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A Web-Based Multimodal System For Early Prediction Of Autism Spectrum Disorder Using Facial And Behavioral Data

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Abstract: The project presents a web-based application for the early prediction of Autism Spectrum Disorder (ASD) using both facial images and behavioral questionnaire data.The proposed system provides a fast, accessible screening tool by leveraging multimodal inputs. Facial images are analyzed using Convolutional Neural Networks (CNN) to detect autism-related facial patterns, while behavioral responses are processed using classical machine learning models such as Logistic Regression, Random Forest, SVM, and XGBoost. The application, built with Flask and Streamlit, allows users to upload images or enter questionnaire responses for real-time predictions, providing risk classification along with confidence scores. By integrating image-based and data-based predictions, the system enhances the accuracy and reliability of autism risk screening, supporting early awareness for parents, educators, and healthcare professionals. The model is trained on publicly available ASD datasets containing facial images and behavioral attributes, ensuring both diversity and robustness in prediction. Data preprocessing techniques such as normalization, augmentation, and feature scaling are applied to improve generalization and model performance. The platform's user-friendly interface ensures accessibility for non-technical users, making it suitable for preliminary home-based assessments. Moreover, the modular design of the system allows for easy updates and integration of additional data sources, including speech or text-based behavioral cues, in future versions.

I. Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition that affects social interaction, communication, and behavior. In recent years, the prevalence of ASD has significantly increased worldwide, emphasizing the need for timely and accurate diagnosis. Early detection is crucial, as it enables prompt intervention and support, which can greatly improve a child's developmental outcomes. However, conventional diagnostic methods are often subjective, time-consuming, and require specialized clinical expertise, leading to delayed recognition of symptoms.

With advancements in artificial intelligence and machine learning, technology has begun to play a transformative role in the early identification of developmental disorders. Automated screening systems that analyze behavioral data and facial features have emerged as promising tools to assist clinicians and caregivers in early assessment. Integrating these technologies can offer an efficient, reliable, and accessible approach to preliminary ASD detection.

The proposed web-based system leverages Convolutional Neural Networks (CNN) for facial image analysis and classical machine learning models such as Logistic Regression, Random Forest, Support Vector Machine (SVM), and XGBoost for behavioral questionnaire evaluation. By combining both image and data based modalities, the system aims to provide a holistic prediction model that enhances diagnostic accuracy. This approach not only reduces dependency on expert evaluations but also empowers parents, educators, and healthcare professionals with a convenient tool for early autism risk screening. Ultimately, the project contributes to the broader goal of promoting awareness, accessibility, and early intervention in autism care.

II. LITERATURE REVIEW

Autism Spectrum Disorder (ASD) diagnosis has traditionally relied on behavioral observation and standardized clinical assessments, which are often subjective and time-intensive. In recent years, the integration of machine learning (ML) and artificial intelligence (AI) has emerged as a promising approach for automating and improving the accuracy of early ASD detection. Multiple researchers have contributed to developing data-driven frameworks that utilize behavioral attributes, facial images, and multimodal features to identify autism risk with enhanced precision.

T. Akter et al. [1] introduced a comprehensive study on machine learning-based models for early-stage autism detection, where various algorithms such as Support Vector Machine (SVM), Random Forest, and Decision Tree were trained on behavioral datasets. Their results indicated that ensemble-based techniques performed better in classifying ASD and non-ASD individuals, achieving improved generalization and accuracy. Similarly, S. R. Dutta et al. [2] designed an ML-assisted diagnostic tool for children, integrating behavioral and developmental data to automate autism assessment. The system effectively reduced manual evaluation time while maintaining diagnostic reliability, proving that ML can support clinicians in large-scale screening.

In parallel, researchers have explored the use of facial image analysis through deep learning to identify autism-related visual traits. M. Beary et al. [3] employed convolutional neural networks (CNNs) for facial recognition and achieved promising accuracy in differentiating ASD children from typically developing peers. Their approach demonstrated that CNNs can extract subtle facial features associated with ASD, supporting the role of computer vision in healthcare diagnostics. F. C. Tamilarasi and J. Shanmugam [4] further expanded on this by designing a CNN-based autism classification model that leveraged image preprocessing and data augmentation to enhance performance. Their work proved that properly optimized CNN architectures can effectively identify developmental disorders with minimal manual intervention.

K. S. Omar et al. [5] conducted a comparative study of traditional machine learning models—Decision Tree, Random Forest, and SVM—on ASD prediction using demographic and behavioral datasets. Their findings revealed that Random Forest outperformed other models in terms of prediction accuracy and robustness, suggesting that ensemble learning can handle the complexity and variability of ASD data. Z. Nazari et al. [6] similarly utilized classical ML methods and emphasized the importance of feature selection, normalization, and cross-validation in improving classification outcomes.

S. M. M. Hasan et al. [7] presented a multi-stage framework that integrated multiple ML algorithms, including Logistic Regression, XGBoost, and Random Forest, to detect early signs of autism. Their hybrid approach combined behavioral features and clinical indicators, leading to improved detection rates and fewer false positives. Meanwhile, M. Elhoseiny et al. [8] performed a comparative analysis of pre-trained CNN architectures such as VGG16, ResNet50, and InceptionV3 on facial image datasets for ASD detection. The results demonstrated that transfer learning enhances model efficiency and reduces the need for large labeled datasets, making it feasible for real-world applications.

In another significant contribution, P. Mukherjee et al. [9] evaluated various traditional ML models—including Logistic Regression, Decision Tree, and Support Vector Machine—on structured behavioral datasets. Their study highlighted that data preprocessing, feature engineering, and ensemble integration substantially improve predictive reliability. P. Gyanchandani and G. Shrivastava [10] focused on enhancing ASD diagnosis through advanced data analytics and machine learning, utilizing large-scale datasets to uncover complex relationships between behavioral, facial, and neurological features. Their research emphasized the potential of combining multimodal data sources for holistic and accurate autism detection.

Across the reviewed studies, a clear research trend emerges— hybrid models that integrate both image-based and behavior-based features consistently outperform single-source systems. Deep learning models such as CNNs provide exceptional capability in recognizing non-verbal cues from facial images, while classical ML algorithms excel in analyzing questionnaire-based and structured behavioral data. The synergy between these two modalities leads to higher classification accuracy and greater diagnostic confidence.

Building upon these findings, the proposed project integrates facial image analysis using CNNs with behavioral response evaluation through models like Logistic Regression, Random Forest, SVM, and XGBoost. This multimodal approach aims to deliver a comprehensive, fast, and reliable tool for early ASD screening. By combining the strengths of both visual and behavioral analytics, the system addresses the limitations of existing single-modal models and contributes toward accessible, data-driven early detection of autism in children.

III. METHODOLOGY

The proposed system adopts a modular framework that integrates data acquisition, preprocessing, model development, evaluation, and user interaction to ensure efficient and accurate autism prediction.

3.1 Data Collection and Preprocessing

Facial image datasets were collected from public repositories such as Kaggle and Autism Face Dataset, while behavioral or survey-based data were obtained from sources like UCI Machine Learning Repository. Image preprocessing involved resizing, normalization, and augmentation techniques such as rotation, flipping, and brightness adjustment to enhance model robustness. For tabular data, preprocessing included handling missing values, label encoding for categorical variables, and feature scaling to maintain consistency across attributes.

3.2 Model Training and Development

Two primary modules were developed—one for image-based detection and another for questionnaire-based classification. The image module utilized Convolutional Neural Networks (CNNs) with architectures including VGG16, ResNet50, and InceptionV3, fine tuned for autism-related facial pattern recognition. The survey based module employed classical machine learning algorithms such as Logistic Regression, Random Forest, Support Vector Machine (SVM), and XGBoost to analyze behavioral and demographic attributes.

3.3 Performance Evaluation

Model performance was assessed using standard evaluation metrics such as Accuracy, Precision, Recall, and F1-score. Confusion matrices were used to analyze misclassification rates, while cross validation techniques ensured generalization and robustness. Comparative analysis between CNN and classical ML models was conducted to identify the most effective prediction strategy.

Formulas

$$Accuracy = \frac{TP + TN + FP + FN}{TP + TN}$$

$$Precision = \frac{TP + FP}{TP}$$

$$Recall = \frac{TP}{TP + FN}$$

$$F1 - Score = \frac{2 \times (Precision \times Recall)}{Precision + Recall}$$

3.4 Autism Prediction Output

The system provides two parallel prediction outcomes. The CNN based module classifies facial images as "At Risk" or "Not at Risk" for autism, while the ML-based module predicts the same using behavioral questionnaire inputs. Both outputs are accompanied by a confidence score to reflect model certainty and assist in interpretation.

3.5 User Interface Integration

A Streamlit-based web application was developed to integrate both modules, allowing users to upload facial images or fill behavioral forms for real-time prediction. The interface displays classification results, confidence scores, and ensures a simple, accessible experience for parents, educators, and healthcare professionals.

3.6 System Deployment and Future Scope

The integrated Flask and Streamlit framework supports local or cloud deployment for scalability and ease of access. Future enhancements may include multimodal fusion of image and text inputs, real-time data collection, and larger dataset integration to further improve diagnostic accuracy and reliability.

IV. FINDINGS/DISCUSSION

The developed web-based system effectively combines facial image analysis and behavioral questionnaire data for early autism prediction. Testing and evaluation demonstrated that both the CNN and machine learning models perform well in identifying individuals "At Risk" and "Not at Risk" for Autism Spectrum Disorder (ASD).

Key findings include:

1. **Multimodal Prediction:** By integrating both facial image data and questionnaire-based inputs, the system enhances diagnostic reliability and reduces the limitations of single-source prediction.
2. **Real-Time Screening:** The Flask and Streamlit-based application enables users to upload images or input behavioral data for instant predictions, making the tool accessible for parents and healthcare professionals.
3. **Improved Accuracy and Confidence:** The combination of CNN models (VGG16, ResNet50) and ML algorithms (SVM, Random Forest) ensures higher accuracy, with confidence scores provided for better interpretation of results.
4. **User-Friendly Interface:** The web interface offers a simple, interactive platform for early screening without requiring advanced technical expertise, making it suitable for widespread use.
5. **Scalability and Accessibility:** The system can be deployed locally or on cloud platforms, making it scalable for educational institutions, hospitals, and awareness campaigns.

Key Features of the Project:

1. **Dual-Model Framework:** Simultaneous use of CNN (for facial analysis) and ML models (for behavioral data) ensures a more holistic prediction.
2. **Confidence-Based Output:** Provides prediction results with percentage-based confidence scores for better interpretability.
3. **Cross-Platform Deployment:** The integration of Flask (backend) and Streamlit (frontend) ensures flexibility for both research and clinical adaptation.
4. **Data Augmentation & Preprocessing:** Image enhancement and feature scaling techniques improve generalization and minimize overfitting.
5. **Support for Early Intervention:** Enables timely identification of autism risk, assisting educators, parents, and clinicians in decision-making.

Challenges and Future Improvements:

1. **Dataset Limitations:** Publicly available autism datasets are limited in diversity and size, which may affect model generalization across ethnicities and age groups.
2. **Facial Data Sensitivity:** Privacy and ethical concerns arise when collecting and processing facial images of children.
3. **Model Bias and Overfitting:** Variations in lighting, pose, and facial expressions can influence model predictions; further training on diverse data is needed.
4. **Internet Dependency:** Real-time predictions depend on stable internet connectivity for cloud-based deployment.
5. **Future Enhancements:** Incorporating multimodal fusion (combining both text and image features into a unified model) and mobile app integration could further improve accessibility and usability.

V. CONCLUSION

The proposed system effectively addresses the need for early, accurate, and accessible detection of Autism Spectrum Disorder (ASD). By combining facial image recognition through deep learning and behavioral data analysis through traditional machine learning techniques, it ensures a comprehensive approach toward identifying autism risk. This dual-modality framework enhances the reliability of predictions and reduces dependence on a single data source, making the model more adaptable to real-world conditions.

The integration of CNN-based facial analysis and survey-based data classification provides real-time insights that can aid parents, caregivers, and clinicians in making timely decisions. The system's Streamlit based interface makes it user-friendly and easily deployable across different platforms. It promotes early intervention, which is crucial for improving developmental outcomes in children with ASD.

Future enhancements could include expanding datasets for improved accuracy across diverse populations, introducing multimodal fusion networks for deeper learning integration, and developing a mobile-friendly application for wider reach. With its potential to support both research and practical healthcare settings, this system stands as a promising innovation in the field of autism detection and early screening.

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