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DETECTION AND PREDICTION OF AUTISM THROUGH CONVERGENCE OF MACHINE LEARNING AND INTERNET OF THINGS

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Abstract: Autism Spectrum Disorder (ASD) is a condition characterized by challenges in social interaction. Early detection of ASD is crucial. The proposed system aims to leverage technological advancements to improve the accuracy and efficiency of autism detection. The current diagnosis of the ASD depends on the informant's evaluation of the patient's behaviour; this is both time and labor demanding. In order to develop a faster diagnostic tool with high accuracy, machine learning (ML) approaches have been proposed. In order to measure system correctness and accuracy there are three different approaches. The demand in the medical field was a questionnaire model, therefore an automated questionnaire model was developed consisting of 23 questions through which the risk of autism is calculated. Depending upon the high, low, or medium risk of autism the user will also be provided with the appropriate actions to be taken. The second model is based on real-time video tracking using an IoT (Internet of Things) device, where a raspberry pi camera will be used to record the eye movements of the user. The third model is based on using an image as an input, where a random forest will be used for image classification. Algorithms like random forest and SVM (support vector machine) were tested on the same dataset, wherein random forest showed better accuracy as compared to SVM which is about 86%. This paper proposes a solution to three different models to automate the autism detection system to provide an efficient tool for early screening and identification of individuals with ASD risk.

***Index Terms* - Autism Spectrum Disorder, Machine Learning, Eye Tracking, Questionnaire, M-Chat.**

I. INTRODUCTION

Autism occurs in early childhood as a complex mental disorder. Predominant research is required for early diagnosis and so better medical recommendations have to be provided with a better understanding of autism. ASD commonly shows signs of a lack in communication. Several previous studies have focused their attention on the communication and social skills of these ASD patients. The primary domain of research lies in considering the impact of autism on the people suffering from it.

The most popular traditional approaches such as observational methods, direct behaviour observational approach, and paper- and-pencil rating approach is utilized by medical specialists to measure the scale of irregularity in autistic patients. There is an alarming need to speed up this traditional method. We need to create an automated screening method in order to take a leap from this traditional method to an automated way of detection. Early free detection of autism will provide a way for making a child realize the risk of autism he is suffering from. Through this, he can analyze the severity of autism he is suffering from. According to the risk, the child can understand if he needs urgent medical attention or not. There are several limitations to the current traditional autism detection method. Manocha et al. [5] We need to overcome them to make detection a faster and more accurate method. In a developing country like India, we need to create awareness about autism because half of the population still believes it to be taboo. Wanglavan et al. [10] There is a need to create awareness and faster detection methods. Detection at an early age can guarantee a better chance of improvement in the child's neurological conditions. The earlier we detect the better can the child cope and improve as we start the treatment from a very young age.

Tremendous amounts of upliftment's in the field of technology have changed the way of working in many other fields. Technology is changing the current industry and updating the way they work. Technology has done this by automating many tasks, this has resulted in a decline in the amount of time required to perform a particular task. Advancements in Artificial Intelligence (AI) and ML have led to the development of several other algorithms for finding cures in the medical industry. Due to the introduction of IoT, many devices can be used for detection purposes which has resulted in higher accuracy. Manocha et al. [5] There are many algorithms that can be used in the process of detection and prediction. Selecting the appropriate algorithm will lead to 0% error and in turn high accuracy. This paper has proposed an idea for using ML models and an IoT device for the detection of autism. Wanglavan et al. [10] By implementing ML models for detection we can detect autism more accurately and in a much faster way. The development of an effective IoT-fog-assisted real-time activity monitoring solution would be advantageous for parental figures and advisors by speeding up the detection process. for providing therapeutic or assistive care to individuals suffering from ASD.

II. Literature Survey

This section briefly describes other related works about different techniques used in the detection and prediction of autism.

Sujuda OV et al. [3] have presented a system that provides a smart IoT controlling system, for receiving efficient communication between the IoT devices and the users. There are mainly 3 modules in the IoT device controller named Catch gesture which include 1) Object Recognition Module, 2) Eye Tracking Module, and 3) Gesture Recognition Module. IoT device control command is obtained and transferred to the IoT devices to control the IoT devices by using hand gestures. The performance evaluation measured the competence and efficacy of the proposed system in detecting IoT devices. CNN is the technology used in this project for object detection. The object detection module adopted a convolutional neural network approach. The following task included eye tracking, also known as gaze tracking; from this task, the user is able to extract the user's eye position, after which the device is capable of recognizing the IoT device. The hand gesture recognition task is then used for device management. The IoT devices are controlled based on the data obtained from the Hand gesture module. The system proposed a framework, which is a hardware device containing a Raspberry Pi 3 that may control the entire system. It consisted of a relay that acted as a switch to control the IoT devices. The accuracy achieved through performance evaluation, the performance of IoT device detection and the IoT device classification of the proposed approach is acceptable (around 90%).

K.Vijayalakshmi et al. [4] have proposed a work that aims at addressing autism clusters: Adolescent, adult, and child datasets using a multi classifier-based regression (MCR) mechanism as a hybrid recommendation model to improve prediction accuracy. It is constructed by integrating naive Bayes classifiers and random forest classifiers with logistic regression via meta-classifiers using raw data and scores considering the probabilities of multiple classifiers and the majority vote average. The proposed work used classifiers such as Random Forest and Naive Bayes along with logistic regression to improve predictive power through the construction of joint MCR models. Since the selected dataset has two-class predicted labels, all machine learning algorithms used in this work are binary classifiers, which makes the MCR model more robust to apply. This experiment used the WEKA tool, which performs both supervised and unsupervised machine learning. This work was investigated using Version 1 - ASD Screening Data for Child Dataset (292, 21) / Adolescent Dataset (104, 21) / Adult Dataset (704, 21) and is suitable for all classification and regression models. There are 292 instances in the child dataset and 104 and 704 datasets with 21 attributes in the youth dataset, of which 10 questionnaires (AQ1-10) deal with behavioural problems and are class-labeled. The efficiency of the MCR model could potentially serve as a highly effective automated recommender system to provide society with a better autism screening model.

Ankush Manocha et al. [5] have proposed a smart physical activity assisted behaviour prediction framework to recognize different stereotypical motor movements of individuals suffering from autism spectrum disorder in real-time. In this framework, the data collection efficiency of smart wearable sensors powered by the Internet of Things (IoT) to record human physical activity was employed. A deep learning inspired multilayer convolutional neural network (CNN) + short-term and long-term memory network has been proposed to predict physical activity. A decision-making module notifies the concerned caretaker or professional in real time of any irregular physical activity performed. Moreover, the process of cloud-based dataset generation also increases the importance of the proposed solution. The predicted SMM directed locomotor movements are further stored in a cloud database to provide a future medical reference. The performance of the proposed system justifies the productivity of the framework for determining complex individual behaviour. The proposed approach is validated by comparing its prediction performance with traditional manual-based and current state-of-the-art approaches based on deep learning such as k-nearest neighbors, hidden Markov models, and CNNs. Overall results outperformed with 91.88% accuracy. As for future work, data security is considered one of the essential research areas for investigation.

Halim Abbas et al. [7] have presented a machine learning approach for early detection of autism by combining questionnaire and home video screening. In this paper, their main focus was to apply Machine Learning (ML) to create a low-cost, quick, and easy to apply autism screening tool. Two algorithms have been trained to identify autism, one based on short, structured parent-reported questionnaires and the other on tagging key behaviours from short, semi-structured home videos of children. A combined algorithm is then used to combine the results into a single assessment of higher accuracy. In order to overcome the scarcity, sparsity, and imbalance of training data, they have applied novel feature selection, feature engineering, and feature encoding techniques. The performance is then validated in a controlled clinical study. Two decision forest ML classifiers were trained. For each classifier, 10 questions were selected using the same robust feature selection method, and the same allowance for inconclusive outcomes was made as for the parental questionnaire classifier. Each model was independently parameter-tuned with a bootstrapped grid search.

III. PROPOSED ARCHITECTURE

This section gives the proposed architecture for the detection and prediction of ASD.

3.1 System Architecture

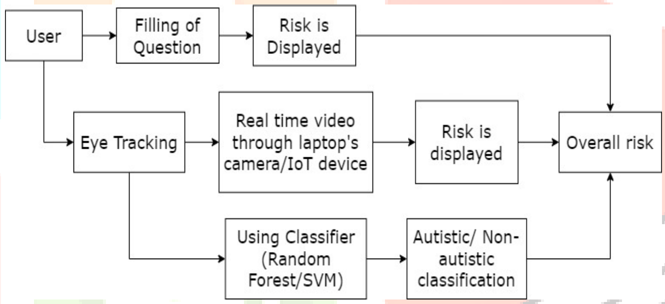

Fig. 3.1. system architecture

Fig 3.1 depicts the overall execution of our model for an automated diagnosis of autism. In order to speed up the autism detection process different machine learning approaches are used as listed below:

3.1.1 Questionnaire Model:

The Modified Checklist for Autism in Toddlers (M-CHAT) is a 23-question parent-report screening tool for autism spectrum disorder (ASD). It is designed to be used by healthcare providers to identify toddlers who may be at risk for ASD. The M-CHAT has been shown to be effective in detecting ASD in toddlers, with a sensitivity of 89% and a specificity of 79%. This means that the M-CHAT is likely to correctly identify 89% of toddlers with ASD, and it is likely to correctly identify 79% of toddlers who do not have ASD. Its purpose is to identify children who may benefit from further assessment and early intervention, enhancing the chances of improving outcomes through targeted interventions and support. If a toddler answers yes to two or more of the questions on the M-CHAT, they are considered to be at risk for ASD and should be referred for further evaluation.

Here are some of the benefits of using the M-CHAT to screen for autism:

i. The M-CHAT is a quick and easy-to-use screening tool.

ii. The M-CHAT has been shown to be effective in detecting ASD in toddlers.

iii. The M-CHAT can help to identify toddlers who are at risk for ASD so that they can be referred for further evaluation and intervention.

The M-CHAT questionnaire helps identify potential red flags associated with ASD, such as social communication deficits and repetitive behaviours. It covers areas like eye contact, pointing, pretend play, their response, and overall social engagement. The answers provided by parents or caregivers offer insights into a child's developmental patterns. When the M-CHAT is administered, each "yes" response is assigned a score of 1, while "no" responses receive a score of 0. The total score is then calculated by summing the scores from all 20 questions. Typically, a total score of 3 or higher raises concerns and suggests further evaluation for ASD. Regular use of the M-CHAT questionnaire aids in the early detection of ASD, allowing for timely intervention and support for children and their families. Early identification and intervention have been shown to have a positive impact on long-term outcomes, as they promote the development of crucial skills and address challenges associated with ASD.

3.1.2 Real-time video tracking using IoT Device:

Real time video tracking helps to analyze and track the eye movements of the user using an IoT device, instead of a normal camera. The low-resolution power of the laptop’s camera may lead to a decrease in accuracy. Hence, instead of using a laptop's camera, a raspberry pi camera can be used to acquire better accuracy in the prediction of the risk of autism. Raspberry Pi 0w is used for taking real time video of the user in order to enhance the prediction of the system. It allows for wireless connection as it has built-in wireless connectivity. It includes both Wi-Fi (802.11n) and Bluetooth 4.2, eliminating the need for external adapters and enabling easy integration with wireless networks and Bluetooth-enabled devices. It also consists of GPIO Pins. Like other Raspberry Pi models, the Zero W features GPIO (General Purpose Input/Output) pins that allow for easy interfacing with a variety of sensors, modules, and devices. These GPIO pins provide flexibility and expandability, enabling users to create projects with a wide range of functionalities. It consumes significantly less power compared to other Raspberry Pi models.

Hence raspberry pi 0w is used for capturing real time video of the user. After the video has been captured, based on the position of the pupil the gaze tracking ratio is calculated, depending upon whether the pupil is in the left or right direction.

If the,

gaze tracking ratio < = 0.40: Depicts that the pupil of the user is in the left direction the maximum number of times.

gaze tracking ratio > = 0.65: Depicts that the pupil of the user is in the right direction the maximum number of times.

0.40< gaze tracking ratio>0.65: Depicts that the user does not have autism.

If the ratio<=0.40 or ratio>=0.65, then the prediction will be that the user has a 30% risk of autism. Else the prediction is that the user has no risk of autism.

3.1.3 Using Random Forest/Support Vector Machine as Classifier:

Different machine learning algorithms such as Random Forest and Support Vector Machine are used as classifiers to classify an image input given to the model, which generates the results whether the person is autistic or not.

Random Forest is an ensemble learning method that combines multiple decision trees to make predictions. It can be utilized for autism detection by leveraging its capabilities in analyzing various features and making accurate predictions. Utilizing Random Forest for autism detection offers the advantages of accurate predictions, feature importance analysis, and interpretability. However, it is important to note that Random Forest alone cannot provide a definitive diagnosis. It serves as a valuable tool in the screening and identification of individuals who may require further evaluation by healthcare professionals specializing in autism spectrum disorders.

Another algorithm used for image classification is Support Vector Machine (SVM). It is particularly effective for binary classification problems. It offers advantages in autism detection by providing a powerful decision boundary that can handle high-dimensional data and nonlinear relationships between features. However, similar to other machine learning approaches, SVM should be used as an adjunct tool to aid in screening and identifying individuals at risk for autism. A comprehensive evaluation by healthcare professionals specializing in autism spectrum disorders is crucial for accurate diagnosis and appropriate interventions.

Both these algorithms are trained on more than 2500+ images of autistic and non-autistic people, and based on the prediction result the algorithm which provides better accuracy and predicts better results is chosen as an image classification algorithm for autism detection. As random forest showed better accuracy of about 86%, it is for image classification.

3.2 UML DIAGRAMS

The system architecture is further explained with the help models occur in sequential order. It visualizes the dynamic of the below listed UML diagrams. These diagrams depict the behavior of the system, focusing on how objects collaborate proposed architecture and its implementation aspects. to achieve various functionalities.

3.2.1 Use Case Diagram:

A use case diagram's main purpose is to visually represent a system along with its main actors, roles, actions, artifacts, or classes, in order to better understand, alter, maintain, or document information about the system as shown in Fig 3.2.

3.2.2 Sequence Diagram:

Fig 3.3. shows how the interactions between three different models occur in sequential order. It visualizes the dynamic behaviour of the system , focusing on how objects collaborate to achieve various functionalities.

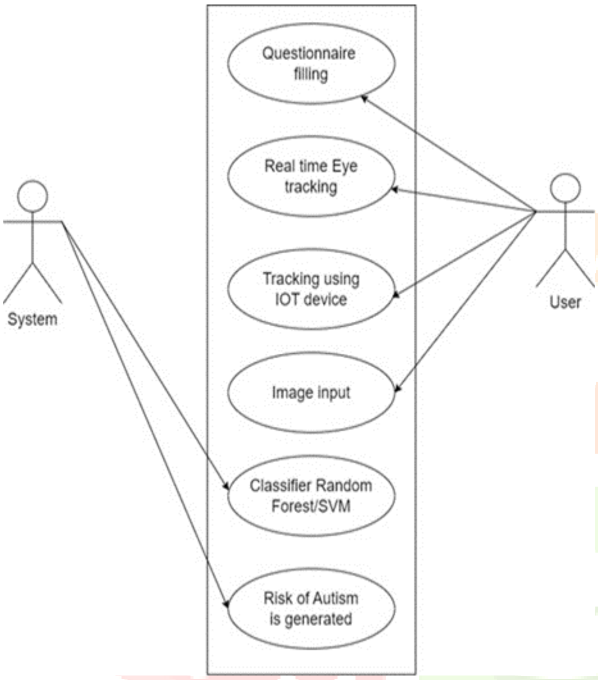

Fig. 3.2. use case diagram

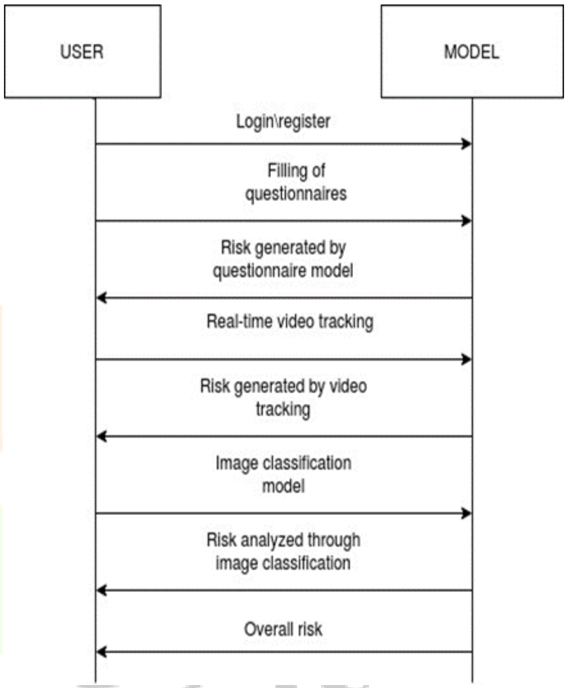

Fig.3.3 sequence diagram

3.2.3 State Transition Diagram:

Fig. 3.4. also known as a state machine diagram or state chart diagram, is an illustration of the states an object can attain as well as the transitions between those representing the entire autism detection system.

3.2.4 Class Diagram:

Fig 3.5. provides an overview of the system's static structure, serving as a blueprint for the software design.

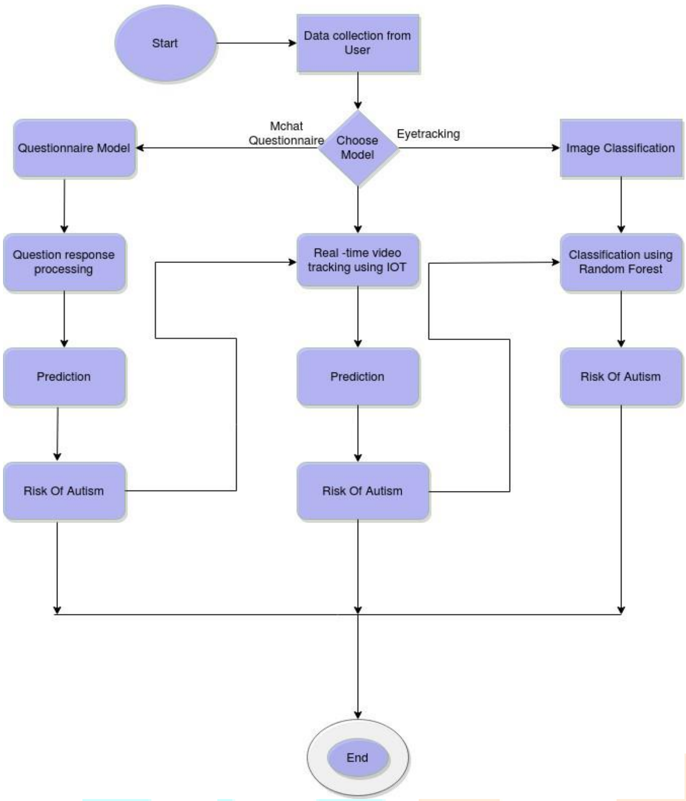

Fig 3.4. state transition diagram

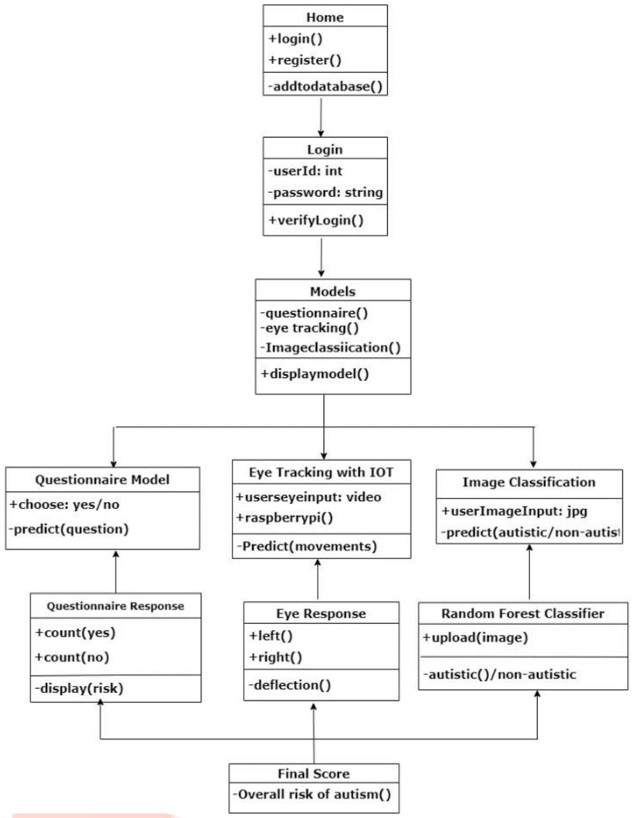

Fig 3.5. class diagram

IV. SYSTEM EFFICIENCY MEASURES

The analysis of both algorithms is based on accuracy, precision, recall, and f1-score. These system efficiency measures are used to analyze different algorithms used in the proposed architecture.

Precision=TP/TP+FP

Recall=TP/TP+FN

F1-Score=(2*Precision*Recall) / (Precision + Recall) Accuracy= (TP+TN) / (TP+TN+FP+FN)

where, TP=True Positive, TN=True Negative, FP=False Positive, FN=False Negative

		Actual Values	
		Positive	Negative
Predicted Values	Positive	21	3
	Negative	4	22

Fig 4.1. confusion matrix

Fig 4.1 shows a confusion matrix which is often used to describe the performance of a classification model or algorithm. It enables the evaluation of the performance of a machine learning model by analyzing the accuracy and error rates across different classes.

V. Results And Discussion

The proposed architecture is tested using an autism dataset consisting of 2540 training images containing 1270 autistic and 1270 non-autistic images and 300 test images containing 150 autistic and 150 non-autistic images. These images are in ".jpg" format. Each image in the dataset is of different dimensions. The autism dataset is available on this link: Autism_Image_Data | Kaggle

5.1 Result of Model 1:

The first model i.e. Questionnaire Model consists of 23 questions which are to be answered as "yes" or "no". Based on the answers provided by the user, the result for this model will be generated. This model is tested by providing different inputs to the questions and the model showed correct results for all possible inputs.

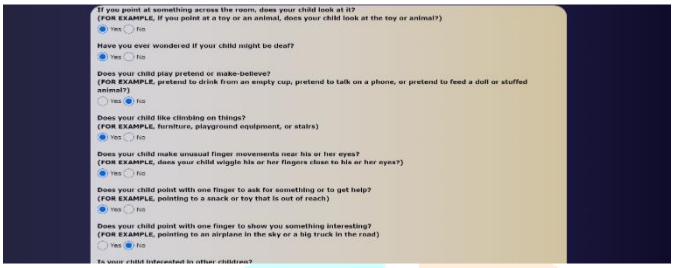

Fig 5.1. model 1 output 1

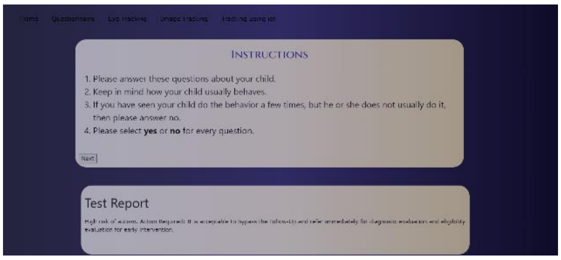

Fig 5.2. model 1 output 2

Fig 5.1 shows the questions that are to be filled by the user for analysis of the risk of autism. Fig 5.2 depicts the output of the questionnaire model based on the number of questions answered by the user and an appropriate action required will also be displayed.

5.2 Result of Model 2:

The second model i.e., Real Time Video Tracking using IoT which tracks the eye movements of the user. This model takes the video using raspberry pi and then displays the risk of autism based on the gaze tracking ratio.

Fig 5.3. IoT device connection

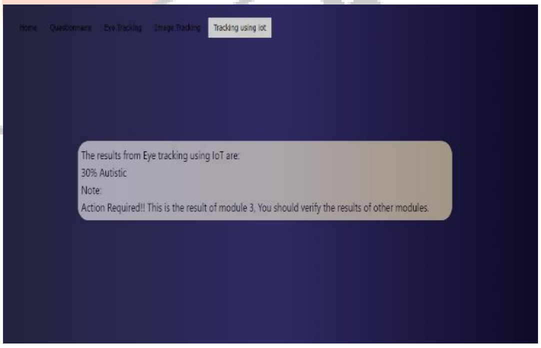

Fig 5.4. model 2 output

Fig 5.3 depicts the connection between raspberry pi and pi camera connection required for real time video analysis to detect and predict autism. Fig 5.4 shows the output of model 2. Based on video taken by the raspberry pi camera the output about risk of autism will be displayed. The output will be either 30% risk of autism or no risk of autism i.e. normal.

5.3 Result of Model 3:

The third model i.e. detection of autism using, an image as an input where the user will provide image input in order to detect and predict autism. The autism dataset consisting of various images of autistic and non-autistic images is trained with two machine learning algorithms i.e. Random Forest and Support Vector Machine.

		Autism	positive(1)										
		Non autism	negative(0)										
			Pass/Fail(1/0)			Random forest				SVM			
Image	Actual	Predicted RF	Random forest	Predicted SVM	SVM	TP	TN	FP	FN	TP	TN	FP	FN
1	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
2	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
3	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
4	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
5	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
6	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
7	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
8	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
9	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
10	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
11	Autism	Non-Autism	0	Autism	1	0	0	0	1	1	0	0	0
12	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
13	Autism	Autism	1	Autism	1	1	0	0	0	1	0	0	0
14	Autism	Non-Autism	0	Non-Autism	0	0	0	0	1	0	0	0	1

Fig 5.5 analysis of random forest and svm

36	Non-Autism	Non-Autism	1	Autism	0	0	1	0	0	0	0	1	0
37	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
38	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
39	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
40	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
41	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
42	Non-Autism	Autism	0	Autism	0	0	0	1	0	0	0	1	0
43	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
44	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
45	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
46	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
47	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
48	Non-Autism	Non-Autism	1	Autism	0	0	1	0	0	0	0	1	0
49	Non-Autism	Non-Autism	1	Non-Autism	1	0	1	0	0	0	1	0	0
50	Non-Autism	Non-Autism	1	Autism	0	0	1	0	0	0	0	1	0
		Total(Pass)	£43.00		40	21	22	3	4	22	18	7	3

Fig 5.6 analysis of random forest and SVM

Fig 5.5 shows an analysis of 50 images from a dataset on both algorithms and their actual and predicted results. This analysis is based on TP (True Positive), TN (True Negative), FN (False Negative), and FP (False Positive) obtained.
Fig 5.6 shows the total number of TP, TN, FP, and FN obtained for random forest and SVM

Table Tabular analysis of both algorithms

Table 1. TP, TN, FP, FN

Algorithm	TP	TN	FP	FN
Random Forest	21	22	3	4
SVM	22	18	7	3

Table 2. TP, TN, FP, FN

Algorithm	Precision	Recall	F1-Score	Accuracy
Random Forest	0.875	0.84	0.857	0.86
SVM	0.758	0.88	0.814	0.80

Table 1 and 2 shows the tabular analysis of random forest and SVM.

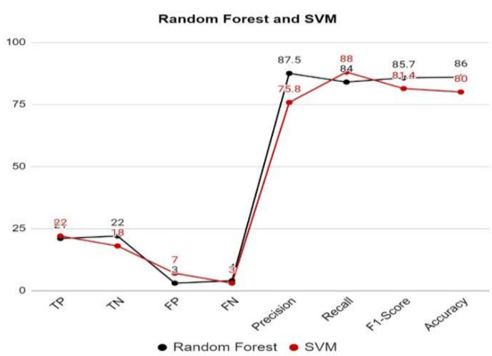

Fig 5.7. graphical representation of analysis of both algorithms

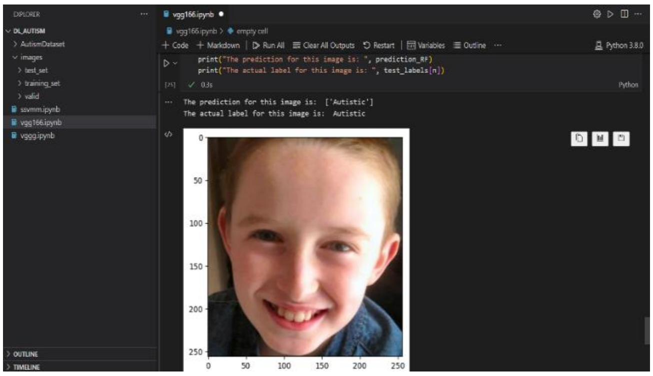

Fig 5.8 result of the random forest as a classifier

Fig 5.7 shows the graphical representation of both algorithms, where it depicts the higher and lower TP, TN, FP, FN, Precision, Recall, and Accuracy values. Fig 5.8 shows the actual and predicted result of using random forest as a classifier.

The observation of the result set is that the random forest is used for prediction using an image as an input as it obtained an accuracy of about 86% which is higher than the accuracy of SVM which is 80%.

VI. Conclusion

The process of autism detection plays a crucial role in early intervention and support for individuals on the autism spectrum. Hence this proposed system provides an automated and efficient solution for the detection and prediction of autism.

VII. Acknowledgment

We'd like to express our gratitude to Dr. Kalpana Thakre who made it possible for us to complete this paper. She supported and encouraged us. Her academic advice and ideas have played an important part in the work proposed in our paper.

References

[1] Shubhangi Kumbhar, Vedika Torawane, Kalpana Thakre, Trupti Landge, Dipti Landge. “A SURVEY ON DETECTION AND PREDICTIONOF AUTISM DISORDER USING MACHINE LEARNING APPROACHES”, IJRAR. 2022, Paper ID: IJRAR22D2668

[2] V. Yaneva, L. A. Ha, S. Eraslan, Y. Yesilada and R. Mitkov, “Detecting High- Functioning Autism in Adults Using Eye Tracking and Machine Learning,” in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 28, no. 6, pp. 1254-1261, June 2020, doi: 10.1109/TNSRE.2020.2991675.

[3] S. Manal, S. OV and S. KG, "Catch Gesture: An Ultimate Action Recognition Technology Using IoT Device," IEEE 2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2020, pp. 363-367, doi: 10.1109/ICICCS48265.2020.9121022.

[4] K. Vijayalakshmi, M. Vinayakamurthy and Anuradha, “A Hybrid Recommender System using MultiClassifier Regression Model for Autism Detection,” 2020 International Conference on Smart Technologies in Computing, Electrical and Electronics(ICSTCEE),2020, pp.139-144, doi: 10.1109/ICSTCEE49637.2020.9277034

[5] Manocha and M. Bhatia, "IoT-Inspired Monitoring Framework for Real-Time Stereotypic Movement Analysis," in IEEE Systems Journal, vol. 16, no. 2, pp. 2788-2796, June 2022, doi: 10.1109/JSYST.2021.3084370

[6] Tang et al., "Automatic Identification of High-Risk Autism Spectrum Disorder: A Feasibility Study Using Video and Audio Data Under the Still-Face Paradigm," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 28, no. 11, pp. 2401-2410, Nov. 2020, doi: 10.1109/TNSRE.2020.3027756.

[7] Abbas H, Garberson F, Glover E, Wall DP. Machine learning approach for early detection of autism by combining questionnaire and home video screening. J Am Med Inform Assoc. 2018 Aug 1;25(8):1000-1007. doi: 10.1093/jamia/ocy039. PMID: 29741630; PMCID: PMC7646881.

[8] Vakadkar, K., Purkayastha, D. Krishnan, “Detection of Autism Spectrum Disorder in Children Using Machine Learning Techniques”, 2021, Springer, SN COMPUT. SCI. 2, 386 doi:10.1007/s42979-02100776-5.

[9] C. Wu et al., “Machine Learning Based Autism Spectrum Disorder Detection from Videos,” 2020 IEEE International Conference on Ehealth Networking, Application Services(HEALTHCOM),2021, pp.1- 6, doi:10.1109/HEALTHCOM49281.2021.939824.

[10] P. Wanglavan, W. Jutharee, T. Maneewarn and B. Kaewkamnerdpong, "The Development of Attention Detection Model from Child Behavior for Robot-Assisted Autism Therapy,"IEEE 2019 19th International Conference on Control, Automation and Systems (ICCAS), Jeju, Korea (South), 2019, pp. 775-780, doi: 10.23919/ICCAS47443.2019.8971509.

[11] Sharma and P. Tanwar, "Deep Analysis of Autism Spectrum Disorder Detection Techniques," 2020 International Conference on Intelligent Engineering and Management (ICIEM), London, UK, 2020, pp. 455-459, doi: 10.1109/ICIEM48762.2020.91601