Autism Spectrum Disorder Using Deep Learning

Neha Palwe, Sreenalini Nambiar, Yash Gupta, Avishkar Raut, and Triveni Dhamale

Pimpri Chinchwad College of Engineering and Research, Pune, India

Abstract *--- Autism Spectrum Disorder (ASD), is a neurodevelopmental disorder. It is characterized by impairment in social interaction, communications, restricted interests and repetitive behaviors. It is important to detect this condition as soon as possible and treat it. These differences helps to identify autism patient. ASD affects the physical appearance of face. Autistic Children differ from children with regular development in their patterns of facial features. With the aid of a web application that uses deep learning to detect autism using their images and implements the Convolutional Neural Network (CNN) algorithm to categorise children as autistic or typically developing, this paper intends to assist families and psychiatrists in making an accurate diagnosis of autism. We have used Tensorflow and Keras library in this process and lots of image processing functions to smooth the model. This model can be implemented in hospitals and clinics as GUI or software to detect autism disorder without any kind of medical operations. retrained models used are VGG16 and VGG19. The facial photos were acquired from a publicly accessible dataset on Kaggle that includes facial images of a diverse range of kids, including autistic kids and kids without autism. The outcomes were assessed using standard evaluation measures like accuracy, specificity, and sensitivity. According to the classification findings' accuracy for the validation data, VGG19 had the highest accuracy (96%), followed by VGG16 with an accuracy of 77.6%.*

Keywords *--- Autism Spectrum Disorder (ASD), Convolutional Neural Network (CNN), Typically developed, autism, deep learning, Tensorflow, Keras.*

1 INTRODUCTION

A neurodevelopmental disease called autism spectrum disorder (ASD) exists. Repetitive behaviours, limited interests, and disability in social interaction and communication are its hallmarks. Although ASD starts in the early stages of development, it can last a lifetime [1]. The average diagnosis age is between 4-5 years [2]. The most typical early warning signs include lack of sharing and showing, lack of gesturing by 12 months, loss of language and social skills, orientation to verbal call, facial expressions, a lack of or poor quality of movements, and joint attention [3,4,7,8]. Between two and six months, the initial reduction in social contacts may take place [5]. A cross-sectional study found that 27.6% of cases showed their first symptoms between 13 and 24 months, and 41.9% between 7 and 12 months. The subjects seek some privacy and avoid making eye contact. Autism is typically identified in young children. ASD in young children can typically be identified by age 2 [9]. Early diagnosis and treatment of ASD can lessen challenges and improve a person's capacity to build on strengths and pick up new abilities. Working closely with the doctor is a key component of choosing the optimal treatment programme because there are now no blood tests that can detect autism nor a single best treatment for ASD [10,11].

The diagnosis of ASD is extremely challenging since it requires extensive tracking and observation of autistic children's behaviour [12]. The early stages of a child's life show indicators of ASD, but it can be difficult to diagnose these conditions, especially in children under the age of three. Developmental disorders are long-term impairments that significantly affect the day-to-day functioning of many people. The prevalence of autism is rising globally, which causes families to worry more about their kids and necessitates a checkup to assure their kids' wellbeing if they have the disorder. A patient with autism need specialised care in order to acquire the perceptual abilities necessary for communication with their family and society. Early diagnosis of autism improves the effectiveness of behavioural therapy for autistic patients. Children with autism share a common characteristic facial feature in comparison to children without autism (non autistic children), according to researchers at the University of Missouri who researched the diagnosis of children using facial traits [13].These characteristics include an exceptionally broad top face, which includes widely spaced eyes, and a shorter middle face region, which includes the cheeks and nose. In Figure 1, the first row of children with autism and the second row of children without autism are contrasted in terms of their facial traits.
The Kaggle database, which was employed in this study, provided those photos. A neurological condition known as autism spectrum disorder (ASD) damages a child's brain from an early age. The verbal and social skills of autistic children are affected, as well as their inability to maintain the proper visual focus of attention. These issues can be identified 36 months later. How to make an accurate diagnosis is the challenge.

Since its symptoms frequently appear in the first two years of life, autism is referred to as a "behavioural disease" and can affect people of any age. Early detection of this neurological issue helps support maintaining the subject's good physical and mental health. Early diagnosis based on several physiological and health factors becomes feasible with the increased usage of machine learning-based algorithms to predict many human diseases. Today, machine learning is utilised to diagnose diseases like ASD and depression. Enhancing diagnostic precision and reducing diagnosis time are the main objectives of employing machine learning techniques to facilitate quicker access to healthcare services. Now, we want to find this sickness using a person's photograph and see how much it can help the medical sector. CNN (Convolution Neural Network), a deep learning method, will be used to create the model. CNN has excelled in a number of fields, including speech recognition, image classification, automotive software engineering, and neuroscience. This enormous advancement is mostly attributable to a mix of algorithmic advancements, advances in computer resources, and easy access to large amounts of data. That is why CNN was our choice for this project. Using a robust dataset, we'll strive to increase accuracy as much as possible.

The manual approach of diagnosing autism is dependent on psychologists spending a lot of time studying a child's behaviour. This task occasionally requires more than two sessions. Technology advancements have made it possible to create screening and diagnostic tools for autism. Researchers are heavily involved in developing methods to diagnose ASD and detect autism at an early age using various technologies, such as brain MRI, eye tracking, electroencephalogram (EEG) signals, and eye contact [15]. The development of artificial intelligence has led to its increased use in the field of health and medical care. A few scientists have used facial characteristics to identify autism.
The primary goal of this project is to create a web application based on deep learning that uses a convolutional neural network to recognise autistic children by their facial traits. This software was created to make it simple and effective for families and psychiatrists to make an autism diagnosis. The Kaggle dataset was used in the current work to apply CNN, one of the most well-known deep learning methods. The dataset comprises of pictures of people's faces categorised into two groups: kids with autism and kids without autism. A person's face has a variety of characteristics that can be used to identify identification, behaviour, mood, age, and gender. To create a deep learning model to categorise autistic and non-autistic children based on their faces, we employed the eye as a facial feature. Various methods, including brain MRIs, eye-tracking, EEGs, and eye contact, can be used to diagnose autism [15].

Our research's primary contributions are as follows:

i. VGG16 and VGG19, two pretrained deep learning algorithms, were used to detect ASD.
ii. The VGG19 model displayed the best results.
iii. A web tool is created to assist health officials in identifying ASD using the eyes and faces.

2 Related Work

With the potential to analyse a big dataset, convolutional neural networks become one of the most successful methods for classifying images.Praveena and Lakshmi [14], Yang [16], and Beary et al. [17] created deep learning models utilising online photos of the faces of autistic and non-autistic children. These studies were based on the facial features from the image of a face. In the imaging data of two groups, ASD and TD youngsters, Grossard et al. [18] discovered a distinct pattern dispersed in the eyes and lips. [16] employed a pretraining model that, when tested against validation data, had a 94% accuracy rate. 90% accuracy was attained by Grossard et al. [18] using their classifier approach. Beary et al. [17] employed the VGG19 pretraining model, which had a validation data accuracy of 0.84%. On a small dataset made up of 19 TD and 20 ASD children, Haque and Valles [19] used a ResNet50 pretraining model and achieved 89.2% accuracy.

A technique to categorise groups of ASD and TD individuals using Deep Neural Network (DNN) and Support Vector Machine (SVM) was developed by Jiang, M., et al. [20] utilising eye tracking data. The collection includes of eye tracking photos with eye fixation and heat maps. The feature is categorised using VGG-16 and Gaze features. This model's accuracy rate is 92%. A deep learning model for autism prediction was created by Wu, et al. [21] utilising synthetic saccade and visual fixation maps. 300 photographs of kids with ASD and TD taken by a Tobii T120 make up their dataset. The images are made up of scanpath information that includes a location and a duration. While the second model is based on picture fixation maps, the first model is based on synthetic saccades utilising scanpaths and STAR-FC. This dataset's accuracy validation result is 65.41%.

To categorise TD and ASD children based on the scanpaths of eye gazing, Tao et al. [22] presented CNN and long short-term memory (LSTM) networks. A model employing the SP-ASDNet dataset, CNN-LSTM was used to extract the features from the saliency maps and sequence of the fixation points in the scanpath. The model's accuracy on the validation dataset was 74.22%. Finally, Xie, et al. [23] create a novel two-stream deep learning network based on the eye movement patterns of individuals with ASD and TD to diagnose autism. There are 700 photos in the dataset. They modify the VGG16 model to create two VGGNets models that can categorise ASD and TD. The outcome for accuracy is 95%.

3 Materials and Methods

Children with autism differ from TD children in terms of the width and spacing of facial landmarks, as well as changed patterns of facial features. Figure 1 illustrates a suggested method for identifying autism from human faces. With the use of deep learning algorithms, these minute face characteristics are retrieved to classify children into autistic and non-autistic groups. This study makes use of CNN, which, by learning the basic forms in the first layers and improving the learning features in the deeper layers, can accurately categorise images. The CNN layers automatically extract features, to put it another way[24]. The advantages of the pretraining model include a reduction in the time required to build and train the model from scratch. It also performs well when using a small dataset, like the one used in this study, to achieve high accuracy.

3.1. *Dataset.* The public could view the Kaggle [25] dataset used in this study at https://www.kaggle.com/datasets/cihan063/autism-image-data. In this collection of 2940 photographs of faces, there are 1470 kids who have autism and 1470 kids who don't. Children with autism were photographed utilising online resources dedicated to the disorder, whereas children without autism were selected at random.

3.2. *Preprocessing.* The developer of the dataset deleted duplicate images from it and then cropped each image such that it only showed the subject's face. After that, the dataset was divided into three groups for training (2540), validation (100), and testing (300). After receiving the data, Keras preprocessing Image Data Generator normalised the dataset by scaling the parameters. The dataset was normalised to make it ready for CNN model training.

3.3. *Convolutional Neural Network Models.* This section describes CNN pretraining models and convolutional neural network architecture. A key element of the CNN model is the convolutional layer, which is used for feature extraction. The first convolutional layer picks up on fundamental properties like edges and lines. The next layer extracts the attributes of squares and circles. Among the more complex components that are removed in the following layers are the face's eyes, nose, and other facial features. The core components of the CNN model are the input layer, convolutional layer, activation function, pooling layer, fully connected layer, and output prediction.

3.3.1. *Pooling Layer.* When the CNN has many hidden layers, the depth of the output layer increases, increasing the CNN's parameters and necessitating the optimisation of the mathematical processes' space complexity and learning time. The pooling layer reduces the number of parameters in the output of the convolution layer using a summary statistical function. The two different kinds of pooling layers are max-pooling and average-pooling. For max-pooling, the maximum values in each window present no issues. Using average-pooling, the mean value for each window is determined sequentially. The input to the subsequent layer in this case reduces the feature map.

3.3.2. *Fully connected Layer.* The fully connected layer receives the output from the convolutional layer and pooling layer, which contains all the features, and then places it in a long tube.

3.4. *Activation Function.* The activation function categorises the output. After training, the CNN model's outcomes in our study predict the output for the input image (ASD or TD).

3.5. *Pretraining Models.* In this study, the CNN pretraining models VGG16 and VGG19 were utilised to identify autism using facial image analysis. The data were then compared to determine which model performed the best.

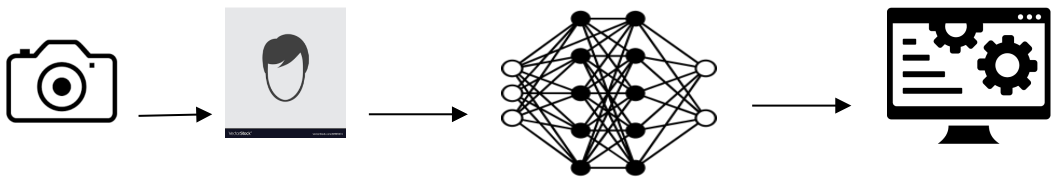

Figure 1: Architecture of Proposed Architecture

4 Results

The models were trained using the Python language and Google Colab environment, which supports the most widely used deep learning packages, such as TensorFlow and Keras. The number of the declaration epochs was 20. For VGG19 and VGG16, respectively, the accuracy scores for the valuation data were 96% and 77.6%. Model accuracy and loss are plotted in figures 3 and 4.

4.1. *Evaluation Metrics.* In this study, a number of metrics, including accuracy, precision, recall, and loss, were utilised to assess the classifier of the models.

4.2. *Confusion Matrix*. The model could correctly identify 211 kids as having ASD for True Positives (TP). The model was able to accurately identify 198 kids as True Negatives (TN) for True Negatives (TN).

In terms of False Positives (FP), the model incorrectly identified 55 kids as TD while in reality they had ASD. 67 children were incorrectly identified by the model as having ASD in False

Negatives (FN), despite not having the disorder. Figure 2 displays the details of the Confusion Matrix.

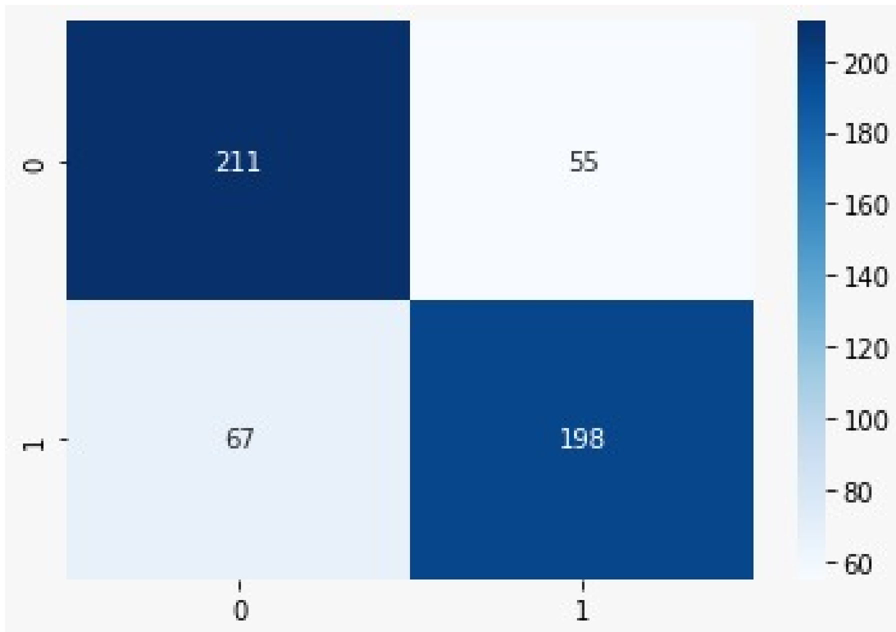

Figure 2: Confusion Matrix

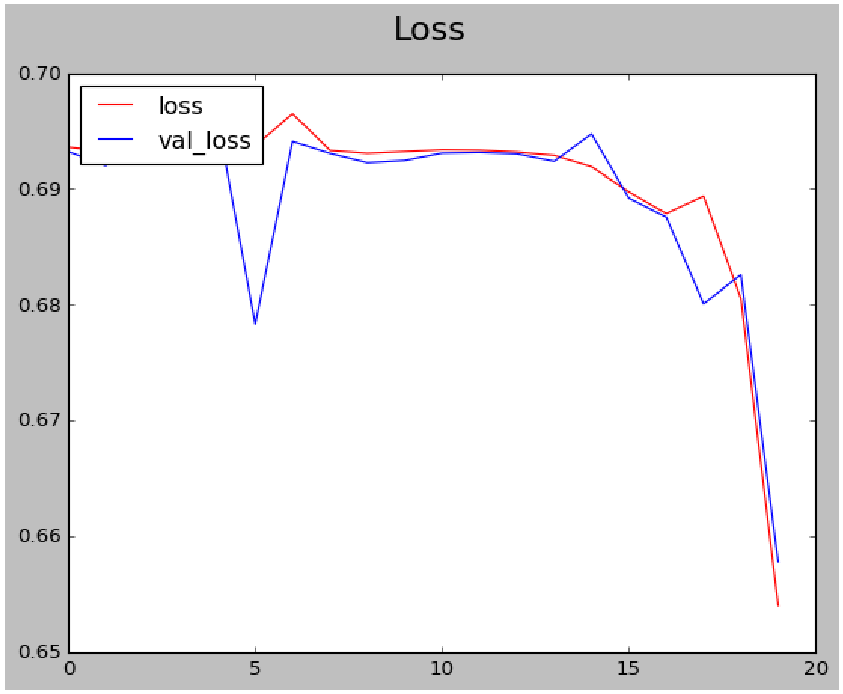

Figure 3: Model Loss

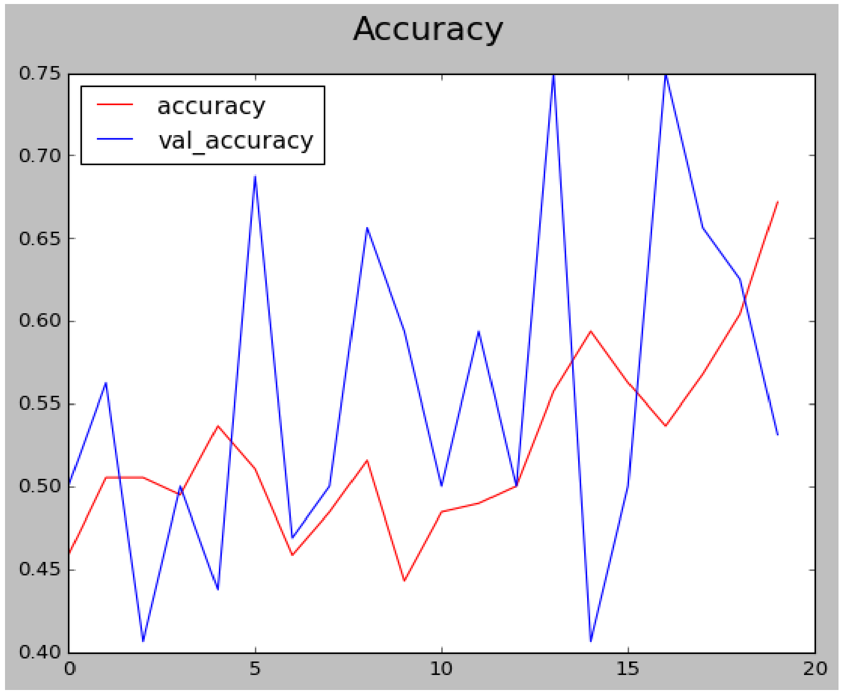

Figure 4: Model Accuracy

5 Conclusions

This study used a convolutional neural network with deep learning to create a web application for detecting autism. By generating patterns of facial characteristics and measuring the distance between facial landmarks, the CNN architecture has the right models to extract the features of facial images, which can classify faces into autistic and non autistic. In order to produce highly accurate findings, the researchers used two pretraining models (VGG16 and VGG19) to the dataset and employed the same fine-tuning of the layers and optimizer. The maximum accuracy, 96%, was attained by VGG19. Consequently, a web application that can identify autism via facial photos was created using a VGG19 model. By enlarging the samples and the information gathered from psychologists' diagnoses of autistic children of various ages, further research will enhance this model. This kind of software will assist parents and clinicians in identifying ASD in children. By selecting an effective course of treatment, children with autism may benefit from receiving a proper diagnosis of their condition.

References

1. American Psychiatric Association, Diagnostic and statistical manual of mental disorders. 5th ed. Arligton: American Psychiatric Pub; 2013 May 22.
2. Mandell DS, Morales KH, Xie M, Lawer LJ, Stahmer AC, Marcus SC. Age of diagnosis among Medicaid-enrolled children with autism, 2001-2004.Psychiatr Serv. 2010;61:822-9.
3. Karmel BZ , Gardner JM, Meade LS, Cohen IL, London E, Flory MJ, et al, Early medical and behavioral characteristics of NICU infants later classified with ASD. Pediatrics. 2010;126:457-67
4. Pineda R, Melchior K, Oberie S, Inder T, Rogers C. Assessment of autism symptoms during the neonatal period: is there early evidence of autism risk? Am J Occup Ther. 2015;69:1-11.
5. Jones W, Klin A. Attention to eyes is present but in deline in 2-6 month olds later diagnosed with autism. Nature. 2013;504:427-31.
6. Antonia Parmeggiani, Arianna Corinaldesi, Annio Posar. Early features of autism spectrum disorder: a cross-sectional study. Italian Journal of Pediatrics. 2019; https://doi.org/10.1186/s13052-019-0733-8; (2019) 45:144.
7. Robins DL, Casagrande K, Barton M, et al. Validation of the modified checklist for autism in toddlers, revised with follow-up(M-CHAT-R/F).Pediatrics 2014;133:37-45.
8. Smith NJ, SeldrickRC, Perrin EC. An abbreviated screening instrument for autism spectrum disorders. Infant Ment Health J 2013;34:149-55.
9. Wafaa Abdulmutalib Naji, Assist. Prof. Mohammed Qasim Waheeb. Autism Spectrum Disorder: Review Article. April 2020.
10. Fernandes FD, Molini-Avejonas DR, Amato CA. Language Therapy with Children with Autism Spectrum Disorders. A Comprehensive Book on Autism Spectrum Disorders. 2011 Sep 15:23.
11. Brugha TS, McManus S, Bankart J, Scott F, Purdon S, Smith J, Bebbington P, Jenkins R, Meltzer H. Epidemiology of autism sectrum disorders in adults in the community in England. Archives of general pstchiatry. 2011 May 2;68(5):459-65.
12. Zeyad Abdulhameed Taha Ahmed, Mukti E. Jadhav , A Review of Early Detection of Autism Based on Eye-Tracking and Sensing Technology, 5th International Conference on Inventive Computation Technologies (ICICT-2020), INDIA, IEEE. “Under Publication”
13. F. W. Alsaade, T. H. H. Aldhyani, and M. H. Al-Adhaileh, “Developing a recognition system for classifying covid-19 using a convolutional neural network algorithm,” *Computers, Materials & Continua*, vol. 68, no. 1, pp. 805–819, 2021.

14. T. L. Praveena and N. M. Lakshmi, “A methodology for detecting ASD from facial images efficiently using artificial neural networks,” *International Conference On Computational And Bio Engineering*, Springer, pp. 365–373, 2019.
15. Z. A. T. Ahmed and M. E. Jadhav, “A review of early detection of autism based on eye-tracking and sensing technology,” in *2020 International Conference on Inventive Computation Technologies (ICICT)*, pp. 160–166, Coimbatore, India, 2020.
16. Y. Yang, “A preliminary evaluation of still face images by deep learning: a potential screening test for childhood developmental disabilities,” *Medical Hypotheses*, vol. 144, 2020.
17. M. Beary, A. Hadsell, R. Messersmith, and M. P. Hosseini, “Diagnosis of autism in children using facial analysis and deep learning,”
18. C. Grossard, A. Dapogny, D. Cohen et al., “Children with autism spectrum disorder produce more ambiguous and less socially meaningful facial expressions: an experimental study using random forest classifiers,” *Molecular Autism*, vol. 11, no. 1, pp. 1–14, 2020.
19. M. I. U. Haque and D. Valles, “A facial expression recognition approach using DCNN for autistic children to identify emotions,” in *2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)*, pp. 546–551, Vancouver, BC, Canada, 2018.
20. Jiang, M., & Zhao, Q. (2017). Learning visual attention to identify people with autism spectrum disorder. In Proceedings of the IEEE International Conference on Computer Vision (pp. 3267-3276)
21. Wu, C., Liaqat, S., Cheung, S. C., Chuah, C. N., & Ozonoff, S. (2019, July). Predicting Autism Diagnosis using Image with Fixations and Synthetic Saccade Patterns. In 2019 IEEE International Conference on Multimedia & Expo Workshops (ICMEW) (pp. 647-650). IEEE.
22. Tao, Y., & Shyu, M. L. (2019, July). SP-ASDNet: CNN-LSTM Based ASD Classification Model using Observer ScanPaths. In 2019 IEEE International Conference on Multimedia & Expo Workshops (ICMEW) (pp. 641-646). IEEE
23. Xie, J., Wang, L., Webster, P., Yao, Y., Sun, J., Wang, S., & Zhou, H. (2019). A Two-stream End-to-End Deep Learning Network for Recognizing Atypical Visual Attention in Autism Spectrum Disorder. arXiv preprint arXiv:1911.11393.
24. S. Kornblith, J. Shlens, and Q. V. Le, “Do better imagenet models transfer better?” in *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, pp. 2661–2671, Long Beach, CA, USA, 2019.
25. K. Ramasubramanian and A. Singh, “Deep learning using Keras and TensorFlow,” *Machine Learning Using R. Apress*, Springer, pp. 667–688, 2019.