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RESEARCH ARTICLE

EARLY AUTISM SPECTRUM DISORDER DETECTION USING CNN-BASED FACIAL IMAGE ANALYSIS

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Abstract – Autism spectrum disorder (ASD) refers to a neurodevelopmental disorder that is described as having issues with socialization, communication, as well as repetitive behavior. Early detection of ASD is critical at an early age so that individuals can receive the required intervention and better developmental outcomes. The conventional methods of diagnosis are generally long procedures which are subjective and need the assessment of experts. This paper presents a solution to the limitations in order to come up with a deep learning model that will be used in detecting autism on the basis of the facial images automatically. This study implements a Convolutional Neural Network (CNN) model that categorizes the images of faces as autistic and non-autistic. Resizing and normalization is a process that is involved in pre- processing so as to create homogenous data. The CNN model suggested here automatically extracts the relevant features of the face and generate accurate diagnostic classifications. The measures of performance are accuracy, precision, recall and F1-score. The model has been demonstrated to be accurate in its operation by both experimentation and is seemingly a comprehensive all inclusive, non-invasive and helpful instrument of early childhood autism diagnosis.

***Keywords** – Autism spectrum Disorder, CNN, Deep Learning, Facial Image Analysis, Image Classification.*

1. INTRODUCTION

Autism Spectrum Disorder (ASD) refers to a neurodevelopmental disorder that affects how a person communicates, interacts and behaves. The World Health Organization says that ASD is a disorder that affects millions of children worldwide. Early diagnosis is important in order to ensure a better development. The traditional diagnostic tools are based on observation and assessment of behaviour, clinical evaluation and the standardized and objective tests that are time-consuming, subjective and need professionals who are experienced [1], [2].

Artificial intelligence and machine learning have advanced significantly in recent years, introducing new possibilities for automated diagnosis of the various diseases. Issues in medicine such as the early diagnosis of autism using behaviour analysis method and machine learning methods in the analysis of medical records have been highly utilized [7], [10]. These techniques can be based on manual feature extraction and human domain knowledge, and thus tend to be ineffective in terms of scaling and efficiency.

The methods of Convolutional Neural Networks (CNNs) have become particularly popular as one of the ways to address such limitations because they can automatically extract meaningful image data properties using raw image

data. CNNs have also been performed better than traditional image classification methods such as medical image and facial recognition. Facial images analysis is becoming a highly promising non-invasive method since the difference in facial structure and the facial expression may yield significant data on the presence of ASD [3], [8].

The deep learning system proposed in this paper would make a diagnosis of early Autism using facial images. The system applies CNN model to automatically learn discriminative features of facial images and identify the image as being non-autistic or autistic. The solution will remove the need to manually design the features to be exploited as well as leverage the potential of deep learning in the process of offering scalable, prompt, and precise early ASD discovery.

2. LITERATURE REVIEW

Autism Spectrum Disorder (ASD) is a subject that has been widely studied because it influences communication, behaviour and socialization. Conventional methods of diagnosis are based on clinical assessments, observation of behaviour and standardized assessment instruments requiring trained professionals. Despite their reliability, the methods are usually very time consuming, costly and are prone to human bias [1], [2]. The value of early diagnosis is essential, as the timely intervention process can be used to make a beneficial contribution to the cognitive and social development of ASD patients.

In order to overcome such shortcomings scholars have looked into automated and data-oriented methods of detecting autism. Decision Trees, Support Vector Machines (SVM), and Random Forest machine learning algorithms have been used in order to classify people using behavioural and clinical data. These models have demonstrated positive findings in enhancing the efficiency of diagnosis as well as saving manual labour [7], [10]. They have also employed feature selection algorithms to discover the most pertinent attributes hence promoting the accuracy of a model and minimizing the complexity of computations [9].

Image based applications have received a lot of interest as a non-invasive way of detecting ASD in recent years. Facial image analysis, and especially facial structure and facial expression analysis in particular has become a potential method showing their capability to provide valuable pointers to autism through subtle facial expression changes. Image processing has been applied to identify facial features like eye positioning, facial symmetry and texture patterns and they are used for classification [3], [12]. These methods minimize reliance on behavioural tests and speed up the screening.

As deep learning has evolved, Convolutional Neural Networks (CNNs) have become the most popular networks to utilize in image-related classification. The CNNs can acquire hierarchical feature representations through the raw images in an automated fashion without the necessity to extract features manually. Research has shown that deep learning models are more accurate and robust than the traditional machine learning models particularly when analysing complex images [8], [14]. They are most appropriate in the diagnosis of medical images based on intricate patterns including the diagnosis of autism.

Although despite these advances, a number of issues are still there. Large and heterogeneous datasets are very important to the performance of machine learning and deep learning models. Change in lighting conditions, facial expressions, and the quality of the images may alter the accuracy of the model [5]. Furthermore, certain deep learning models are intensive in terms of computational resources which might restrict their real-time use and implementation in resource-constrained settings [11].

Consequently, a scalable, efficient and accurate system for early autism detection is required. The proposed work attempts to solve these issues and propose a CNN-based approach to face image classification, hoping to obtain high accuracy and at the same time, be computationally efficient. This intervention is effective and non-invasive in terms of screening early ASD, as well as helping to intervene at the right time.

3. PROPOSED METHODOLOGY

The proposed system will find a solution that will efficiently and automatically detect Autism Spectrum Disorder (ASD) through the analysis of facial images. The proposed method is based on the idea of a Convolutional Neural Network (CNN) that learns and extracts the relevant features automatically in the facial images, in contrast to traditional methods which focus on behaviour evaluation or the efforts to extract the features by hand. Fig 1 This will facilitate non-invasive, accurate, and quick screening of ASD.

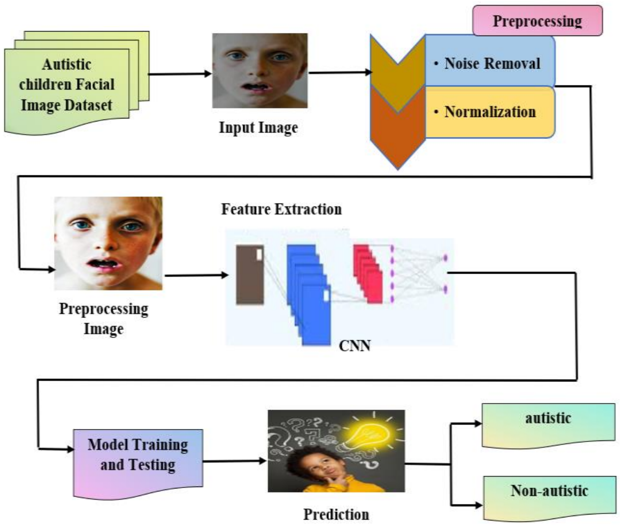

Figure 1. system architecture

3.1. Data Acquisition

The data included in this study consists of the facial images where the images were put in two classes that comprised of the autistic and non-autistic. The pictures involve differences in the conditions of lighting, the facial expressions, and orientations to enhance the ability of the model to generalize. The data will be split into training and testing data to test the model performance effectively

3.2. Data Preprocessing

Validating Preprocessing is also important to make sure that there is consistency and ultimately enhance model accuracy. Images of all sizes are brought to a fixed size (e.g., 200×200 pixels) to have the same input size. The pixel values are brought to a scale of 0 to 1 to promote the convergence in the process of training in Fig 2. All the corrupted or irrelevant pictures are eliminated with the aim of maintaining data integrity. The data is then randomly shuffled to remove bias in training.

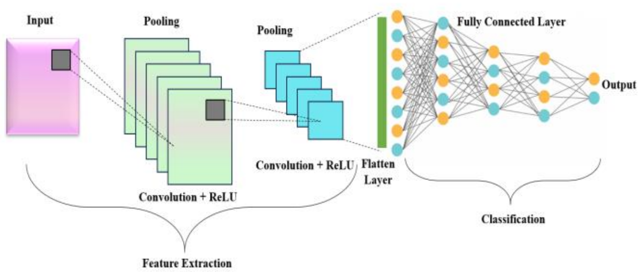

Figure 2. CNN Model Architecture

3.3. CNN Model Architecture

The structure of the system is a Convolutional Neural Network that is aimed at classifying images. The architecture is structured into various layers which are:

3.3.1. Convolutional Layers

Obtaining spatial features of the face by extracting edges, textures, and patterns in the faces.

3.3.2. Activation Function (ReLU)

Provides non- linearity to enhance the ability to learn.

3.3.3. Pooling layers

Reduce spatial dimensions and computation while preserving important features without significant loss of information.

3.3.4. Flatten Layer

Identifies feature maps and transforms them into a single-dimensional vector.

3.3.5. Fully Connected Layers

High level reasoning and classification.

3.3.6. Output Layer

It is a layer that uses a sigmoid activation function to categorize the image as autistic or non-autistic.

3.4. Model Training

CNN model is trained by use of the training dataset in several epochs. Classification error is measured by binary cross-entropy loss and optimized by an optimizer like RMSprop or Adam. accuracy and loss values are monitored during training so that appropriate learning takes place and to identify overfitting.

3.5. Model Evaluation

The training model is tested with the use of the test set. Standard measures are used to gauge performance such as:

a. Accuracy: overall correctness of the model. b. Precision: correct positive predictions.

c. Recall: The capability to identify actual positive cases.

d. F1-Score: Trade-off between accuracy and recall.

The metrics can give a complete analysis of the effectiveness of the model.

3.6. Prediction

New, unseen facial images are then categorized into the model after successful training and evaluation. This system gives the prediction as autistic or non-autistic so that the system can be used practically in terms of timely screening.

4. RESULTS AND DISCUSSION

The suggested Autism Spectrum Disorder (ASD) detection system, implemented by using the Convolutional Neural Network (CNN), was tested and assessed on a set of facial images, classified as either autistic or non-autistic. The data was split into training and testing data on which the correct assessing of the generalization ability of the model will occur.

In the course of training, CNN model has been trained to extract discriminative facial features automatically, which does not require manual engineering of the features. The model performance has been considered in terms of conventional measures like accuracy, precision, recall, F1-score.

4.1. Performance Metrics

The model had a total accuracy of 94 percent which shows that it was useful in classifying facial images correctly. The recall value of 95% indicates that the model has managed to detect most cases of autism making it significant in detection at an early stage. Fig 3 The precision (92%) is also good and the F1- score (93%) is also good since there are few false positives and high recall.

The results of evaluating the proposed system are presented in Table 1.

Table 1. Performance Metrics of the Proposed CNN Model

Metric	Value (%)
Accuracy	94.0
Precision	92.0
Recall	95.0
F1-Score	93.0

Figure 3. Accuracy graph

4.2. Training and validation Analysis

The curves of the training process and the accuracy of the validation demonstrate incremental growth per epoch, which proves that the model works well with the dataset. Fig 4 On the same note, the loss curves also show the decreasing trend and it is a sign that the model is properly optimised.

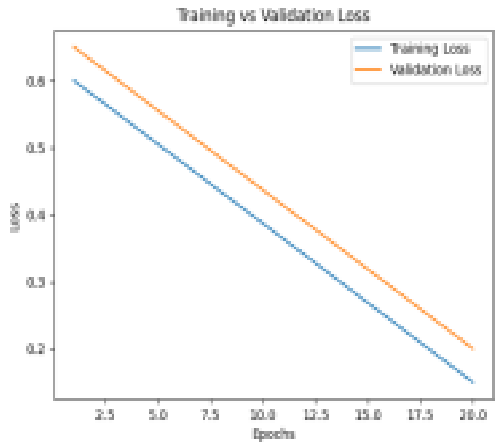

Figure 4. Loss graph

The accuracy graph depicts that accuracy in both training and validation are on an increasing trend and for this, this represents good learning behaviour. The fact that the difference between the curves is minimal leads to imply that the model is not over-fitted to an extent. The loss graph indicates that the loss has been decreasing steadily and it proves that the model is converging effectively.

4.3. Confusion Metrics

The performance of the classification by the model can be analysed in detail by the means of a confusion matrix Fig 5.

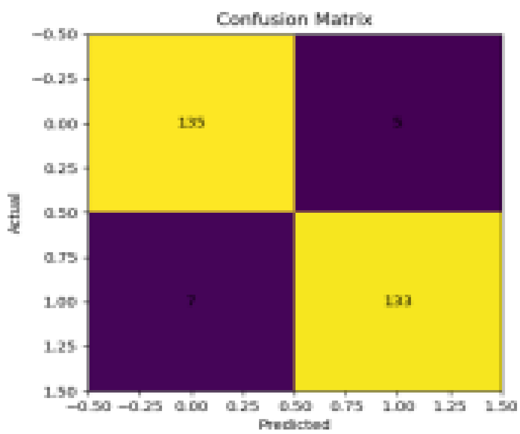

Figure 5. Confusion matrix

Example values:

	Expected Autistic	Expected Non - Autistic
Actual Autistic	135	5
Actual Non Autistic	7	133

Explanation:

According to the confusion matrix, most of the samples are correctly represented. False positives and false negatives are also very little and it means that the model is reliable at both classes.

4.4. ROC Curve Metrics

It is measured using the Receiver Operating Characteristic (ROC) curve which shows class differentiation Fig 6.

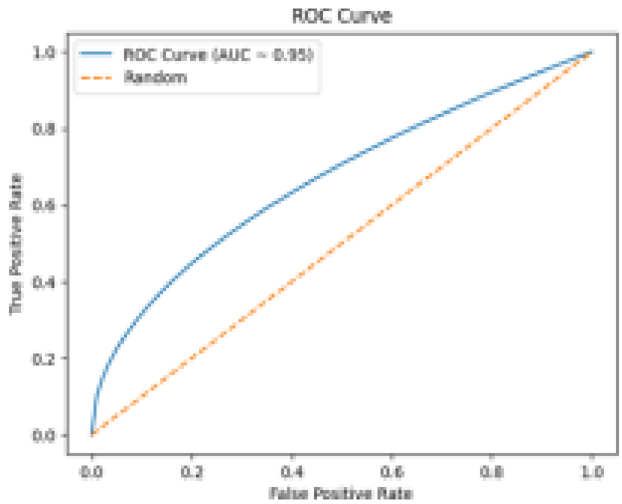

Figure 6. ROC curve

Explanation:

The ROC curve shows the trade-off between the false positive rate and the true positive rate. The Area Under Curve (AUC) value is near 1, which means that there is a good classification performance and high discriminative power of CNN model is strong.

4.5. Discussion

The experiment findings confirm that the developed CNN based system proves to be very useful in the detection of autism by using faces. The deep learning allows the automatic extraction of complex facial features, classification performance is much higher than in the traditional methods of the machine learning.

The system shows uniformity in various measures of evaluation which is a sign of strength and stability. The facial image analysis method is non-invasive; hence, it can be applied in the screening of large populations and real- life scenarios.

Nonetheless, the model has the risk of being affected by the sizes of datasets, quality of the images, and the changes in lighting and facial expressions. Further system improvement can be made by increasing data heterogeneity, as well as adding real-time data.

5. CONCLUSION

This paper has presented the introduction of a deep learning-based approach of early diagnosis of Autism Spectrum Disorder (ASD) by analysing face images. The proposed system uses a Convolutional Neural Network (CNN) to employ automatic detection of suitable elements of faces and categorise them into an autistic and non- autistic image set. Overall, it can be stated that the article attributes to the deep learning approaches the potential of their application in healthcare, particularly, in the early diagnosis of the neurodevelopmental illnesses. The proposed system can be applied as a supportive technique by healthcare professionals, which will enable them to act in a timely manner and improve the living conditions of the ASD patients.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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