Prediction of Autism Spectrum Disorder in Children: A Detailed Systematic Review on Machine Learning and Deep Learning Methods

S.Mary Sebasti Rubala [1], Dr.M.Elamparithi[2], Dr.V.Anuratha[2]

[1] *Research Scholar, Department of Computer Science, Kamalam College of Arts and Science, Anthiyur, Bharathiar University, Coimbatore, Tamilnadu, India*

[2]*Associate Professor, Department of Computer Science, Kamalam College of Arts and Science, Anthiyur, Bharathiar University, Coimbatore, Tamilnadu, India*

Abstract: Autism spectrum disorder (ASD) is a serious, chronic neurodevelopmental illness characterized by developmental difficulties that are permanent or restrict the growth of thinking, behaviour, activities, and social-communication skills. The signs of autism are more pronounced and more straightforward to identify in youngsters between the ages of two and three. Although there is no permanent cure for ASD, it is still challenging to identify meltdowns or other difficulties in the early stages of medical care. In order to promote brain development and raise awareness of ASD among parents and caregivers, the survey's objective was to identify ASD at an early stage. Methods like deep learning (DL) and machine learning (ML) are currently employed to predict autism spectrum illnesses. This study provides an in-depth review of papers that predict ASD using ML and DL, as well as data analysis and classification techniques. Additionally, this survey intends to categorize and examine the various ML and DL approaches, as well as to describe the characteristics of ASD, assess performance, and show the scope of future research. For upcoming academics who want to study ASD prediction using ML and DL, this publication offers a road map.

1. INTRODUCTION

The term "autism spectrum disorder" (ASD) refers to a disorder where a neurological abnormality interferes with a person's ability to develop normally and impacts their behaviour. This developmental disorder typically restricts social interaction and communication behaviour. As a severe mental illness, it is discovered in childhood. For the rest of their lives, it continues. The diagnosis of autism in children often occurs too late in developed nations. These kids struggle with proper comprehension and learning, particularly communication and interaction. By using proper medication and enough training, it is possible to improve their behavioural and communication abilities [1]. As a result, ASD diagnosis and treatment have drawn significant attention and become a global public health issue. Behaviour diagnosis and scale evaluation are the pillars of clinical ASD diagnosis. The severity of the condition and the brain processes underlying ASD are, however, poorly understood. ASD diagnosis also lacks skilled professionals. In order to identify and diagnose ASD in children and help doctors arrive at an appropriate diagnosis, there is an increasing need for objective and efficient techniques [2].

DL and ML techniques have recently become more prevalent in ASD prediction. Systems that use ML learn from experience without having that knowledge explicitly built into them. In order to accurately classify and predict various sorts of data, ML is utilized [3]. DL is a branch of machine learning that produces superior outcomes compared to ML techniques. It does not need hand-engineered features because it can automatically learn them from the data [4, 5]. This was the motivation behind the survey, since early ASD detection utilizing ML and DL methods will help lessen the consequences of symptoms with effective and prompt treatment, eventually enhancing the quality of life of the patients and their family members.

The remaining part of the paper is outlined as follows: Section 2 discusses the background information on ASD in children's prediction systems. Section 3 reviews methods for ASD prediction using ML and DL. Sections 4 and 5 present the discussion and conclusion for future studies.

2. BACKGROUND INFORMATION

Autism in early childhood is a pervasive developmental disease that impairs self-control, relationships with others, and interaction. The best results from therapies require an early diagnosis of ASD. The general framework for ASD diagnosis in children is shown in Figure 1. Data collection, preprocessing, and classification are crucial phases for identifying ASD.
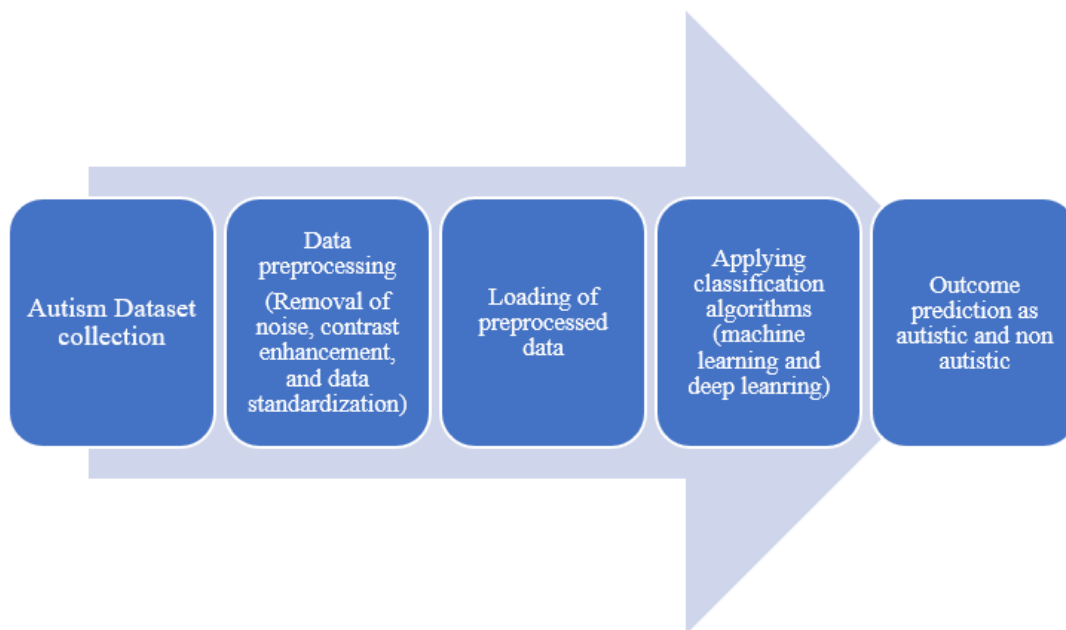

Figure 1: General architecture of ASD prediction

2.1 Dataset collection

Data collection is the first stage of the ASD prediction system. A sizable dataset is necessary for models to be trained to operate at their best. The model will become substantially more accurate as it is trained for every possible scenario. Many different datasets have been gathered for this research topic. The Kaggle dataset contains one of the most frequently used datasets. This data includes information for adults, children, and youth. The dataset contains two classes: autistic and non-autistic children. A person's face has various characteristics that can be used to identify identification, behaviour, state of mind, age, and gender. The authors of this study created an effective model to categorize autistic and non-autistic children based on facial traits.

2.2 Preprocessing

Preprocessing is the next stage in the ASD prediction system. Researchers encounter a few challenges while training networks on image-based datasets. Not many annotated medical images are available, and gathering this information requires resources and effort. Contrarily, it is not easy to standardize the data because the images from various sources have varying acquisition techniques, image modalities, and image resolutions. Preprocessing is crucial to clean up the data and convert it into a format that models can use [6]. By removing noise, correcting distortions, and adjusting brightness and contrast, preprocessing techniques like image cropping, image resizing, noise removal, normalization, and standardization help to improve the accuracy of facial feature detection and recognition [7].

2.3 Classification

Classifying data from a dataset involves making predictions about its classes. The classification problem typically takes the form of a binary classification, such as autistic or not autistic. Binary classification includes dividing all

features or data items into two categories based on established classification criteria. Several researchers have recently concentrated on ML and DL algorithms for categorizing ASD. ML is a rapidly expanding study area to create optimal predictive models from the relevant study information. It includes mathematical modelling, artificial intelligence, search techniques, and other prediction components. Random Forest (RF), Logistic Regression (LR), Naive Bayes (NB), Support Vector Machine (SVM), and K-Nearest Neighbor (KNN) are examples of standard machine learning techniques [8]. The DL model is also more effective than other methods. From the dataset, it automatically learns features. The time required to develop and train the model from the beginning is also reduced [9]. Additionally, it helps in getting high accuracy from a small dataset.

2.4 REVIEW ON METHODS FOR AUTISM SPECTRUM DISORDER ANALYSIS

Accurate and prompt ASD diagnosis is critical for allowing immediate intervention while offering individuals personalized treatment. Numerous studies have focused over the years on examining the effects of early ASD detection by various ML algorithms. Table 1 reviews the recent works on ASD prediction using ML methods.

Table 1: Review on ML methods for ASD prediction

Author & Ref. No	Method used	Dataset used	Outcomes	Benefits	Limitations
Irena Voinsky *et al.* [10]	RF	73 ASD children and 26 neurotypical (NT) controls in two cohorts (Israel and USA)	Accuracy=82%	It helped decision trees become less overfitted and increased accuracy.	It was significantly slower than previous classification algorithms since it made predictions using numerous decision trees.
Kaushik Vakadkar *et al.* [11]	LR, NB, SVM, KNN, and RF	1054 instances along with 18 attributes	Accuracy of LR was 97.15%, NB was 94.79%, SVM was 93.84%, KNN was 90.52%, and RF was 81.52%	Instead of relying on a single model for contribution, many machine learning algorithms were able to perform better and attain higher predicted accuracy.	Due to the need for training, storing, and merging different models' outputs, the use of several ML techniques was computationally expensive and time-consuming.
Muhammad Shuaib Qureshi *et al.* [3]	RF, NB, SVM, and Multi- layer Perceptron (MLP)	Autism Brain Imaging Data Exchange (ABIDE) dataset	Accuracy of RF was 89.23%, NB was 85.43%, SVM was 81.84%, and MLP was 80.43%	Hybrid ML models' overall output was consistently less noisy than the sum of its component parts, which promotes model reliability and robustness.	If the underlying models were inadequate or firm, or the aggregation process was too simple or advanced, it may be susceptible to overfitting and underfitting.

Yu-Hsin Chen et al. [12]	LR and RF	Market Scan Health Claims Database 2005–2016	Area under Curve (AUC) of LR was 0.758% and RF was 0.775%	When the dataset had features that could be linearly separated, LR was quite effective. Additionally, it was simple to use and understand while still being effective for training.	If the sample size is too small and the data is overfit on high dimensional data, LR may not be reliable.
Pramit Mazumdar et al. [13]	Ensemble Tree Bagger classifier	ICME Grand challenge	Accuracy=0.59% and F1=0.61%	It enables a group of weak learners to work together to outperform one strong learner.	It reduced a model's capacity to be interpreted, and it had far lower accuracy than other approaches.

Accurately predicting ASD has not proven easy owing to the screening tests' complexity and the numerous characteristics and hidden elements involved in ASD diagnosis. The dataset's available features allow data-driven DL techniques to examine the dataset's hidden characteristics in great detail. Another DL idea is transferring learning, which entails modifying the final output by applying the intended tasks using the weights and parameters of these pre-trained models (e.g., VGG, ResNet, Xception, etc.). This improves classification or prediction accuracy. Recently, most studies have used transfer learning and DL techniques to predict ASD in young children.

The hybrid technique developed by **Anupam Garg et al.** [14] combines deep learning and Explainable Artificial intelligence (XAI) to identify the most helpful features in the accurate and early prediction of ASD. The algorithm was initially trained and tested using facial image data from the ASD screening dataset. The autistic children were then identified using the dataset's necessary features, which were retrieved using XAI. The framework provided a better forecast than existing approaches, achieving 98% accuracy. Based on DL models, **Zeyad A. T. Ahmed et al.** [15] proposed a facial features detection system to identify children with ASD. Initially, the dataset was pre-processed to eliminate duplicate data and remove the images to highlight the face. Next, the features of autistic and non-autistic children were classified using a convolutional neural network (CNN), and the final output was predicted. The RMSprop optimizer was then used to lower the model error in output during training by changing the custom parameters. The facial images were acquired from an openly accessible Kaggle data set with 3,014 facial images. The system's highest accuracy was 95% based on the accuracy of the classification findings for the validation data.

Based on DL algorithms, **Fawaz Waselallah Alsaade et al**. [5] proposed pre-trained CNN models for detecting ASD. After preprocessing, the system used CNN techniques like Xception, Visual Geometry Group Network (VGG19), and NASNETMobile, which learned features from the input and outputted two classes: autistic and non-autistic. In total, 2,940 images were obtained from Kaggle, and the Xception provides better outcomes than other pre-trained models with an accuracy of 91%. **K. K. Mujeeb Rahman and M. Monica Subashini [16]** presented a deep neural network for ASD prediction with statistical feature learning. The system used five pre-trained CNN models: Xception, MobileNet, EfficientNetB0, B1, and B2 for feature extraction. Then, the extracted features were given to DNN for final classification. The experiments on Kaggle showed that the Xception model demonstrated better outcomes than others by achieving 96.63% AUC and 88.46% sensitivity.

Mohammad Shafiul Alam *et al.* [6] developed hybrid deep learning approaches for ASD prediction. Once the Kaggle dataset was collected, the data standardization was performed, and the system detected the face and aligned it using multi-task cascaded convolutional networks (MTCNNs). Finally, the detected facial images were given to pre-trained deep networks such as Xception, ResNet50V2, and MobileNetV2 for feature learning and classification. The system attained a combined accuracy of 98.9% in ASD prediction, which was higher than previous models. Tania Akter *et al.* [17] presented a pre-trained MobileNet-V1 model for ASD prediction in children. The system attained 90.67% accuracy on the Kaggle data repository, which was better than other pre-trained models. **Md Shafiul Alam *et al.*** [18] presented several variants of CNN pre-trained models such as Xception, VGG19, MobileNetV2, residual network-50 version 2 (ResNet50V2), and EfficientNetB0 for detecting ASD. The system used Adagrade for tuning the pre-trained networks. The system attained higher results for the Xception network with 95% accuracy on the tested Kaggle facial image dataset.

Ying Li *et al.* [19] presented two hybridized variants of the MobileNet model, such as MobileNet V2 and MobileNetV3, for ASD prediction. The hybrid model attained an accuracy of 90.5% and an AUC of 96.3% when tested on the facial images obtained from autism-related websites and Facebook pages. **Hasan Alkahtani *et al.*** [20] developed a transfer learning model for ASD based on facial landmarks. The Kaggle public dataset containing 2940 autistic and non-autistic facial images was taken for analysis. Then, the pre-trained models, such as VGG19 and MobileNetV2, were utilized for feature extraction and the extracted features were given to the ML models such as SVM, RF, LR, gradient boosting, decision tree, multi-layer perceptron and KNN for ASD prediction. The outcomes proved that the MobileNetV2 model attained better accuracy (92%) than the VGG19 model for ASD prediction on Kaggle.

3. DISCUSSIONS

In conclusion, based on a critical examination and analysis of recent investigations, this study showed several applications of methodologies for diagnosing and classifying ASD, along with its advantages and disadvantages. Practically speaking, a clinical examination of ASD is impossible for a large population. Using technology in the clinical sector increases the efficiency and precision of the assessment process. The researcher thus concentrated on using ML to detect autism. Classification, detection, and prediction are all excellent applications of ML. Beginning with the standard clinical dataset for ASD identification with full features, the ML model was utilized. The majority of the author's application of RF, a machine learning algorithm to forecast ASD, is shown in Table 1. RF has a greater accuracy rate than other ML techniques. It is difficult to understand, and while they indicate the significance of a feature, linear regression does not give complete visibility into the coefficients. For large datasets, RF can be computationally demanding. Additionally, the custom features used by the ML models make the prediction more difficult.

When compared to ML techniques, DL-based systems have demonstrated improved performance for feature extraction and classification tasks. DL uses fewer CPU resources by requiring less image processing and feature extraction. The deep learning algorithm CNN is demonstrated to be a robust algorithm for analyzing visual data. By transferring knowledge from earlier tasks, the idea of transfer learning improved the performance of CNN models. However, further development is still required to get 100% accuracy. More excellent prediction rates were achieved with less computational time when DL approaches were combined with transfer learning or attention mechanisms. There is excellent potential for ML and DL researchers to collaborate and encourage other scholars to join in the effort to recognize and address this incredible challenge.

4. CONCLUSION

The increasing recognition of autism has promoted improved global health knowledge and capabilities. Early ASD prediction is difficult since many questions are raised by the parents, carers, doctors, therapists, etc. ASD diagnosis is challenging to comprehend before the onset of the disease's apparent symptoms. This typically occurs between the ages of 16 and 18 months, when social deficits, difficulty in communicating, and other issues arise. This research demonstrates a new method of autism screening and diagnostics analysis that therapists and doctors may utilize to support formal screenings utilizing a variety of ML and DL methodologies. In terms of ASD prediction, both models perform excellently. However, there are so many attributes in face images that the typical ML models cannot handle the volume of data. DL models are replacing conventional models for extracting and classifying

features. Although DL can produce correct decisions, several difficulties must be considered. Shortly, a combination of DL with the attention mechanism and transfer learning techniques will be created to create an application for a better understanding of children with ASD and identifying the illness early, providing doctors and therapists with more knowledge and with their formal screening.

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