Screening Tool for Autistic Children

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Abstract— **Autism is a neurological disability that has been caused due to brain abnormality in a person. A person with Autism Spectrum Disorder(ASD) usually has difficulty in social and communication skills. In the past few years there hasn't been a proper way of identifying Autistic children in Sri Lanka. In this research paper, we will discuss how to identify an autistic child by considering mobile application with the following factors. Identify the eye contact, responsiveness to stimulus, analysis of vocal behavioral patterns and questionnaire. The above four factors will be the main key areas in screening process. This tool is created especially for identifying children with autism in rural areas in Sri Lanka. The major three areas eye contact, vocal behavior and responsiveness are the screening process is developed for proof of concept in this research.**

Keywords— Eye Gaze; Responsiveness; Vocal Disability; Questionnaire; Convolutional Networks; Image Processing;

I. INTRODUCTION

Autism is an integral neurobehavioral issue that includes social and communication behavioral difficulties. According to the researchers, Autism Spectrum Disorder(ASD) affects approximately one child in hundred children [1:100] in Sri Lanka, as recorded in 2013. Children diagnosed with ASD are difficult to discover due to the lack of facilities available in Sri Lanka.

In order to identify an autistic child, we considered 04 features that can identify autistic children,

I. Eye Contacting
II. Responsiveness
III. Vocal Behavioral Pattern Analysis
IV. Questionnaire

Children who have diagnosed with ASD might have responses that are uncommon to normal children. Resistance to change their routines, aggressiveness and self-injurious behavior are some common features that can be seen in autistic children. For an autistic child, typically it seems like they do not realize people, objects or activities in their environment [1]. These children can suffer sensory disturbances that may manifest as sensitive reactions to sounds which cause challenges in social interaction. This makes it very difficult for them to express themselves either with verbal or nonverbal communication methods [2]. Poor development of speech and the lack of language skills are acknowledged as of the most concern in distinguishing ASD [3]. When it comes to clinical based screening, the doctor conducts a Q&A session with the guardian. In our application, this procedure is made with a model to predict whether the child has autism. But in our other three research areas; eye contact, vocal test and responsiveness are based on proof of concept.

We only considered children of ages from 12 to 60 months for our research. During that time period children will behave differently according to the age group and its easy to treat them if the disorder is identified at an early age. Since most of the children in Sri Lanka speak in Sinhala, it is hard to identify the ones who suffer from this disorder because there is no specific autism screening tool that has been developed using the native language to address this problem. This research paper consists of a solution that addresses the hardships of identifying children with ASD.

The remainder of this research paper consists of several parts including an in-depth explanation of the methodology that is used in the screening tool that is being developed, and also the conclusion and future work that we'll be carrying out regarding this research.

II. RELATED WORK

In this research related in autism screening process for eye contact identifying techniques, many commercially used eye tracking devices were found. '*Tobii Pro*' which is an application which studies the differences in social interaction of ASD children [4]. In the applications that are being developed so far, the main focus on treatments children who are currently suffering from ASD. The Eye Tribe, Smart Eye, Pupil Labs and Gaze Point are some of the companies build their own eye tracking systems used in commercially and research publications. Many of the applications are forces on medical researchers, but not related with ASD.

For the identifying of responsiveness, '*EarlySee'* is an application which helps to recognize facial expression to identify the risk. The mobile camera is used to detect the behavioral pattern of the child for a mere 40 seconds. After the time is up, the researchers can estimate any possibilities of the child is not responding or not. Based on the child behavioral, researchers estimate the result. They send back results to the parent within two or three weeks [5].

'*Volafriends'* is an application to recognize the emotions of the autism children [6]. It identifies the facial landmarks and head pose estimation with face alignment framework using global and local CNN features [7].

When considering on making a questionnaire for screening purposes, M-Chat (Modified Checklist for Autism in Toddlers) which is available in the United States of America and Q-Chat (Quantitative Checklist for Autism in Toddlers) an application used in Iran are developed focusing on the children in their societies [8, 9]. Based on this fact some countries have developed similar culturally adopted their own screening applications. Indian Scale for Assessment of Autism (ISAA) diagnostic tool for ASD are such examples for culturally adopted applications available [10].

Even though recognition and analysis of speech patterns have not been used in any commercial applications related to autism screening of the children. Some of the applications such as '*Alexa*', created by Amazon and Shazam use the properties of audio analysis to perform various tasks. Dr. Riccardo Fusaroli, who is an associate professor in Cognitive Science at the Interacting Minds Center and at the School of Communication and Culture, Aarhus University, Denmark claims that there is a possibility to distinguish patients suffering from ASD from neurotically people by analyzing voice patterns with the help of machine learning [11] which also has an impact on the research area of voice pattern analysis with regards to this research.

III. SCREENING METHODOLOGY

This paper considers about image processing techniques to extract the features of major four areas in the autism screening. As a result of early identification of the symptoms of an autistic child, the possibility of curing the child to a near normal state with proper treatment is more than 90%. During the process, the parent / guardian is allowed to interact with the child to capture his head pose estimations and eye contact.

We used a small puzzle game to detect the eye contact of the child, head pose estimated with the response of the parent and whereas the voice of the child is recorded manually and analyzed with the pitch of normal children.

We used *Tensorflow Keras* library for vocal behavior analysis, *Weka* Tool making a model for the questionnaire, *Python* is used to identify the eye contact and the head pose estimation to come up with the results. To develop this screening tool, the overall result that is obtained from the gathered data will be taken and a probability for the level will be calculated according to international medical measurements of ASD.

A. Eye contacting

In this screening application, it identifies the eye gaze while the child looks at the screen, which captures the position of where the eye gaze matches on the screen. In this research, the pair of eyes gaze will be forced into a puzzle game which will be used to identify the eye contact time duration of the child with the image puzzle.

Gaze position of the pair of eyes are forced into a single gaze position which averaged position. The final result indicates the position of the eye pointing area whether the child is looking *Right* or *Left.* The viewing of ASD children is averagely shorter than normal children. We calculated the pair of eye gaze pointing position to normal distance (40-76cm).

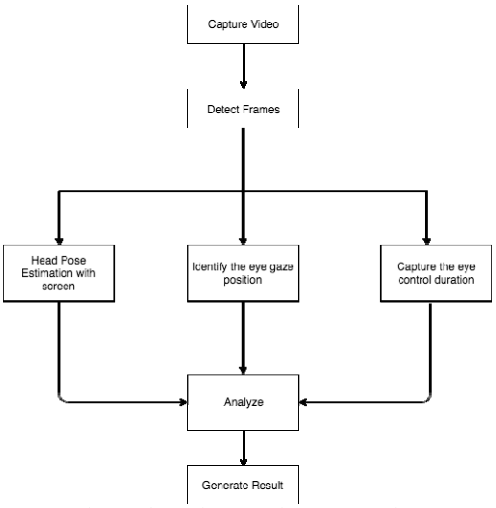

Fig. 2. Flow Diagram of Eye Contacting

To identify the eye contact, making a puzzle and categorizing the images will be randomly generated into the application. Time taken to identify the image by the children with ASD is compared with the normal children. Gathering of data with identified images was based on child interaction.

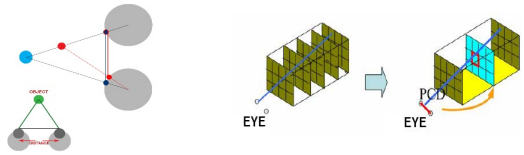

Fig. 3. Relationship of the Gaze Depth

These special children are not able to use their hands, feet or their voice in the correct way. Therefore, these children are not able to use this tool and the game as they cannot access the tool in a correct way [12]. For these kinds of scenario eye gaze is the most efficient way that allows the children to interact with the tool. The pupil is identified by the Viola-Jones library features which calculates the center point between the two eyes. This technique is based on the eye gaze position [13]. Afterwards the distance between the center point to the pupil will be calculated. From the difference in the distance as the child looks the direction can be monitored. To calculate the distance between right edge to center point from the facial features this will be helpful.

Features of the eye contact,

I. Video Stream Analysis:
We analyzed the application through a web camera. The resolution of 320x240 with a 3-5 seconds delay.

II. Eye Contact Analysis:
Identify the child is looking at the screen or not. Our research will indicate the gaze position of the baby is looking at the screen area. Calculate the eye contact duration within the period of child focus on display.

III. Puzzle Image Capturing:
We are providing some categorized images to children. We can identify the time taken to make eye contact with the objects in the screen. The puzzle is used to attract the kids to identify the eye contact.

B. *Responsiveness*

Head movements and facial landmarks are used to identify the responses of children. The parent/doctor must stay in front of the child and call with his/ her name and start the recording. Within 90 secs recording will be stopped. The result will be calculated according to child response. Application tracks the head movement and time period of the child takes to respond to their parents. Head movements X coordinates is used to identify the child left or right movements. Facial landmarks are identified face using OpenCv and dlib library and shape prediction [14].

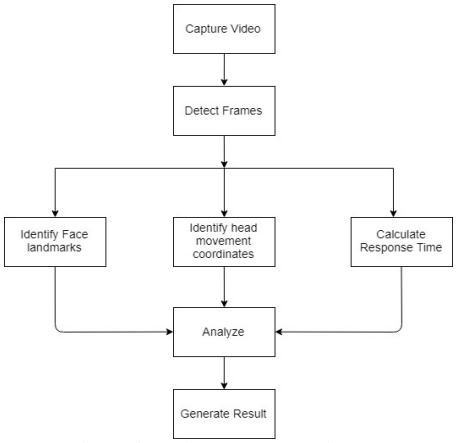

Fig.4. Flow Diagram Responsiveness

Head Movement Equation:

$$\mathbf{HME = (noseT - 2 * noseB + chinB + lipU - lipL) * 4,}$$
$$\mathbf{(noseT - 2 * noseB + chinB + lipU - lipL) *4}$$

Head Movement Equation= HME
noseT - Nose Top Point
noseB - Nose Bottom Point
chinB - Chin Bottom Point
lipU - Upper LIP Bottom MID Point
lipL - Lower LIP Top MID Point

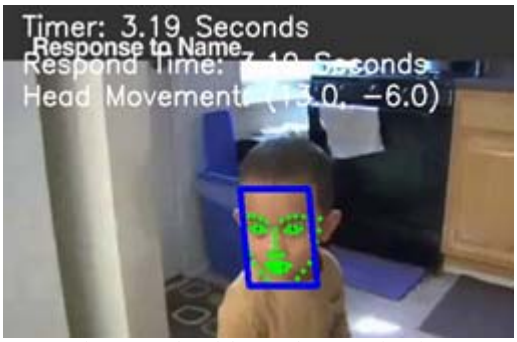

Fig. 5. Results of the Head-Pose Estimation

C. *Vocal Behavioural Pattern Analysis*

Children who are suffering from ASD can be identified in many different ways when considering and analyzing their vocal patterns. When it comes to these children, some may be completely unable to speak while the others might have the ability to develop extensive Sinhala vocabularies and create complete sentences. Even Though they are capable of speaking, they might speak in an unexpressive, monotonous tone of voice. Some children may babble, hum, or make "throaty" sounds. Another characteristic that is used to identify autistic children is that they tend to repeat certain words or sentences over and over again [15]. On abnormal speech spectrum and increased pitch variability in young autistic children, by analyzing spectrograms of voice of autistic and non-autistic children it has been found out that the spectrograms of a non-autistic children consist of sharper and more numerous peaks whereas the spectrograms of autistic children seem to be much shallower.

In order to predict the autistic level of a child using voice pattern analysis, a set of audio data was created by using voice clips of 5 autistic children and 5 non-autistic children whose ages vary from 18 - 48 months. Since the screening tool that we are developing is targeted on Sri Lankans, the language that was used in the audio clips that were used for the data sets was Sinhala. The audio data was then converted to spectrograms and the following features were considered when analyzing the spectrograms.

i. Long-Term Average Spectrum Analysis
ii. Pitch Analysis
iii. Spectral Variability

The Spectrogram images were trained using an image classifier which was built using a Convolutional Neural Network model, which was then used to predict the autistic level of a given child.

D. *Questionniare*

The PAAS (Pictorial Assessment for Autism Screening) prediction research component is based on a manual assessment conducted focusing on the Autistic children in Sri Lanka. The assessment is called PAAS which was conducted by the Consultant pediatricians in Sri Lanka [10]. In the PAAS, they have given twenty-one questions manually to the parents of the children regarding the behavior of the children and the parents have marked whether the children satisfy the assessment or not. After getting the feedback, the results are then entered in to the databases by a separate manual process and finally these entered data has used in predictions. The PAAS prediction questionnaire is mainly focused on automate the current manual process of Autism prediction by applying data mining techniques and classification techniques to generate an accurate prediction result as soon as possible from the time of answering the questions.

There are 246 instances in the dataset of both Autistic and non-Autistic children as the PAAS has been conducted on both the categories. All the attributes of the data set are measured in a categorical way. In the data preprocessing step, missing values and incorrect values were corrected. The mode value of the column (feature) is used for the correction of these errors. Then the data set is divided into two parts, one third of data as testing data set and two third of data as training data set. All the techniques were applied for the training data set which consisted with 163 records. Next classification algorithms are applied on the data set to create a classification model. Diagnosis feature is the prediction feature. The algorithms applied are AdaBoostM1, Random Forest, Random Tree and zeroR Algorithm from the Weka Tool. Some out of them, Random Tree model which has the highest accuracy, is used as the classification model of the function. The data mining is done

using the Weka 3.8. the android application is used to get the feedback for the questions in the questionnaire. Classification model created by Weka and the data set is developed using Java Weka API. The server side application and the android application is interconnected using REST API calls.

IV. Results and Discussions

We worked on three optimal screening areas which includes the eye contact, responsiveness, vocal behavior and one of data collected using data mining methodology. 75% accuracy level achieved with these major areas in this screening application which has been tested with 2-5 age group.

A. Eye Contact

As in study, we supposed to get data from much variations of children behaviors for early exploration. We found some similarities with the participants. The gaze pattern of attention children should:

i. Focal points other than one center.
ii. Attention with the device screen.
iii. Recurring to look the same images

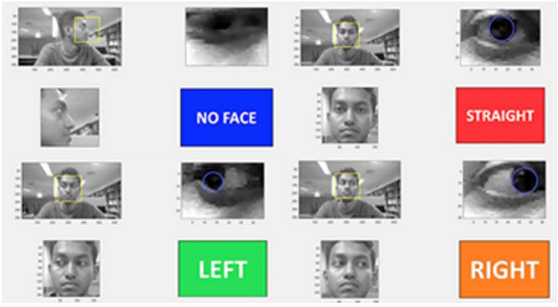

Fig. 6. Eye Contact Identification

The results will figure out the child is looking at the device screen or not. If the child is looking at the screen then, the application will identify the eye gaze in his/ her. It's going to identify the area of which he she is looking in.

B. Responsiveness

The results of the below table describe children looking at the camera then the application will identify the head movement, facial landmarks of the child and the response time.

Age Group (Months)	Response Time(Seconds)	
	Normal Children	ASD Children
0-6	12	46
7-12	8	38
13-18	7	37
19-24	6	36
25-30	3	38

Table. 1. Average Autistic Children Response Time

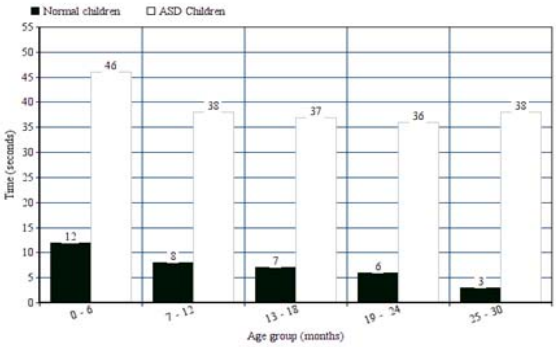

Fig. 7. Average Response Time Chart

The results of the Fig. 7 we can analyze the behavior of normal children responding time is very less than normal children. According to a past researches, the mean reaction time of normal children is 31.2 Seconds and mean reaction time of autism children is 66.2 Seconds for the 2-5 age range [16].

C. Vocal Behavioural Pattern Analysis

When analyzing the spectrograms, we realized that the frequency level indicated in the spectrums of autistic children are comparatively lower than that of the non-autistic children. To prove this fact furthermore, we analyzed the frequencies of a sample dataset of 40 audio recordings (20 Recordings of Autistic Children and 20 Recordings of Non-Autistic Children). A graphical representation of these frequency values is shown below,

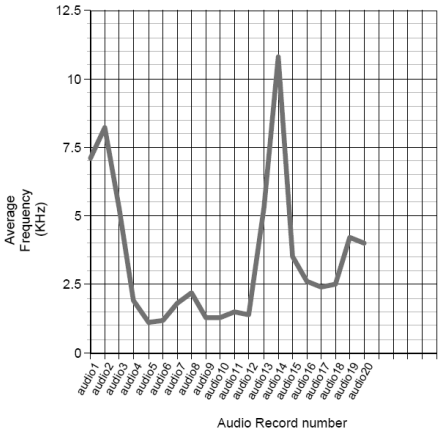

Fig. 9. Graph Depicting the Frequencies of Autistic Children

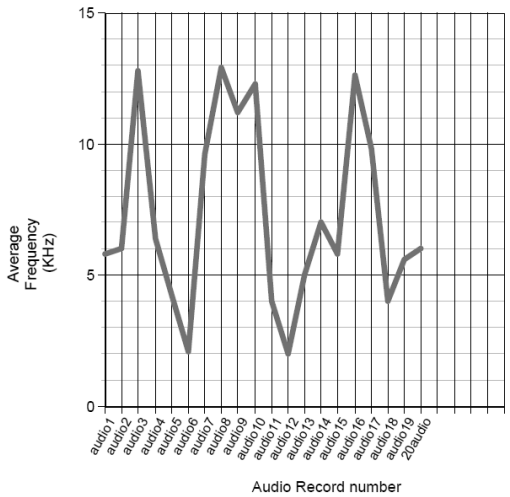

Fig. 10. Graph Depicting the Frequencies of Normal Children

Note that, in the following graph, the X-axis represents the audio file whereas the Y-axis represents the average frequency value of that particular audio files.

D. Questionniare

Correctly Classified Instances	**150**	**92.0245 %**			
Incorrectly Classified Instances	**13**	**7.9755 %**			
	TP Rate	**FP Rate**	**Precision**	**Recall**	**F-Measure**	**Class**
	0.959	**0.412**	**0.952**	**0.959**	**0.956**	**1**
	0.588	**0.041**	**0.625**	**0.588**	**0.606**	**2**
Weighted average	**0.920**	**0.373**	**0.918**	**0.920**	**0.919**	
a b <-- classified as **140 6 | a = 1** **7 10 | b = 2**						

Table. 4. Training Data Results

Correctly Classified Instances	**150**	**87.9518 %**			
Incorrectly Classified Instances	**13**	**12.0482 %**			
	TP Rate	**FP Rate**	**Precision**	**Recall**	**F-Measure**	**Class**
	0.949	**0.292**	**0.889**	**0.949**	**0.918**	**1**
	0.708	**0.051**	**0.850**	**0.708**	**0.773**	**2**
Weighted average	**0.880**	**0.222**	**0.878**	**0.8800**	**0.876**	
a b <-- classified as **56 3 | a = 1** **7 17 | b = 2**						

Table. 5. Results for Testing Data

The training and testing data sets were re-evaluated with the Random Tree classification model. The results that were obtained are displayed above.

To get a probability of the autistic level, we got the percentage of each disability and calculated an overall possibility level of the result. It does not tell that child has ASD or not, but warns the parents for any possibilities that might be available for the child to have autism.

CONCLUSION

In this screening application will help parents/guardians and doctors in identifying autism in young children easily, which will save a lot of time and money for them. Currently, the application that we developed only supports android devices. We will be upgrading this tool for IOS devices in future. Furthermore, the accuracy of identifying eye contact, responsiveness and the vocal behaviors would like to increase with efficiency.

In future we hope to predict our result more accurate through a model which having collected data of autistic and non-autistic children.

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