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A Review on Autism Spectrum Disorder

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Abstract

Autism Spectrum Disorder is a neurodevelopmental disorder that involves difficulties with social communication and interaction, which can often be detected within the first two years of life. It is usually diagnosed in childhood but continues to influence people into adolescence and adulthood. With ASD affecting 1 in 44 children worldwide, the need for faster, accurate, and cost-effective diagnosis has become critical. The current methods are time consuming, expensive, and often subjective, leading to delays in treatment and impacting negatively on individuals and their families. This project utilizes Machine Learning techniques to improve the ASD diagnosis process through image and video analysis. Advanced ML models, by observing behavioral patterns, facial expressions, and gestures, can detect and classify autism levels. The approach is non-intrusive, scalable, and efficient, providing a faster, more accurate, and widely accessible solution. This will enhance the diagnostic process and outcomes for individuals with ASD and their families.

Keywords: *Autism Spectrum Disorder, ASD, Machine Learning, Image Analysis, Video Analysis, Behavioral Patterns, Facial Expressions, Diagnosis Efficiency.*

1. Introduction

Autism Spectrum Disorder is a neuro developmental disorder which significantly impacts an individual's social interaction, effective communication, and adaptation to changing circumstances. According to the estimation of the World Health Organization (WHO), around 1 of 100 children worldwide suffers from ASD. ASD is considered to be a" spectrum" because of the wide range in symptoms and severity across patients. While some individuals may present with mild symptoms and can function relatively independently, others may require substantial support in daily living activities. Early diagnosis of ASD is critical because timely interventions can significantly improve cognitive, social, and behavioral outcomes. However, diagnosing ASD is not an easy task. It involves multi-faceted assessments, including clinical observations, behavioral analysis, and standardized diagnostic tools such as the Autism Diagnostic Observation Schedule (ADOS) and the Modified Checklist for Autism in Toddlers (M-CHAT) hybrids add additional improvement for the analysis of non-verbal communication.

1.1 Detection Using Normal Datasets

In the early days of ASD research, detection methods were based on normal datasets. These are structured collections of textual and diagnostic information that do not contain images or video data. These datasets form the basis of understanding ASD through quantitative behavioral metrics and clinical observations. Some of the key components of these datasets include: Behavioral and Diagnostic Records: The ADOS and MCHAT are standardized tools that provided intensive details regarding the child's behavior, including response to social cues, motor coordination, and repetition. These provided struc tured output in the forms of symptom severity scores, for instance, which can easily be computed and analyzed with a combination of statistical and machine learning models

1.2 Problem Statement

This project aims to revolutionize Autism Spectrum Disorder (ASD) diagnosis using Machine Learning (ML) techniques. Traditional methods, though accurate, are costly, time-consuming, and subjective, delaying early intervention. With ASD affecting 1 in

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44 children globally, a swift, accessible, and affordable diagnostic tool is crucial. The proposed solution leverages ML to analyze behavioral patterns, facial expressions, and gestures from images and videos, enabling faster, more accurate, and scalable diagnosis. This approach enhances early detection, improving treatment outcomes and quality of life for individuals with ASD and their families.

2. Methodologies

Machine Learning Techniques for ASD Detection: Machine learning has significantly improved Autism Spectrum Disorder (ASD) detection by leveraging structured behavioral and diagnostic datasets. Early methods used feature selection techniques like swarm-based selection to enhance accuracy. Challenges like data imbalance were addressed through normalization and synthetic data generation. Classification models, including SVMs, Random Forests, and XGBoost, analyzed behavioral patterns like repetitive actions and social interaction anomalies. Ensemble learning further enhanced accuracy and robustness by combining multiple models.

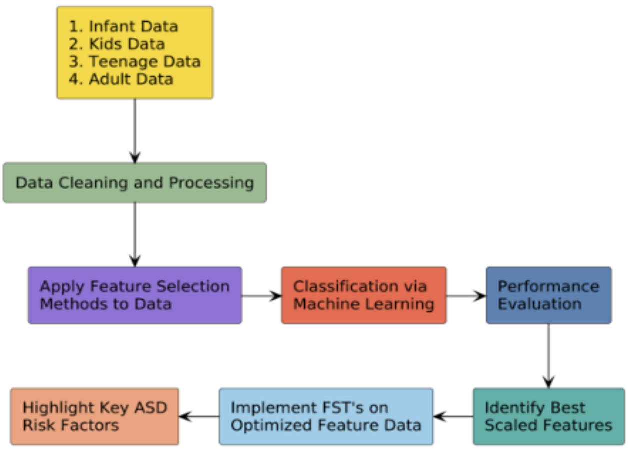

Figure 1 Step-By-Step Process of ASD Detection Using Machine Learning Techniques

Figure 1, The process of detecting ASD is based on machine learning. Preprocessing of data normalizes, cleans, and balances data from various age groups. Feature selection identifies important features for diagnosis, which are categorized by algorithms like SVM, Random Forests, and Gradient Boosting. Accuracy and precision are used to evaluate performance, with feature scaling to optimize model performance. FSTs enhance predictions in some cases. The system analyzes ASD risk factors and provides diagnostic information in a stepwise, organized format.

2.1 Deep learning Techniques for ASD Detection

Deep learning greatly improved detection of ASD through image and video analysis. CNNs detect subtle facial expression features, detecting local (eye) and global (face symmetry) features. Transfer learning from the ASD dataset improves the accuracy of the classification. Multi-scale CNNs improve detection by using shallow and deep feature extraction. In video-based detection, CNNs extract spatial features, while LSTMs extract motion, gaze, and repetitive behavior. Optical flow and CNN-RNN hybrids add additional improvement for the analysis of non-verbal communication to ensure accurate ASD trait detection.

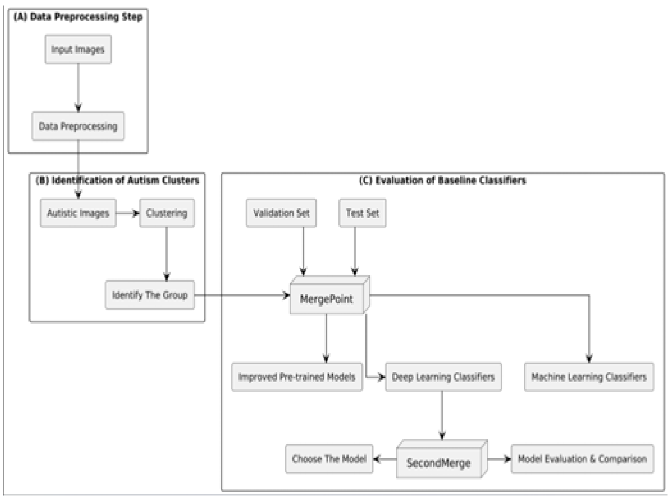

Figure 2 Step-By-Step Process of ASD Detection Using Image Processing

Figure 2, represents a workflow in the structured approach to detect Autism Spectrum Disorder using image data and machine learning techniques. The process begins with the Data Preprocessing Step (A), where input images are preprocessed for consistency and quality before being analyzed. The preprocessed images are then divided into the training and validation sets and the test set for model evaluation. In the section named evaluation of baseline

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Classifiers (B), it uses the data for training and comparing three categories of models, namely Improved Pre-trained Models, Deep Learning Classifiers, and Machine Learning Classifiers. Model Evaluation and Comparison help in choosing the best-performing model. Lastly, in Identification of Autism Clusters (C), autistic children's images are grouped for pattern identification, and the best performing groups are further analyzed to find meaningful insights. In 13 a flowchart manner, preprocessing, model training, evaluation, and clustering have been systematically integrated to arrive at accurate ASD detection and classification, which indicates an end-to-end machine learning-based solution.

2.2 Gaze-Based ASD Detection

Deep learning greatly improved detection of ASD through image and video analysis. CNNs detect subtle facial expression features, detecting local (eye) and global (face symmetry) features. Transfer learning from the ASD dataset improves the accuracy of the classification. Multi-scale CNNs improve detection by using shallow and deep feature extraction. In video-based detection, CNNs extract spatial features, while LSTMs extract motion, gaze, and repetitive behavior. Optical flow and CNN-RNN hybrids add additional improvement for the analysis of non-verbal communication to ensure accurate ASD trait detection.

2.3 Neuroimaging-Based ASD Detection

Functional MRI and machine learning have been used extensively to grasp and classify Autism Spectrum Disorders. In one approach resting-state fMRI is considered to assess the functional connectivity patterns of the brain as well as to identify neural markers that are specific to ASD for distinguishing them from neurotypicals. The functional connectivity map is used to evaluate associations between the brain regions in which the machine learning classifiers classify the ASD based upon these features of connectivity, showing the neurobiological signature of ASD [5]. Another approach uses task-based fMRI, in which specific tasks activate functional brain regions. Features derived from task-specific brain activation patterns are used to grade ASD severity levels, with machine learning models predicting severity based on variations in functional responses [23]. These studies together indicate the value of resting-state and task-based fMRI in the identification of ASD traits and assessment of severity, which also holds promise for machine learning in providing an accurate and objective analysis of ASD

3. Results and Discussion

Performance analysis in detection of ASD compares different approaches based on accuracy, sensitivity, and specificity. Behavioral Data Models, employed through structured tests, are readily available but have difficulty with noisy data, with an accuracy of about 80%, 85% sensitivity, and 80% specificity. Gaze-Based Approaches, employing eye tracking, perform well in early detection with a maximum accuracy of 88% but are device sensitive. Neuroimaging Methods, including fMRI, offer neural information, with task-based fMRI achieving 90% accuracy but at the cost of high computational power. Multimodal approaches, integrating behavioral, gaze, and neuroimaging information, achieve more than 92% accuracy but are resource and complex-intensive. Video Processing Methods record temporal patterns with 89% accuracy but require high-quality datasets. The method of choice is based on diagnostic requirements, trading off accuracy, scalability, and resources. Table 1 is the comparison between various Autism Spectrum Disorder detection techniques on the basis of three factors: quantitative analysis (sensitivity, specificity, and accuracy), qualitative analysis (advantages and disadvantages), and alternative comparison. It names several approaches like machine learning, gaze tracking, fMRI, video analysis, and multimodal. The table emphasizes that machine learning and gaze tracking are economical but are limited. FMRI-based techniques yield in-depth information but need intensive computational power, and multimodal techniques offer maximum accuracy but are complex and require intensive resources. The selection of the method relies on the availability of data, cost, and diagnostic requirements. Multi-scale CNNs improve detection by using shallow and deep feature extraction. In video-based detection, CNNs extract spatial features.

Table1 Performance Analysis Table

Title	Quantitative Analysis	Qualitative Analysis	Comparison with Alternatives
Machine Learning Techniques to Predict Autism Spectrum Disorder	Accuracy: 83%, Sensitivity: 85%	Cost-effective and scalable but impacted by noisy datasets.	Simpler than multimodal approaches but less precise for complex ASD traits.
Identifying ASD via Gaze Tracking	Accuracy: 88%, Sensitivity: 84%	Effective for early detection; device and environmental dependencies noted.	Outperforms behavioral models in detecting social deficits but lacks neuroimaging depth.
Grading Autism Severity Levels via Task-Based fMRI	Accuracy: 90%, Sensitivity: 86%	Neural biomarkers provide deep insights but are computationally expensive and require standardized tasks	Superior to resting-state fMRI for severity grading; less scalable than behavioral methods
CNN and Prototype Learning Framework for Brain Networks	Accuracy: 87%, Sensitivity: 83%	Reliable connectivity mapping; computationally demanding.	Matches fMRI methods in precision but requires advanced computational resources
Video-Based ASD Detection	Accuracy: 89%, Sensitivity: 87%	Captures complex behaviors but is resource-intensive and dataset-reliant.	Excels in analyzing motion and interaction behaviors but less suited for neurallevel insights.
Early Detection Framework for Autism	Accuracy: 82%, Sensitivity: 81%	Comprehensive feature extraction enhances accuracy; limited by dataset variability.	More flexible than neuroimaging methods; less depth compared to multimodal approaches.
Local and Global Feature Representation for Facial Image Analysis	Accuracy: 86%, Sensitivity: 84%	Combines local and global features effectively; impacted by dataset size.	Superior for image-based ASD detection; less holistic than multimodal systems.
Computer Vision for Interaction and Emotion Analysis	Accuracy: 91%, Sensitivity: 88%	Combines visual cues and human pose analysis; dependent on diverse video data availability.	Excels in detecting emotional and interaction deficits; lacks neurobiological insights
Response-to-Name Protocol Screening	Accuracy: 84%, Sensitivity: 82%	Integrates auditory stimuli effectively; impacted by variability in response accuracy.	More precise than gaze-only methods for social responsiveness but less versatile than multimodal systems.

Conclusion

This review examines the revolutionary impact of Machine Learning (ML) and Deep Learning (DL) on Autism Spectrum Disorder (ASD) diagnosis, improving precision, efficiency, and accessibility.

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Conventional behavioral evaluations are increasingly supplemented by artificial intelligence-based techniques that provide objective, scalable, and affordable screening. Machine learning algorithms such as SVMs, Random Forest, and Gradient Boosting inspect structured behavioral data with minimal prejudice, whereas Deep Learning models in the form of CNNs and CNN-LSTM hybrids improve diagnosis by scrutinizing facial expressions, gaze patterns, and movement behavior. Multimodal strategies involving behavioral histories, video observations, and neuroimaging offer maximum accuracy but require high-level computing capacity, accurate data synchronization, and high-impact infrastructure. Overcoming difficulties like diversity of datasets, processing in real time, and privacy issues related to data confidentiality is crucial for ensuring generalizability and public trust. In the face of such challenges, persistent development in AI, better means of data gathering, and collaboration across disciplines are propelling progress. The inclusion of AI tools in real-life applications, remote screening, and telemedicine holds the promise to fill gaps in accessibility and make early diagnosis a reality, especially among underserved populations. This transition from traditional techniques to AI-based solutions is a major advance in the detection of ASD, as diagnosis becomes more accurate, equitable, and affordable and improves outcomes for patients with ASD and their families.

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