

ALIZA: SMART MIRROR AS AUTISTIC EDUCATION ASSISTANT

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

I declare that this is my 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 my 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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The above candidate has carried out research for the B.Sc. Dissertation under my supervision.

Signature of the supervisor:

.....

(Jesuthasan Alosius)

Date

.....

ABSTRACT

Aliza smart mirror is developed to make an impact in ASD child education. It has four major parts attentiveness tracker, verbal trainer, writing and math mentor. There are systems that already provide support in Autism education, it is only up to a standard level although they are not efficient and accurate. Math mentor is gamified system that provide activities for the students to improve their skills in math. This research is done with an objective of providing a system that can interact with the student and also function precise and efficient.

Convolutional neural network(CNN) converts the raw image into a 28*28 pixels image and tested with a trained model. The accuracy and the prediction value is taken into the consideration.

ACKNOWLEDMENT

I am grateful to our project supervisor Mr. Jesuthasan Alosius and our cosupervisor Ms. Anjalie Gamage, for their guidance and excellent support given for the project execution.

Also, I wish to express my respect to our project coordinator Dr. Janaka Wijekoon for his great support and encouragement.

Finally, my respect goes to our friends and parents, who helped me in many ways. Also, I would like to pay my gratitude for all the other personnel and individuals who supported to complete this project successfully.

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LIST OF ABBREVIATIONS

ASD	Autism spectrum disorder
CNN	Convolutional neural network

1. INTRODUCTION

1.1. Background Literature

Autism is disability that impact from the early childhood, it can also affect a person's social skills, verbal communication, bond with other people and self-realization. It is also defined as "spectrum disorder" by a set of behaviors that affects a normal people in different varies. According to a survey of world health organization one in 160 children is found with autism spectrum disorder [1]. While some people can live their life independently others needs long time care and support.

Early diagnosis can help an ASD children for a better support and services that they require, which can lead them to a quality life with lot of opportunities. Autism is not a boundary for people to achieve, legends like Bill Gates, Steve Jobs, Nikola Tesla have also found with autism[3], but they still managed to achieve something which we never had dreamed of.

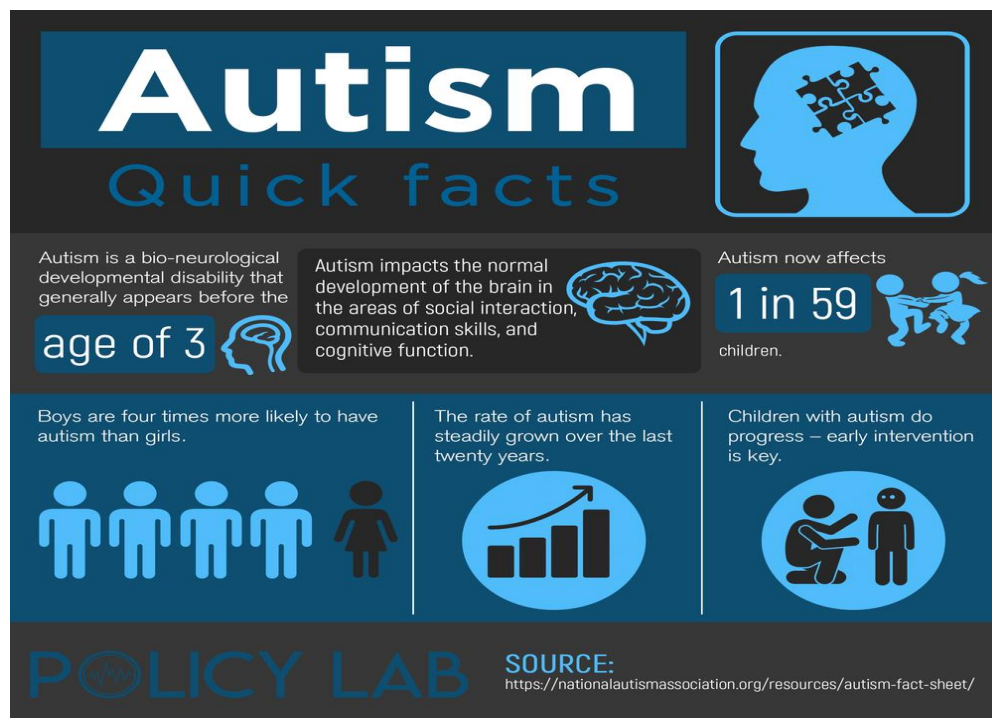


Figure 1.1 What is autism ?

Early signs of autism:

- Loss of speech, babbling or social skills.
- Avoiding eye contact
- Delayed language development
- Echolalia

Above mentioned are some early signs of autism.

In Sri Lankan autism schools do not have enough facilities or human resource to educate autism children. Autism students need more care and time when comparing to normal student. ASD kids need more time to process for an answer also it takes time for them to understand a simple question. Traditional method of teaching in the classrooms won't make much impact on their education.

There are some similar system to teach math for autism students. But these systems failed to reach their goal of reaching to the hand of every autism student.

Otsimo

Otsimo is an educational game application developed for children who need special education, the games in the application aims to improve children's speaking, reading and writing, communication and math skills.[2]

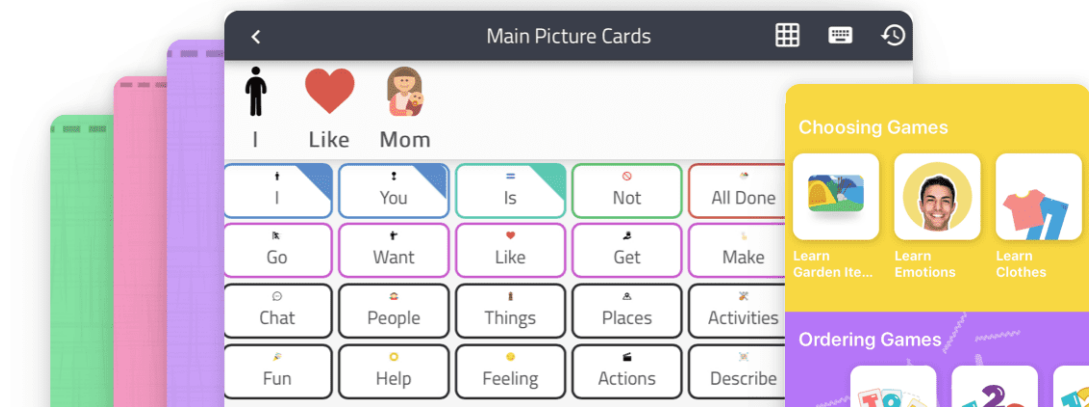


Figure 2 otsimo application activities

Otsimo provides reports and analyzes about the development of children in order parents to follow the educational process of their children and actively participate in this process while being a helpful resource for children's education.

It includes 60 plus games which helps children to learn reading and writing, mathematic , vocabulary and core skills. There are also AAC application that helps children with impairments to communicate with significant others.

Also, there are some several apps like basic math tutor, first then visual schedule, choice works calendar to learn numbers for the ASD students. Moreover, these applications are commonly used by everyone, they are cheap and user-friendly applications.

Away from that there are some researches on how to teach math to autism children. From all those researches the conclusion is to use visual objects rather than talking, step by step approach, play games, abacus.

With a complete research of background study, it has been identified that there is no implemented solution for this problem. “Aliza” smart mirror fills all these gaps using a different methodology and approach on autism education.

1.2. Research Gap

Nowadays everything is automated technology have conquered manpower. In education also we have come up with some automated solution. We don’t need lecturers, teachers to learn these days instead of that we are using robots or AI for that. So, when we consider special education those children need special care and attention.

Using a manual teaching model won’t help them improve. With lack of sources special education schools can’t pay special attention to each student. So, using IOT devices or an AI system is the best way. When we consider this there are some mobile application like Otsimo, match and find that teach basic mathematics for autism children. But those don’t have a pre-evaluation to find the level of the student. They treat everyone in the same way. Even Otsimo provide an analytical report consumer have to pay 14\$ every month for its premium package.







Product	Math activities	Pre evaluation	Level up	Type	Cost
Aliza	yes			Smart mirror	Moderate
Otsimo	yes			Mobile application	Cheap
Other application	yes			Mobile application	Cheap

Table 1.2.1 Comparison of similar products

The smart mirror concept which is proposed have a pre evaluation plan that will calculate the level of the user. Level ups when it identifies develop in the student. Always keep track of the attentiveness and keep them focused on the session.

1.3. Research Problem

Nowadays autism is considered as a serious issue. In a report from the world health organization says that 1 in 160 children is identified with autism spectrum disorder. These do not easily socialize with other people, lack in communication and social skills. Some of them are managed to lead an independent life, but most of them need care and attention more than anyone else.

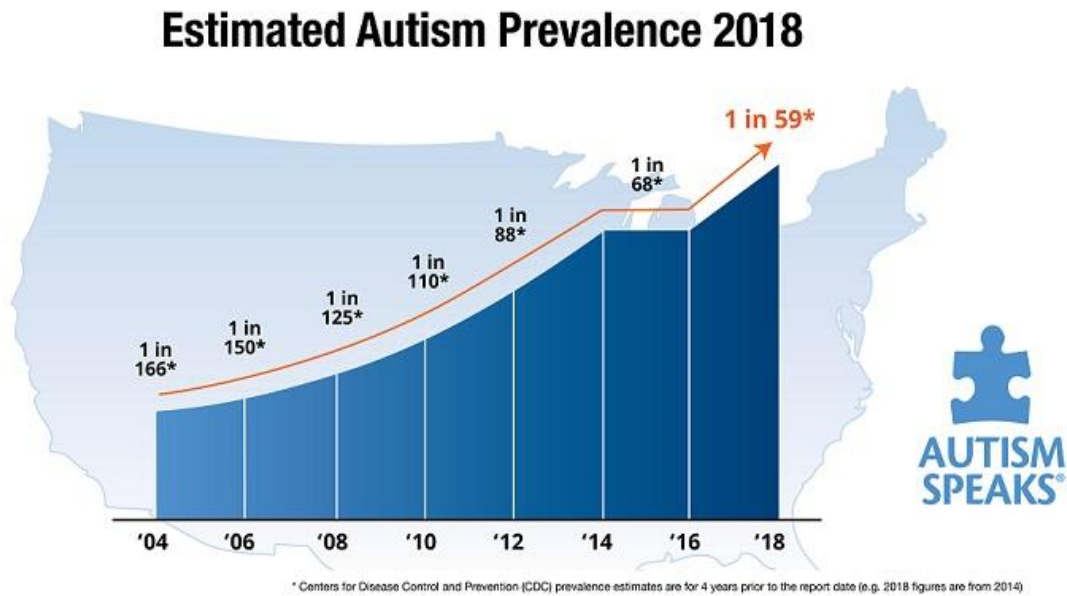


Figure 3 The estimated increase of autism

ASD person will have a special area that they can perform extremely well. For example, achievers like Nikola Tesla, Steve Jobs, Albert Einstein are found with autism. But they have achieved something impossible. All they need is an early diagnosis and a perfect guidance which can lead them to successful life.

In Sri Lanka autism is not considered as a serious issue but 1 in 93 children is found with autism. Autism schools do not meet the standards to teach the autism children. ASD child are having problem in identifying simple math symbols that is why they need a human support to do their basic activities. It is impossible for a teacher to consider every student and help them individually. Moreover, ASD children avoid interacting with people, most of the time they wanted to be alone. There are some existing application that provide math learning for autism kids but they don't meet the user requirements.

A child's brain development begins in the adolescent age. Approximately at the age of 5 experts says that 85% of the brain development has occurred [7]. Thus, advancement of the technology can be used for the math learning. Numerous numbers of apps and robot were introduced to facilitate such numeric learning. Even though there are ample of study material the parents of these kids prefer manual learning processes and method due to unavailability of understanding users' levels, and expensive to afford. (The milo robot costs 5000\$ = 1,000,000LKR)

Addressing this issue this study plans to build an innovative IOT device, a smart mirror. This study purpose of "Aliza" is to give ASD children an affordable cost of therapy and learn math in an organized way that is easy and fun with animations

1.4. Research Objectives

Implementing a smart mirror to make use for special education to autism children. Education playing a major role in everyone's life but when we consider an autism child this will be the beginning to his social life. School is the only place where autism children get to familiarize with others. It's being too difficult for ASD student to learn basic lessons. We are implementing a mirror that can make a change in the way of educating an ASD student. Moreover, it will be more user friendly, so the student doesn't need to have a support of others while they are using the smart mirror. By using this mirror the student will develop his communication, social skills, memory power and improvement in their IQ levels.

1.4.1 Specific objectives

Specific objectives of math mentor in ALIZA smart mirror are as follows:

An ASD student should -

- Able to count numbers from 1 to 10.
Autistic students have a difficulty in remembering. It's a big achievement if they can count numbers until 8. But our target it's to make them count until 10. We are going to achieve this by giving them different activities using animations. There is also a voice assistance that will always guide the student to do the correct thing. The system will make the activities harder when finding an improvement in the student.
- Identify numbers from 1 to 10.
The system Aliza is developed with touch screen, so we have activities like connecting the dots, or matching numbers with quantity and more. By giving these activities again and again at the end student will have a knowledge to connect or match the given numbers.
- Write numbers

- Improving IQ level.

At the beginning we will evaluate the student's IQ level and give them basic activities according to that, after onwards when they complete each and every level we will compare their improvement with a normal student and continue the session according to that as a result the ASD child's IQ level will rise.

Requirements

6.1 Functional Requirements

- The user will be able to create individual account for each of them
- Students will be given activities to improve their math knowledge
- The answers from the students have to be evaluated real time
- Important data from the students have to be stored in the database

6.2 Non-Functional Requirements

- Usability
- ASD students are with lack of motor skills also have to be able this system without any others help. Everyone actions have to be easier so that even a student with low IQ level will be able to use the system easily.
- Affordability

The price of the system have to be lesser so that middle class people who is in need for this will be able to buy and install it in their home.

- Entertainable

If we consider a normal student they can't even sit in a place and study for too long so we can't expect a ASD to child to do the activities with full

concentration. So the activities should not bore the student. It have to more fun with animations so the student wont lose their attention on the session.

- Security

ASD students faces, personal details and other data must be more secured. They have to maintained confidentially. Even their parents hesitate to share their details.

2. METHODOLOGY

2.1. Methodology

To develop the system, I followed agile software development procedure as it allows to continuously engage with the team members and have discussions that will allow to make changes rapidly. Research projects often have rapid changes it will be difficult for a team to follow a sequence of order. Agile method allows for a much more flexible than the traditional method.

Aliza is been developed considering all the aspects of autism education with a help from an autism school in Borella. Aliza has four major components which are verbal trainer, attentiveness tracker, writing mentor and math mentor. When its comes to education I think math plays a major role in our day to day life. so it is important to learn math in early stage life. with the consideration of autism kids the math mentor have been developed as game which the student can play without any human interactions, it is also very easy to use.

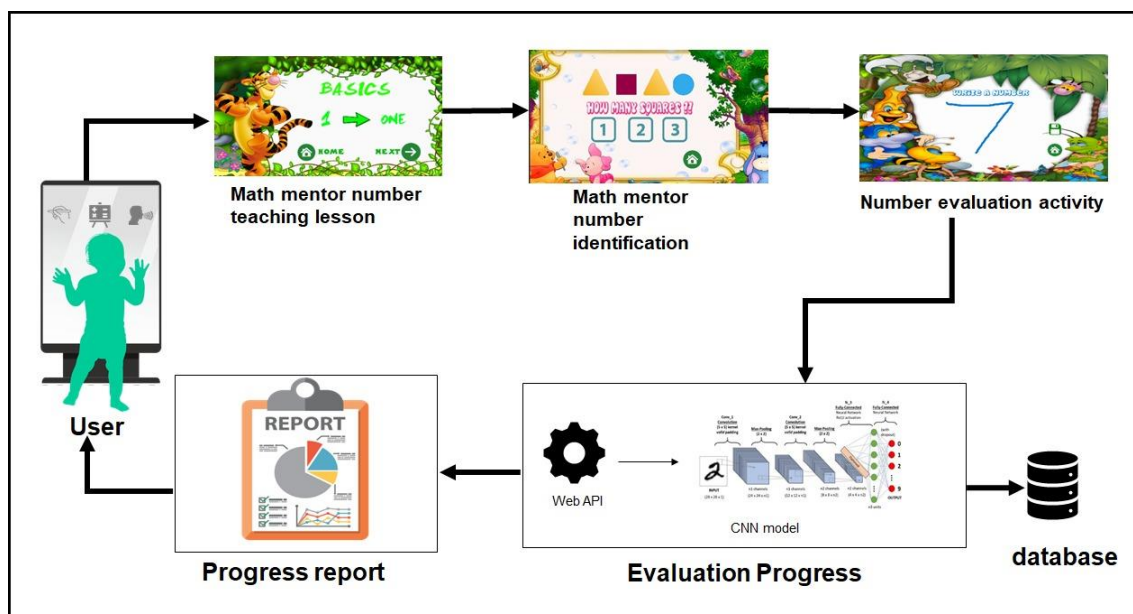


Figure 4 systeml diagram of math mentor

2.2. Data set collection and pre-processing

Due to covid 19 pandemic situation all the autism schools are been closed so we couldn't able to collect the targeted data. Although for this study I was able to gather sample data from randomly selected 80 ASD students in the age group between 5 to 12 from 4 different autism school in Jaffna district. The data was collected through their usual routine lessons using a document which the students must write the given number. These collected data will be kept confidential and secure due to the wish from the schools and their parents in the concern of the students. Some other public data like Mnist are also used to train the Convolutional neural network model.

5. Drawing number

1	1
2	2
3	3

Figure 2.1 Data collection

Initially after the data is collected the single number images have been cropped and stored in separate files with their label on it. Afterwards these files have to be uploaded to the google drive to be used in google Colab. In the CNN model the data will be imported from the google drive and classified into 9 classes and set to 48,48 rows and columns. Also data augmentation such as rescale, rotation, shear range, zoom, width shift, height shift, horizontal flip and filling have been used to increase the trainable and testable parameters.

```
train_datagen = ImageDataGenerator(  
    rescale=1./255,  
    rotation_range=30,  
    shear_range=0.3,  
    zoom_range=0.3,  
    width_shift_range=0.4,  
    height_shift_range=0.4,  
    horizontal_flip=True,  
    fill_mode='nearest'
```

Figure 5 data augmentation

At last 3906 images have been allocated for training the model and 317 images to model testing.

2.3. Game development

Unity 2D is used to develop the game with animations, music and images to make the user pay more attention towards interacting with the system. It is built inside a magic mirror module in Linux environment. Aliza has four major gaming activities math mentor, writing mentor, attentiveness tracking games and verbal training. Each user will have a specific login credentials.

As an initial stage of math mentor, the game begins with an intro game which is really a basic one that displays the number, text format and audio of the number. By repeating this activity, the user will be able to identify and understand the number from 1 to 10. User can be able to count the number.



Table 2.2 intro game

Second game is counting, it has 3 levels easy medium and hard.



In this stage the ASD student will have a basic knowledge of numbers, so the student must count the objects on the screen and choose the correct number from the given

answers. Counting game has three levels easy, medium, and hard. In the level easy the system will indicate the correct answer in green color and wrong answers in red so the user can differentiate them with the colors, also the user must count single object. For example, if the object is an apple only that will be displayed in the screen, so the user won't face difficulty in differentiating between the objects. In the level medium the user must count a particular object which means not only counting they have to differentiate between the shapes. In the hard level no hints will be given.



Figure 6 Counting games in ALIZA

Next game is identifying, in this stage a sequence of four numbers will be displayed the user have to count the numbers in the correct sequence and find the missing number, then choose the correct answer given below.



Figure 7 identification of numbers game

As a final stage, the user must write numbers on a blank screen, in real time this number will be saved as an image and will be evaluated using a CNN algorithm. ASD student handwriting is way more different than a Non ASD student so the system can't simple predict and classify the number, so a self-learning deep learning is used to classify the written numbers.

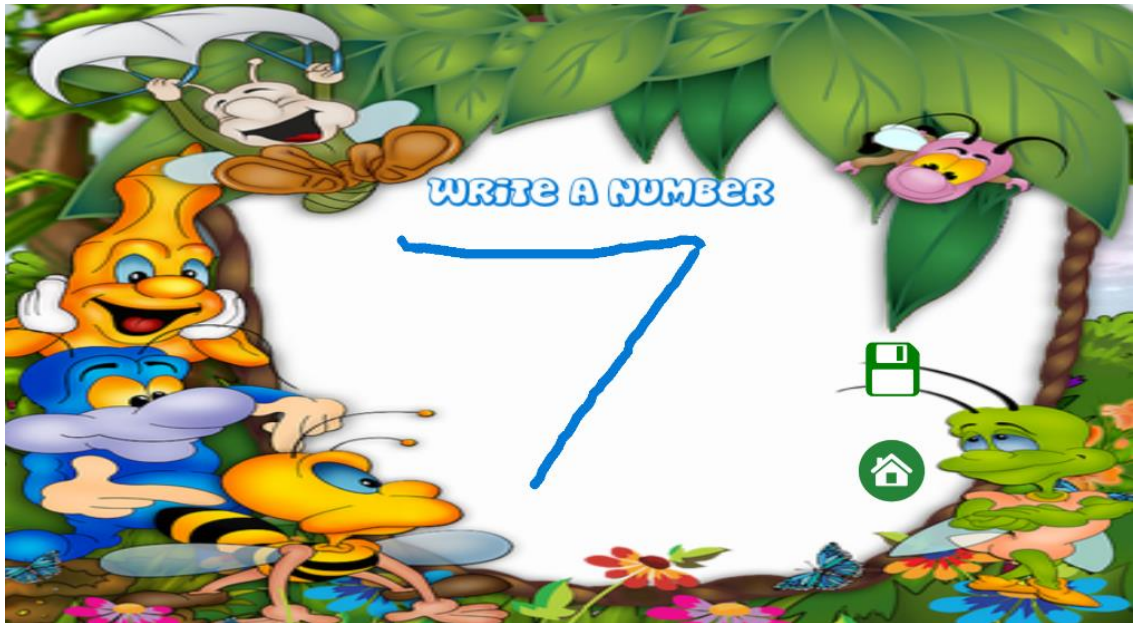


Figure 8 Number writing game in ALIZA

2.4. CNN layers

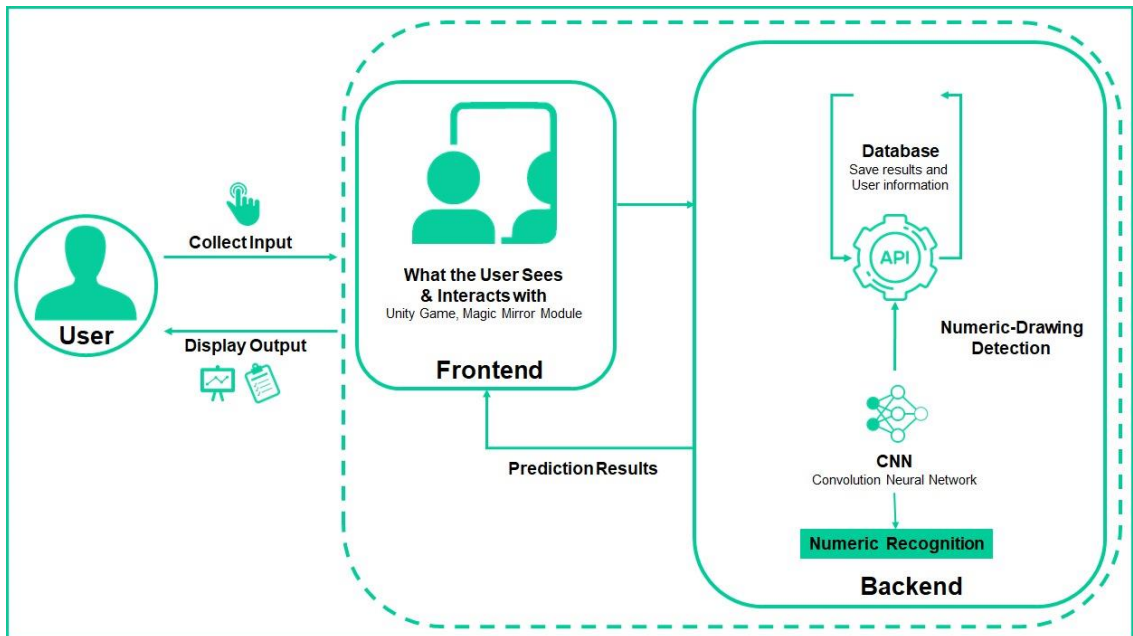
To improve the accuracy of training and testing 15 layers such as flatten, dense, activation, conv2D, maxpooling2D, Batch normalization are used. Batch size set to 32 it controls the number of training samples to work through before the model's internal parameters are updated.

In order to avoid dying neurons problem ELU activation is used. When compared with other linear non saturating activation function ELU leads to faster training times also the gradient of ELU is non-zero for all negatives.

Max pooling is used to help over-fitting by providing an abstracted form of the representations. Also it reduces the computational cost by reducing the number of

parameters to learn and provides basic translation invariance to the internal representation.

2.5. High level architecture

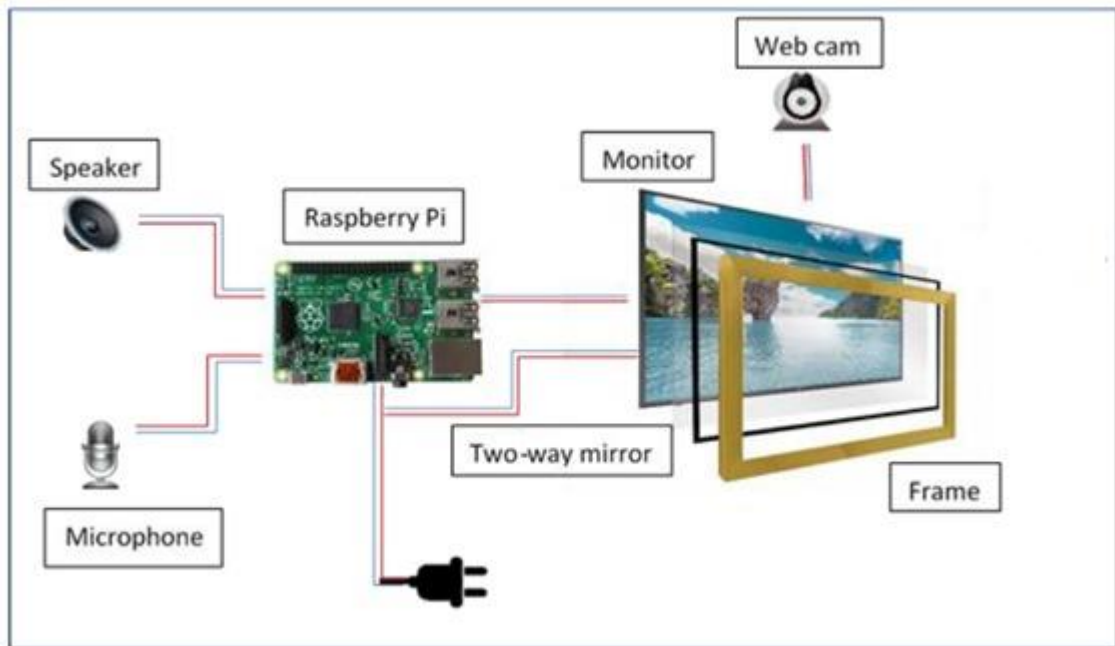


The user gets to interact with the system using the smart mirror. Once the user gets to the writing activity an API is called to run the CNN model using flask deployment method. At the end of the process results is sent to be stored in the database in meanwhile a report will be given to the user to calculate and analyze their progress.

2.6. Hardware components of ALIZA

A LED monitor is used to display the game, A two way mirror will cover the screen with a thickness of 0.2 and reflection of 75%. So the ASD kids can see their faces in the mirror it will feel like interacting with their self. A wooden frame will cover the entire

system. it includes a micro phone, speaker, raspberry pi and a camera in top of the screen. A mouse and is connected to the raspberry pi for the user to interact with the system.



Ubuntu 64bit OS is installed in the raspberry pi to run the magic mirror module. Aliza is installed inside the magic mirror module as a sub system. so the user can play it as a game.

2.7. Commercialization Aspects of the Product

The commercial value of the proposed solution is increased through below mentioned information:

- The system accommodates many users through one mirror which can be used in schools and homes as well.
- The system provides parents with the facility to easier way to track their child's progress

- Since the system is wall mounted smart mirror therefore easy to use and attracts many users.
- The system provides the facility to swap game activities by user as per their convenience.

Especially this smart mirror has a user friendly voice assistant. In case if a student can't use their hands to interact with the system this voice assistant will be helpful for them through out all the activities.

2.8. Testing and Implementation

2.8.1 Implementation

Mainly there is 2 python classes to run this model

- Testing_model.py
- Training_model.py

Training_model.py includes Training and validation models. Training has 3906 images that can be used to train the model and 317 images been used to train the validation model.

Layer (type)	Output Shape	Param #
conv2d_16 (Conv2D)	(None, 48, 48, 32)	320
activation_22 (Activation)	(None, 48, 48, 32)	0
batch_normalization_20 (Batch Normalization)	(None, 48, 48, 32)	128
conv2d_17 (Conv2D)	(None, 48, 48, 32)	9248
activation_23 (Activation)	(None, 48, 48, 32)	0
batch_normalization_21 (Batch Normalization)	(None, 48, 48, 32)	128
max_pooling2d_8 (MaxPooling2D)	(None, 24, 24, 32)	0
dropout_12 (Dropout)	(None, 24, 24, 32)	0
conv2d_18 (Conv2D)	(None, 24, 24, 64)	18496
activation_24 (Activation)	(None, 24, 24, 64)	0
batch_normalization_22 (Batch Normalization)	(None, 24, 24, 64)	256
conv2d_19 (Conv2D)	(None, 24, 24, 64)	36928
activation_25 (Activation)	(None, 24, 24, 64)	0
batch_normalization_23 (Batch Normalization)	(None, 24, 24, 64)	256
max_pooling2d_9 (MaxPooling2D)	(None, 12, 12, 64)	0
dropout_13 (Dropout)	(None, 12, 12, 64)	0

Figure 9 CNN model layer

Once the image is uploaded for testing, in the testing_model.py the data will be resized to 48 * 48 size image and converted into gray scale, then it will be set to an array and push into a number analysis. Then the evaluated the results will be sent to the user.

```

x = image.img_to_array(img)
x = np.expand_dims(x, axis = 0)

x /= 255

custom = model.predict(x)
number_analysis(custom[0])

x = np.array(x, 'float32')
x = x.reshape([48,48]);


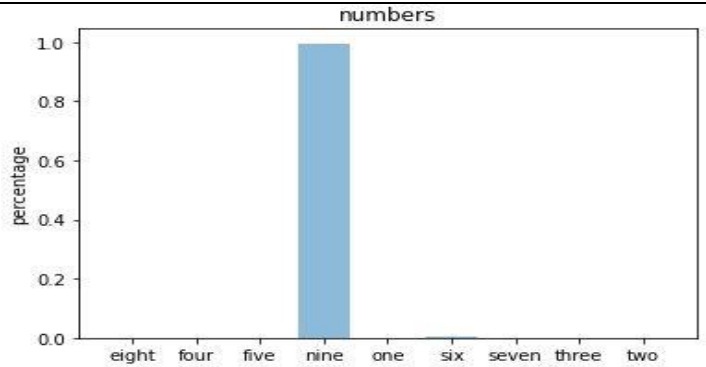
```


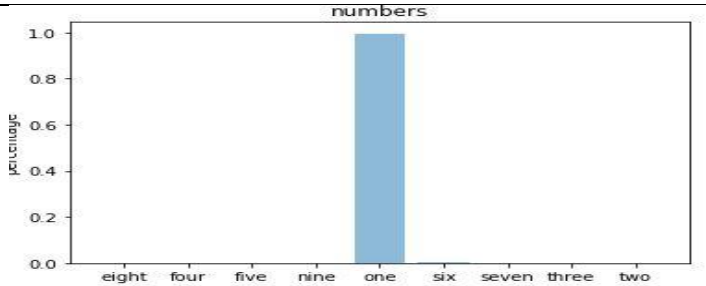
2.8.2 Testing

Testing is important since it discover the bugs and defects before the product is delivered to the customer or end-user. This makes the system more reliable and easier to use. In the case of ALIZA each and component math mentor, writing mentor, verbal trainer and attentiveness tracker are been tested individually before integrating. Especially math mentor is been tested under unit testing and integration testing. The below components show the test that run over math mentor and founded bugs are been fixed and integrated with other components.

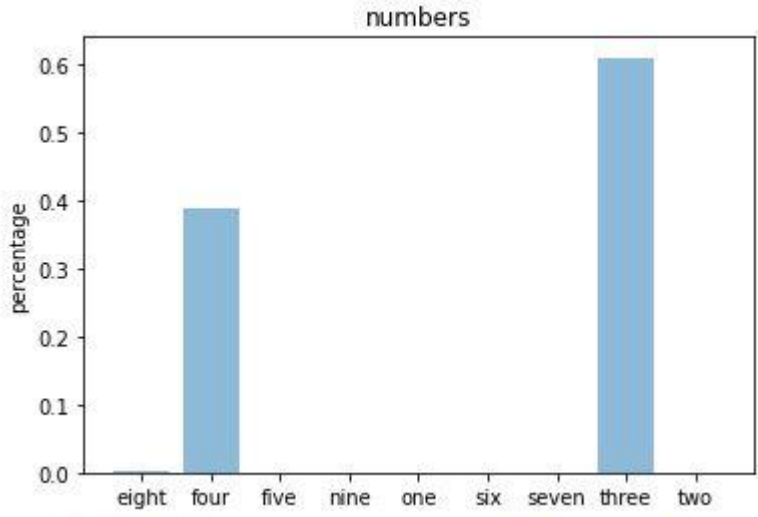
Unit testing

Unit testing is carried out to test individual units or components of a software. It is white box testing methodology normally performed automatically. Every component in Aliza have gone through this testing to make sure it meets the functionality. Below details are some test cases of math mentor.

Test case	01																				
Input data																					
Expected output	Correct prediction of number nine																				
Actual output	 <table border="1"> <caption>Actual output data for Test case 01</caption> <thead> <tr> <th>Number</th> <th>Percentage</th> </tr> </thead> <tbody> <tr><td>eight</td><td>0.0</td></tr> <tr><td>four</td><td>0.0</td></tr> <tr><td>five</td><td>0.0</td></tr> <tr><td>nine</td><td>1.0</td></tr> <tr><td>one</td><td>0.01</td></tr> <tr><td>six</td><td>0.0</td></tr> <tr><td>seven</td><td>0.0</td></tr> <tr><td>three</td><td>0.0</td></tr> <tr><td>two</td><td>0.0</td></tr> </tbody> </table>	Number	Percentage	eight	0.0	four	0.0	five	0.0	nine	1.0	one	0.01	six	0.0	seven	0.0	three	0.0	two	0.0
Number	Percentage																				
eight	0.0																				
four	0.0																				
five	0.0																				
nine	1.0																				
one	0.01																				
six	0.0																				
seven	0.0																				
three	0.0																				
two	0.0																				

Test case	02																				
Input data																					
Expected output	Correct prediction of number one																				
Actual output	 <table border="1"> <caption>Actual output data for Test case 02</caption> <thead> <tr> <th>Number</th> <th>Percentage</th> </tr> </thead> <tbody> <tr><td>eight</td><td>0.0</td></tr> <tr><td>four</td><td>0.0</td></tr> <tr><td>five</td><td>0.0</td></tr> <tr><td>nine</td><td>0.01</td></tr> <tr><td>one</td><td>1.0</td></tr> <tr><td>six</td><td>0.0</td></tr> <tr><td>seven</td><td>0.0</td></tr> <tr><td>three</td><td>0.0</td></tr> <tr><td>two</td><td>0.0</td></tr> </tbody> </table>	Number	Percentage	eight	0.0	four	0.0	five	0.0	nine	0.01	one	1.0	six	0.0	seven	0.0	three	0.0	two	0.0
Number	Percentage																				
eight	0.0																				
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nine	0.01																				
one	1.0																				
six	0.0																				
seven	0.0																				
three	0.0																				
two	0.0																				

Test case	03
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Input data	3																				
Expected output	Correct prediction of number three																				
Actual output	 <table border="1"> <caption>Data for 'numbers' bar chart</caption> <thead> <tr> <th>Number</th> <th>Percentage</th> </tr> </thead> <tbody> <tr><td>eight</td><td>0.0</td></tr> <tr><td>four</td><td>0.39</td></tr> <tr><td>five</td><td>0.0</td></tr> <tr><td>nine</td><td>0.0</td></tr> <tr><td>one</td><td>0.0</td></tr> <tr><td>six</td><td>0.0</td></tr> <tr><td>seven</td><td>0.0</td></tr> <tr><td>three</td><td>0.61</td></tr> <tr><td>two</td><td>0.0</td></tr> </tbody> </table>	Number	Percentage	eight	0.0	four	0.39	five	0.0	nine	0.0	one	0.0	six	0.0	seven	0.0	three	0.61	two	0.0
Number	Percentage																				
eight	0.0																				
four	0.39																				
five	0.0																				
nine	0.0																				
one	0.0																				
six	0.0																				
seven	0.0																				
three	0.61																				
two	0.0																				

Integration testing

This testing is to make sure that after the integration of all the other components the system works without any mal function. Sometimes integration brings some fault in the individual component integration testing ensure that even after integration the system runs without any interruption.

3. RESULTS & DISCUSSION

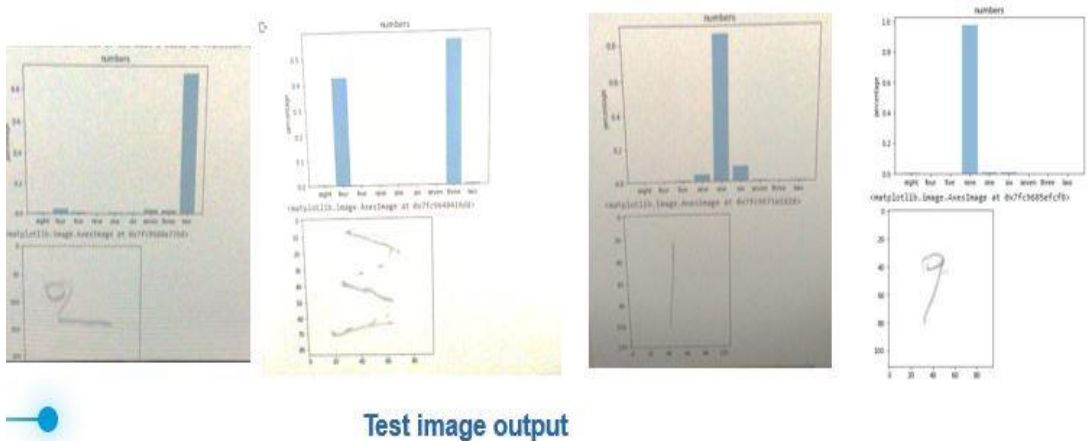
3.1. Results

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.

Numbers	Accuracy rate	No of test runs
01	100	7
02	80	7
03	60	7
04	80	7
05	100	7
06	100	7
07	100	7
08	100	7
09	100	7

Train accuracy: 78.31541299819946
Test accuracy: 87.06624507904053

Improved test accuracy



Test image output

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

3.2. Research Findings and discussion

Autism is a life long 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 consist of the same teaching method that is been followed by the teachers in autism schools. So we came up with a came game developed using unity 2D. These games includes 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 a 86% percentage of accuracy. With these simple method 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.

4. CONCLUSION

Math is an automated system that teaches numbers using counting, identification and writing activities to improve their ability in math. The user gets to interact with a smart system that includes attentiveness tracking, verbal training, math and writing mentor. The system keeps the user under a continuous monitoring if the system find the user is having any uncomfortableness in any of the activity the system will automatically swap the activity. These features will give the user an extra interest and focus towards using smart mirror.

With this study, I learned so many things about autism especially autism education. The methods they used to teach the ASD kids are really impressive. Also, the use of Convolutional Neural Network brings up a new era of machine learning in my mind. The results shown above are achieved by applying different methods and techniques in CNN Deep Learning model.

With the achievements that is gained with this research I think this system will make a huge impact in autism education. also the flexibility of this system will attract more students towards using the smart mirror ALIZA.

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

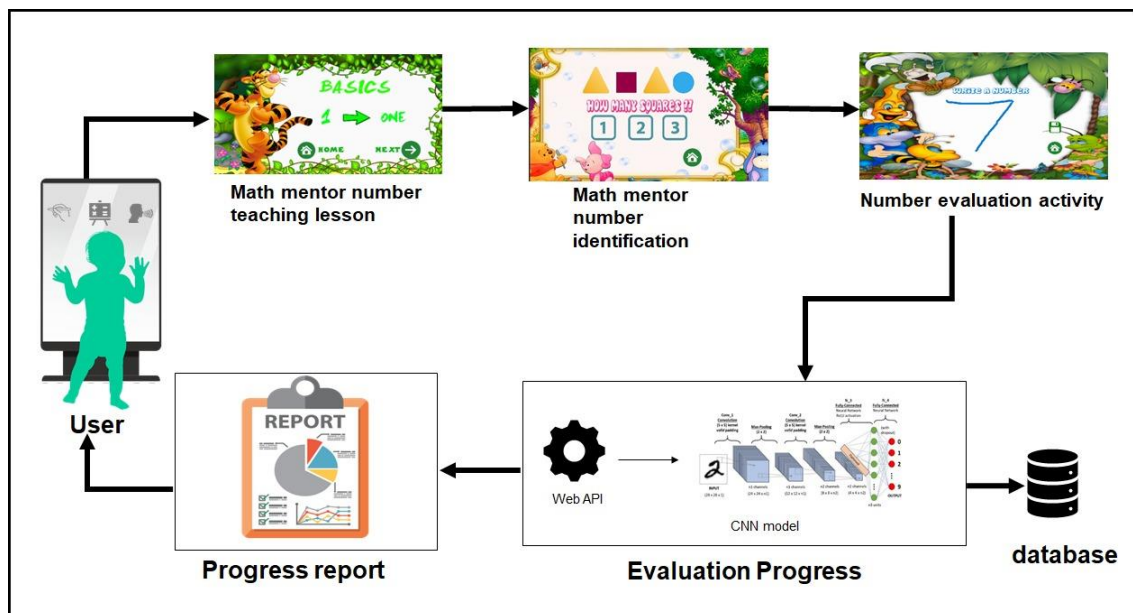
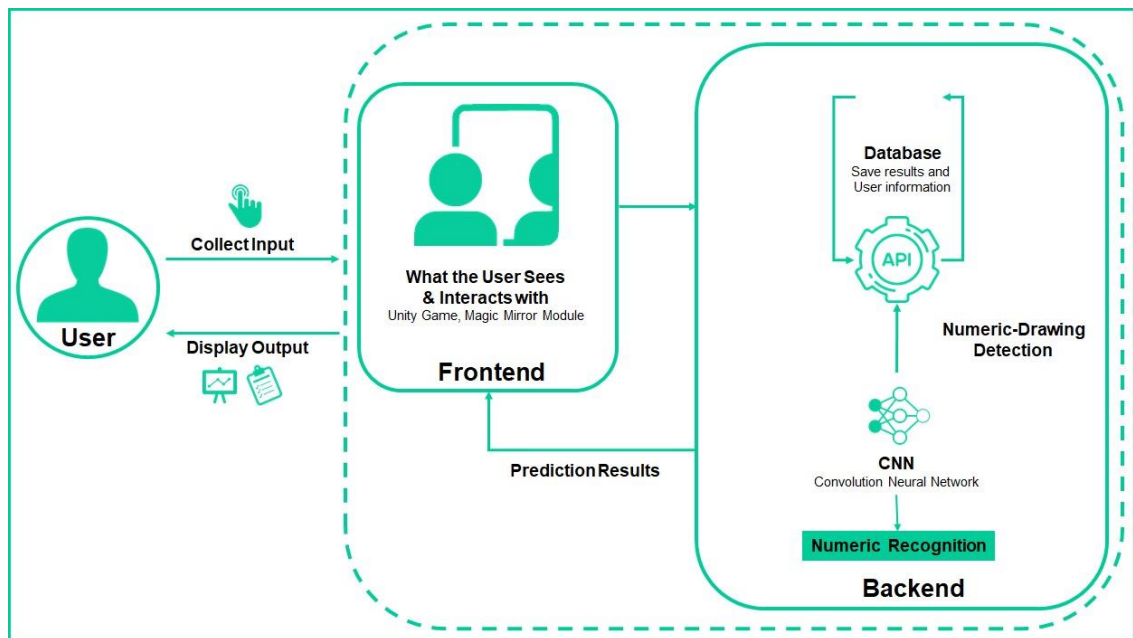
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APPENDIX A: system and high level architecture



APPENDIX B: Aliza

