MEDDOCS Open Access Publisher

Journal of Autism Research

Open Access | Review Article

An Empirical Study on Autism Spectrum Disorder in Image Processing

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Received: Mar 12, 2024

Accepted: April 02, 2024

Published Online: April 09, 2024

Journal: Journal of Autism Research

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/

Keywords: Autism spectrum disorder; Decision tree; Random forest; SVM; CNN; Mobile Net-V2.

Abstract

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by a range of symptoms and challenges related to social communication, repetitive behaviour's, and restricted interests. People with ASD might find it difficult to talk or understand words, and they might use fewer words to express themselves. Understanding facial expressions and emotions can also be tricky for some individuals with ASD. The prevalence of Autism Spectrum Disorder (ASD) has been estimated to be around 1 in 54 children. Early detection of ASD traits in toddlers is critical for timely intervention and support. This Empirical study utilizes machine learning techniques for the automated detection of ASD traits in toddlers through the integration of diverse data modalities. The study leverages a rich dataset that combines behavioural observations, parent-reported assessments, and demographic information from a cohort of toddlers. The algorithms such as Decision tree, Random forest, SVM, CNN, Mobile Net-V2, VGG16 are tested using the autism spectrum dataset and comparison is made using the performance metrics. The results of the research work indicate that Mobile Net is better than other techniques.

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects how a person thinks, interacts, and perceives the world. It's characterized by a wide range of symptoms and challenges that can vary greatly from one individual to another. ASD is often referred to as a "spectrum" because it encompasses a diverse set of symptoms, strengths, and difficulties, and the severity of these symptoms can vary significantly from person to person [1].

Common features and characteristics associated with ASD include: Individuals with Autism Spectrum Disorder (ASD) face a range of challenges that impact various aspects of their lives. One significant area of difficulty lies in social interactions, where individuals with ASD may encounter obstacles such as making eye contact, interpreting social cues, and establishing relationships. Communication poses another hurdle, as many individuals with ASD may struggle with both verbal and non-verbal expression. This can manifest in delayed speech development, challenges in initiating or sustaining conversations, and limited use of gestures and facial expressions. Repetitive behaviours and intense interests characterize the behavioural patterns of individuals with ASD. This may involve activities like hand-flapping, repetitive movements, or a strong fixation on specific topics or routines. Sensory sensitivities are also common, with heightened reactions to stimuli such as lights, sounds, textures, or tastes. The intellectual spectrum within the ASD population is broad, ranging from individuals with intellectual disabilities to those with average or above-average intelligence. Furthermore,

Cite this article: AKALYA T, Ramyachitra D. An Empirical Study on Autism Spectrum Disorder in Image Processing. J Radiol Med Imaging. 2024; 7(1): 1003.

communication abilities vary, with some individuals being non-verbal, while others exhibit extensive vocabularies and effective communication skills [2].

Despite these challenges, individuals with ASD often showcase unique strengths and talents, particularly in areas such as mathematics, music, art, or technology. Recognizing and understanding these diverse characteristics are crucial for providing effective support and fostering an inclusive environment for individuals with ASD. ASD is typically diagnosed in early childhood, and early intervention can significantly improve outcomes. The exact cause of ASD is not fully understood, but it is believed to involve a combination of genetic and environmental factors. While there is no cure for ASD, various therapies and interventions can help individuals with ASD develop skills, improve their quality of life, and maximize their potential. It's important to recognize that every person with ASD is unique, and their experiences and needs can vary widely. As a result, ASD is often described as a spectrum to emphasize the diversity and individuality of individuals with the condition [3].

In light of recent advancements in detective analytics and facial-pattern recognition, the field of autism research has witnessed a surge in intensive initiatives aimed at analysing data related to autistic children with the goal of diagnosing Autism Spectrum Disorder (ASD) at an earlier stage. Lord. C et al. Proposed an automated method for identifying facial expressions in neurological conditions, specifically focusing on Autism Spectrum Disorder (ASD) detection. Where the initial CNN was trained to segment crucial facial components and a second CNN was utilized for the recognition of facial expressions. This approach further divided the system into four distinct CNN models [4].

Mujeeb Rahman KK, et al. Proposed the facial recognition system, harnessing transfer learning to augment the accuracy of autism diagnosis. The methodology entails the assembly of a substantial dataset incorporating facial images from both individuals with autism and those without the condition. This dataset undergoes comprehensive analysis utilizing a diverse range of machine learning, deep learning, and state-of-the-art pretrained models [5]. The effectiveness of these classifiers is rigorously evaluated using a range of metrics, including accuracy, the Area under the Curve (AUC), sensitivity, specificity, fall-out rate, miss rate, among others. This involves visually demonstrating the implementation process of the transfer learning model through computer vision techniques, offering readers a clear observation of our methodology. Currently recognized for its superior accuracy in this context [6].

Image processing in health care

Autism Spectrum Disorder (ASD) is increasingly being incorporated into healthcare through image processing technologies to aid in the diagnosis, assessment, and treatment of individuals on the autism spectrum. Here are some key ways in which ASD is used in healthcare through image processing.

Early diagnosis: Image processing techniques can analyse facial features and expressions, allowing for the early detection of potential signs of ASD in children. Subtle facial cues and characteristics may be indicative of the condition, and image analysis can help healthcare professionals identify these markers [7].

Facial recognition: Image processing tools are used to develop facial recognition systems that can identify and track facial expressions, eye contact, and other social behaviours. These systems are valuable for monitoring and assessing the social interactions and communication skills of individuals with ASD [8].

Behaviour analysis: Video analysis and image processing can be used to monitor and analyse the behaviour and activities of individuals with ASD in clinical and home settings. This data helps healthcare professionals tailor interventions and therapies to specific needs [9].

Brain imaging: Functional Magnetic Resonance Imaging (fMRI) and other neuroimaging techniques use image processing to study brain activity in individuals with ASD. This helps researchers better understand the neurological basis of the condition and develop targeted interventions [10].

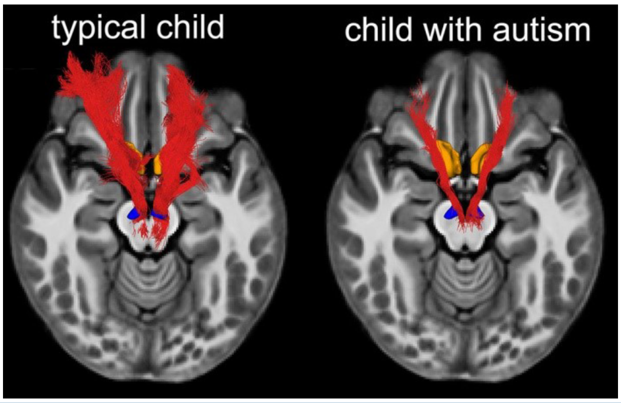

Figure 1: MRI image of autism disorder.

Eye-tracking: Eye-tracking technology, often integrated with image processing, is used to study eye movements and gaze patterns in individuals with ASD. This aids in understanding visual and social perception differences, which are common in people with ASD [11].

Treatment evaluation: Image processing is used to assess the effectiveness of behavioural therapies and interventions for individuals with ASD. By tracking changes in behaviour and facial expressions, healthcare providers can make data-driven decisions about the progress of treatment [12].

Detective analytics: Image processing can assist in developing detective models to assess an individual›s risk of developing ASD based on early childhood facial characteristics and behaviour patterns [13].

Assistive communication: In some cases, image processing is employed to develop assistive communication devices that interpret gestures, facial expressions, and other non-verbal cues to help non-verbal individuals with ASD express themselves.

Overall, image processing in healthcare for ASD enhances the understanding and management of the condition. It empowers healthcare professionals and researchers with valuable tools to provide early diagnosis, individualized care, and targeted therapies for individuals on the autism spectrum [14].

Methodology

The methodology used in Autism Spectrum Disorder (ASD) image processing typically involves a series of steps to acquire process, analyze, and interpret images to gain insights into ASD-related factors. Here's a general outline of the methodology used in ASD image processing.

Image data acquisition

The first step is to gather image data. This data can include various types of images, such as facial images, brain scans (e.g., fMRI or MRI), eye-tracking data, or video recordings of behavioral observations. For example, in the case of facial analysis, images of individuals with ASD and without ASD may be collected [15]. In this paper the various images of Facial expression images and brain scan like (MRI, CT) are used.

Preprocessing

It is a crucial step in deep learning algorithms for identifying Autism Spectrum Disorder (ASD) in children based on facial landmarks. Proper preprocessing helps prepare the data and enhance the performance of a model [16]. The image is verified for diversity in terms of age, gender, and ethnicity for comprehensive analysis. The size of the images used in this study is 224 x 224 and 128 x 128.

Data Analysis

Image data, especially when it comes to ASD, is typically analyzed using machine learning and statistical techniques. The approaches used in this research work are SVM, Random forest, CNN, mobile net, VGG-16 and Decision tree to classify the autism disorder [17].

Classification

Building detective models to classify individuals as either having ASD or not ASD is based on image features. Machine learning algorithms like support vector machines, decision trees, or deep learning models may be used [18].

The methodology in ASD image processing may vary depending on the specific focus of the research, whether it's facial analysis, neuroimaging, eye tracking, or other modalities. It is a multidisciplinary field that combines elements of computer science, psychology, neuroscience, and medical research to contribute to our understanding of ASD and the development of effective diagnostic and therapeutic tools [19]. In this research work, facial analysis is used for detecting the autism disorder.

Decision trees

Decision Trees (DT) categorize data using a tree-like model based on criteria, progressively subdividing datasets to construct a decision tree. It's widely recognized for its accuracy in various fields, such as medical diagnostics, particularly in tasks requiring minimal criteria for classification or regression [20].

Decision tree is a class representing a node in the decision tree. Each node has a feature, a threshold, and pointers to the left and right sub trees. It is used as image enhancement techniques to improve the quality of the images. Extract features from the images, such as facial landmarks of ASD children.

The information gain algorithm selects the attribute that maximizes Information Gain and used for splitting. It helps to creating a tree that efficiently separates the data into classes. The Gini Index is used as a criterion for making decisions about how to split the data. In decision trees, in random forest it selects the attribute that minimizes the Gini Index when creating a split.

Random forests

Random Forest leverages multiple decision trees to make precise classifications, excelling in handling complex facial feature data. By combining outputs from numerous trees, it enhances accuracy and robustness in ASD identification. Its proficiency in managing high-dimensional data, feature selection, and revealing feature importance contributes significantly to early ASD diagnosis and intervention efforts [21].

A Random Forest classifier is created with a set random classifier for reproducibility, and the class weights are set to balance. The number of images in the data is 50 and the 2 to 4 images is the minimum sample of the node. The maximum number of features to consider for splitting a node (x_training), (y) training), the trained set is the best model in the random forest.

SVM

In ASD identification through facial landmarks, SVMs are crucial. They excel in binary classification, distinguishing between ASD and non-ASD children based on facial features. SVMs handle high-dimensional data effectively, find optimal decision boundaries, and enhance ASD identification accuracy, supporting early diagnosis and intervention for children with ASD [22].

The SVM image can resize the normalizing images. The training and testing can evaluate the ASD and non ASD children. The Access matrix such as Precision, Recall, F1-Score, support. It also has the default image of 224 X 224 X3 size and 128X128 images.

The SVM model is used to detect on the input futures from the training dataset. It is used for classification tasks and contains different hyper parameter. The accuracy of the model on the training data, which is the ratio of correctly detecting the total number of autism and non-autism images. The recall score finds whether the child is affected from autism or not.

CNN model

Convolutional Neural Networks (CNNs) introduce a computational load on neural networks, which have demonstrated their effectiveness in the classification and detection of Autism Spectrum Disorders (ASDs). CNNs, often referred to as ConvNets, derive their name from the layered structure they employ, reminiscent of inscriptions veiled within their architecture. A CNN consists of three integral components: convolution, pooling, and a fully connected layer. Convolution is employed to capture local image features, pooling reduces dimensionality, and the fully connected layer generates the necessary output. This approach accentuates local image attributes, employing brighter pixels to delineate image boundaries and promoting more efficient processing [23].

Within each foundational layer of the network, an activation function is often integrated alongside the convolution and pooling operations. The output of the convolution process aligns with the input image, accompanied by the influence of a single filter. The performance of the neural network is influenced by several factors, including image size, which is typically represented as 224 × 224 × 3, incorporating height, width, and channels. In a practical scenario, the image channel may encompass 200 by 200 pixels, resulting in a processing size of 49,152 bytes. The image channel adheres to the RGB color model with dimensions of 224 × 224 × 3. For instance, if the image dimensions expand to 2048 by 2048 in three dimensions, the requisite weighted extent size escalates to a substantial 12 million [24].

The CNN model Pre-process the images, which may include resizing and normalization. A common structure consists of convolutional layers followed by pooling layers, The CNN model is the training set .The Access matrix such as Precision, Recall, F1-Score, support.

CNN is used for collecting the image from the dataset model and increase the filter size (128 and 224); it uses brighter image pixels and followed by batch normalization, max-pooling, and dropout layers. These layers are common components in CNN architectures and help extract hierarchical features from the input images while reducing over fitting.

Mobile net architecture

Mobile Net, a deep learning model designed for efficient image classification across a range of technology platforms, including mobile devices, embedded systems, and low-power PCs lacking a GPU, offers a visual depiction of the architectural framework underlying the Mobile Net model. A distinguishing characteristic of this CNN model, setting it apart from its counterparts, is the incorporation of depth-wise separable filters, capable of executing both depth-wise and point-wise convolutions [25].

Mobile Net, the deep neural network is used for detecting the facial expression of Autism children. This algorithm build the data frame, and provides an image a value of 0 for children in the Normal Control (NC) group and a value of 1 for children with ASD. The input of the image size is 224 X 224, the dataset of testing image were have 100 images and taken the 1 image analyse whether the child have autism or not. If the child have autism the result will show 1, and the child does not have autism the result will show 0.

Vgg-16 with machine learning models

The Visual Geometry Group (VGG) at the University of Oxford is credited with the creation of a pre-trained image recognition model, known as VGG-16. This model underwent training using a vast collection of images from the Image Net dataset, encompassing over 14 million images spanning more than 1000 distinct categories. Throughout the training process, the model extracts image features, enabling it to identify and categorize objects within the images it analyses. Verification of the deep neural network's correct operation typically involves increasing the network's size.

In the case of convolution within network C, a 1 × 1 filter size is employed. However, network D diverges from this approach, commonly utilizing a 3 × 3 filter size for convolution operations, thereby necessitating the training of 138 million parameters. Meanwhile, Network E, known as VGG-19, derives its name from its 16 convolution layers and 3 fully connected layers, constituting a total of 19 layers. While all VGG networks incorporate ReLU (Rectified Linear Unit) activation functions, they may not fully utilize them due to the resource-intensive nature of local response normalization during training [26].

The training set of Autism and Non-Autism is stored in the path of the file, each file test the condition of the children by analyse the image. 100 testing image were used both autism and non-autism and the 82 images has non autism and the 18 image are affect from autism.

Clinical implication

Clinical implications in the context of deep learning algorithms for identifying Autism Spectrum Disorder (ASD) in children based on facial landmarks are significant, as they directly impact the practical application and effectiveness of such systems. Here are some ways in which clinical implications can be utilized in this domain.

Early detection and intervention

Deep learning algorithms can aid in the early detection of ASD by analysing facial landmarks. Clinical implications here involve the ability to identify children at risk or exhibiting early signs of ASD. Early detection allows for timely intervention and support, which can have a substantial positive impact on the child's development and overall well-being [27].

Enhanced monitoring

Deep learning systems can be used for continuous monitoring and tracking of facial features over time. This can assist clinicians in observing changes and trends in a child's facial landmarks, which might be indicative of ASD progression or response to treatment [28].

Treatment plans

The clinical implications extend to tailoring treatment and therapy plans based on the deep learning analysis. By understanding the specific facial features and patterns associated with an individual child, clinicians can develop personalized intervention strategies [29].

Facial landmark detection

Facial landmark detection in autism research offers the potential for early diagnosis and intervention. Using computer vision, it analyses specific facial features, like the eyes, nose, and mouth, to identify distinctive characteristics in autistic children. Detecting these deviations objectively reduces subjectivity in diagnosis, lowers costs, and enhances ASD identification accuracy, promising improved long-term outcomes through timely interventions [30].

Results and discussion

Mobile Net Model Performances

The Mobile Net learning models were trained using the Keras API library, and various data visualization and analysis tools such as Matplotlib, Sklearn, and Pandas were employed to assess the model's effectiveness. To compare the performance of the models used in this research work, 1054 patients, out of which, children with autism are 69.1%, and without autism are 30.9% used. The entire plot size is 10 inches, the training set has 843 data and the testing set has 211 data. The dataset was taken from Kaggle. The system is required with four Gigabytes (GB) of Random Access Memory (RAM) and a five hundred and twelve -Gigabyte (GB) hardware disk for storage. The hardware requirements based on complexity of image processing suitable for real - time processing and the software tools is based on the objectives like Open CV, Tensor flow etc.. Compare to other algorithm Mobile Net gives better accuracy value and the Mobile Net model achieved an impressive accuracy of 96%.

Table 1: Performance comparison of various machine learning models.

ALGORITHMS	Precision	Recall	F1- Score	Accuracy
Decision tree	66	65	66	66.15%
Random forest	75	93	79	79%
SVM	82	80	82	81.46%
CNN	87	78	85	84%
Mobile Net	86	92	96	96%
VGG-16	83	81	82	82.14%

From the Table 1, it is inferred that Mobile Net has highest accuracy and F1 score, whereas Random has better recall value and CNN has better precision measure. Mobile Net also performs well when Recall and precision measures are considered.

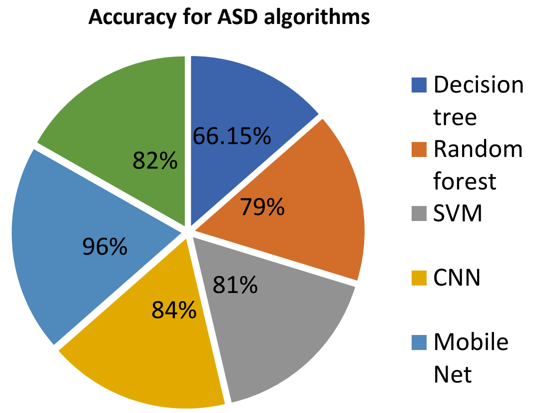

Figure 2: Accuracy value for ASD Algorithms.

The utilization of facial landmarks holds great promise as a screening tool for Autism Spectrum Disorder (ASD). In this study, a comparison of the methods for diagnosing ASD in children based on their facial expressions is done. And approach bridges the gap between ASD classification and facial analysis, offering an automated and more cost-efficient alternative. Their model integrated Mobile Net with various machine learning models to achieve this goal. Training and validation utilized a dataset of 1054 data, from the data 69.1% of the children with autism and 30.9% of children without autism. The study indicates that a single image may suffice for an accurate diagnosis of ASD in children.

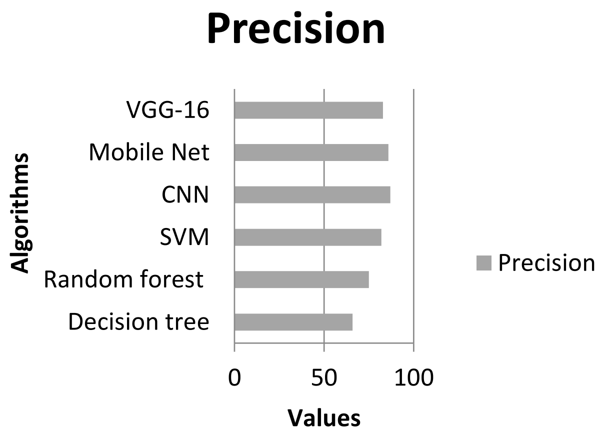

Figure 3: Precision values for ASD algorithms.

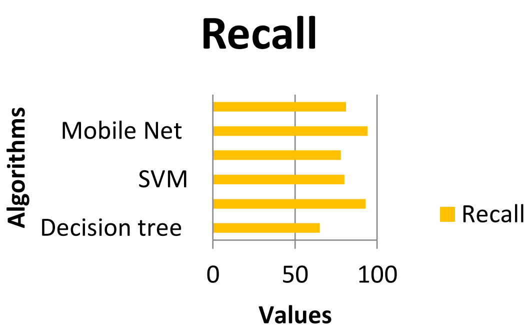

Figure 4: Recall values for ASD Algorithms.

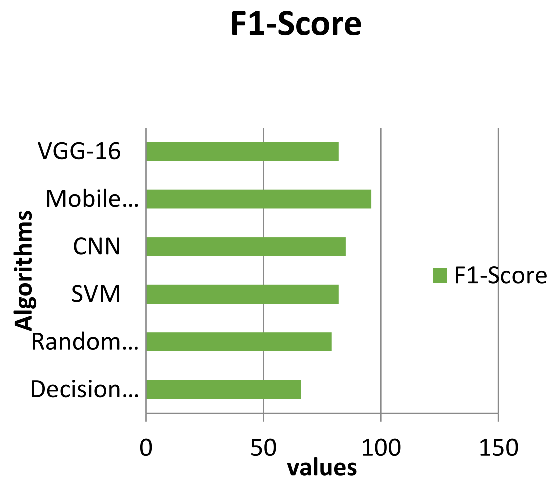

Figure 5: F1-Score values for ASD Algorithms.

In this figure 3, the bar chart mention the PRECISION score of ASD using the algorithms and the CNN model score high value 87% compare to others. The Figure 4 represent the Recall values the Random forest score high value of 92% and the Figure 5 represent the F1-Scores in this chart also mobile net score 96% of value , it is the strongest algorithm compare to others.

Conclusion and future direction

ASD diagnosis is crucial for long-term health; it relies on costly and subjective methods. This study advocates a Machine learning system using facial landmarks; Image processing tools can find the early detection and diagnosis of ASD. Decision tree, random forest, SVM, CNN model, Mobile Net and VGG-16 were compared and the Mobile Net algorithm achieved 96% accuracy than others. The utilization of image processing techniques has enabled researchers to analyse and interpret visual information related to autism. However, the future directions include multi-modal data integration, real-time detection and prediction personalized treatment plans, and the development of cross-culturally valid models. And it can detect and predict from the AI technologies and collaboration between machine learning, clinical practitioners, and researchers in the field of ASD is for advancing these algorithms, enhancing their accuracy, and ensuring their responsible and ethical application in clinical settings.

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