A Survey On Autism Spectrum Disorder using Machine Learning Techniques

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Abstract: Autism Spectrum Detection (ASD) is a serious development disorder. It affects the linguistic, communicative, social skills and learning skills of the person. The diagnosis of ASD can be performed by looking at a person's development and their behaviour. Autism spectrum is detected using various screening tests. In order to make this process less time consuming, various machine learning techniques are used to predict autism at an early stage. Support Vector Machine (SVM), Decision tree, Naïve Bayes, Random Forest, Logistic Regression and K-Nearest neighbour are some of the machine learning techniques used in this research area. Various advancement in the field of machine learning and Artificial Intelligence (AI) has helped in the development of ASD Detection using Machine learning and Deep Learning.

Index Terms - **Autism Spectrum Disorder, Machine Learning, Convolutional Neural Network (CNN), k-nearest neighbors (KNN), Artificial Intelligence, Support Vector Machine, Multilayer Perceptron**

I. INTRODUCTION

Autism Spectrum Disorder (ASD) can be defined as a complex development condition. This condition involves problems in social interaction, speech, communication and also results in repetitive or restricted behaviour. According to a research by CDC, one in 59 children is estimated to have autism [14]. There has been rapid growth in the cases of autism in recent years.

Autism is a lifelong disorder. But recently various treatments and services are helping in improving the person's symptoms and health condition. Some of the common symptoms of Autism Spectrum disorder include: Making inconsistent eye contact, tending not to look or listen to people, failing to respond to someone calling their name, do not feel comfortable with physical contact, not being able to express their gestures, less interactions with others, repeating certain behaviour like repeating certain words or phrases, having more interest in certain specific topics, having overly focused interest, speech disorder, etc. Usually, autism is caused in a person if the person has a sibling with ASD or having older parents or suffers from certain genetic condition or has lower birth weight.

Early detection of ASD is very important in order to decrease the symptoms of ASD in the patients. Recently there has been a rapid growth in the field of Artificial Intelligence and Machine learning. These research areas are helping bring a major improvement in the health sector. There has been much research in this area in order to help detect Autism at an early age. Various researchers have used various machine learning algorithm in order to detect Autism among Adults, Children and Adolescent. Recently deep learning methods are also being utilized to detect autism using Magnetic resonance imaging (MRI) images, image classification, etc. Various datasets have also been developed in order to help autism detection through various machine learning and deep learning methodologies.

This research paper provides a brief overview of various research work performed in the field of Autism detection using machine learning and deep learning methods.

II. LITERATURE SURVEY

Autism Spectrum Disorder is a neurological disorder which needs to be detected at an early stage in order to reduce its symptoms. Various development in the field of machine learning is helping more innovations and development in this medical area. Various researchers have utilized various machine learning algorithms in order to detect Autism at an early stage. Some deep learning-based methods such as CNN have also been used to detect autism in kids using image classification of MRI images.

In the work by Raj et al. [1] "Analysis and Detection of Autism Spectrum Disorder Using Machine Learning Techniques" the authors have proposed the use of methods like- CNN, Support Vector Machine (SVM) and Artificial neural network (ANN). In this work, the missing values were handled first. Later, the authors have used CNN based classifier instead of SVM by including

all its features attributes. Here, both the SVM and CNN based models showed the same accuracy of prediction of about 98.30 % for ASD Child dataset. They have used Adam optimizer to optimize and handle loss functions.

Another researcher M. S. Mythili et al. [2] have used classification techniques in order to detect Autism. In Neural Network methods, Support Vector Machine and Fuzzy Logic was used to analyze Autism in students. The dataset utilized in this research work consists of various attributes such as Language data, social skill data, Behavior data, etc.

In another work by Omar et al. [3] the authors have proposed effective prediction of autism using various machine learning techniques. Here, the authors have also developed a mobile application for predicting autism in people of any age. In this work, the authors have performed predictions based on Tree-CART classifier. At the beginning, the tree root consists of the whole dataset. Later on, the dataset is split based on feature selection. They have also performed prediction using Random Forest-CART method. They have claimed that the Random Forest Method performs better than another classifier. J.A. Kosmicki et al. [15] have proposed to search least set of features to detect autism. They have used machine learning based approach to detect autism. They have employed 8 different machine learning algorithms.

In another work by Misman et al. [16], the authors have used Deep Neural network architecture for appropriate classification. In this work the authors have developed a deep neural network using Keras Sequential Model API [17]. Here, the authors have used two main hyper parameters in neural network which are number of layers and number of nodes. They have later compared this deep neural network model with other machine learning algorithms such as SVM. The authors have claimed that the accuracy of this model is higher and provides accurate results.

Computer vision has also developed a lot in last few years. Computer vision is helping in various medical research areas. It is now being used in the analysis of Autism Spectrum disorder in order to perform early diagnosis and treatment of this disease. Along with these machines learning based methods, visual attention-based methods were also implemented to detect autism in kids.

For this purpose, many researchers also developed eye tracking based methodology to detect Autism. In the research work by Wan et al. [4], the authors have utilized eye tracking method to detect autism. Eye tracking method helps in early detection of Autism. Detection of Autism in young children using eye tracking small informative video were used. In this research work the authors have used 37 ASD and 37 Typically developing children of age 4 to 6 and created a dataset by making them watch a 10 second video of female speaking. Reductions in fixation time was observed in ASD children.

Another researcher utilized video analysis in order to detect autism. In the research work by Zunino et al. [13], the authors have created a video analysis dataset to detect autism. This work by the researcher focuses at providing an objective support to the doctor for the early assessment of diagnosis. Here, the researchers have created a specific experiment in order to record videos of the children. They have recorded the patient performing simple gesture like grasping a bottle. They have processed the video data using recurrent deep neural network. This resulted in proper discrimination between the two classes.

Another research work by Sherkatghanad et al. [5] proposed Autism detection using Convolutional Neural Network. Here, the researchers have utilized Brain imaging dataset to perform the detection process. They have used CNN on the dataset containing brain images. The resting-state functional magnetic resonance imagining (fMRI) data from the dataset named Autism Brain imaging exchange (ABIDE) were used to detect Autism patients. Various patterns were utilized by authors to classify patients. They achieved an accuracy of 70.22 % using the ABIDE dataset.

In another similar work by Anibal Heinsfeld et al. [18], the authors identified autism spectrum disorder among patients using large brain imaging dataset by using deep learning algorithms on them. They have also used the ABIDE dataset. The authors have performed study on patterns of functional connectivity. These patterns are useful in identifying the ASD participants using the functional brain imaging data. The authors also tried to identify and study the neural patterns that emerged from the classification. The model developed by authors achieved an 70% accuracy in identification of ASD versus normal patients in the dataset. Anti-correlation of brain function between anterior and posterior areas of the brain were obtained from the patterns obtained through classification [18]. In the work by Liu et al. [6], the authors in order to perform early identification of autism in children have developed a computer vision-based system. They have considered reduced levels of response to languages as the base in order to detect autism in children. Here, the subjects are recorded while they play with the toys. The response of subjects to instructions is measured by vision-based techniques like hand tracking and object recognition. Based on this the subject is classified into appropriate class.

From the above research works it is evident that various conventional machine learning methods as well as deep learning and computer vision-based methods are paving the way in diagnosing Autism at an early stage. This early-stage detection can be of great help in this medical area.

III. DATASET AND EVALUATION

Various dataset has been collected in this research area. One of the datasets has been collected from the UCI Machine learning Repository [22] which is available publicly. This dataset contains data for Adults [10], Children [11] and Adolescent [12]. This dataset contains 20 attributes in order to predict Autism Spectrum Disorder. Table 1 shows the attributes that the dataset contains.

TABLE I
VARIOUS ATTRIBUTES OF DATASET [1]

Attribute ID	Attribute Description
1	Patient Age
2	Sex
3	Nationality
4	The patient suffered from Jaundice problem by birth
5	Any family Member suffered from pervasive development disorders
6	Who is fulfilment the experiment
7	The Country in which the user lives
8	Screening application used by user or not?
9	Screening test type
10-19	Based on the screening method answers of 10 questions
20	Screening Score

Recently fMRI data is also being utilized to detect autism. Various functional and structural brain imaging datasets have been provided by Autism Brain Imagining Data Exchange (ABIDE) [8]. These images were collected from several brain imaging centers around the world. Preprocessed connectomes project (PCP) from the ABIDE has openly released 539 individuals who have ASD and 573 TD to the public. All these 1112 dataset consists of structured and pre-processed resting state functional MRI data along with phenotypic information. Many researchers have provided insight on using facial morphology to detect autism. Some of these methods involved physical measurement of facial features and then its data analysis in order correlate these measurements with the presence of Autism. One of the researchers released dataset containing images of children with Autism and without Autism [19]. The images in the dataset were gathered through variouss online sources. This data set contains 1667 images of Autistic children and 1667 images of Non-Autistic children. Facial features were used in order to perform Autism detection among kids. Fig 1 shows the images contained in the dataset.

Figure 1: Images of Non-Autistic kids from Dataset [19]

Another dataset being explored recently is autism detection using eye movement tracking methodology. Duan el al. [7] published an open dataset of eye movements of children with Autism Spectrum Disorder. This dataset consists of 300 natural scenes images. The dataset consists of images of various animals, images of buildings or objects, natural scene images, images of multiple people in one image, images of multiple people and object in one image, images of solo person and object in one image, etc. The authors have utilized T120 Eye tracker in order to display the images and record the eye movements.

Another author Carette et al. [20] developed a setup to track eye movement of various participants. The visualizations that were produced through this experiment are made publicly available in an image dataset. This isxperiment was performed on a group of 59 participants. The participants were invited to watch a variety of videos. The videos were planned in such a way that it can stimulate eye movement. The SMI RED mobile was the main instrument used for this eye tracking experiment. Various dynamics of eye movement were captured using this instrument. The eye tracking records were converted into visual patterns. The dataset produced contains total of 547 images, 328 images for the non-ASD class, and 219 for the TS class. The dataset is publicly available through the Figshare data repository [21]. Figure 2 and Figure 3 shows the visualization examples of ASD and non-ASD participants.
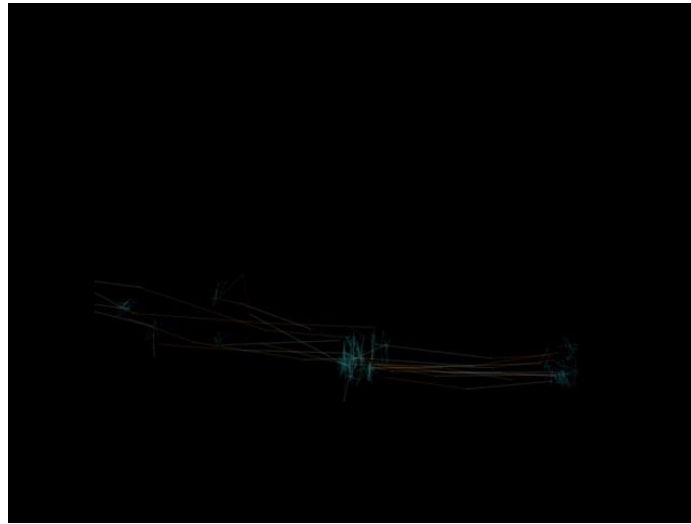
Fig. 2. Eye tracking visualization of non-ASD participant from Dataset [21]
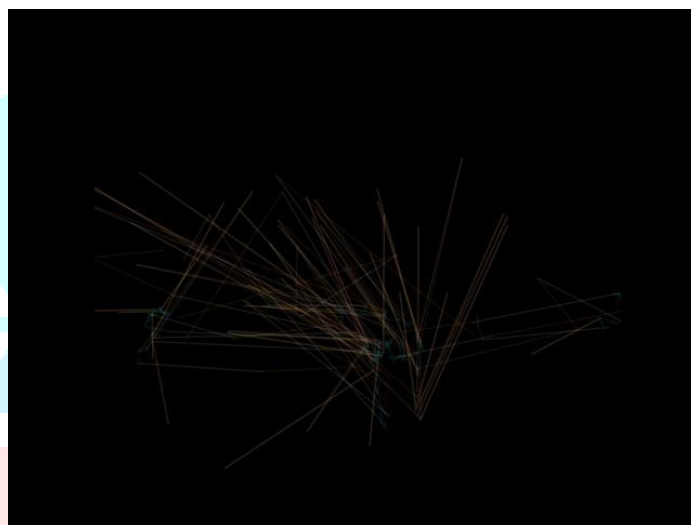

Fig. 3. Eye tracking visualization of ASD participant from Dataset [21]

Autism detection was also performed using video gesture analysis. Zunino et al. [13] created a video gesture dataset. The authors created this dataset with the help of 20 children with ASD and 20 typically developed children. These children were brought to Child Neuropsychiatry Unit of the IRCCS Giannina Gaslini Hospital and primary schools in Genova. The dataset was created by conducting the test of children individually in a quiet room. These children weree seated on an adjustable chair. They were asked to rest their right elbow and wrist on the table. The children were asked to assume a position in order to perform the testing. Using that particular position, they were asked to reach towards the object and grasp it to place it in a box. Other actions involved pouring some water into a glass, or passing of bottle to another person, who would either place the bottle in a box or pour some water. Based on this they were asked to perform movements and their movements were recorded. The final dataset contains 1837 video sequences. Figure 4 shows the sample frame from a video of the dataset.

Fig. 4. Shots from Dataset [13]

So far, many research works have been carried out in the field of Autism spectrum disorder. Various researchers are utilizing various features such as speech features, eye movements analysis, video gesture features in order to detect autism.

For classification-based approach, various evaluation metrics were utilized. Some of these metric measurements are accuracy, sensitivity, specificity and confusion matrix. Table 2 shows the elements of confusion matrix.

TABLE II
ELEMENTS OF CONFUSION MATRIX [13]

	Predictive ASD Values	
Actual ASD value	True Positive (TP) False Negative (FP)	False Positive (FP) True Negative (TN)

Specificity ratio measures the ability of the test to correctly generate negative results for people who don't have conditions for which the person is being tested (known as True Negative). Sensitivity ratio measures the ability of the test to correctly generate a positive result for people who have the condition for which the person is being tested (known as True Positive). Following are the formulas for Specificity, Sensitivity and Accuracy.

$$\text{Specificity} = \frac{TN}{TN + TP}$$

$$\text{Sensitivity} = \frac{TN}{TN + FN}$$

$$\text{Accuracy} = \frac{TN+TP}{TN + TP + FN + FP}$$

Accuracy gives a measurement to identify the accurate predictions made based on the overall number of tests. These are some of the common evaluation metrics utilized in the field of Autism Spectrum Disorder.

These were some of the datasets and evaluation metrics used in the field of Autism Spectrum Disorder.

IV. CONCLUSION

Machine learning algorithms have aided in the detection of Autism in child, adult and adolescence. Various datasets and evaluation methods have been proposed in order to detect autism based on machine learning techniques. Along with these some of the other methods have also been proposed such as Autism detection using eye movement analysis, image classification and video gesture analysis. Some of the future work in the field of autism detection will involve predicting autism detection using video communication methodology.

V. ACKNOWLEDGMENT

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