Autism Spectrum Disorder Detection in Children using the Efficacy of Machine Learning Approaches

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Abstract
For the future prosperity of any society, the sound growth of children is essential. Autism Spectrum Disorder (ASD) is a neurobehavioral disorder which has an impact on social interaction of autistic child and has an undesirable effect on his learning, speaking, and responding skills. These children have over or under sensitivity issues of touching, smelling, and hearing. Its symptoms usually appear in the child of 4- to 11-year-old but parents did not pay attention to it and could not detect it at early stages. The process to diagnose in recent time is clinical sessions that are very time consuming and expensive. To complement the conventional method, machine learning techniques are being used. In this way, it improves the required time and precision for diagnosis. We have applied TFLite model on image based dataset to predict the autism based on facial features of child. Afterwards, various machine learning techniques were trained that includes Logistic Regression, KNN, Gaussian Naïve Bayes, Random Forest and Multi-Layer Perceptron using Autism Spectrum Quotient (AQ) dataset to improve the accuracy of the ASD detection. On image based dataset, TFLite model shows 80% accuracy and based on AQ dataset, we have achieved 100% accuracy from Logistic Regression and MLP models.

Keywords
Autism Spectrum Disorder, KNN, Gaussian Naïve Bayes, Random Forest, Multi-Layer Perceptron, Logistic Regression, Autism Spectrum Quotient

1. Introduction

Autism spectrum disorder (ASD) is the disorder of neurodevelopment of child and can be detected in early age. This disorder can be cured easily at primary level but if it is neglected then it can harm the whole life of the individual suffering from it [1]. The interaction and communication with others will be decreased and it will be difficult for the individual to survive in ups and downs of life. Autism can be caused by environmental and genetic problems. Its major symptoms are problem in eye contact, repetitive behavior, and increase in response time, communication problems, inappropriate giggling and laughing, no sensitivity of pain, no proper response to sound, not able to express their gestures and usage of echo words [2]. These symptoms are usually recognized by teachers and parents. Autism detection is very extensive and expensive method that requires a very large number of sessions with the psychiatrists. The common methods used in clinics are Autism Diagnostic Observation Schedule Revised (ADOS-R) and Autism Diagnostic Interview Revised (ADI-R). The ADI-R method contain verbal sections and the child who is not big enough and having delayed speaking issues can score 25%, in this way the answer could not obtained correctly for the patient. While conducting the interview, the trained examiner takes 90 to 150 minutes session with the caregiver which is time taking and the data can also be missed during the interview. The ADOS-R method depends on the provided answers and measured the result on the basis of scoring. The disadvantage of this approach is over classification because children could have other clinical disorders also. These are very lengthy procedures and for the early detection it will take at least 12 to 13 months and in the meantime the level of ASD could be increased. Many individuals are suffering from it and are increasing day by day in the population because of the bottleneck of these traditional methods that are very hectic and time consuming in nature. Thus, the professionals required an easy and accessible method that is time efficient also to detect ASD accurately. In this way, they can tell the individual whether they are suffering with ASD symptoms or not so that they can go for the clinical diagnosis as early as possible.

To alleviate and decrease the symptoms of ASD, it is very crucial to detect the autism in its early stages that can help the individuals to improve the quality of life as autism affects the economy of the world as well. For the early detection of autism accurately and quickly, we can use machine learning techniques to help the families in taking timely consultations with the psychiatrists [3]. There are some screening methods to detect the ASD in children of age 4 to 11 including Autism Spectrum Quotient (AQ), Childhood Autism Spectrum Test (CAST) and Social Communication Questionnaire (SCQ). In this study, we have used AQ for children of age 4 to 11.

AQ screening method is developed in the study [4]. These are 10 questions that are based on the behavior of child. This method helps to classify the autistic person from non-autistic one. We use machine learning techniques to automate the process of classification and to give accurate and optimal result. The preprocessing is applied to the dataset [5] to make improvement in classification. We have used five different machine learning models to detect the individual is suffering with ASD or not. These models include KNN, Gaussian Naïve Bayes, Logistic Regression, Random Forest and MLP. We used different features like age, ethnicity, gender etc. and

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determine the best model by evaluating each classifier. Then 10-fold cross validation technique is applied on these classifiers and MLP outperformed in it.

Autism can also be detected by extracting the facial features of the individual. The image processing helps us here to process the face images of child from dataset [6] and classify them based on their facial features. These features include wider mouth, shorter middle face, broader top face, wider eyes, and philtrum. The child with any of these facial features might have symptoms of autism. We have used TFLite model for the classification of images as by default it uses CNN which is deep learning technique. Therefore, autism can be detected by using the images of child and much easier for the person who is diagnosing the unknown autistic child.

The structure of remaining paper includes "Related Work" summarize the survey about the literature. The "Methodology" contains sub-sections in which "data Analysis and Preprocessing" includes description about the "dataset collection" and "Data Preprocessing", and "Applying Classification Techniques" section contains different classifiers in detail. At the end, results are discussed in which various experiments and there comparisons are performed.

2. Related Work

Several research have used machine learning to improve and speed up the diagnosis of ASD in various ways. The study in literature [7] used forward feature selection and under sampling to distinguish between autism and schizophrenia. A 65-item Social Responsiveness Scale was used to diagnose ADHD. The study in literature [8] based their measures onto predict ASD, researchers looked at brain activity. Techniques of soft computing such as artificial neural networks (ANN) and probabilistic reasoning have also been employed. Data from brain neuroimaging was used in a few researches [9].

The study in literature [10] used the ABIDE database to extract 6 personal traits from 851 respondents and used a cross-validation technique for training and testing machine learning models. This was utilized to distinguish between patients with and without ASD. The study in literature [11] presented the Rules Machine Learning, (RML), a new Machine
learning technique that provides users with a knowledge base of rules for comprehending the fundamental causes for classification as well as detecting ASD symptoms. The study in literature [12] uses various machine learning models on datasets of toddlers, children and adults.

The study in literature [13] applies five CNN pre-trained models on the photographs of children to detect autism in them. This study investigates the utility of static features taken from autistic children's facial pictures as a biomarker for distinguishing them from usually developing children. The study in literature [14] use Support Vector Machines (SVM), Logistic Regression (LR), K-Nearest Neighbor (KNN), Naïve Bayes (NB) and Random Forest Classifier (RFC) classifiers on the dataset of children to detect autism.

The major goal of this article is to see if the child is at risk for ASD in its early stages, which will assist speed up the diagnosis process. According to these findings, on AQ dataset Logistic Regression had the highest accuracy for the dataset we chose. We used five ML models to identify individual subjects as having ASD or not having ASD in this work, using numerous variables such as age, sex, ethnicity, and others, and evaluating each classifier to determine the best performing model.

3. Methodology

The methodology used in this paper is two-fold that includes AQ and image based ASD detection to increase the detection accuracy as shown in Figure 1. The following sub-sections elaborate both phases in detail.

3.1 AQ based ASD Detection

Firstly the AQ dataset is collected, data pre-processing is applied, and at the end, machine learning based models are trained to detect ASD. These phases are discussed below.

3.1.1 *Dataset Collection*

The ASD dataset [5] contains 21 attributes and 292 samples. Dataset contains binary attributes in which includes 10 screening questions A1 to A10, numeric attributes like age and result and also contains categorical attributes that consist of autism, used_app_before, ethnicity, gender, relation, jaundice, class/ASD, age_desc and contory_of_res. The data is collected and on the basis of answers of A1 to A10 questions, the class value is assigned. If the total score is less than 7, then the class value "No" is assigned which represents that the autism is not detected in the child. Otherwise, the class value "Yes" is assigned that represents the autism is detected. Dataset contains 141 ASD cases and 151 Non_ASD cases.

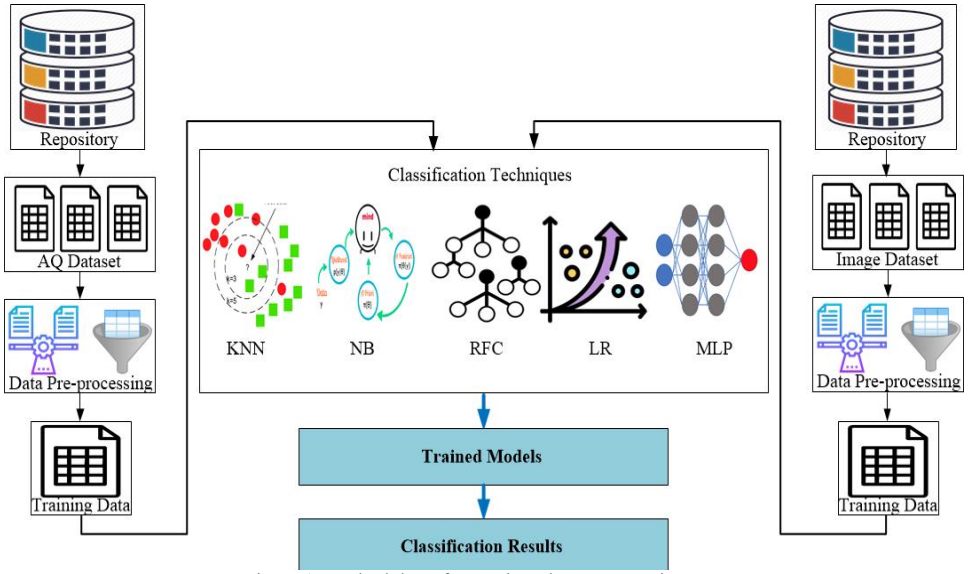

Figure 1. Methodology for AQ based ASD Detection

3.1.2 *Data Preprocessing*

For improvement of classification and simplification of our model, we preprocessed our data by removing the instances that contains the missing values. Then we cleaned our dataset by dropping the attributes that contains the meta information. The attributes that contains Meta information are Id, age_desc, Contory_of_res, Used_app_before and result. We determined that the attribute "score" contains the value greater than or equal to 7 is considered as the child is autistic, that is classified as ASD/Class Yes. Therefore, if we include this attribute for classification the outcome of target variable is already defined for algorithm. That's why; during analysis this attribute is removed. We select the 16 attributes of the ASD dataset for the detection. The list of 16 attributes that we used includes A1-A10, age, gender, ethnicity, jaundice, autism and relation.

3.1.3 *Classification Techniques*

For training the model, we split the dataset into training and testing. In which the training part contains 80 percent data and testing part contains 20 percent data that will be used for testing the accuracy of the model and the effectiveness of the model on the unseen data. This will help us for determining the over fitting and under fitting of the model. After performing the data preprocessing, we apply the different machine learning techniques in which include KNN, Gaussian Naïve Bayes, Logistic Regression, Random Forest and MLP for determining the highest accuracy. As, no single technique is perfect for different classification problems and datasets. The detailed description about the classification techniques are given as:

a. KNN

The KNN [15] is a classification algorithm that consist of two parts distance metric notion and the points are similar that are close to each other. The Euclidean distance metric is used for find the number of training points (k) closed to the new data point (x) that we want to predict. Then KNN performs the voting and determine the labels for x that have voting in majority.

b. Logistic Regression

Logistic Regression [16] is a classification technique that finds the model having best ft which means the relationship between the set of independent variable and the binomial characters. To find the optimal curve to the data points, logistic regression uses logistic function.

c. Random Forest

Random forest [17] is a flexible technique that is used for the regression and classification. On arbitrary data points, it creates multiple decision trees and gets the prediction from each tree. By voting, it selects the best solution

d. MLP

Multi-Layer Perceptron [18] is a classification technique that is multi-layer neural network which is fully connected. It includes the three layers input layer, output layer and hidden layer. As output of previous layer will become the input of the next layer. MLP classifier works iteratively, every time the derivatives of loss function are computed to update the parameters of the model.

e. Gaussian Naïve Bayes

Gaussian Naïve Bayes [19] is a classification technique that based on the counting and bayes theorem (conditional probability). It assumes that all input features are conditionally independent that's why the word 'naïve' comes. The Gaussian naïve bayes convergence rate is higher than the logistic regression if its assumption is true. That's why; less training data is required for the naïve bayes classifier. The disadvantage of this classifier is that for small amount of data there is a high bias, and it works on the limited features.

3.2 Image Based ASD Detection

Secondly, the image based dataset is collected, data pre-processing is applied, and at the end, TFLite based models are trained to detect ASD. These phases are discussed below.

3.2.1 *Dataset Collection*

In our research, we faced difficulty to find an open access image dataset that is required for image-based classification model. For creation of our model, we used dataset from Kaggle that is the only dataset we found for classification of autism. This dataset consists of child images of age 2 to 14 with the majority of age 2 to 8, the images are 2D face colored photos of total 2936. This dataset did not contain the information like ethnicity, child's clinical history, socio-economic background and ASD severity score. The dataset contains three folders valid, train and test with subfolders autistic and non-autistic. The validation folder contains 100 images, training folder contains 2536 images and test folder contains 300 images that are equally divided between the subfolders. To achieve the consistent result, the training set has images that consist of entire spectrum to classify the autism in children. Generally, the image classifiers use the very large amount of image data for their algorithm, comparison to this the size of available dataset is small.

3.2.2 *Data Preprocessing*

The images of children faces are collected from Kaggle repository and applied preprocessing. The features that are used in detection of autism are upper face, middle face, eyes, mouth, and the philtrum.

a. Upper Face

The human face can contain broader or shorter upper face. The study shows that the one with broader upper face can contain the symptoms of autism.

b. Middle Face

The middle face of human can be broader or shorter. The autistic individuals mostly have shorter middle face. Though, this feature can help for the detection of autism.

c. Eyes

We can also detect autism by measuring the size of eyes. The wide eyes show that a child might have symptoms of autism.

d. Mouth

The facial feature for the classification of autism also contains the size of mouth. Bigger mouth is shown in the faces of the autistic individuals.

e. Philtrum

The philtrum is mainly visible in autistic individuals.

3.2.3 *Classification Techniques*

The classification technique that we applied in the image based detection of autism is described as:

a. Convolutional Neural Network (CNN)

Convolutional neural network (CNN) is a deep leaning neural community. It's far typically used in feature extraction, photo type, and computer vision. It does not require tremendous pre-processing of the input photo and it uses parallel processing computing techniques so that it may run on the GPU that effects in a faster building and training of models. CNN model includes three layers input layer, hidden layer, and output layer. The CNN structure includes a max-pooling and convolutional layer that acts as a feature extractor, and a fully related layer that performs a nonlinear transformation at the extracted features and acts as a classifier alongside the output layer.

b. TFLite

The trained (CNN) models are big and complicated and are not appropriate for running on low-powered small devices inclusive of Android and iPhones. Therefore, the model is converted using TFLite to make it suitable for small gadgets. TFLite is a useful tool made by Tensor Flow as it transforms the complicated Tensor Flow models into smaller and less complicated models to improve the accessibility of fashions. After getting the trained model for the class of personal developments the android app is advanced the usage of flutter, and then the digital camera is used to take the picture.

4. Results and Discussion

A. Model Result for AQ Based ASD Detection

We applied different machine learning classification models which includes KNN, Logistic Regression (LR), Gaussian Naïve Bayes (NB), Random Forest (RF) and Multi-Layer Perceptron (MLP). For performance evaluation of all the models, we used accuracy, F1 score, and support. The comparison results of all classifiers are shown in Table 1. The table shows LR and MLP outperforms KNN, NB, and RFC with 100% accuracy.

TABLE 1: COMPARISION OF MODEL RESULTS

	KNN	NB	RFC	LR	MLP
Accuracy	86.44%	88.13%	93.22%	100%	100%
F1 Score	0.87	0.86	0.93	1.00	1.00
Support	30	27	28	34	25

Across the set of thresholds crisp class labels for the probability predictions are created, in this way we generate precision and recall curve. The precision and recall values are calculated for each threshold value. The graph is created along the recall on the x-axis and precision on the y-axis. The precision recall curves are created against all the applied classifier including KNN (shown in Fig. 2), Logistic Regression (shown in Fig. 3), Naïve Bayes (shown in Fig. 4), Random Forest (shown in Fig. 5), and Multi-Layer Perceptron (shown in Fig. 6).

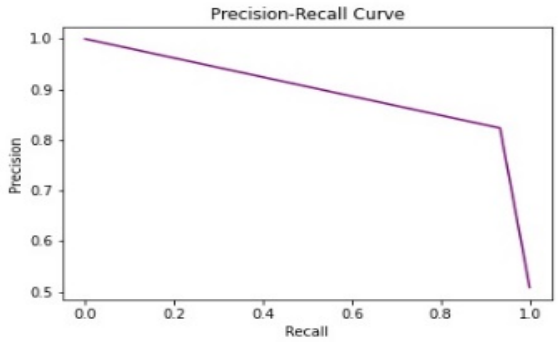

Figure 2. Precision-Recall Curve for KNN

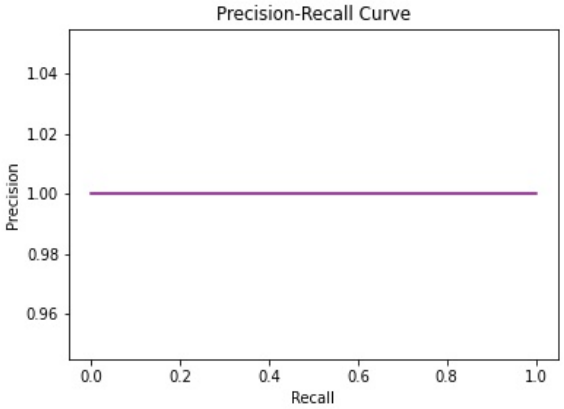

Figure 3. Precision-Recall Curve for Logistic Regression

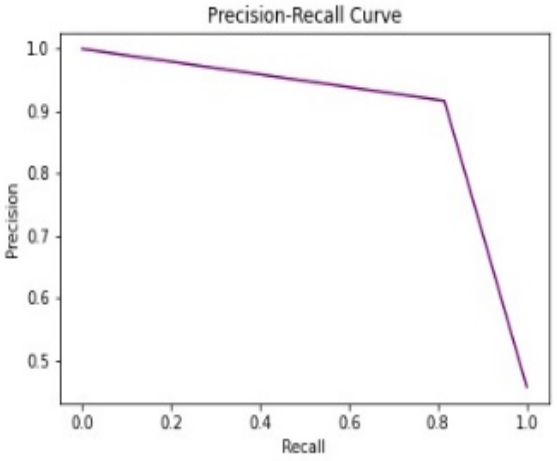

Figure 4. Precision-Recall Curve for Naive Bayes

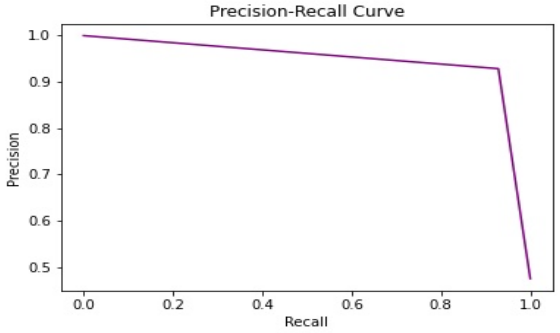

Figure 5. Precision-Recall Curve for Random Forest

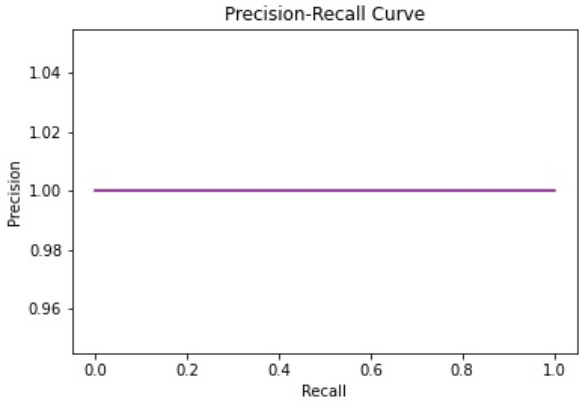

Figure 6. Precision-Recall Curve for Multi-Layer Perceptron

B. Model Result for Image Based ASD Detection

We trained the TFLite model having default efficient net lite 0 with Convolutional Neural Network Based architecture. For training the model we split the data into training and testing 90% and 10% respectively. After splitting we train the model on the training dataset with 5 epochs and batch size 82. For every epoch the accuracy of the model increases,

and the loss decreases respectively. In this way, the model becomes more and more accurate. The model training and testing is shown in Fig. 7.

```
Total params: 3,415,586
Trainable params: 2,562
Non-trainable params: 3,413,024
_________________________________________________________________
None
Epoch 1/5
/usr/local/lib/python3.7/dist-packages/keras/optimizer_v2/gradient_descent.py:102: UserWarning:
  super(SGD, self).__init__(name, **kwargs)
82/82 [==============================] - 70s 826ms/step - loss: 0.6115 - accuracy: 0.6883
Epoch 2/5
82/82 [==============================] - 67s 812ms/step - loss: 0.5432 - accuracy: 0.7611
Epoch 3/5
82/82 [==============================] - 69s 835ms/step - loss: 0.5282 - accuracy: 0.7691
Epoch 4/5
82/82 [==============================] - 69s 839ms/step - loss: 0.5140 - accuracy: 0.7824
Epoch 5/5
82/82 [==============================] - 69s 840ms/step - loss: 0.5194 - accuracy: 0.7778
10/10 [==============================] - 10s 713ms/step - loss: 0.4924 - accuracy: 0.8055
```

Figure 7. Model Training and Testing

Table 2 shows the training accuracy obtained by model is 77.78% with the loss 51.94% on 90% of the dataset with 5 epochs. Then we test our model on remaining 10% of the dataset and it gives accuracy 80.55% with the loss 49.24%.

TABLE 2: TESTING/TRAINING RESULTS

	Accuracy	Loss
Training	77.78%	51.94%
Testing	80.55%	49.24%

5. Conclusion and Future Directions

The detection of autism is time taking process; therefore, we have automated this process by using the efficacy of machine learning techniques. In our study, we analyzed the AQ based and image based dataset of children of age 4 to 11. The machine learning classifiers that we applied on AQ based dataset are KNN, Random Forest, Logistic Regression, Gaussian Naïve Bayes and MLP and MLP gives 100% accuracy. After applying 10 folds cross validation Multi-Layer Perceptron outperforms among all. We applied TFLite model on image-based ucithat gives accuracy of 80% by extracting facial features like broader top face, shorter middle face, wider eyes, bigger mouth and philtrum.

In future, our aim is to collect the large datasets for improved performances as the existing dataset did not have enough number of instances in it. We can work with deep learning methods that will use classification and feature assessment integrations. We would also predict the type of ASD (Autistic Disorder, Asperger Syndrome and Pervasive Development Disorder) by collecting the datasets and performing classification algorithms on it.

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