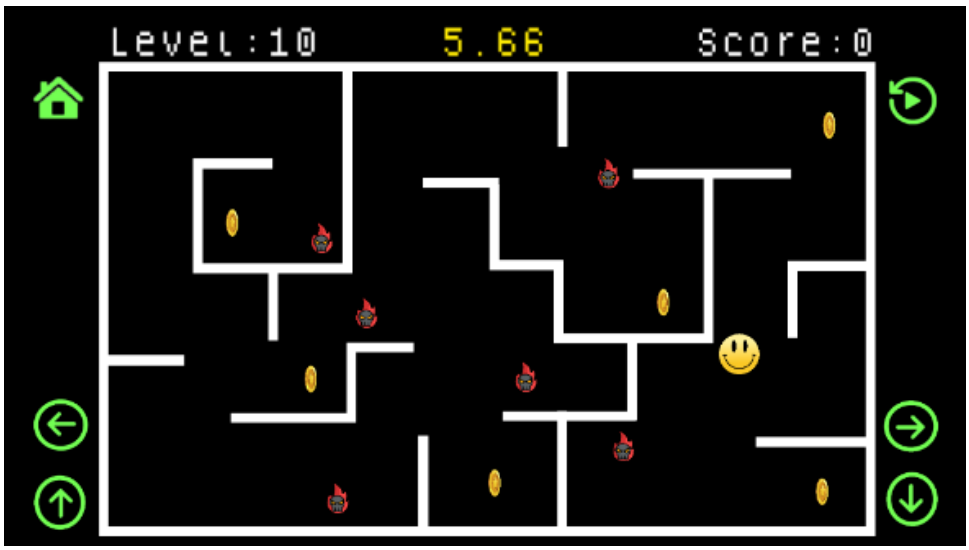


Figure 2-4: Maze game level 10

Figure 2-5: Maze game report

Initially a maze game is introduced for users for better improvement of their concentration and produced an auto generated report of their game play [Figure 2-4, 2-5]. When users are given the smart mirror to interact, a real-time emotion recognition model commences. Therefore, the teaching can fluctuate according to their emotions.

The proposed algorithm recognize emotions by,

1) Face detection using viola-jones detector

2) Captured image frames pre-processed and normalized

3) Apply 7 layers of convolutional neural network layers

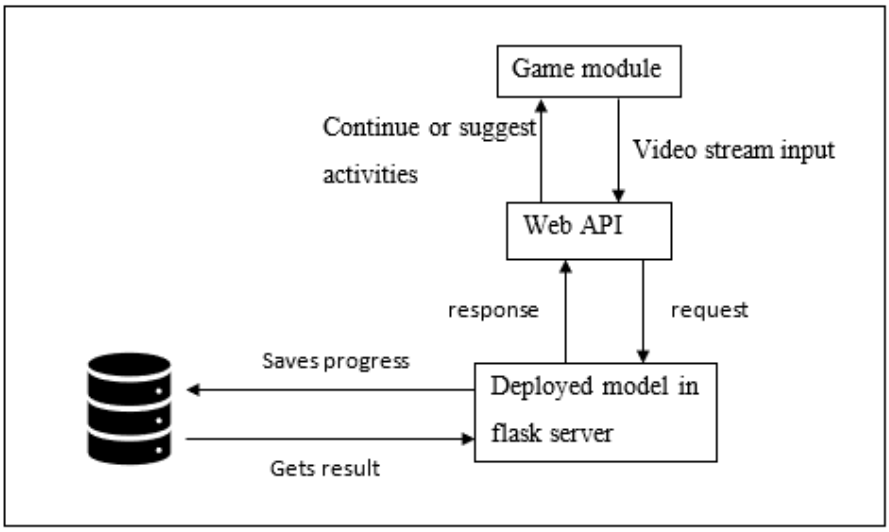


Figure 2-6: Attentiveness tracker block diagram

According to the block diagram [Figure 2-6], using ‘haar cascade’ a fontal face is detected in each frame from the web camera input. Then the images are converted to 48 by 48 grayscale images. The pre-processed data filters through 7 sequential Convolutional neural network layers in order to ideally fit the model. In the convolutional layers, ‘ELU’ activation is used and for model compilation, ‘Adam’ optimizer is used. The overall trained model flatten, compiled and optimized to demote the possibility of over fitting or under fitting. The saved model and model weights are then loaded to detect the actual face with emotions which is sent by the unity game. If negative emotions are detected the game prompts the user to swap to suggested activities of their predilection or if positive to continue with the same activity and track the concentration level of that game.

System Diagram

Above mentioned pre-trained models are deployed using Flask as a web service. Relevant services are called within the unity application during the game play. Finally, processed model results and user details are saved in the database. The overall system diagram is as shown Figure 2-7.

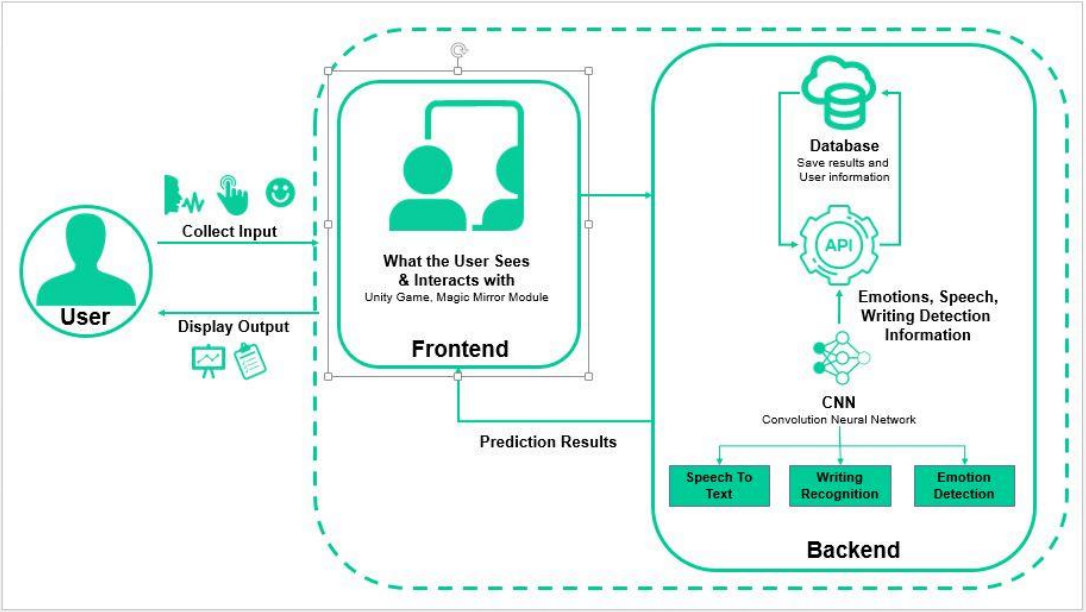


Figure 2-7: Aliza System Diagram

2.3. Limitations

The system takes input from micro phone, camera and user interface.Visual data are taken using a web camera, the quality and the angle of the image is more important to detect the facial expressions. because low light and external accessories (scarf, mask) affects the emotion prediction. Environment noises up to a certain level can affect the prediction of speech.

2.4. Implementation

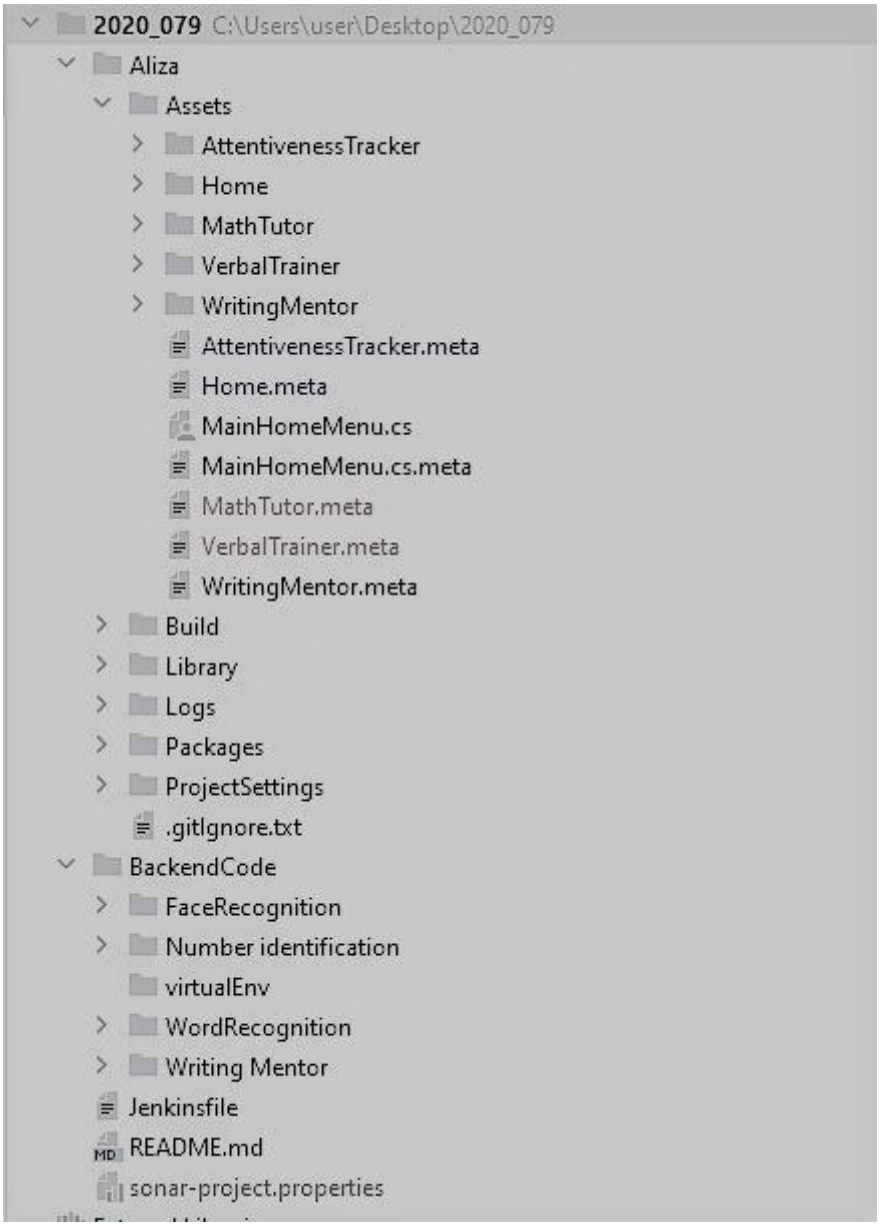


Figure 2-8: Project structure of Aliza

Above Figure 2-8 is the project structure of Aliza. It is divided into two parts 2020_079>>Aliza>>Assets containing the game folders of each component and 2020_079>>BackendCode containing backend code.

Assets folder mainly consists of created unity scenes, images, audio files, animations with C# codes for the game play. These C# files also consists codes of API calls at an end of an activity. The BackendCode folder consists of DB connections of all components, virtual environment for python, flask deployment, trained and saved models in h5 and JSON format, model notebooks, and codes for exposing web API.Lastly the Sonar property file is configured to check the quality of code and the README file consists of documentation of Aliza.

Moreover, Appendix A presents the assembling of the hardware components of Aliza.

During the requirement analysis phase, some technical requirements were identified as follows:

Hardware Requirements

1. Camera - Video Compression Format: H.264.(inbuilt with microphone)
2. Raspberry pi 3A+ - 4GB
3. monitor 22" LED
4. Two power cables
5. Two-way mirror 75% reflection
6. HDMI cable
7. Dual Speakers USB 2.0 with audio jack
8. Wired mouse
9. USB hub 2.0

Software Requirements

1. Operation System: Ubuntu
2. Unity game development tool

2.5. Testing

Unit testing is carried out by isolate sub-parts of the system and conduct the testing process as individual parts. For the Aliza function in the proposed system was executed manually. To verify how accurate the operations were, the actual results were detected by comparing the expected results with the actual results. Following are some of the test cases of drawn-shapes of Aliza system.

Writing Mentor

Table 2-1: Detect Circle shape - Test Case 1

Test Case ID	**1**
Test Case Name	Recognize shape ‘Circle’
Test Input Data	Circle shape .jpg image file from the selected test sample.
Expected Output	Must show the correct shape type word as 'Circle'
Actual Output	Printed the word ‘Circle’

Table 2-2: Detect Rectangle shape - Test Case 2

Test Case ID	**2**
Test Case Name	Recognize shape ‘Rectangle’
Test Input Data	‘Rectangle’ shape .jpg image file from the selected test sample.
Expected Output	Must show the correct shape type word as ‘Rectangle’
Actual Output	Printed the word ‘Rectangle’

Table 2-3: Detect Horizontal-Line shape - Test Case 3

Test Case ID	**3**
Test Case Name	Recognize shape ‘Horizontal-Line’
Test Input Data	‘Horizontal-Line’ shape .jpg image file from the selected test sample.
Expected Output	Must show the correct shape type word as ‘Horizontal-Line’
Actual Output	Printed the word ‘Horizontal-Line’

Table 2-4: Detect Perpendicular-Line shape - Test Case 4

Test Case ID	**4**
Test Case Name	Recognize shape ‘Perpendicular-Line’
Test Input Data	‘Perpendicular -Line’ shape .jpg image file from the selected test sample.
Expected Output	Must show the correct shape type word as ‘Perpendicular -Line’
Actual Output	Printed the word ‘ Perpendicular-Line’

Table 2-5: Detect Half-Circle shape - Test Case 5

Test Case ID	**5**
Test Case Name	Recognize shape ‘Half-Circle’
Test Input Data	‘Half-Circle’ shape .jpg image file from the selected test sample.
Expected Output	Must show the correct shape type word as ‘Half-Circle’
Actual Output	Printed the word ‘Half-Circle’

Math Tutor

Table 2-6: Prediction of Nine

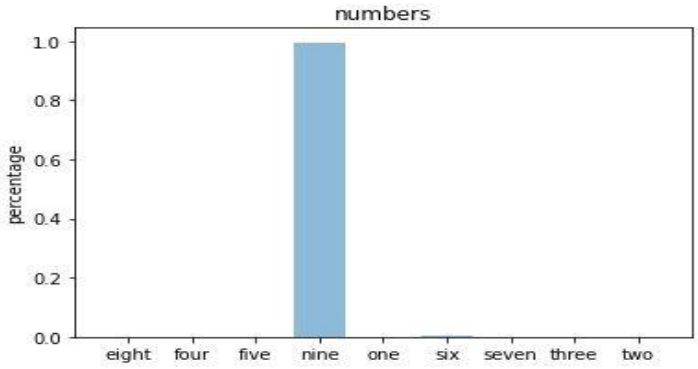
Test case	**01**
Input data	
Expected output	Correct prediction of number nine
Actual output	

Table 2-7: Prediction of Number one

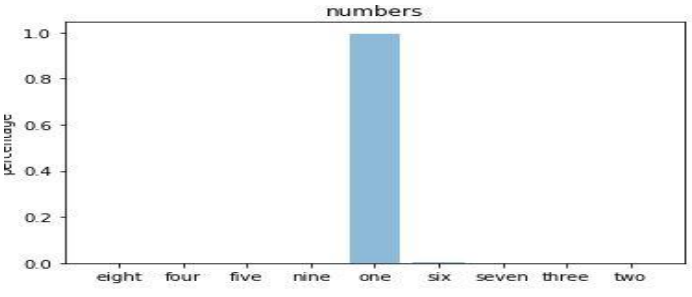
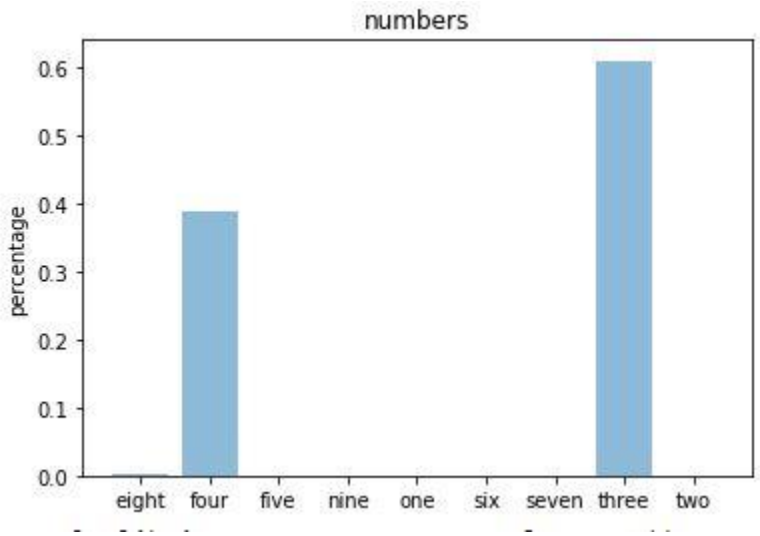
Test case	02
Input data	
Expected output	Correct prediction of number one
Actual output	

Table 2-8: Prediction of Number three

Test case	03
Input data	
Expected output	Correct prediction of number three
Actual output	

Verbal Trainer

Table 2-9: Recognition of Word 'Cat'

Test Case ID	1
Test Case Name	Recognize word ‘Cat’ in isolated area
Test Input Data	Pronounce a word from the selected list of words
Expected Output	Text form of the spoken word ‘Cat’
Actual Output	Printed the word ‘Cat’

Table 2-10: Recognition of Word 'Dog' in noisy area

Test Case ID	**2**
Test Case Name	Recognize word ‘Dog’ in noisy area
Test Input Data	Pronounce the word ‘Dog’ from a noisy area
Expected Output	Text form of the spoken word ‘Dog’
Actual Output	Printed the word ‘Dog’

Table 2-11: Recognition of Word 'Cup'

Test Case ID	**3**
Test Case Name	Identify the unknown word
Test Input Data	Pronounce ‘Cup’ that is not in the selected words list
Expected Output	Label the word as ‘Unknown’
Actual Output	Printed the word ‘Up’

Attentiveness Tracker

Table 2-12: Detect frontal face from an image

Test Case ID	**1**
Test Case Name	Detect frontal face from an image.
Test Input Data	Test image with a person facing the camera.
Expected Output	Blue frame around face area
Actual Output	Blue frame around face area.

Table 2-13: Detect frontal face from a video source

Test Case ID	**2**
Test Case Name	Detect frontal face from a video source
Test Input Data	Web camera video stream with a person facing the camera.
Expected Output	Blue frame around face area.
Actual Output	Blue frame around face area in the video stream.

Table 2-14: Test Case Name Detect emotion in frontal face from an image.

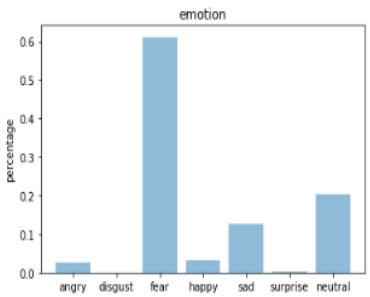
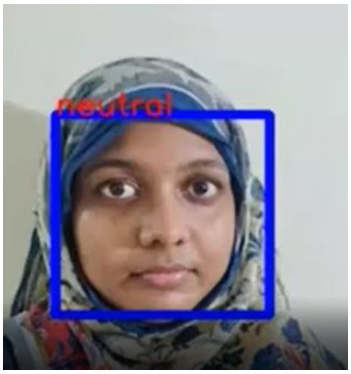
Test Case ID	**3**
Test Case Name	Detect emotion in frontal face from an image.
Test Input Data	Test image with a person facing the camera.
Expected Output	Emotion percentage.
Actual Output	 

Table 2-15: Detect emotion in frontal face from a video source.

Test Case ID	4
Test Case Name	Detect emotion in frontal face from a video source.
Test Input Data	Web camera video stream with a person facing the camera.
Expected Output	Face marked with blue frame and emotion in red tag
Actual Output	

2.6. Commercialization Aspects of the Product

Students with autism are visually oriented. Therefore, technology offers a wide variety of possibilities for teachers and educators to teach autism to students easily. There are very few systems that perceive the pre-writing activities, math activities and verbal training with attentiveness tracker. Among them, none of the systems has been developed so far based on Smart Mirror based teaching with a unity game. In this way, the system proposed above will make it easier for students with autism to teach pre-writing with the help of modern technology and monitor the progress of learning activities.

There are different type of robots, mobile applications and softwares available in the market for autistic student's education. Most of it teaches social skills and writing activities only. But there are no possible products to monitor the skills progress of autistic students or their intellectual distractions.

As a result of such situations, there is a need for a complementary system to address these for the current market. As a solution to this our proposed system introduces an innovative approach to teach autistic students. It provides a complete pre-education system for

autistic students and diverts their attention back to learning by observing their distractions and offering appropriate games.

In the current market, Search for this kind of product is high among autism student's parents, teachers and educators. Through this, the opportunities to create a brand for our product in the Sri Lankan markets are high.

3. RESULTS & DISCUSSION

3.1. Results

Writing Mentor

Real data was collected from the autism students and the given data samples were processed through each module respectively as per the proposed system procedure mentioned above. The following Figure 3-1 shows some of the shapes used for the testing and the Figure 3-2 shows the results after testing them using the proposed CNN model.

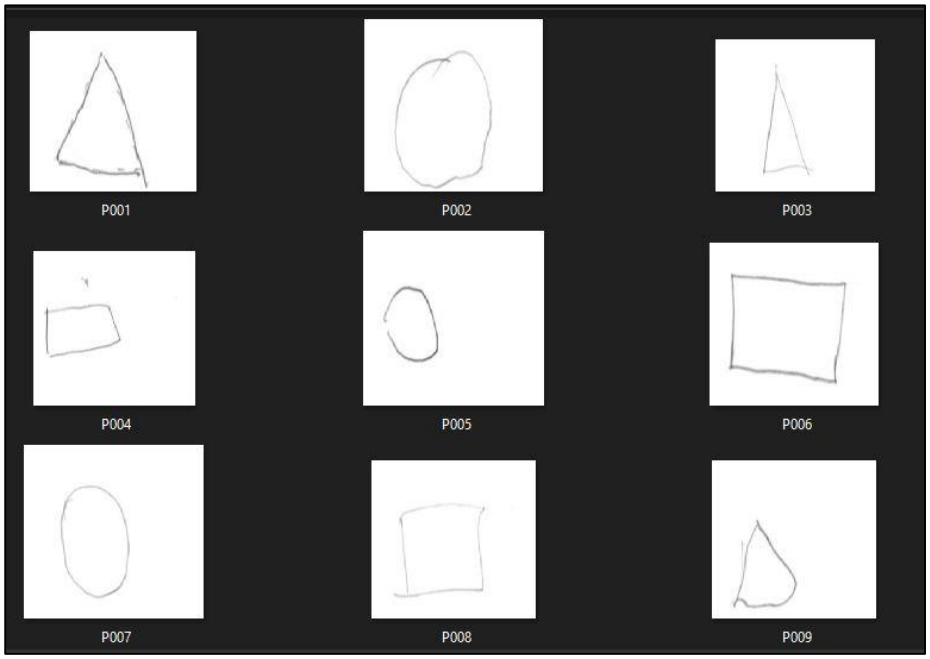


Figure 3-1: Shapes use for testing

```
[104] pred_dict

{'P001.jpg': 'Triangle',
 'P002.jpg': 'Circle',
 'P003.jpg': 'Triangle',
 'P004.jpg': 'Rectangle',
 'P005.jpg': 'Circle',
 'P006.jpg': 'Rectangle',
 'P007.jpg': 'Circle',
 'P008.jpg': 'Rectangle',
 'P009.jpg': 'Triangle'}
```

Figure 3-2: Results for tested shapes

Following in Table II shows the rates of testing done with sample images of handwritten shape in the model.

Table 3-1: Test rates of Writing Mentor subsystems' shape recognition CNN model

Shapes	Success Rate (%)	No Of Test Run Images
HorizontalLine	100	10
Vertical Line	100	10
Left Angle Line	100	10
Right Angle Line	100	10
PerpendicularLine	90	10
Intersecting Line	90	10
3 Parallel Line	70	10
4 Parallel Line	70	10
Quarter Circle	90	10
Half Circle	100	10
3 Quarter Circle	90	10
Z Curve	70	10
Curve 1	80	10
Curve 2	80	10
Curve 3	80	10
Curve 4	80	10
Circle	90	10
Square	100	10
Rectangle	90	10
Triangle	90	10
Oval	80	10
Moon	60	10

The model testing returned an output accuracy of 88% to 92% which is an ideal test prediction of the writing mentor component. Writing mentor predicts all types of shapes fed into the system and evaluates accordingly.

Math Tutor

The math mentor game is designed to teach math for the autism students. In order to do that the system, have to identify their handwritten numbers in real time. It must able predict any number even when it written slightly, upside down and more. Below table and the image shows the test result of the CNN model developed for Math mentor.

Table 3-2: Math Tutor test rates

Numbers	Accuracy rate	No of test runs
1	100	7
2	80	7
3	60	7
4	80	7
5	100	7
6	100	7
7	100	7
8	100	7
9	100	7

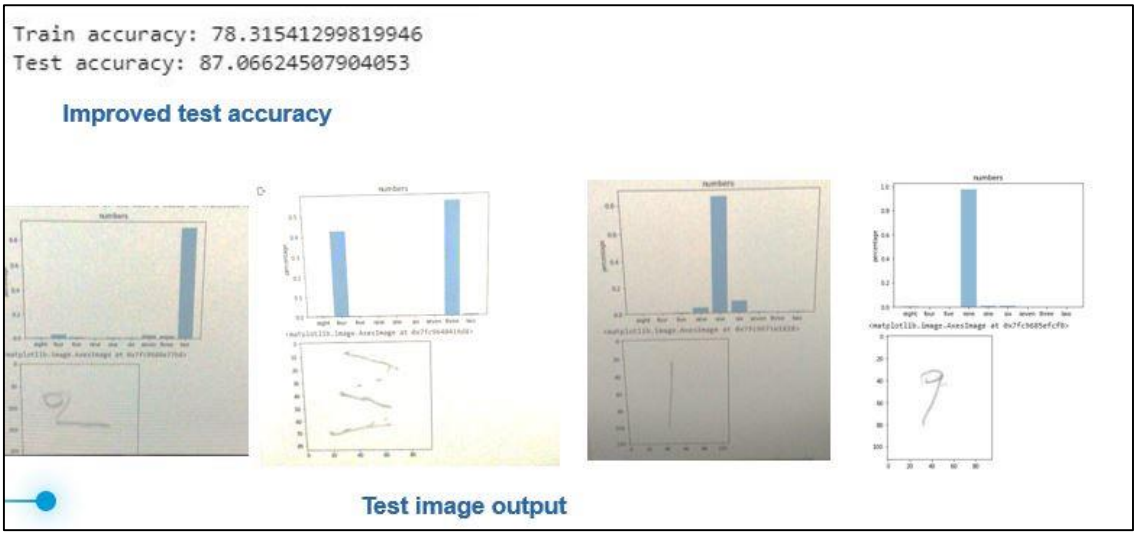


Figure 3-3: Accuracy of Math Tutor model

The developed CNN model able to achieve an accuracy rate of 86% and it can predict any number between 0-9.

Verbal Trainer

The verbal trainer component has a speech command recognition to detect the word spoken by the kid along with the game. To classify the word according to a preexisting word, an attention model with RNN has been used with data augmentation to increase its noise robustness. The model has achieved a test accuracy rate of 94%.

```
Evaluation scores:
Metrics: ['loss', 'sparse_categorical_accuracy']
Train: [0.05770860239863396, 0.9866088032722473]
Validation: [0.2226995974779129, 0.9476487040519714]
Test: [0.2320713847875595, 0.941844642162323]
```

Figure 3-4: Evaluation scores of model

Figure 3-5 shows the confusion matrix of predicted labels.

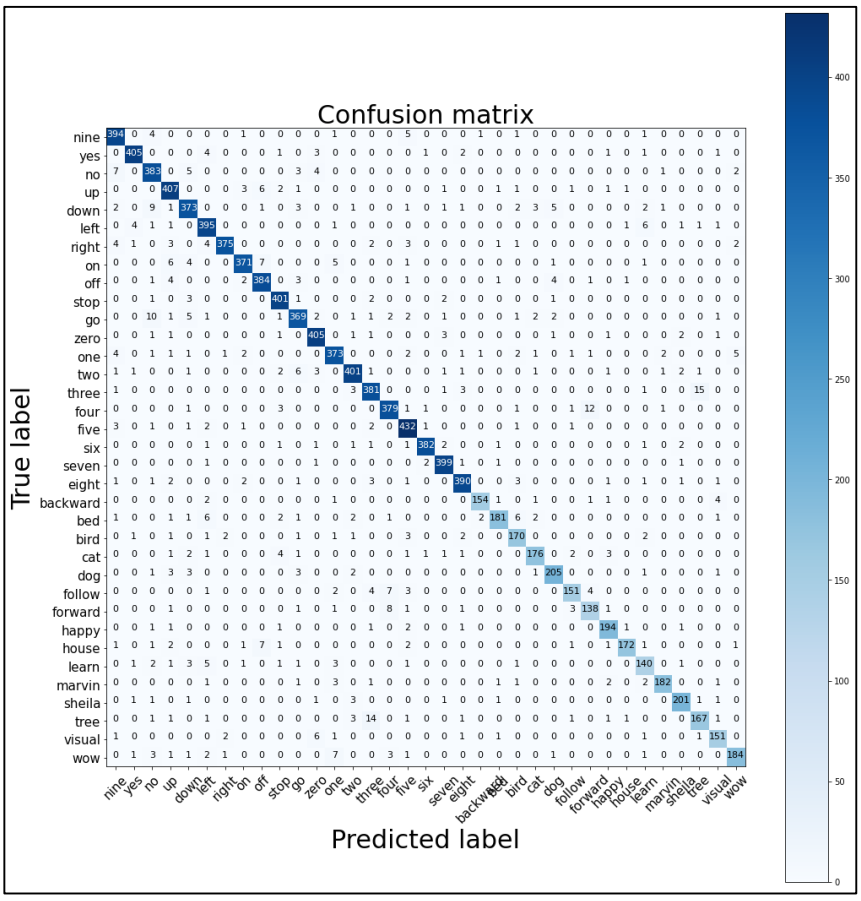


Figure 3-5: Confusion matrix of the model

Attentiveness Tracker

The Attentiveness tracker component is designed to detect emotions of the users. The model accurately detects the face with different poses (straight, side view). It also detects emotions when accessories are worn (spectacles, jewels, scarfs). Supports emotion recognition under various lighting conditions. Below is the output of emotions recognized with a simple video stream given as an input to the system.

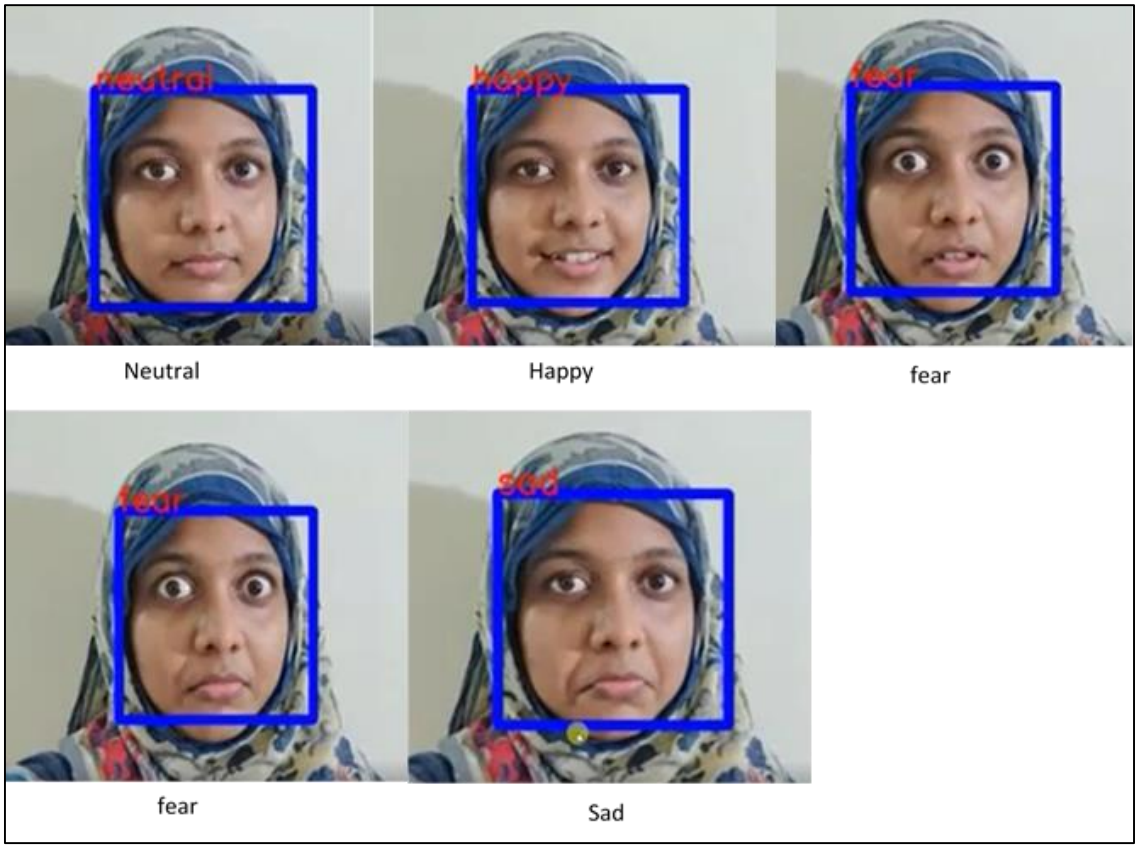


Figure 3-6: Output images of a test video stream

After Testing the Attentiveness Tracker detected facial emotions in different lights and positions with achieving overall accuracy of 88%, and with validation accuracy of 80%. The test results are according to Table 3-3.

Table 3-3: Attentiveness tracker test rates

Emotions	Success Rate (%)
Happy	87.50
Surprise	75
Angry	75
Sad	87.50
Fear	62.50
Disgust	62.50
Neutral	100

3.2. Research Findings Discussion

Writing Mentor

Students with autism are visually oriented. Therefore, technology offers a wide variety of possibilities for teachers and educators to teach autism to students easily. There are very few systems that perceive the recognition and classification of pre-writing shapes such as lines, curves, circle, square, rectangle and triangle shapes. Among them, none of the systems have been developed so far based on Smart Mirror based teaching with a unity game. In this way, the system proposed above will make it easier for students with autism to teach pre-writing with the help of modern technology and monitor the progress of learning activities.

In order to teach the best pre-writing activities in this research, the pre-writing activities were explored by going directly to one of the schools of students with autism. As well as, the researcher was consulting with a specialist educator for students with autism. Finally, a teaching approach to drawing pre-written shapes by combining dots for this research was chosen. This kind of pre-writing teaching approach was implemented by a game-assisted Writing Mentor sub-system created using the Unity Game Development engine.

The pre-writing improvement evaluation process of autistic students using this Writing Mentor system was carried out through a technique called Convolutional Neural Network

(CNN) of Deep Learning. To create this CNN model, data were collected from autistic students. During this, many realistic problems had to be faced, the number of autism students between the ages of 4 and 12 in Sri Lanka is low. Also due to COVID 19, the environment was created where data collection should be taken only in Jaffna district. Thus the number of data obtained from autism students was low. Due to this, the accuracy of recognition and classification of pre-writing shapes was obtained less. Data augmentation technique was used in this study as a solution to address this shortcoming. The collected data through the data augmentation technique were multiplied and used in the shapes recognition and classification model training.

The main objective of the research is the recognition and classification of pre-writing shapes and improving pre-writing skills among autism students. So, the recognition and classification of the pre-writing shapes have been tested under different drawn shapes. Initially, the writing mentor was trained with 1000 data samples using the seven-layer CNN model, TensorFlow and Keras libraries. Even though the accuracy was up to 80%. The CNN models' libraries were changed from TensorFlow and Keras library to torch library, the number of layers was increased up to eleven-layers, data samples increased by data augmentation which resulted in a better and faster model with 90% accuracy.

Math Tutor

Autism is a lifelong non curable issue face, some people managed to get through this and able to live individually but there are still people out there who are suffering to lead a successful and meaningful life. At first in my opinion early diagnosis and paying more attention towards the ASD child can improve their life much better. According to a survey a World Health Organization 1 in every 160 children is identified with autism. These stats show the importance we have pay towards autism.

Before starting something, we have built it up from the beginning, In this case we have pay much more attention towards autism education. Improvement in their autism education can lead them to a life with full of opportunities. Technology adaption will be better solution for these autism schools to make huge impact in their teaching methods.

In order to do that ALIZA smart has been developed under the guidelines from some schools in Jaffna and Colombo. There is no such system to teach ASD children using a

smart mirror concept. The sub system math mentor consists of the same teaching method that is been followed by the teachers in autism schools. So, we came up with some games developed using unity 2D. These games include counting, identification and writing activities.

For evaluation and number identification a Convolutional neural network model is used to make it easier for the system to function real time. The data collected from the autism schools in Jaffna used to train this model. Due to the Covid-19 situation it was impossible to collect more data. Even though using data augmentation and multiple layer CNN model we were able to achieve an 86% percentage of accuracy. With these simple methods of teaching an ASD student will be able to identify, read and write numbers from 0-10 which will be a huge achievement for our research.

Verbal Trainer

There are existing researches which has tried to implement games with speech recognition system. Those systems have used existing technologies such as SPHINX4 and Microsoft speech technology which is built for adult speech and not specific to the autism kids which is a drawback to the system. According to the literature review, they have used some advanced technique to obtain the accuracy and overcome the data scarcity for autism speech. All these techniques are implemented for long speeches which can cause to high computational time and less accuracy than the command classifying approach.

In this system, the backend of the game is approached as command recognition which will classify the correct label of word which can add more accuracy in identifying the pronounced word. During the implementation, in the first phase, the audio signal was preprocessed and fed to the model for training. This model had four convolutional layers and used adam optimizer for the best results. Even though this model was able to achieve 56% of the test accuracy which is very low. Therefore, in the second phase after the preprocessing, the feature extraction step was added to the techniques. For the feature extraction, MFCC is used which is more human representative. Since MFCC is an image data, it is approached as image classification and used a Convolutional neural network with eight layers. This model has achieved a test accuracy of 70%. After further research on the context, an attention model using RNN[21] has achieved a significant accuracy of

94% which has given a better result while testing it with microphone input after deploying to flask server.This model starts by computation of mel spectrogram as non-trainable layer. Kapre library provides the facility to use mel spectrogram as layer.

In addition, according to an existing literature [22], Data augmentation technique was utilized to improve noise robustness. The dataset has already provided long audio clips of noises recorded from the environment and mathematically generated. These noise files were merged with the audio files to train the network to recognize the word even in a noisy environment. This technique helped to further enhance the accuracy of the model.

Attentiveness Tracker

There are variety of ASD applications existing in the current world, but those applications are focused on teaching the ASD children on how to recognize the human emotions, but none of these systems perceive the ASD students' emotions into count when teaching. Emotions play a vital role as ASD children cannot express their needs in a linguistic manner their emotions help tutors to figure if they are interested or bored. Many researches state how important emotions are and has used may advance technologies in recognizing them. One of which is recognizing emotions through video input streams. All previous research advancements are done for non-ASD people which is vastly different when comparing it to ASD children's emotions.

In this Attentiveness tracker system, the model recognizes the emotions based on the real-time video input and labels the emotions to the current activity. Initially the model was created using 5 convolutional layers, "RELU" activation and Adam as an optimizer which resulted in 93% model accuracy and 62% of test validation accuracy. Due to the poor state of detection the model was enhanced with 7 convolutional layers "eLU" activation and RMSprop optimizer. This enhancement further decreased the model accuracy to 63% and test validation of 53%.

This was mainly due to the imbalance of the categorized images of the dataset. Therefore, the model was improved to increase the data samples by data augmentation then normalized and gray scaled and send the resulting pre-processed data sent into a sequential stacks of layers consisting a mix of 8 convolutional layers, 3 dense layers, 4 max pooling totaled to 15 layers. Early stopping of model training and saving of model

was done when no improvement was shown within 9 epochs. This trained model contributed a satisfactory result of 88% of model accuracy and 80% of test accuracy. Yet the model optimizer was changed to RMSprop, and SGD, Adam optimizer resulted with the optimum solution when compared with the others.

4. SUMMARY OF EACH STUDENT CONTRIBUTION

G.Vishaliney – IT17421768

Writing Mentor:

- Collect pre-writing real-world data
- Create writing therapy animations and pictures.
- Create pre-writing activity game.
- Create CNN model for progress evaluation.
- Make progress report for autism children

Uthayan.J - IT17035040

Math Tutor:

- Collect written numbers data
- Create exercises for autistic children to identify numeric through animations and pictures.
- Create simple mathematic calculation exercises.
- Evaluate autism children's study levels by Deep Learning.
- Make study level report for autism children.

R.P.Lojini - IT17131216

Verbal Trainer:

- Collect voice data
- Convert voice input to text using speech recognition.
- Evaluate their verbal activity or reply back to their queries by analyzing using NLP.
- Convert back to voice along with visuals.
- Make study level report for autism children.

R.S.Najeeb - IT17137560

Attentiveness Tracker:

- Data Collection.
- Create prototype for facial reactions real time.
- Match the facial feature with the trained model of expressions.
- Create activities and play videos to keep them engaged.
- Create activities to train social ethics.

5. CONCLUSION

With the increase in autism children [23] there is a lack of resource to cater to the needs of all. Nevertheless, this research paper states how ‘Aliza’ smart mirror sets a new standard among the training and teaching methods. Therefore, this research holds training and teaching methods based on game activities which are helps to increase interest and focus of autism students and it accommodates basic education for age groups of three to ten aged children. This game device is built using all aspects of applied behavior analysis (ABA) teaching technique. This includes an emotion tracking system that will help to track concentration level of the activities of Autism students. Unlike other systems available in the global market, ‘Aliza’ is at an affordable cost which can be consumed by single or multiple users and educate students based on their emotions for a better understanding of the programs given. Smart concept is currently adapted in many industries and enormously increasing the use in daily household. Therefore, same concept is adapted for autism education for a better change.

To maintain the product more sustainable and reliable some future enhancement works have been outlined to be achieved. The feature enhancements are mainly focused on supporting local languages such as Sinhala and Tamil, then to develop a facial recognition system for login. Also teaching moral values, health exercises, and social skills activities are added as value added services. The future work planned is not only enhancing the market value of the product nonetheless to be an innovative solution to the users and to give autistic children a better experience in their journey of learning.

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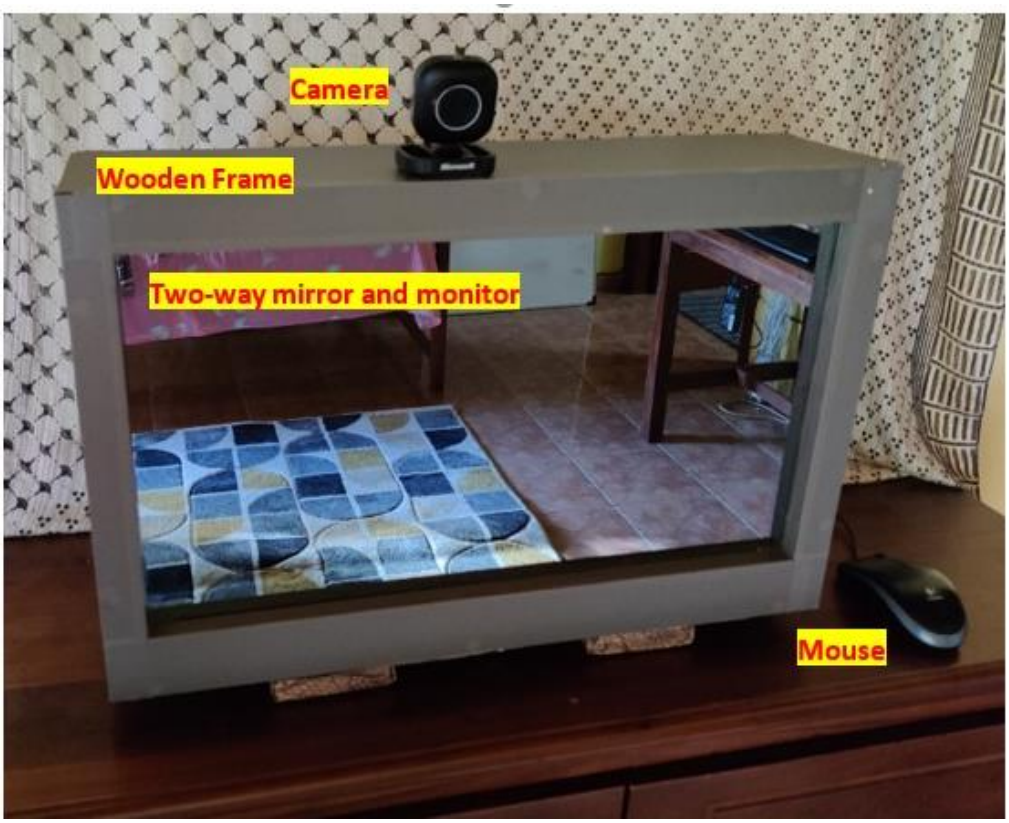
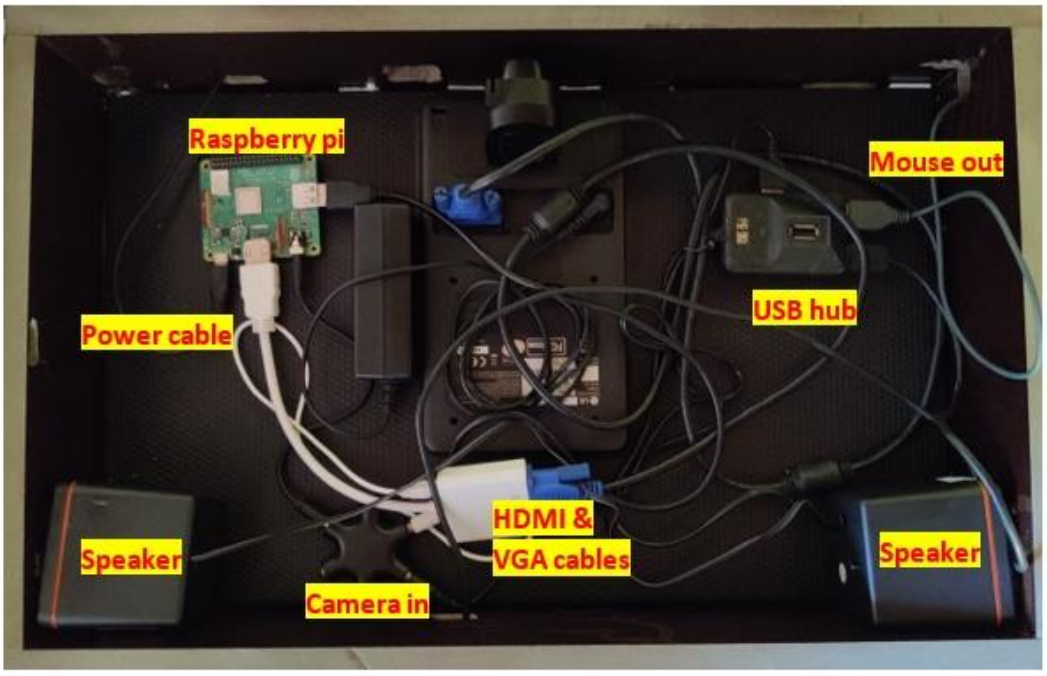
APPENDIX A: Aliza product



Aliza smart mirror front view



Aliza smart mirror back view