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

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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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(Jesuthasan Alosius)

ABSTRACT

Globally, Autism spectrum disorder (ASD) is a crucial cause of childhood incapacitation. Researches have shown that 3 to 10 years old autism children experience challenges during the learning process on language abilities, reading, writing and listening. Since writing skills are so necessary to everyday life, it is important to help autistic children develop writing abilities with the support of modern technology approaches. One of the aims of this research is to develop a pre-writing system as a Writing Mentor. This system enables ASD children to successfully develop their pre-writing skills such as Lines, curves and shapes drawing. Writing mentor system help to practice and improve prewriting skills through Convolutional Neural Network (CNN) technique using smart mirror mechanism. This mirror mechanism-based teaching is an important role in autism spectrum disorder children's education. This system encouraged autistic children to do their writing exercises by themself. They are constantly monitored and evaluated during their training.

This study collected necessary data about randomly selected 3 to 10 years old100 ASD children from 3 selected schools in the Jaffna district and make used of this as data for creating evaluation models. This research expects that hopefully can produce pre-writing learning system based on machine learning approaches in order to assist educating ASD children. The outcome of this research is, can improve ASD children's pre-writing skills with the help of the Writing Mentor system.

Keyword - Autism spectrum disorder (ASD), Writing Mentor, Convolutional Neural Network (CNN), Pre-Writing skills.

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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 and Literature Survey

Autism is a complicated, long-lasting developmental disorder of brain functions, but it is not a disease. Autism spectrum disorder generally appears during early childhood that can impact a person's social skills, communication, relationships, and self-regulation. According to the Indian Journal of Psychiatry, approximately in Sri Lanka up to 1.07% of the children are affected by this disorder in 2019 [1].

ASD children with learning disabilities are as smart as or smarter than their peers, but they may have difficulty in reading, writing, listening, spelling, reasoning, recalling or organizing information if left to figure things out by them or if taught in conventional ways [2]. However, ASD children with learning disabilities can succeed in their school education and later in their life if they have the right education method. Parents can help their children with learning disabilities to achieve such success by encouraging their strengths, knowing their weaknesses, understanding their educational system, and learning about strategies for dealing with specific learning difficulties.

Writing-skills is helping to express for self-expression, communication, and recording of thoughts and experiences. Informal reports show a high level of writing-skills impairment have among children with autistic spectrum disorder (ASD). Therefore, necessary to come up with a solution with the help of modern technology approaches to solve this writing-skills impairment to ASD children.

According to the National Center on Educational Statistics approximately 90% of children with the age of five to seven use computers to their needs [3]. In contrast, children with disabilities are significantly less likely to use computers than their typical peers. Today's children with disabilities also need to be skilled in the use of technology in order to become successful workers in the future. The use of technology to teach children with ASD is not a new concept. In fact, technology has been used to teach children with ASD for over 35 years [4].

In this research, we have introduced a writing mentor system with the help of a smart mirror called Aliza. It is like an advanced self-teaching software. This system will help autism students to use modern technology and help to improve their learning skills like

ordinary children. Also, it can help to replace or improve the traditional existing teaching method which is presently applied for autism children.

The system pre-evaluate when the users who have autism, initially starting Writing Mentor system (Aliza) with the help of Convolutional Neural Network (CNN) technics the system find their writing skill level. Based on this evaluation system will provide some pre-writing skill activities such as lines, curve and shapes drawing to ASD children. For example, drawing line activities based on dot-connecting approach [5] with the help of drawing guidance. Figure 1-1 shows one of the activities in the Writing Mentor system.

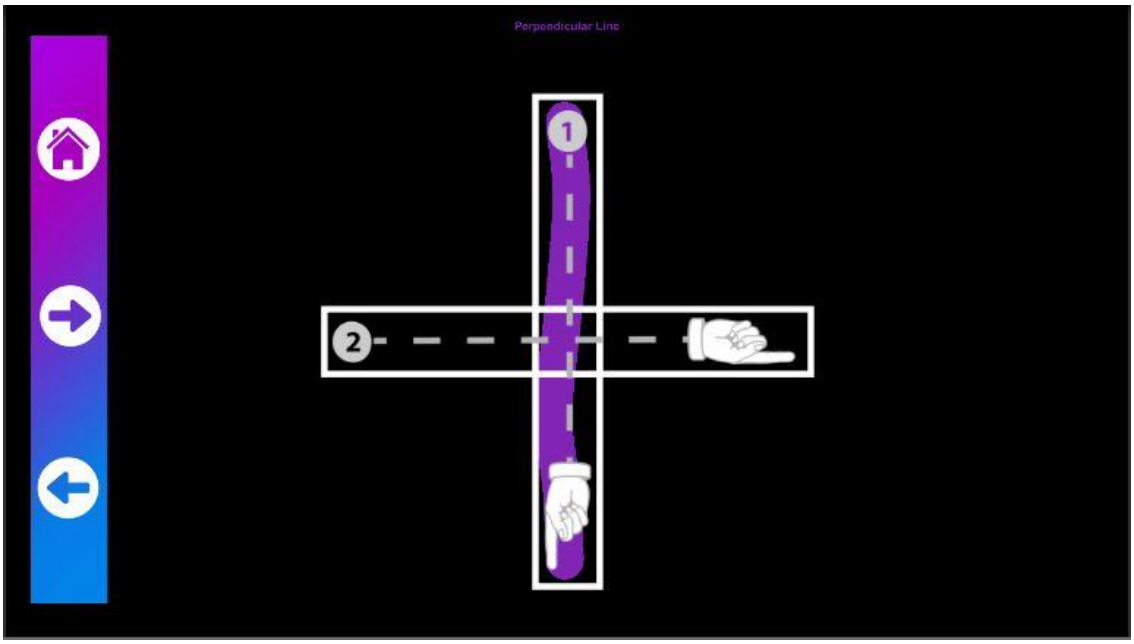

Figure 1-1: Hard Level lines drawing activity in the Writing Mentor System

Aliza Writing Mentor system have contains 5 levels of activities for pre-writing skills such as low level, hard level lines drawing activities, low level, hard level curves drawing activities, and shapes drawing activities. Figure 1-2 shows activities levels in the Writing Mentor system.

The system continuously evaluates these children when they are practicing with the help of Convolutional Neural Network (CNN) technics. The pre-writing task 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 levelled up, if

not, then the 1st level activities will continue until the user gets the progress level above 80%.

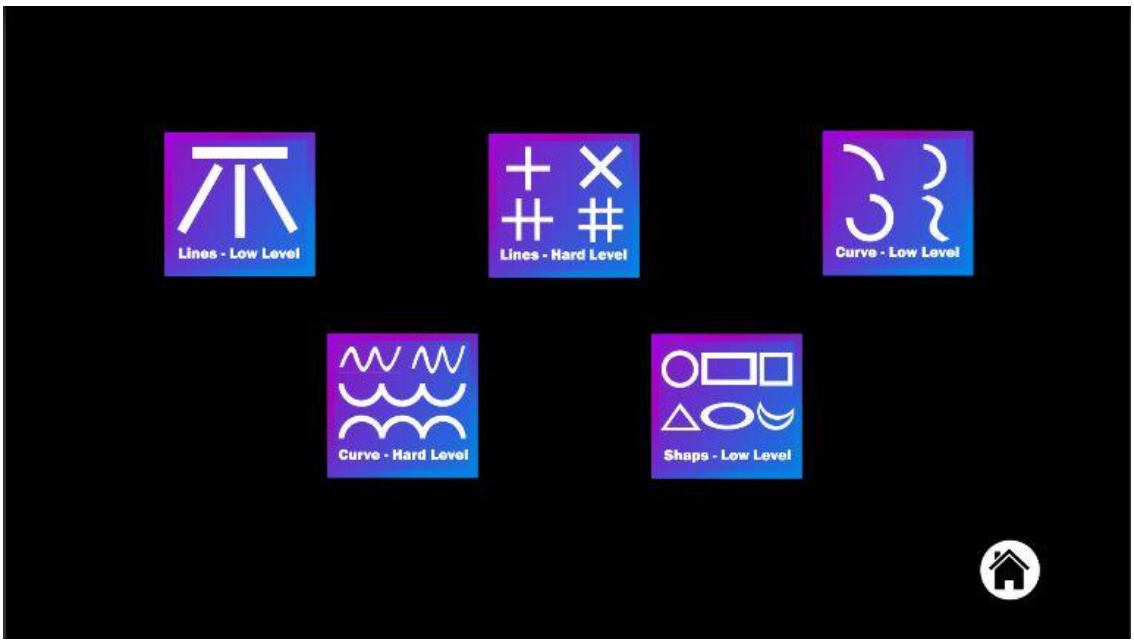

Figure 1-2: Activities levels in the Writing Mentor system.

Based on Aliza-Writing Mentor system, we predict that the ASD students would increase the overall quality and knowledge of the ASD children's pre-writing skills after using the Aliza-Writing Mentor system. We also expected a few peer interactions, but given that socialization was not the primary purpose of this system.

There are three studies which were identified empirically examined for autistic children education based on modern technology approaches studies. This has been identified by conducting thorough background research on the existing solutions.

Colby conducted one of the first studies examining the use of computers to teach students with ASD in 1973. Colby used a computer program consisting of various computer games organized at various levels of complexity with 17 students with ASD. For example, in one game, the child pressed a letter on the computer and simultaneously heard the computer say the letter. The purpose of the study is to increase students understanding of how letters and sounds form words, and how words can form expressions. Results claim that 13 of the 17 children showed an increase in understanding the letters and sounds [6].

One of the studies is a mobile platform called “Picaa” based on iPad and iPod touch devices. It may also encourage children with ASD to be more active participants in their writing skills. Alvaro Fernandez-Lopez, Maria Jose Rodríguez-Fortiz, Maria Luisa Rodriguez- Almendros and Maria Jose Martinez-Segura examined the use of Picaa by 39 students with special education needs from Spain. Picaa's one of the activity is writing activities. The purpose of the Picaa was developing of learning basic skills such as language, math, environmental awareness, autonomy and social for children who have special educational needs. Results claim that language skills (writing skills) were up 5.76% on average [7].

Frank Jamet, Olivier Masson, Baptiste Jacquet, Jean-Louis Stilgenbauer, and Jean Baratgin conducted research on AI robot help to teach writing skills based on the concept of learning by teaching to ASD children. This study concentrates on ASD children 6 to 8 years old. One of this study's goal is to teach how to draw letters using a humanoid robot (NAO) to ASD children. In its design, the experimental setup allows the child to draw many times and to be motivated in order for it to be efficient. Results show the children progress in various areas of learning such as reading, writing, language and reasoning [8].

Also, there are some mobile applications available for teaching writing skills to ASD children. Writing Wizard [9] is one of the apps to help ASD children learn how to write the letters of the alphabet, numbers and words through a fun system and it is allowed to check learning progress with reports.

Autism Read & Write App [10] also one of the apps to help ASD children to learn the basic of reading and writing. Autism Read & Write App also one of the apps to help ASD children to learn the basic of reading and writing skills using images. Another mobile application for teaching ASD children is called “Otsimo”. Otsimo App [11] aims as to teach fundamental education about core skills such as words, alphabet, numbers, emotions, colors, animals and vehicles through assistive matching, drawing, choosing, ordering and sound games.

As per the above-mentioned studies, there are researchers prevailing in the area of teaching writing skills with the help of modern technology smart device for ASD

children, but there are no researches prevalent regarding the evaluation based teaching pre-writing skills with the help of the modern technology smart device.

1.2. Research Gap

Background research suggests that a number of studies have been carried out to study improve ASD children's writing skills with the help of modern technologies. Moreover, most of these studies have mainly considered the teaching words to ASD children.

Research A [6] has concerned about identifying alphabets and words through various levels based game playing activities to ASD children (Table 1.1) and the research B [7] has concerned only writing words activities (Table 1-1). Finally, research C [8] has concerned about encouraging to drawing lines, curve and shapes (pre-writing skills) and finding words by learning by teaching approach. (Table 1-1). There is no research that would provide a progress report based on ASD children's writing activity evaluation.

Table 1-1: Comparison of former researches

	Pre-writing activities (Line, Curve, shape)	**Game Based Activities**	**Leveling Up tasks**	**Evaluation**
Research A	✗	✓	✓	✗
Research B	✗	✗	✗	✗
Research C	✓	✗	✗	✗
Aliza	✓	✓	✓	✓

According to the available related works, there are several mobile applications also developed for improving ASD children's writing skills (Table 1-2). Many mobile applications are mainly concerned with teaching shape drawing prewriting activities for ASD children (Table 1-2).

Writing Wizard – Handwriting App [9] and Otsimo App [11] provides pre-writing activities, but it is not have leveling up activity based on evaluation (Table 1-2). Autism Read & Write App [10] provides only shape drawing activity and also, provides

evaluation's reports for those activities (Table 1-2). There are no products that would provide suggestions to leveling up activity based on evaluations.

	Pre-writing Drawing Activities			Leveling Up tasks	Evaluation	Type	Cost
	Line	Curve	Shape				
Writing Wizard – Handwriting App 	✓	✓	✓	✗	✗	Mobile App	cheap
Autism Read & Write App 	✗	✗	✓	✗	✓	Mobile App	cheap
Otsimo App 	✓	✓	✓	✗	✗	Mobile App	cheap
Aliza 	✓	✓	✓	✓	✓	Based on smart mirror	mode rate

Table 1-2: Comparison of related work

The Aliza: Writing Mentor system which is proposed, is designed with many more functionalities than other researches which are currently prevailing. By the proposed

solution the Aliza: Writing Mentor would suggest probable solutions to the teaching ASD children problems.

The proposed system is creating an Aliza: smart mirror as autistic education assistant to teach pre-writing activities such as lines, curves and shapes for ASD children. Proposed system continuously evaluates ASD children when they are practicing Alize: Writing Mentor system. The pre - writing task will be leveled up through every evaluation report.

1.3. Research Problem

According to the Autism and Development Disability Monitoring Network (ADDM), the increases in autism children is about 1 child of 1000 in 1970. But in 2018, the increase of autism children is about 1 child of 59. Through this, the statistics show annually the rate of autism children is increased [12] [Figure 1-3].

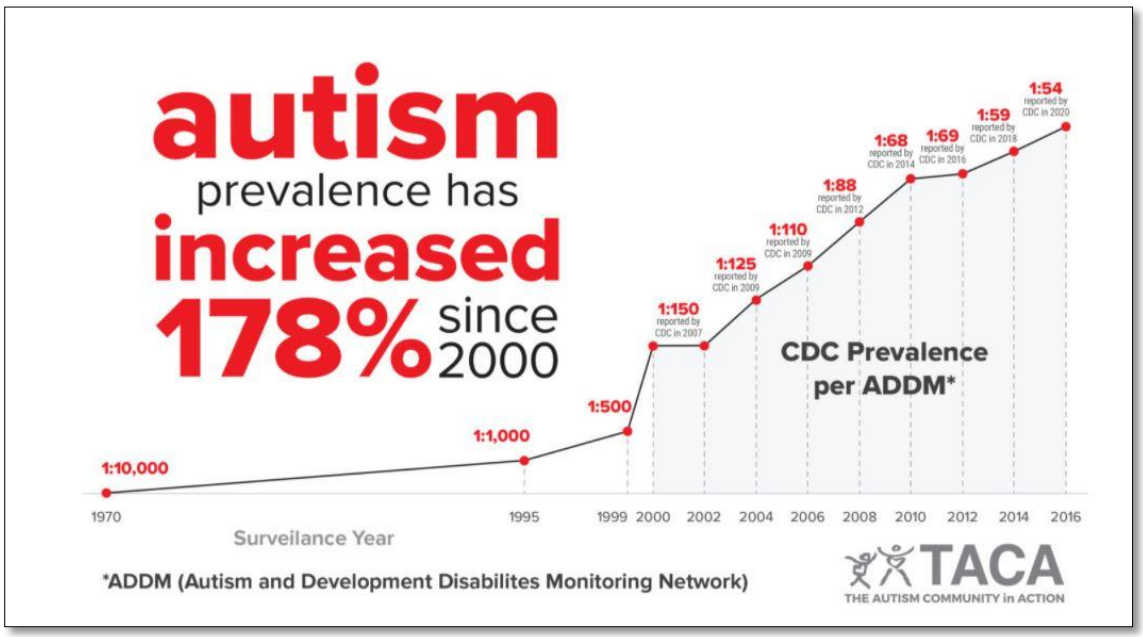

Figure 1-3: The autism statistics prevalence of children (https://tacanow.org/autism-statistics/)

Such an increase in the number of people with ASD depends on the methods used to handling and treating of the autism people. Besides, teaching writing skills is not a trivial task. Autistic kids spend a huge amount of time learning pre-writing skills [13].

Therefore, we need to find modern technology methods to help teach children with autism.

The new development of technologies is now extending its functions to assist the children suffering from Autism Spectrum Disorders (ASD) in areas of socialization, communication, and playful behavior through AI application-based intervention.

Therefore, this research studied and analyzed previous studies of the existing system for using different types of modern technologies based systems in autistics children. Even though research and computer-based interventions for pre-writing skills don't have level up based activities or task and progress. Computer-based interventions and robots based tutor systems are very expensive.

We used these previous researches and existing system results as a key for our research to choose the suitable type of system and methods to enhance educate pre-writing skills for children with autism. The results helped to design and implement an Aliza writing mentor system for teaching children with ASD based on the smart mirror.

1.4. Research Questions

1) In what way does the use of technology contribute to the prewriting education of children with autism and what are the implications and impact of such activities?

2) Which pre-writing activities are considered educating children with autism?

3) How can monitoring and evaluation using technology during the prewriting activities help children with autism?

1.5. Research Objectives

1.5.1 Main objectives

The main objectives of this research are as follows:

- To develop a writing mentor system based on autism student pre-writing teaching methods such as ABA (Applied Behavior Analysis) and AAC (Alternative and Augmentative Communication) techniques.

- To develop a model, based on CNN (Conventional Neural Network) method for level assessment.

1.5.2 Specific objectives

The Specific objectives of this research are as follows:

- 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.

2. METHODOLOGY

"Aliza: Smart Mirror As Autistic Education Assistant" system uses to teach pre-writing, basic math and speech training to autistic students using smart mirror based on digital modern teaching approaches. Also, it monitoring every single move of that autistic student through a camera, which analyses their focus in order to teach in an interesting and interactive way.

The "Writing Mentor" is one of the subsystems of Aliza. This Writing Mentor subsystem plays a major role in Aliza system. Writing Mentor system utilizes for shapes-drawing practice, shapes reorganization and shapes classification to autistic students learning activities. The development of the platform is consistent with the Linux operating system.

It will facilitate teaching pre-writing skills using games which have five levels. Autistic students are evaluated at the end of each level using Convolutional neural network (CNN) with previous progress. Furthermore, the Writing Mentor is developed with an attractive user-friendly game interface on a smart mirror that allows the autistic students to learn easily with involvement.

In order to implement the proposed system, the Software Development Life Cycle approach was used. The following subsections mainly pinpoint on the methodology followed in developing the Writing Mentor subsystem.

2.1. Requirement Analysis and Specification

The Writing Mentor system is mainly designed to improve the pre-writing skills of autistic students' education. The prime requirement of this system is recognizing and classifying the shapes drawing by the user on the smart mirror and find the progress of the writing skills of the user. For this, all the shapes drawn by the user during the evaluation activities are captured and stored as an image and send it to the model for the evaluation process. After successful recognition of the shape, the system finds the writing skills progress of the user.

The writing mentor system was required to cater to several features in order to support self-learning which was lacking in existing systems available in the present market. Such features are,

- game-based teaching
- smart mirror teaching approach
- supporting for image detection in any place of the drawing area

2.2. Feasibility Study

The feasibility examines the viability of a project, help to define project goals and help to develop and execute the plans. Therefore, feasibility study plays an important role in software development. The feasibility of the writing mentor subsystem can be determined beneath technical, operational and economic feasibility.

Technical feasibility means the evaluation of the software, hardware and other technical necessities of the proposed system. The development of a writing mentor system requires certain skills such as basic knowledge in unity game development, understanding of software development and capability to learn and adapt new technologies. Also, for this system, implementation requires knowledge in new concepts such as Convolutional neural network (CNN) and Raspberry Pi OS. All individuals of the research group have the specialized capacity and basic training to develop sub-systems assigned to them. From this, it's explicit that the Writing Mentor system is technically feasible.

Operational feasibility means how a research plan accomplishes the requirements identified in the requirements analysis phase of system development. The most important part of the operational feasibility of the writing mentor system is the pre-writing teaching approach based on the smart mirror and monitoring the progress of autism students using CNN. The smart mirror-based teaching approach greatly increases the interest in learning among autistic students and also extend the time for learning. Through the focus of the autistic students' pre-writing learning problem by the research team, it was determined that this proposed solution is acceptable and addresses the expected problem of the autistic students. Therefore, the implementation of the Writing Mentor system ensures this system is operationally feasible.

All the components in the system including the shape-drawing recognition and classification module is developed with unity and torch library. The core package of Torch is torch library is a free and open-source library to provide a flexible N-dimensional array or Tensor. Also in this system used unity free version software for

game development. Writing mentor system of Aliza is cost-benefit than other autism students' pre-writing learning products presently available in the market. Therefore it's explicit that the Writing Mentor system is economically feasible.

2.3. 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.

2.4. Design

The Writing Mentor sub-system mainly focuses on the evaluation of the progress level of autism students' pre-writing skill using CNN technique. The Writing Mentor sub-system is developed with unity, torch library, and Convolutional neural network (CNN). Unity is a cross-platform game engine developed by Unity. In this Writing Mentor sub-system, used unity to its game development. The torch is an open-source library and it is

a scientific computing framework. The torch libraries are simple to use while having maximum flexibility in implementing complex neural network topologies.

There are several approaches used to handwriting recognition in the past years such as Random Forest, Naive Bayes and Support Vector Machine, Convolution Neural Network(CNN) but due to their expert's suggestions and some drawbacks, researchers are moving on to explore faster options. However, most of the researchers and experts suggest to Convolution Neural Network (CNN) approach for handwriting recognition. Therefore, Writing Mentor sub-system used CNN approach for shape-drawing recognition using Python.

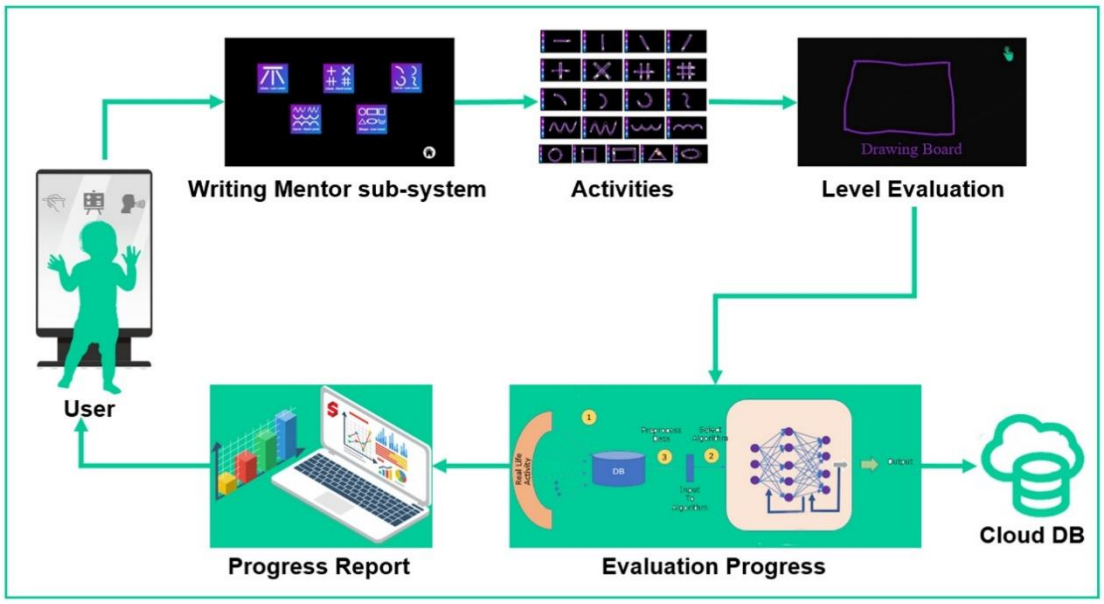

Figure 2-1: Writing Mentor Overall System diagram

As the initial phase of the Writing Mentor sub-system's procedure, the user needs to be entered into the Writing Mentor sub-system. Then the user can start the pre-writing activities from level 1 with the guidance of Writing Mentor. After completing level activities, the system evaluates the user through some drawing activities without nay guidance of Writing Mentor. In this stage evaluation activities, drawn shapes are captured as .jpg image format. After that, the jpg image will proceed to the CNN model, which is evaluating the inputs jpg image and accuracy of the shapes. Then the result will return to the user as a report. At the same time, the results will be saved into the cloud for later uses of progress improvement analyzation. The following diagram (Figure 2-1) is an overview of the system diagram of the Writing Mentor sub-system.

High-Level architecture

In the below High-level diagram (Figure 2-2) shows the graphical way of Writing Mentor sub-system.

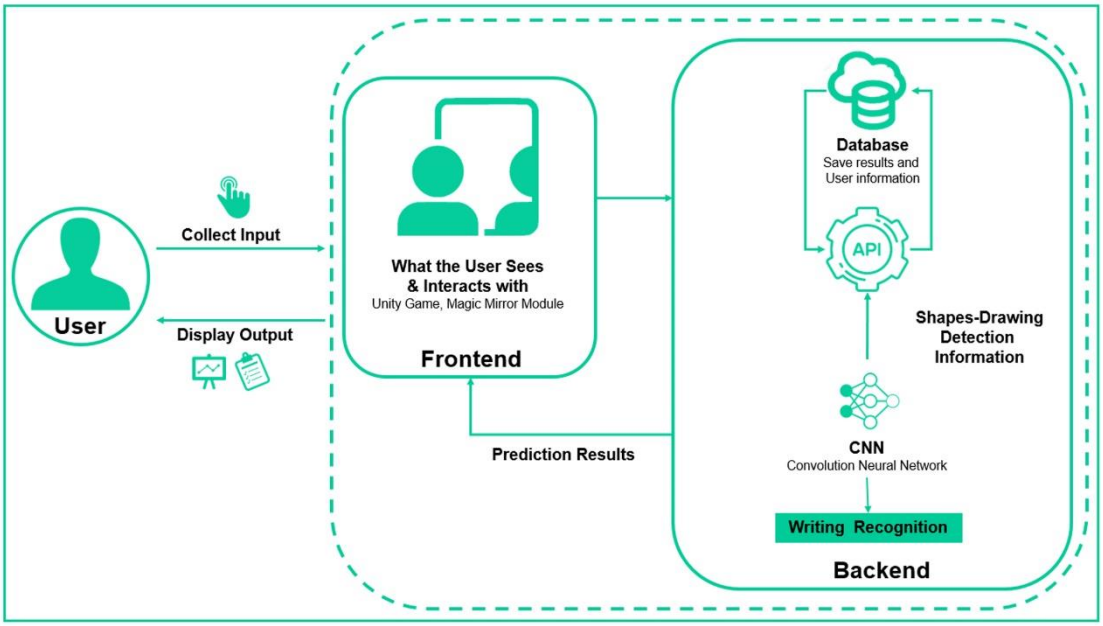

Figure 2-2: High-level diagram

Game activities and levels

Learning pre-writing skills through the game, can further enhance the sense of presence, engaging even more deeply the ASD child with the game and, consequently, further foster motivating them to learn, Because of this we teach pre-writing skills through AI games to ASD children. The pre-writing activity games are based on tracing and connecting dots strategy. Through this strategy, ASD children can easily able to develop their pre-writing skills [14].

To design the level of the Writing Mentor game, the first user has to choose the Writing Mentor menu. Then the 5 levels of the game will appear on the smart mirror screen (Figure 1-2), the user only needs to select levels from the basic level thereafter the shape tracing board appears on sma.t mirror screen to be played. The user has to go through an evaluation activity to get to the next level in the game. If the progress is above 80% during the evaluation process the user will be promoted to the next level. If not the user will train again at the same level until reaches the specified progress. The following

diagram (Figure 2-3) represents a basic workflow carried out of game levels in Writing Mentor sub-system.

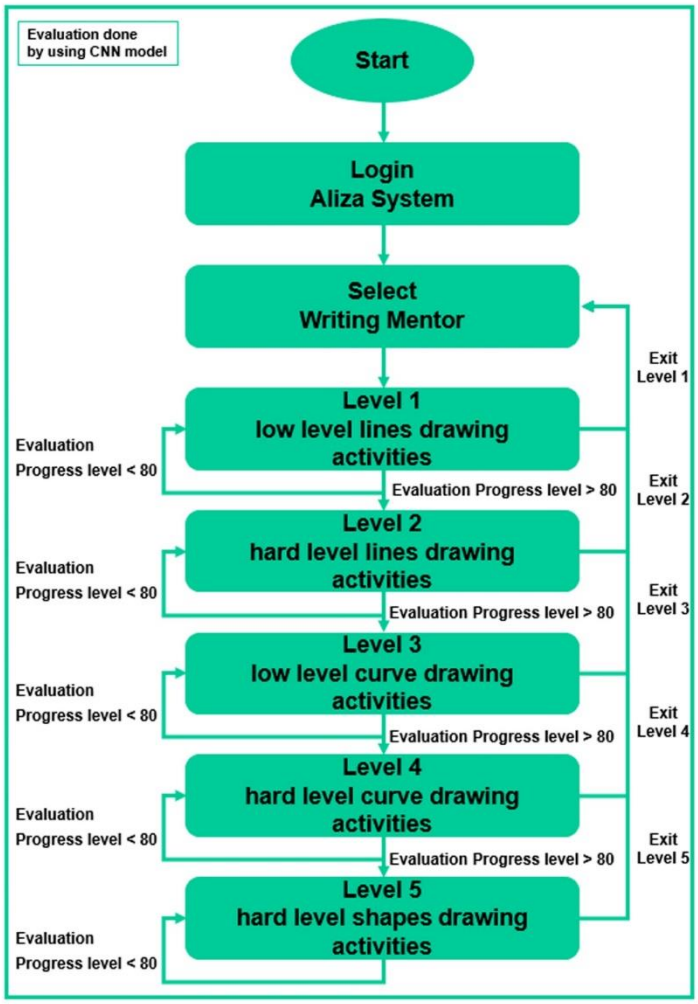

Figure 2-3: Game Workflow of Writing Mentor

To conduct this research we have divided our pre-writing activity games to 5 levels as low level, hard level lines drawing activities, low level, hard level curves drawing activities, and shapes drawing activities. Following figures (Figure 2-4, 2-5, 2-6, 2-7 and 2-8) shows the activities of the 5 levels in the Writing Mentor system.

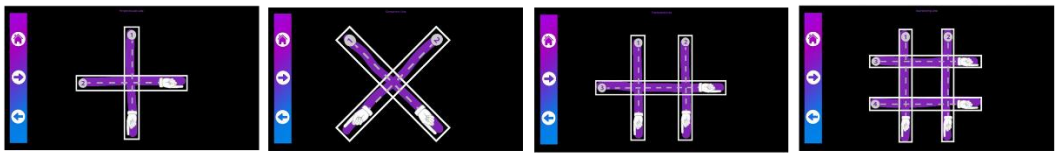

Figure 2-4: Level 1 - Low level line drawing activity

Figure 2-5: Level 2 - Hard level line drawing activity

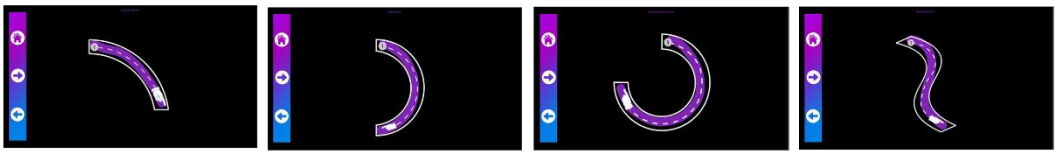

Figure 2-6: Level 3 - Low level curve drawing activity

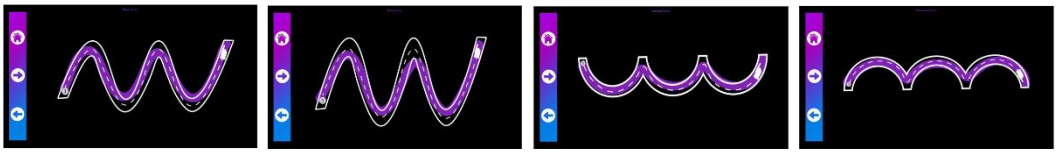

Figure 2-7: Level 4 - Hard level curve drawing activity

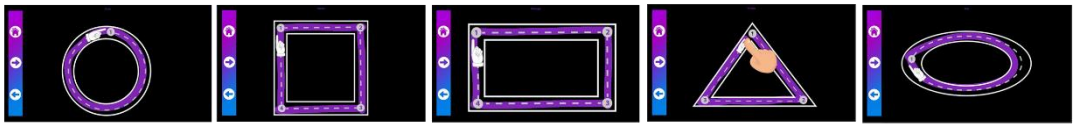

Figure 2-8: Level 5 - Shapes drawing activity

CNN Model to classify drawn lines, curves and shapes

To recognize the lines, curve and shape drawing, Writing Mentor sub-system is used as a seven-layered CNN strategy. An eleven-layered convolutional neural network with one input layer followed by nine hidden layers and one output layer is designed and illustrated in Figure 2-9.

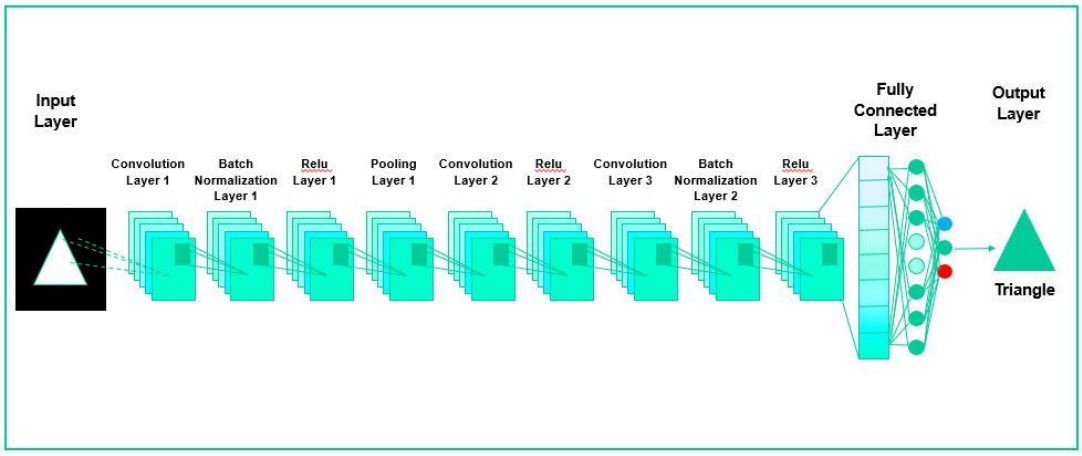

Figure 2-9: The overall architecture of the Convolutional Neural Network

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.

Evaluation

Level evaluation is done when the ASD children are practicing with the help of Aliza. End of each level writing mentor system will be given an evaluation test activity. Through this can find out the pre-writing skill's knowledge of children with autism. The system will be analyzed in the current evaluation test report with a past evaluation report to find the ASD children's progress. When the progress report agrees with the levelled up conditions, then the ASD children's pre-writing game activity is levelled up to the next level.

2.5. Implementation

Data collection and preparations

The study was planned to collect primary data from nearly 100 autism students in Colombo and Jaffna. But, due to the COVID 19 pandemic situation, there were difficulties in storing the data as planned. However, the required primary data for this proposed research were obtained from approximately 58 selected autism children aged 5 to 12 years from 3 selected schools in the Jaffna district. The required pre-writing day-to-day written works such as line, curve and shape drawing data were collected from the selected autism students by the document data collection method. With this, approximately 1200 data were collected for this research. The following table shows the details of selected schools in the Jaffna district and details of collected data for data collection.

Table 2-1: schools details and collected datas' details

Schools Name	No of Students	No of Collected data	Collected Data	Age limit
J/ Sivapoomi school	39	819	Pre-writing written works: line, curve and shape drawing works	5 - 12
J/ Holy Family Convent	11	231		5 - 12
J/ Muthuthamby Maha Vidyalayam	8	168		10 - 12

The data retrieved from the autism student were analyzed and transferred into a digital image. Then the images were converted into a 28x28 pixel images. Original black and white images were converted to greyscale during the data Pre-processing process. This data were used as inputs of CNN model training process.

Deep learning CNN model needs a huge number of data to be trained effectively. It will help to increase the performance of the model. Augmentation technique was used to increase the number of data due to an insufficient amount of data collected for this research. Image augmentation is a most popular technique which is used to synthetically generate new and different images from the existing image data set by applying different

transformation techniques such as rotating, zooming, shearing and cropping the existing image.

Model implementation

The implementation of the shapes evaluation process is performed by the following three Python classes.

DataAugmentation.py

GeometricShapesClassifier.py

PredictionGeometricShapes.py

In the Data Augmentation.py, collected training data sets size were expand by creating modified versions of images in the dataset. In this python file, collected data geometrically transformed by using rotations, width shift, hight shift and zoom features of data augmentation technique.

```
datagen = image.ImageDataGenerator(
            rotation_range = 40,
            width_shift_range = 0.2,
            height_shift_range = 0.2,
            shear_range = 0.2,
            zoom_range = 0.2,
            fill_mode = 'nearest')

img = image.load_img('/content/drive/My Drive/data/Circle/C001.jpg')
x = img_to_array(img)
x =x.reshape((1,) + x.shape)
```

Figure 2-10: A snippet of data augmentation process from Data Augmentation.py file

In the GeometricShapesClassifier.py scraped content data will be taken as 28 X 28 image format and all the images are converted into the grey scale. These python classes are able to run independently. The output of this Python class is the information on how well the drawn pictures provided as input are consistent with the accuracy of the trained data. In this python class mainly used torch libraries. As per above mentioned, nine hidden layer CNN model has used to recognize the drawn-shapes in this system. Following figure (Figure 2-11) define the CNN architecture which is used in this system. The PredictionGeometricShapes.py file is used to test some sample drawn images.

```
class ConvNet(nn.Module):
    def __init__(self,num_classes=3):
        super(ConvNet,self).__init__()
        #convulation layer 1
        self.conv1=nn.Conv2d(in_channels=3,out_channels=12,kernel_size=3,stride=1,padding=1)
        #batch normalization 1
        self.bn1=nn.BatchNorm2d(num_features=12)
        #Relu 1
        self.relu1=nn.ReLU()
        #Pooling layer 1
        self.pool=nn.MaxPool2d(kernel_size=2)
        #convulation layer 2
        self.conv2=nn.Conv2d(in_channels=12,out_channels=20,kernel_size=3,stride=1,padding=1)
        #Relu 2
        self.relu2=nn.ReLU()
        #convulation layer 3
        self.conv3=nn.Conv2d(in_channels=20,out_channels=32,kernel_size=3,stride=1,padding=1)
        #batch normalization 2
        self.bn2=nn.BatchNorm2d(num_features=32)
        #Relu 3
        self.relu3=nn.ReLU()
        #fully connected layer
        self.fc=nn.Linear(in_features=75 * 75 * 32,out_features=num_classes)
```

Figure 2-11: A snippet of CNN architecture from GeometricShapesClassifier.py file

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

2.6. Testing

The testing was carried out after the implementation of the Writing Mentor sub-system, which helps to clear the bugs and errors in the development phase. It gives further improvements in the performance of the system. In here implemented system, testing conducted in several levels such as unit testing, integration testing and functionality testing. In order to accomplish the testing process in here used manual test methodology.

Unit Testing

Unit testing is carried out by isolate sub-parts of the system and conduct the testing process as individual parts. For the shapes classification and recognizing 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 Writing Mentor sub-system.

Table 2-2: 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 2-3: 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 2-4: 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 2-5: 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 2-6: 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’

Integration Testing

The integration testing was tested as a combined module to determine if the integrated system run smoothly and correctly by Bottom-up integration Testing method. If the units of the system are working properly during the unit testing, it can be ensured that the integrated system will also work smoothly.

Functionality Testing

In the functional testing, all functions are tested to ensure that the requirements stated in the requirements analysis phase are met.

3. RESULTS & DISCUSSION

3.1. Results

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.

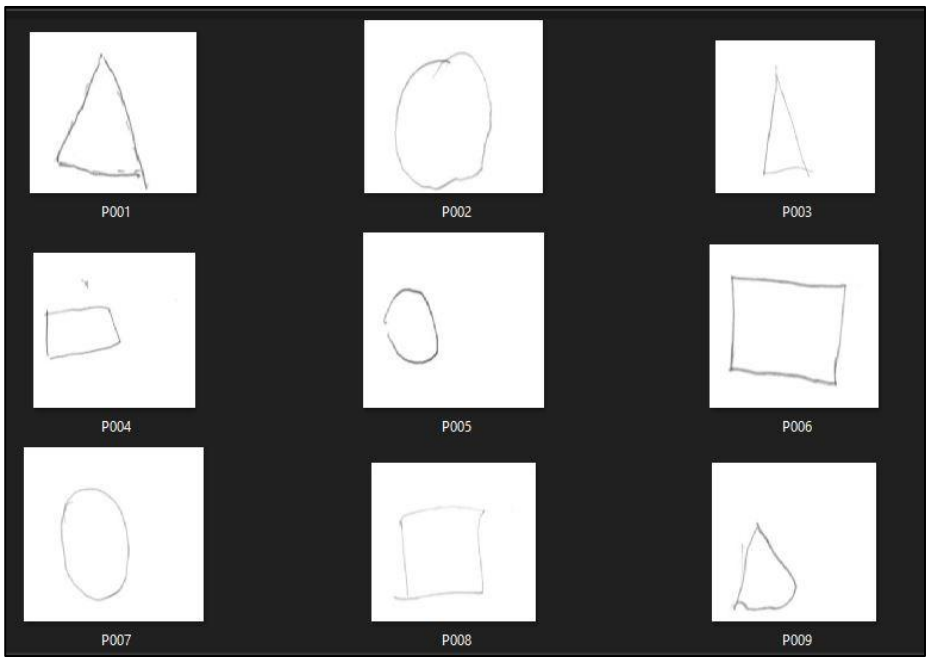

Figure 3-1: Shapes use for testing

```
[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.

3.2. Research Findings Discussion

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.

4. CONCLUSION

The Writing Mentor system a smart mirror-based pre-writing self-teaching system developed for autism students to improve their pre-writing skills. The main objective of this system is to enhance the pre-writing skills of autism students through continuous evaluation with the help of modern technology and modern teaching techniques for autism students. This system holds training and teaching methods based on game activities which help to increase more interest and focus of autism students and it accommodates basic pre-writing education for age groups of four to twelve aged children.

In this research, I examined the ability to evaluation with Convolutional Neural Network model. In this research, I explored how learning processes can be evaluated using the Convulsive Neural Network model. The methods I have proposed above have greatly contributed to the results of the research.

The results shown in Figure 3.2 were obtained by implementing approaches based on Figure 2.1. A limitation of implemented approaches will require high computational power in running the shape tracing game. However, this can be easily overcome by increasing the SD capacity.

The results of this research show that this system is very relevant and effective compared to the existing pre-writing teaching application for students with autism. Also, the experiments are proving that the CNN technique is most suitable for the geometric shape classification and recognition.

The feature enhancements will be mainly focused on supporting local languages such as Sinhala and Tamil. The planned future work will not only enhance the product market value but also provide an opportunity for all autism students living in Sri Lanka using different languages to use this system and provide a better experience in their learning journey.

REFERENCES

[1] Pranab Mahapatra, Sanghamitra Pati, Rajeshwari Sinha, Abhimanyu Singn Chauhan, Rakesh Ranjan Nanda, and Srinivas Nallala, "Parental care-seeking pathway and challenges for autistic spectrum disorders children", 2019 Jan-Feb, [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6341916/ [Accessed: 05 Feb 2020].

[2] Afiza Ismail, Nazlia Omar and Abdullah Mohd Zin, "Developing Learning Software for Children with Learning Disabilities through Block-Based Development Approach", 2009 International Conference on Electrical Engineering and Informatics, Selangor, Malaysia, 5-7 August 2009.

[3] National Center on Educational Statistics, "Computer and internet use by children and adolescents in Washington", U.S. Department of Education, 2001.

[4] Afiza Ismail, Nazlia Omar and Abdullah Mohd Zin, "Developing Learning Software for Children with Learning Disabilities through Block-Based Development Approach", 2009 International Conference on Electrical Engineering and Informatics, Selangor, Malaysia, 5-7 August 2009.

[5] Sally J. Rogers and Geraldine Dawson, "Early Start Denver Model for Young Children with Autism", 09 December 2009, [Online]. Available: https://books.google.lk/books?id=EDrT4fu7xzoC&pg=PA256&lpg=PA256&dq=matching
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[6] Kenneth mark Colby, "The Rationale for Computer-Based Treatment of Language
Difficulties in Nonspeaking Autistic Children", Journal of Autism and Childhood Schizophrenia, Stanford University, 1973.

[7] Alvaro Fernandez-Lopez, Maria Jose Rodríguez-Fortiz, Maria Luisa RodriguezAlmendros and Maria Jose Martinez-Segura, "Mobile learning technology based on iOS devices to support students with special education needs", Computers & Education journal, 24 September 2012.

[8] Frank Jamet, Olivier Masson,Baptiste Jacquet,Jean-Louis Stilgenbauer, and Jean Baratgin, “Learning by Teaching with Humanoid Robot: A New Powerful Experimental Tool to Improve Children’s Learning Ability”, Hindawi Journal of Robotics, 18 November 2018.

[9] Writing Wizard – Handwriting, L'Escapadou, [GooglePaly]. Available: https://play.google.com/store/apps/dev?id=7403312528799372286 [Accessed: Feb. 19, 2020].

[10] Autism Read & Write, Green Bubble Labs, [GooglePaly]. Available: https://play.google.com/store/apps/details?id=com.benitez.autismrandwfree [Accessed: Feb. 19, 2020].

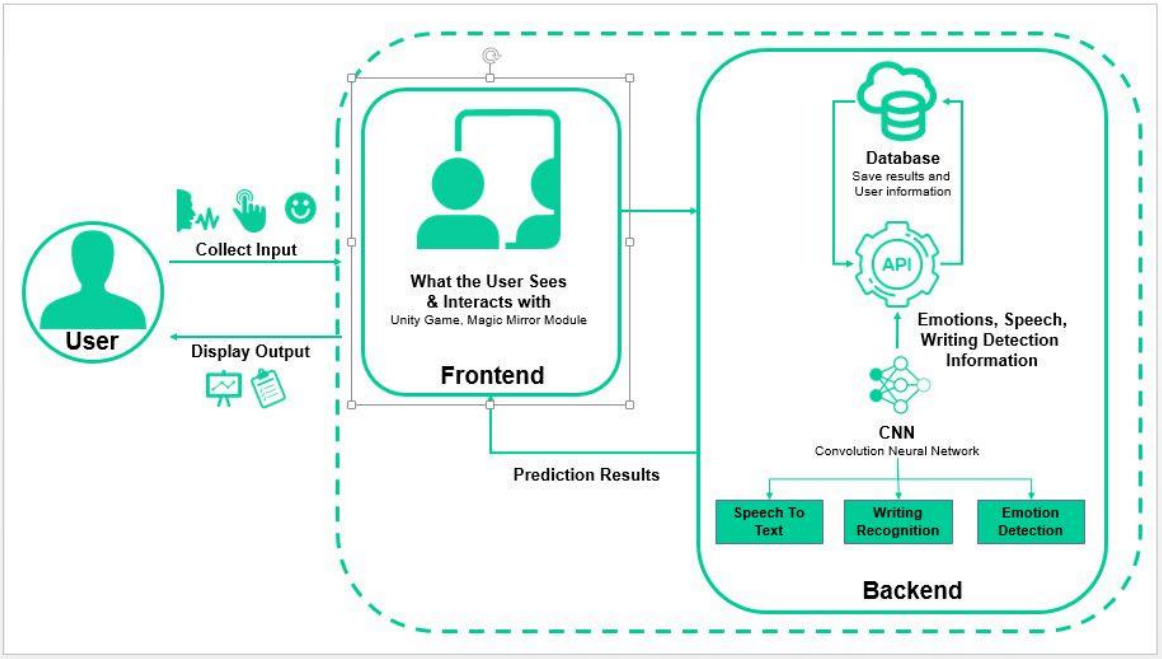
[11] Otsimo | Special Education ABA Therapy Autism Game, Otsimo, [GooglePaly]. Available: https://play.google.com/store/apps/details?id=com.otsimo.app [Accessed: Feb. 19, 2020].

[12] The Autism Community in Action, “Autism Statistics & Cost”. [Online]. Available: https://tacanow.org/autism-statistics/ [Accessed: Feb. 17, 2020].

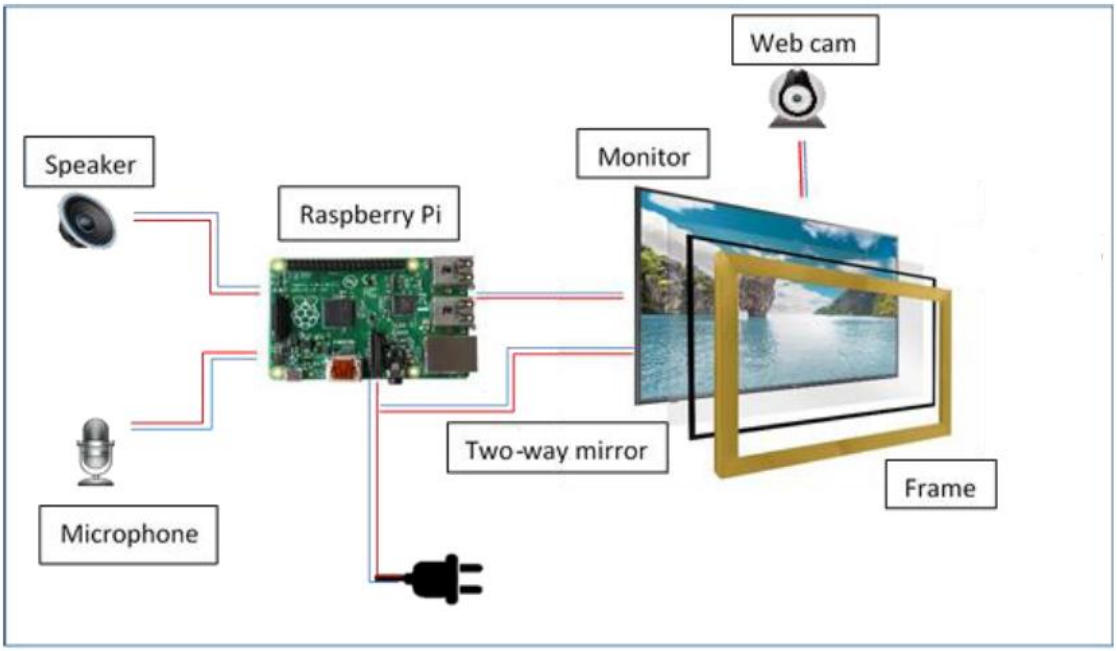
[13] Lisa Jo Rudy, Why School Is So Challenging for Children With Autism, September 23, 2019, [Online]. Available: https://www.verywellhealth.com/whyschool-is-so-challenging-4000048 [Accessed: 23-jan-2019].

[14] Yanirys Rios, “Tracing with Dots as a Strategy to Teach Writing to Young Children with Autism Spectrum Disorder”, Florida International University.

APPENDIX A: Aliza High-Level Architecture Diagram

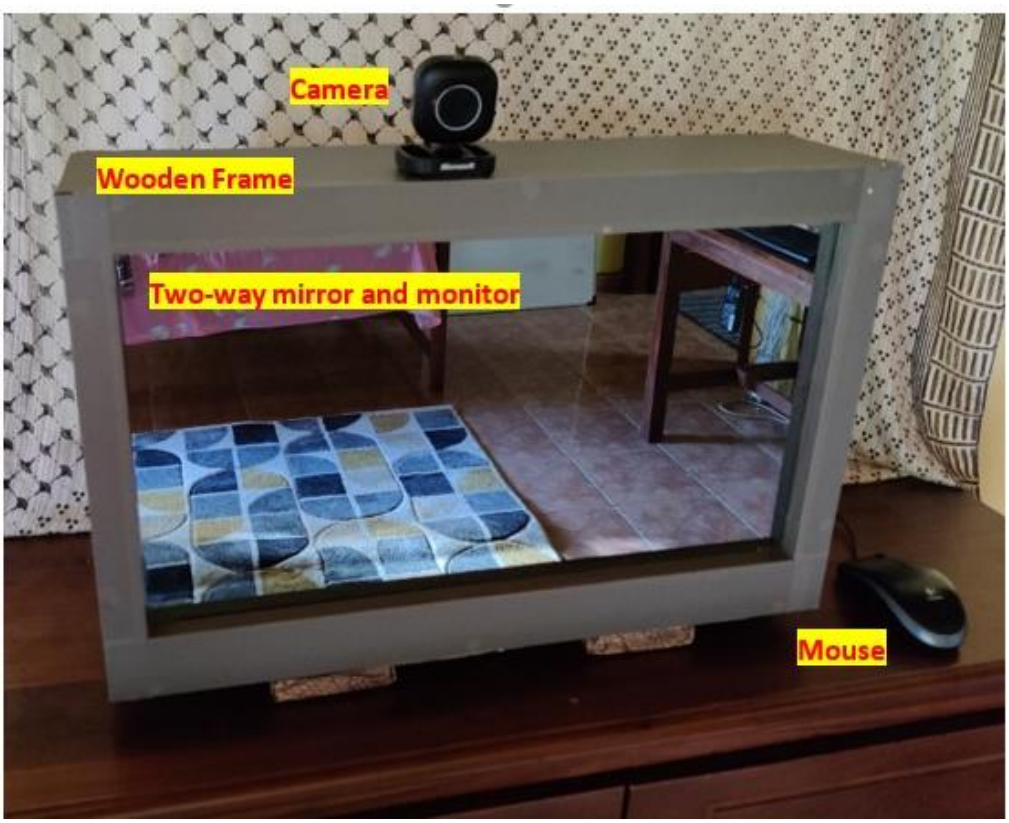


Aliza High-Level Architecture Diagram

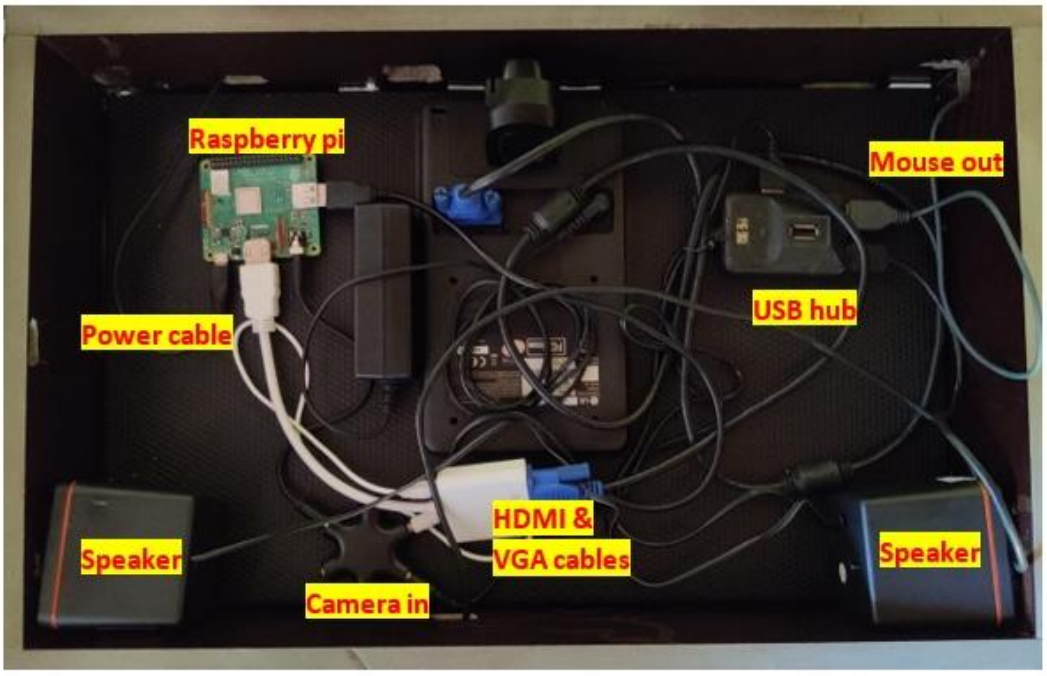


Aliza Overall Hardware Components

APPENDIX B: Aliza



Aliza smart mirror front view



Aliza smart mirror back view

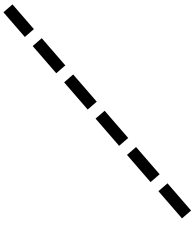
APPENDIX C: Title: Data Collection Form

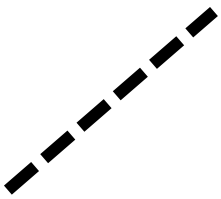
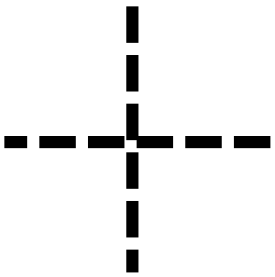
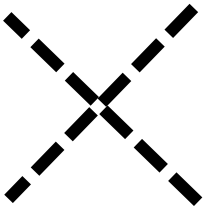
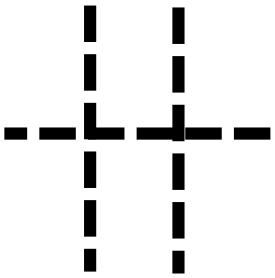
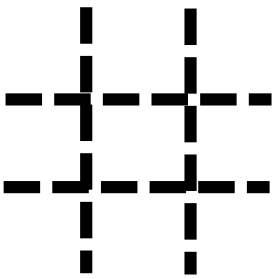
Sri Lanka Institute of Information Technology- SLIIT

Aliza: Smart Mirror for Autism Education

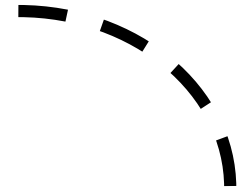
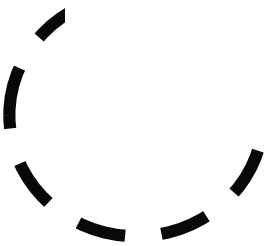
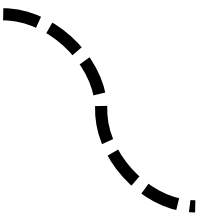
Data Collection Form

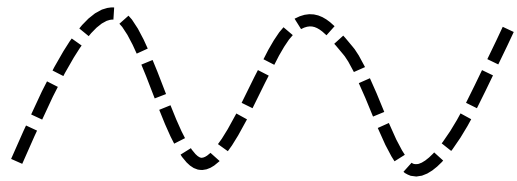
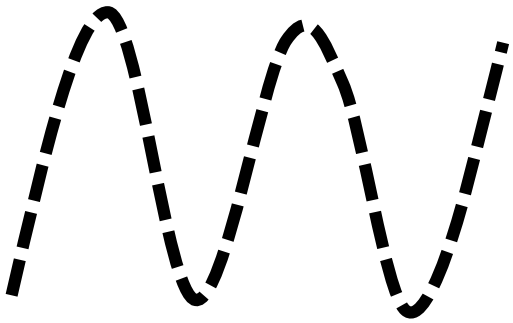
1. Draw Lines

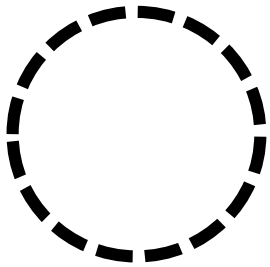
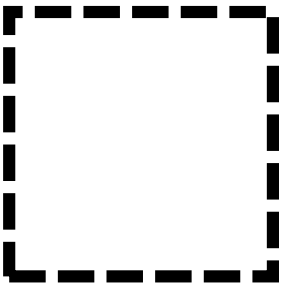
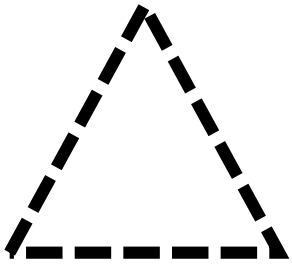
	
	
	
	
	

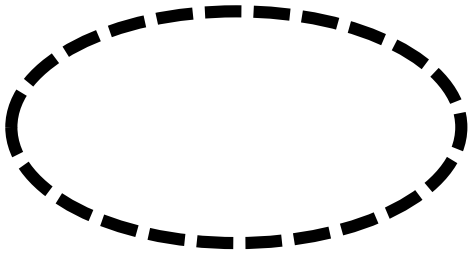
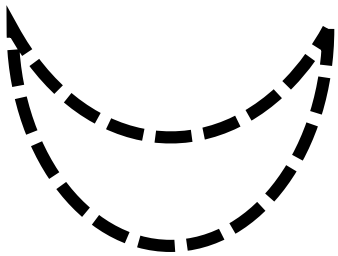
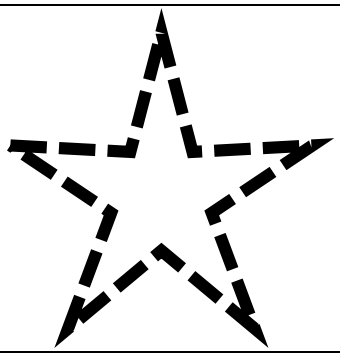
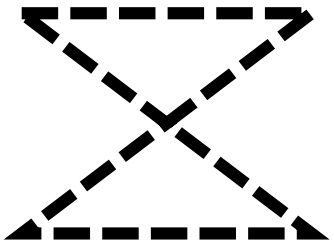
2. Draw Curves

3. Draw Shapes

4. Connect the dots