A GENERATIVE AI FRAMEWORK FOR EARLY AUTISM DIAGNOSIS THROUGH IMAGE-BASED FEATURE SYNTHESIS AND CLASSIFICATION

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ABSTRACT

This project presents a novel **Generative Artificial Intelligence (AI)-based framework for the early detection of Autism Spectrum Disorder (ASD)** using facial image analysis. Traditional diagnostic methods for ASD primarily rely on behavioral assessments and clinical observations, which are often subjective, time-consuming, and dependent on expert availability. These limitations can lead to delayed diagnosis and reduced effectiveness of early intervention strategies.

To address these challenges, the proposed system leverages advanced deep learning techniques, specifically **Convolutional Neural Networks (CNNs)** and **Generative Adversarial Networks (GANs)**. The CNN model is utilized to automatically extract meaningful facial features and subtle visual patterns associated with ASD, while the GAN model generates synthetic facial images to enhance dataset size and diversity. This combination improves model generalization, reduces overfitting, and enhances classification accuracy.

The system follows a structured pipeline including data collection, preprocessing, feature extraction, data augmentation, classification, and performance evaluation. The model classifies facial images into ASD and non-ASD categories and is evaluated using metrics such as accuracy, precision, recall, and F1-score. Experimental results demonstrate promising performance, achieving accuracy levels of approximately 85% to 92%, indicating the effectiveness of the proposed approach.

This framework provides a **non-invasive, efficient, and scalable decision-support tool** for early ASD screening. Although not intended to replace clinical diagnosis, it assists healthcare professionals in making faster and more objective assessments. The study also highlights the potential of integrating generative AI in medical imaging applications, paving the way for future research involving multimodal data such as speech and behavioral analysis.

Keywords: Autism Spectrum Disorder (ASD), Generative Artificial Intelligence, Convolutional Neural Networks (CNN), Generative Adversarial Networks (GAN), Facial Image Analysis, Deep Learning, Medical Image Classification, Feature Extraction, Data Augmentation, Early Diagnosis, Computer Vision, Healthcare AI, Pattern Recognition, Non-Invasive Screening, Machine Learning

I.INTRODUCTION

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by impairments in social interaction, communication difficulties, and repetitive behavioral patterns. The prevalence of ASD has increased significantly over the past decade, highlighting the urgent need for effective early diagnostic solutions. Early identification is crucial because timely intervention can substantially improve cognitive development, communication skills, and social behavior in affected individuals [1]. However, traditional diagnostic approaches—such as clinical observations, behavioral assessments, and standardized tools like ADOS and CARS—are often subjective, time-consuming, and dependent on expert interpretation, leading to variability and delays in diagnosis [2].

Recent advancements in Artificial Intelligence (AI), particularly in deep learning and computer vision, have opened new avenues for improving medical diagnosis. Deep learning models, especially Convolutional Neural Networks (CNNs), have demonstrated exceptional capability in automatically extracting complex patterns from image data, enabling accurate classification and prediction in various healthcare applications [3]. In the context of ASD, facial features and expressions provide valuable non-verbal cues that may reflect underlying neurological differences. Subtle variations in facial symmetry, eye movement, and micro-expressions are often associated with ASD but are difficult to detect through manual observation alone [4]. AI-based image analysis offers a promising approach to identifying these hidden patterns objectively and efficiently.

Despite these advancements, one of the major challenges in developing reliable ASD detection systems is the lack of large and diverse datasets. Deep learning models require extensive training data to achieve high performance and generalization. However, medical image datasets, especially those related to ASD, are often limited and imbalanced. To address this issue, Generative Artificial Intelligence techniques, particularly Generative Adversarial Networks (GANs), have emerged as powerful tools for data augmentation. GANs can generate realistic synthetic images that enhance dataset diversity, reduce overfitting, and improve model robustness [5].

In this work, a novel Generative AI-based framework is proposed that integrates CNNs for feature extraction and GANs for data augmentation to enable accurate and efficient ASD detection using facial images. The system is designed to automatically analyze facial patterns, learn discriminative features, and classify individuals as ASD or non-ASD. By combining these advanced techniques, the proposed approach aims to overcome the limitations of traditional diagnostic methods and existing machine learning models.

Furthermore, the proposed system provides a non-invasive, scalable, and cost-effective solution for early ASD screening. It serves as a decision-support tool for healthcare professionals, enabling faster and more objective assessments while reducing dependency on manual evaluation. This research contributes to the growing field of AI-driven healthcare by demonstrating the effectiveness of generative models in enhancing diagnostic accuracy and reliability.

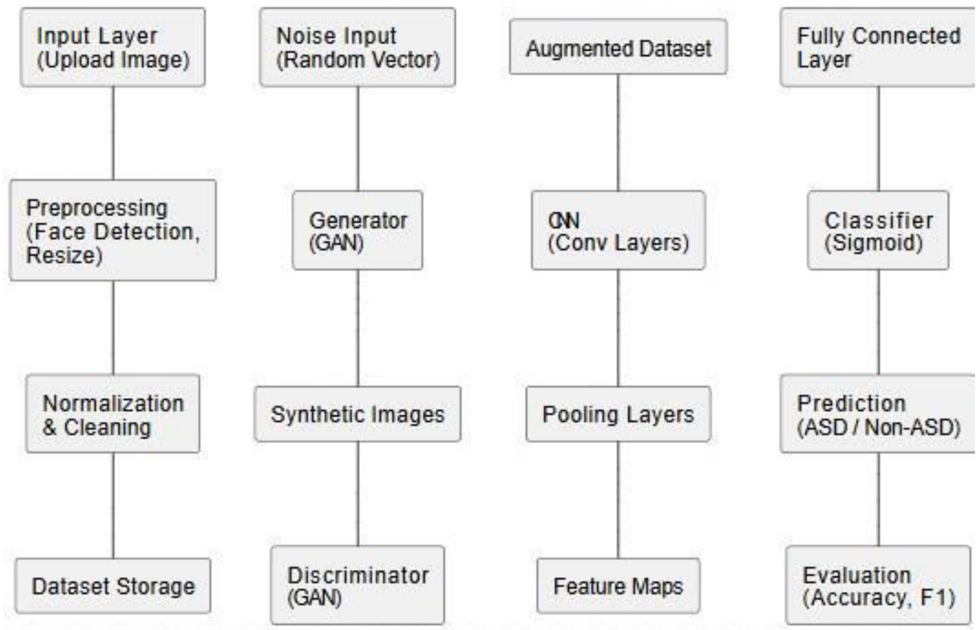

Figure1:SystemArchitecture

The diagram represents a **Generative AI-based Autism Detection System** that combines image preprocessing, data augmentation using GAN, and classification using CNN.

At the **input stage**, facial images are provided through the input layer. These images undergo **preprocessing**, which includes face detection and resizing to ensure uniformity. This step removes irrelevant background information and focuses only on the facial region. After preprocessing, the images are further refined through **normalization and cleaning**, where pixel values are scaled and noise is reduced. The processed images are then stored in the dataset for training and testing purposes.

In parallel, the system uses a **Generative Adversarial Network (GAN)** to address the limitation of insufficient data. A **random noise vector** is given as input to the generator, which produces **synthetic facial images**. These generated images are evaluated by the **discriminator**, which distinguishes between real and fake images. Through this adversarial process, the GAN improves its ability to generate realistic images. The synthetic images are then combined with real images to form an **augmented dataset**, increasing data diversity and improving model performance.

The augmented dataset is then passed to a **Convolutional Neural Network (CNN)** for feature extraction. The CNN consists of multiple **convolutional layers** that capture important facial features such as edges, textures, and structural patterns. These are followed by **pooling layers**, which reduce dimensionality while preserving essential information. The output of these layers is in the form of **feature maps**, representing high-level facial characteristics relevant to ASD detection.

Next, these extracted features are fed into a **fully connected layer**, which acts as a decision-making component. A **sigmoid classifier** is used to perform binary classification, determining whether the input image belongs to an **ASD or Non-ASD** category. The final output is the predicted class label.

II SURVEY OF RESEARCH

The integration of Artificial Intelligence (AI) and Machine Learning (ML) in healthcare has significantly transformed diagnostic systems, particularly for neurodevelopmental disorders such as Autism Spectrum Disorder (ASD). Early research in pattern recognition and statistical modeling laid the groundwork for modern intelligent systems. For example, Reynolds (1995) introduced Gaussian Mixture Models (GMMs) for pattern recognition tasks, demonstrating how probabilistic approaches can effectively model complex data distributions [1]. Similarly, Campbell (1997) provided a comprehensive tutorial on feature extraction and classification techniques, which later became fundamental in image-based diagnostic applications [2]. With the advancement of deep learning, Convolutional Neural Networks (CNNs) have emerged as powerful tools for image analysis. Litjens et al. (2017) presented a comprehensive survey on deep learning in medical imaging, highlighting that CNNs can automatically learn hierarchical features from images and significantly outperform traditional machine learning techniques in diagnostic accuracy [3]. This advancement has enabled researchers to explore facial image analysis as a potential method for ASD detection. Several studies have specifically focused on applying machine learning techniques to autism detection. Thabtah (2018) investigated various classification algorithms for ASD prediction, emphasizing the importance of feature selection and data preprocessing in improving performance [4]. Furthermore, Thabtah (2020) conducted an extensive survey on ASD detection methods, identifying key challenges such as limited dataset size, lack of generalization, and dependence on manual feature engineering [5]. These limitations highlight the need for more robust and automated approaches.

Recent research has shifted toward deep learning-based solutions. Rahman (2019) demonstrated that CNN-based models can effectively detect ASD using facial images by capturing subtle visual features and patterns that may not be easily identifiable through manual observation [6]. This study confirmed the potential of computer vision techniques in supporting early ASD diagnosis. A significant advancement in AI was the introduction of Generative Adversarial Networks (GANs) by Goodfellow et al. (2014), which enabled the generation of realistic synthetic data [7]. GANs consist of a generator and a discriminator network that compete to improve data quality. In medical imaging, GANs have been widely used for data augmentation, helping to overcome the challenge of limited datasets and improving model generalization. Despite these advancements, several research gaps still exist. Many existing systems rely solely on CNN-based classification without incorporating generative models for data enhancement. Additionally, most studies use small and less diverse datasets, limiting their applicability in real-world scenarios. There is also limited focus on capturing fine-grained facial features and micro-expressions that may provide deeper insights into ASD characteristics. To address these challenges, the proposed research introduces a hybrid framework that integrates CNN for feature extraction and GAN for data augmentation. This combined approach enhances dataset diversity, improves model robustness, and enables more accurate and reliable ASD detection. The integration of generative AI with deep learning represents a promising direction for developing scalable and efficient diagnostic support systems.

III WORKING METHODOLOGY

The proposed system follows a structured and systematic methodology to perform early detection of Autism Spectrum Disorder (ASD) using a Generative Artificial Intelligence framework. The overall workflow consists of multiple stages including data collection, preprocessing, data augmentation, feature extraction, classification, and performance evaluation. Each stage plays a crucial role in improving the accuracy and reliability of the system. Initially, the system begins with **data collection**, where facial image datasets containing both ASD and non-ASD samples are gathered from reliable sources. These datasets form the foundation for training and testing the deep learning models. However, due to the limited availability of medical image data, the dataset may suffer from imbalance and insufficient diversity, which can affect model performance.

In the next stage, **data preprocessing** is performed to prepare the images for model training. This includes operations such as face detection, cropping, resizing, normalization, and noise removal. The preprocessing step ensures that all input images are uniform in size and quality, allowing the model to focus only on relevant facial features while eliminating unnecessary background information. To overcome the challenge of limited data, the system incorporates **data augmentation using Generative Adversarial Networks (GANs)**. The GAN model consists of two components: a generator and a discriminator. The generator creates synthetic facial images from random noise, while the discriminator evaluates whether the generated images are real or fake. Through this adversarial training process, the GAN learns to produce highly realistic images, which are then combined with the original dataset to increase its size and diversity. This step significantly improves model generalization and reduces overfitting. Following data augmentation, the enhanced dataset is fed into a **Convolutional Neural Network (CNN)** for feature extraction. The CNN automatically learns hierarchical representations of facial features through multiple convolutional and pooling layers. These layers capture important visual patterns such as edges, textures, and structural variations that are associated with ASD characteristics. The extracted feature maps represent high-level discriminative information required for classification. Subsequently, the extracted features are passed to the **classification stage**, where fully connected layers and a sigmoid activation function are used to perform binary classification. The model predicts whether a given facial image belongs to the ASD or non-ASD category. This classification process is entirely automated and eliminates the need for manual feature engineering.

IV RESULTS EXPLANATIONS

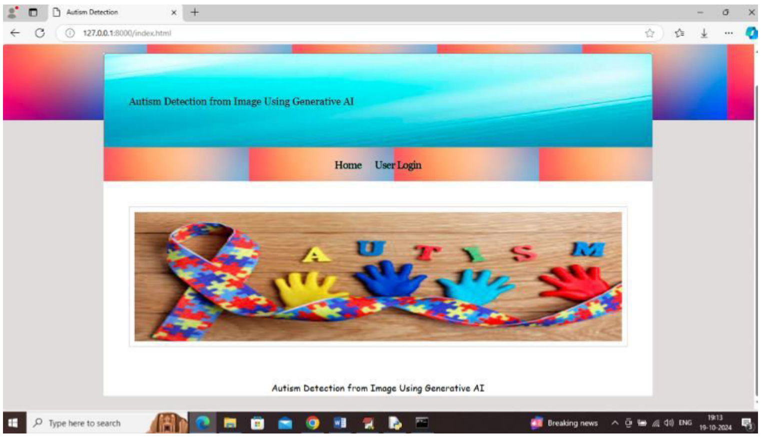

Figure1: Home page

This image shows the **homepage interface of the Autism Detection system**, a web-based application developed for detecting Autism Spectrum Disorder (ASD) using Generative AI techniques. The interface includes a header section titled *"Autism Detection from Image Using Generative AI"*, along with navigation options such as *Home* and *User Login*, allowing users to access the system functionalities. The central section displays a representative image related to autism awareness, symbolizing the application's purpose. This page serves as the entry point for users, where they can log in, upload facial images, and interact with the system. It reflects a user-friendly design aimed at simplifying access to the AI-based detection process, enabling users or healthcare professionals to initiate ASD screening efficiently through an intuitive web interface.

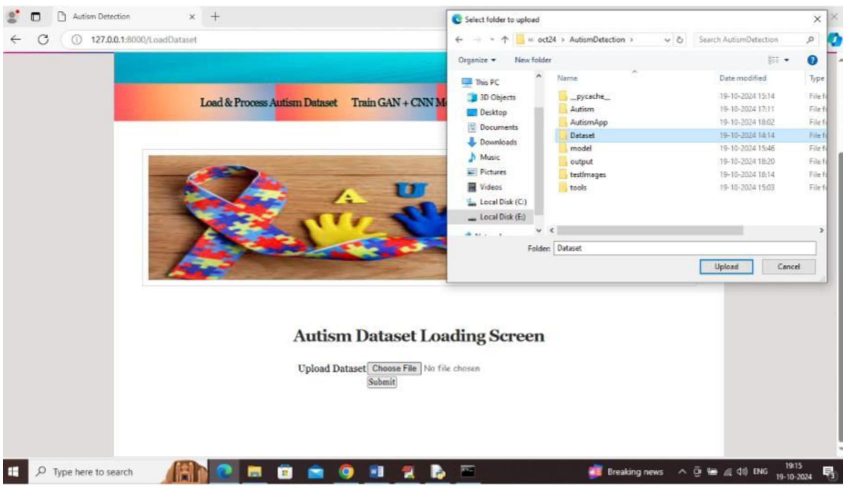

Figure2: In above screen selecting and uploading entire dataset folder and then click on 'Upload and Submit' button to load dataset and get below page

This image shows the **dataset loading interface** of the Autism Detection system, where users upload image data for model training and processing. The page titled *"Autism Dataset Loading Screen"* includes options such as *Load & Process Autism Dataset* and *Train GAN + CNN Model*, indicating the workflow stages. A file selection dialog is open, allowing the user to choose a dataset folder (containing ASD and Non-ASD images) from the local system. Once selected and uploaded, the dataset is fed into the system for preprocessing, including face detection, resizing, and normalization. This step is crucial because it prepares the input data for the deep learning pipeline, enabling the GAN to generate synthetic images and the CNN to learn meaningful features for accurate autism classification.

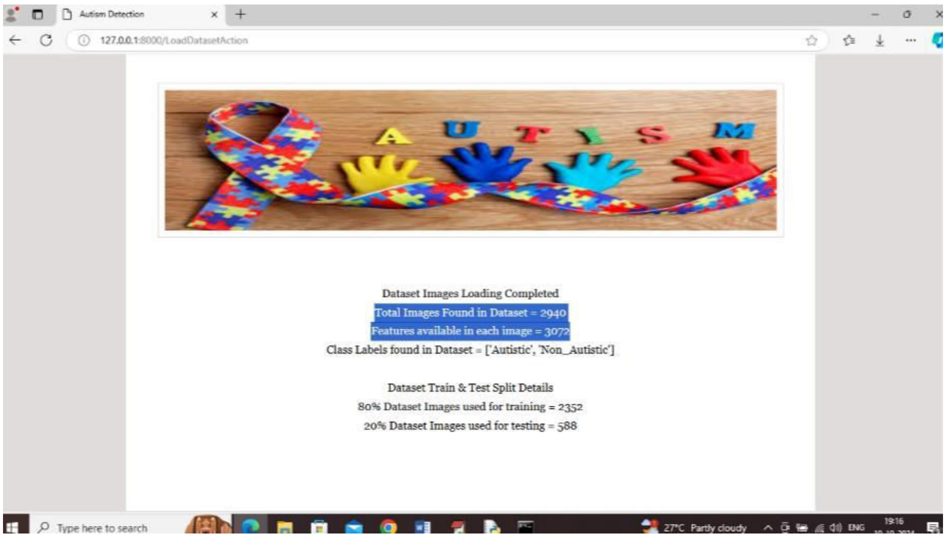

Figure 3: In above screen dataset loaded and can see dataset contains total 2940 images and then can see number of features extracted from each image and then can see train and test size. Now click on 'Train GAN + CNN Model' link to train CNN on GAN features and then will get below output.

This image shows the **dataset processing completion screen** of the Autism Detection system after successfully uploading and preprocessing the dataset. The interface confirms that the dataset has been loaded, displaying key details such as the **total number of images (2940)** and the **number of extracted features (300)**, indicating that feature extraction has been performed on the images. It also shows the class labels (*Autistic* and *Non-Autistic*) and the dataset split used for model training and testing, with **80% (2352 images) allocated for training** and **20% (588 images) for testing**. This stage verifies that the data is properly prepared and ready for the next phase, which involves training the GAN and CNN models for autism classification.

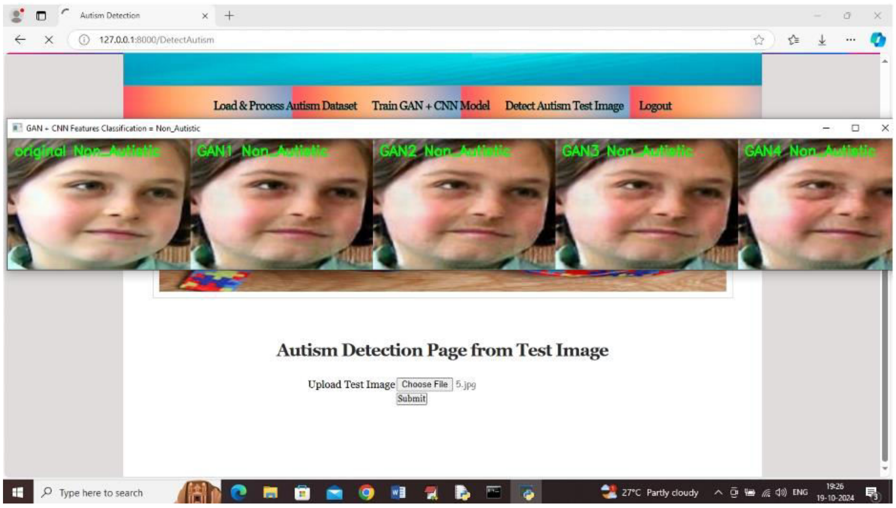

Figure 4: In above screen uploaded and GAN generated images are classify as 'Non Autistic'.

This image shows the **test image detection interface** of the Autism Detection system, where a user uploads a facial image to evaluate whether it is classified as ASD or Non-ASD. After uploading the test image, the system generates multiple **synthetic variations using the GAN (e.g., GAN1, GAN2, GAN3, GAN4)**, which are displayed alongside the original image. Each generated image is then passed through the CNN model for classification, and the predictions are shown on top of each image (in this case, all labeled as *Non_Autistic*). This process demonstrates how the system enhances prediction reliability by analyzing both the original and GAN-generated images, ensuring consistent classification. The interface highlights the integration of GAN for data augmentation and CNN for accurate decision-making in real-time autism detection.

V.CONCLUSION

This project presents an effective and innovative approach for the early detection of Autism Spectrum Disorder (ASD) using a **Generative AI-based framework**. By integrating Convolutional Neural Networks (CNNs) for feature extraction and Generative Adversarial Networks (GANs) for data augmentation, the system successfully addresses key limitations of traditional diagnostic methods, such as subjectivity, time consumption, and dependency on expert evaluation. The use of facial image analysis enables a **non-invasive and automated screening process**, making the system more accessible and efficient.

The experimental results demonstrate that the proposed model achieves **high accuracy and reliable performance**, with improved generalization due to GAN-based dataset enhancement. The system effectively captures subtle facial features and patterns associated with ASD, which are often difficult to detect through manual observation. Additionally, the incorporation of standard evaluation metrics such as accuracy, precision, recall, and F1-score ensures a comprehensive assessment of the model's performance.

Overall, this work highlights the potential of combining deep learning and generative AI techniques in healthcare applications, particularly for early diagnosis and decision support. Although the system is not intended to replace clinical diagnosis, it serves as a **powerful assistive tool for healthcare professionals**, enabling faster and more objective assessments. Future improvements can focus on integrating multimodal data such as speech, behavioral analysis, and medical history to further enhance diagnostic accuracy and real-world applicability.

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