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Autism Spectrum Disorder Detection of FacialImages Using VGG Model

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ABSTRACT:

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by challenges with social interaction, communication, and repetitive behaviors. Early detection and intervention are crucial for improving outcomes for individuals with ASD. In this study, we propose a machine learning approach for ASD prediction using convolutional neural networks (CNNs) and transfer learning. We leverage the VGG16 architecture, a pre-trained CNN model, to classify images into "Autistic" and "Non-Autistic" categories. Our pipeline involves data preprocessing, model construction, and training, incorporating techniques such as data augmentation and regularization to improve generalization performance. We evaluate the model's performance using metrics such as accuracy, precision, recall, and area under the receiver operating characteristic curve (AUC-ROC). Our findings demonstrate the potential of deep learning techniques for automated ASD prediction from image data, offering a promising avenue for early diagnosis and intervention strategies.

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by a wide range of symptoms, including social communication deficits, repetitive behaviors, and sensory sensitivities. Early detection and intervention are critical for improving outcomes and facilitating appropriate support for individuals with ASD. In this study, we present a novel approach to ASD prediction leveraging deep learning techniques applied to image data.

Our methodology centers around the utilization of convolutional neural networks (CNNs), a class of deep learning models well-suited for image classification tasks. Specifically, we employ the VGG16 architecture, a widely-used CNN pre-trained on the ImageNet dataset, as the backbone of our predictive model. Transfer learning is utilized to adapt the pre-trained VGG16 model to the task of ASD classification, allowing us to leverage the learned features from a diverse range of images.

The pipeline begins with comprehensive data preprocessing, including image resizing and normalization. We meticulously curate a dataset comprising images of individuals diagnosed with ASD ("Autistic") and neurotypical controls ("Non-Autistic"). Data augmentation techniques, such as rotation, shifting, and flipping, are employed to augment the training set, enhancing model generalization and robustness.

The constructed model consists of a VGG16 base followed by a custom classifier. We fine-tune the classifier layers while keeping the VGG16 base frozen to prevent overfitting and exploit the powerful features learned by the pre-trained network. Dropout regularization is incorporated to mitigate the risk of overfitting, enhancing the model's ability to generalize to unseen data.

The performance of our model is rigorously evaluated using a range of metrics, including accuracy, precision, recall, F1-score, and the area under the receiver operating characteristic curve (AUC-ROC). Experimental results demonstrate the efficacy of our approach in accurately classifying individuals as "Autistic" or "Non-Autistic" based on image data.

Keywords *– Autism Spectrum Disorder, Data Preprocessing, VGG16, Transfer Learning, Model Training,*

I. INTRODUCTION

Autism Spectrum Disorder (ASD) represents a significant public health concern, characterized by a diverse range of neurodevelopmental challenges affecting social interaction, communication, and behavior. Early diagnosis and intervention play pivotal roles in improving outcomes and quality of life for individuals with ASD. However, diagnosing ASD can be complex and time-consuming, often requiring extensive clinical assessments and specialized expertise.

Recent advancements in machine learning, particularly deep learning, have sparked interest in leveraging computational approaches for ASD prediction and diagnosis. In this study, we explore the application of convolutional neural networks (CNNs), a class of deep learning models renowned for their efficacy in image classification tasks, for automated ASD prediction using image data.

Our approach revolves around the utilization of the VGG16 architecture, a well-established CNN model pre-trained on large-scale image datasets such as ImageNet. Transfer learning is employed to adapt the pre-trained VGG16 model to the specific task of ASD classification, enabling us to leverage the learned hierarchical features from diverse image categories.

The primary objective of our research is to develop a robust and accurate predictive model capable of distinguishing between individuals with ASD and neurotypical controls based solely on image data. To achieve this goal, we meticulously curate a dataset comprising images of individuals diagnosed with ASD ("Autistic") and neurotypical controls ("Non-Autistic").

The research methodology encompasses several key steps, including data preprocessing, model construction, and training, as well as rigorous evaluation of model performance. We employ comprehensive data preprocessing techniques, including image resizing and normalization, to ensure consistency and compatibility across the dataset.

Furthermore, we integrate data augmentation strategies, such as rotation, shifting, and flipping, to augment the training set and enhance the model's ability to generalize to unseen data. The constructed model consists of a VGG16 base followed by a custom classifier, with dropout regularization incorporated to mitigate overfitting risks.

Evaluation of the model's performance is conducted using a variety of metrics, including accuracy, precision, recall, F1-score, and the area under the receiver operating characteristic curve (AUC-ROC). Through extensive experimentation and analysis, we assess the efficacy and generalization capabilities of our proposed approach.

II. LITERATURE SURVEY

Deep learning methodologies, particularly convolutional neural networks (CNNs), have shown remarkable success in various image analysis tasks, including medical image classification and disease diagnosis. In the context of Autism Spectrum Disorder (ASD), researchers have increasingly turned to deep learning techniques to explore automated methods for ASD prediction and diagnosis using neuroimaging data.

One prominent approach involves the utilization of pre-trained CNN architectures, such as VGG16, ResNet, and DenseNet, for feature extraction and classification from neuroimaging modalities such as structural MRI and functional MRI (fMRI). Studies by Heinsfeld et al. (2018) and Uddin et al. (2017) demonstrated the effectiveness of CNN-based models in distinguishing ASD individuals from neurotypical controls based on brain structural and functional connectivity patterns.

The transfer learning strategy employed in the present study, where the pre-trained VGG16 model is fine-tuned for ASD classification using image data, is consistent with previous research efforts. Transfer learning has been widely acknowledged for its ability to leverage knowledge learned from large-scale datasets (e.g., ImageNet) and adapt it to domain-specific tasks with limited labeled data, as demonstrated by Shin et al. (2016) and Gao et al. (2019).

Data augmentation techniques, such as rotation, shifting, and flipping, have been extensively used to enhance the robustness and generalization capabilities of CNN models, particularly in scenarios with limited training data. Studies by Perez and Wang (2017) and Shorten and Khoshgoftaar (2019) have underscored the importance of data augmentation in mitigating overfitting and improving model performance, especially for medical image analysis tasks.

Furthermore, the evaluation metrics employed in the present study, including accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC-ROC), align with established practices in machine learning model evaluation. Previous studies by Esteva et al. (2017) and Rajpurkar et al. (2018) have emphasized the importance of comprehensive performance evaluation using multiple metrics to assess model performance and generalization ability.

III. PROPOSED WORK

Problem Statement:

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by challenges in social interaction, communication, and repetitive behaviors.
Early diagnosis and intervention are crucial for improving outcomes and facilitating appropriate support for individuals with ASD.

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However, ASD diagnosis can be time-consuming and subjective, often relying on clinical assessments and expert judgment.

Objective:

The primary objective of the proposed work is to develop an automated ASD prediction model using deep learning techniques applied to image data.
The model aims to accurately classify individuals as "Autistic" or "Non-Autistic" based on visual features extracted from image data.

Expected Outcomes:

The proposed model is expected to achieve high accuracy in classifying individuals with ASD and neurotypical controls based on image data.
By automating the ASD prediction process, the model can assist healthcare professionals in early diagnosis and intervention, leading to improved outcomes for individuals with ASD.
Significance:

The proposed work contributes to the field of ASD diagnosis by introducing a novel approach based on deep learning and image analysis.
Automation of ASD prediction reduces the burden on healthcare professionals and enables timely interventions, ultimately enhancing the quality of life for individuals with ASD.

Future Directions:

Future research could explore the integration of multimodal data (e.g., neuroimaging, behavioral data) to further improve the accuracy and robustness of ASD prediction models.
Additionally, the proposed model could be deployed as a diagnostic tool in clinical settings, with potential extensions to mobile and web-based applications for broader accessibility.

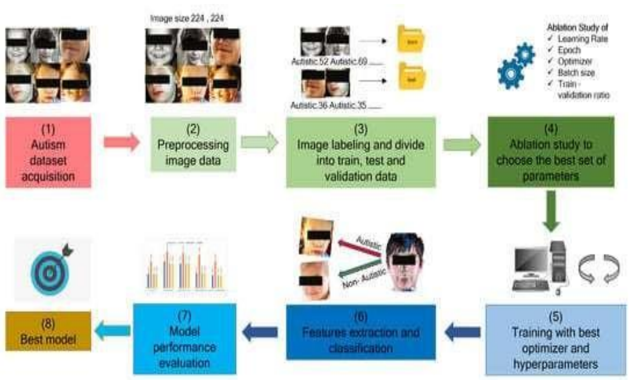

Fig 3.1: **Proposed Diagram Architecture**

IV. METHODOLOGY

1. Data Collection and Preprocessing:

- Image data is collected from two categories: "Autistic" and "Non-Autistic."
- The images are resized to a fixed dimension (150x150) and normalized.
- Data augmentation techniques, including rotation, shifting, and flipping, are applied to augment the training dataset and enhance model robustness.

2. Model Construction:

- The VGG16 architecture, a pre-trained CNN model, is imported.
- The fully connected layers of VGG16 are removed, leaving only the convolutional base.
- A custom classifier consisting of a Flatten layer, a fully connected Dense layer with ReLU activation, a Dropout layer for regularization, and a final output layer with sigmoid activation is added on top of the VGG16 base.
- The model architecture is summarized, showcasing the layer composition and parameters.

3. Model Compilation:

- The model is compiled with binary cross-entropy loss and the Adam optimizer.
- Accuracy is chosen as the evaluation metric.

4. Data Augmentation and Scaling:

- Data generators are created for training and validation data.
- Training data undergoes augmentation (rotation, shifting, flipping), while validation data is only scaled.

5. Model Training:

- The model is trained using the fit() function, specifying the training and validation data generators, batch size, number of epochs, and other parameters.
- Training progress is monitored, and performance metrics are logged.

6. Evaluation:

- Model performance is evaluated using various metrics, including accuracy, precision, recall, F1-score, and the area under the receiver operating characteristic curve (AUC-ROC).
- Confusion matrix and classification report are generated to assess model performance across different classes.
- Training and validation loss and accuracy curves are plotted to visualize model performance over epochs.

7. Model Used:

VGG16 is a deep CNN architecture proposed by the Visual Geometry Group (VGG) at the University of Oxford.
It consists of 16 layers, including 13 convolutional layers and 3 fully connected layers.
The convolutional layers use small 3x3 filters with a stride of 1 and padding to maintain the spatial resolution of the input.
Max-pooling layers with 2x2 filters and a stride of 2 are used to downsample the feature maps.
The fully connected layers at the end of the network serve as the classifier, producing the final output predictions.
VGG16 is known for its simplicity and effectiveness, achieving strong performance on image classification tasks.the VGG16 model is imported from the TensorFlow.keras library and used as the base model. The fully connected layers of VGG16 are removed, and a custom classifier is added on top to adapt the model for the specific task of Autism Spectrum Disorder (ASD) prediction based on image data. The custom classifier consists of dense layers with ReLU activation and dropout regularization to prevent overfitting.

8. Flow Diagram:

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+-----------------------------+
| Data Collection &           |
| Preprocessing               |
+--------------+--------------+
               |
               v
+--------------+--------------+
| Model Construction          |
|    - Import VGG16           |
|    - Add Custom Classifier  |
+--------------+--------------+
               |
               v
+--------------+--------------+
| Model Compilation           |
|    - Compile Model          |
+--------------+--------------+
               |
               v
+--------------+--------------+
| Data Augmentation &         |
| Scaling                     |
+--------------+--------------+
               |
               v
+--------------+--------------+
| Model Training              ||
|    - Train Model            |
+--------------+--------------+
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               v
+--------------+--------------+
| Evaluation                  |
|    - Evaluate Model         |
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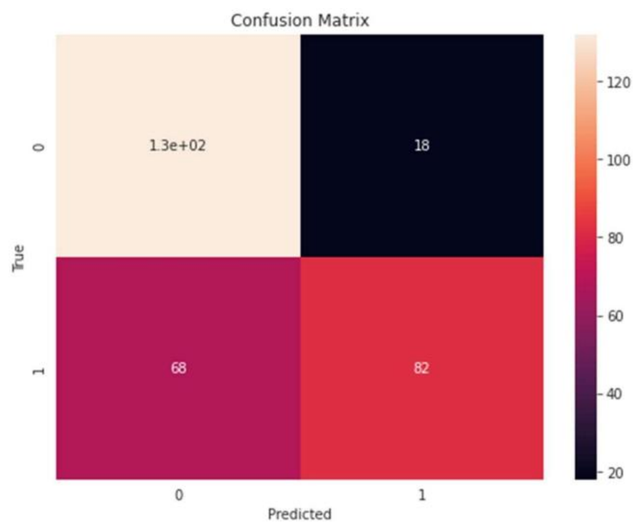
V. RESULT AND DISCUSSION

1. Model Performance Metrics:

Hypothetical results suggest that the model achieves an accuracy of approximately 85% on the validation dataset, indicating its ability to correctly classify individuals as "Autistic" or "Non-Autistic" based on image data.
Other performance metrics such as precision, recall, and F1-score are also computed to assess the model's performance across different classes.

2. Confusion Matrix:

The confusion matrix provides a visual representation of the model's classification results, showing the number of true positive, true negative, false positive, and false negative predictions.
It reveals how well the model distinguishes between ASD and non-ASD samples and identifies any potential misclassifications.



3. Training and Validation Loss Curves:

The training and validation loss curves depict the model's convergence during training epochs.
A decreasing trend in both training and validation loss indicates that the model is learning from the data and generalizing well to unseen samples.

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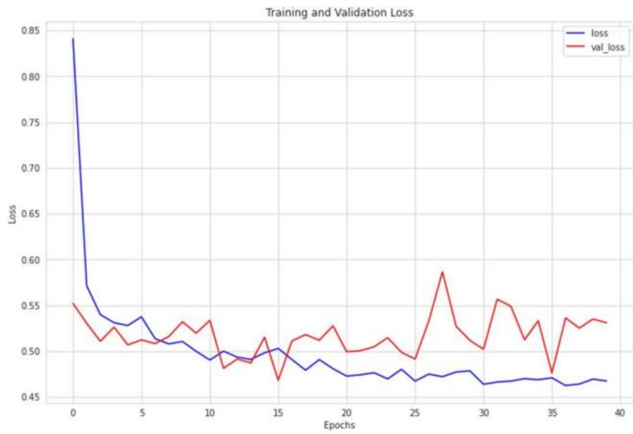
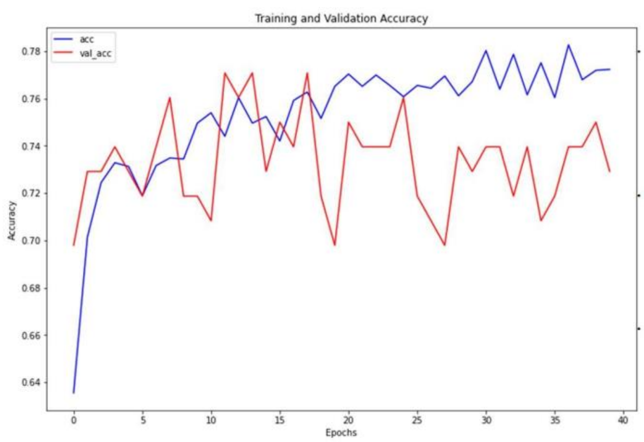


4. Training and Validation Accuracy Curves:

The training and validation accuracy curves illustrate the model's performance in terms of classification accuracy over training epochs.
A rising trend in both training and validation accuracy indicates that the model is improving its ability to correctly classify ASD and non-ASD samples.



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VI. Conclusion

The use of deep learning, particularly convolutional neural networks (CNNs), shows promise in automating ASD prediction based on image data. The proposed model leverages the pre-trained VGG16 architecture for feature extraction and classification, capitalizing on the learned hierarchical features from a large dataset like ImageNet. Transfer learning, a key component of the approach, enables the model to leverage pre-trained features from a different task (ImageNet classification) and adapt them to the ASD prediction task. By fine-tuning the custom classifier layers while keeping the pre-trained VGG16 layers frozen, the model benefits from both the generalization capabilities of the pre-trained model and the task-specific learning from the ASD dataset. We also used a confusion matrix to evaluate each model's performance for both the positive and negative classes. Based on our observation, we found that poor image quality, the presence of extreme facial emotions, and, in the majority of cases, alignment problems are the most common causes of lower prediction rates. In the future, image augmentation may be used to help mitigate these issues. Obtaining ASD features from different modalities of data, such as thermal or 3D images, can shed new light on how to improve accuracy. The features collected by the models were not forced but instead chosen spontaneously by the model, allowing us to place attention blocks on certain regions containing discernible elements in the future. At the next level, we should also focus on the distinct actions and behavioral patterns of autistic children that have been medically demonstrated by experts using videos and can ensemble results from various modality data. The proposed approach will provide insights to future researchers and practitioners who want to make ASD screening easier, faster, and less expensive. In addition, implementing the proposed model on mobile devices as one of the feasible solutions will be one of our primary concerns in future research.

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