Detection of Multiple Sclerosis using Deep learning.

***Abstract*— Multiple sclerosis is a chronic neurological disorder characterized by its adverse effects on the central nervous system. Hence, early and correct diagnosis are needed for effective management. The goal of this study is to find a deep learning-based approach of MS detection involving a combination of U-Net for segmentation purposes and EfficientNet for classification, using MRI images. The U-Net model is used to segment MS lesions from MRI scans accurately by capturing fine-grained spatial details using its encoder-decoder architecture. For classification, EfficientNet is used to classify MS cases based on two dimensions of MRI images: MS Axial and MS Sagittal. EfficientNet's optimized architecture ensures high classification accuracy with reduced computational complexity. Integration of U-Net for lesion segmentation enhances the model's interpretability and gives it valuable insights into clinical analysis. Our approach is trained and tested on benchmark MRI datasets with strong performance both in segmentation and classification tasks. Our system implemented in TensorFlow gives an efficient and scalable solution to automate MS detection for radiologists for early diagnosis and treatment planning. This project provides combined advanced deep learning techniques that develop tools for AI-assisted medical imaging, further enhancing patient care and diagnostic accuracy.**

Keywords*— Multiple Sclerosis, MRI images, deep learning, segmentation, classification, U-Net, EfficientNet.

I. INTRODUCTION

MS is an autoimmune disease against the central nervous system tha is chronic in nature, which involves inflammation, demyelination, and neurodegeneration. It interferes with the transmission of nerve signal that affects various parts of the body such as leading to muscle weakness, vision loss, cognitive dysfunction, and loss of coordination. MRI is, therefore used to diagnose MS by detecting lesions in the brain and spinal cord. Manual evaluation of MRI scans consumes considerable amount of time and is also observer-dependent, however, deep learning, especially Convolutional Neural Networks, has been proven to be very effective for automatic medical image analysis, resulting in increased accuracy and efficiency. This project uses a hybrid deep learning approach combining U-Net for lesion segmentation and EfficientNet for MS classification. U-Net is an advanced CNN architecture designed for biomedical image segmentation. Its encoder-decoder structure allows precise localization of lesions by capturing fine spatial details through skip connections, ensuring high segmentation accuracy. The segmented regions help focus classification models on relevant areas, improving overall diagnostic performance

This approach reduces false positives and improves generalization across different MRI datasets. Implemented using TensorFlow, our system provides an efficient, scalable, and automated solution for MS detection. Advanced CNN architectures in this study contribute to AI-assisted diagnostic tools, enhancing early detection, clinical decision-making, and patient care in neurological disorders.

II. MOTIVATION

Multiple sclerosis (MS) is a disabling neurological disorder that requires early and accurate diagnosis for proper treatment. Manual MRI analysis is labor-intensive and prone to variability, necessitating automated solutions. Deep learning, particularly CNN architectures like U-Net and EfficientNet, offers a powerful tool for precise MS lesion segmentation and classification. U-Net is efficient at lesion segmentation, and EfficientNet enhances the accuracy in MRI planes (Axial and Sagittal). Combining these architectures enhances diagnostic consistency, reduces human error, and improves clinical workflows. This work aims to develop a scalable, AI-driven system for MS detection, enhancing early diagnosis and patient care.

III. LITERATURE REVIEW

Multiple sclerosis is a chronic neurological disorder that affects the central nervous system, causing demyelination and MRI imaging is an important diagnostic tool for detecting MS lesions, but manual segmentation is time-consuming, subjective, and prone to errors. The integration of AI in medical imaging has significantly improved MS detection and segmentation, with ML and DL techniques offering results. Among the recent models which have been explored in AI based diagnostic systems for MS, include SVM and RF, CNNs, have shown excellent performance in medical image analysis. Among these architectures, U-Net, EfficientNet, and Tiramisu showed high performance. Due to its ability to capture fine spatial detail, U-Net has shown to be very effective in lesion segmentation, using MRI scans. EfficientNet makes use of optimal scaling to boost the classification performance with reduced complexity in computation. The integration of segmentation and classification models, like U-Net for segmentation and EfficientNet for classification, improved the automated detection systems of MS, making them more reliable and scalable. Additionally, the use of 2.5D stacked slices has been proposed to incorporate adjacent slices from different anatomical planes, providing richer spatial context while maintaining computational efficiency. Unlike traditional 3D CNNs, which require significant memory and computational resources, the 2.5D approach balances global structural information with local lesion details, improving segmentation accuracy. .
One of the key challenges in MS detection is distinguishing lesions from other abnormalities, requiring advanced preprocessing and feature extraction techniques. Studies emphasize the importance of large, multi-center datasets to improve model generalization. Additionally, incorporating attention mechanisms and hybrid models that integrate segmentation and classification further enhance the reliability of AI-driven MS diagnosis systems. Evaluations on benchmark datasets, including the ISBI Longitudinal MS Lesion Segmentation Challenge, have demonstrated the effectiveness of these deep learning-based methods, achieving high accuracy and outperforming traditional approaches. The combination of U-Net, EfficientNet, and Tiramisu models in MS detection offers

an efficient, scalable, and accurate solution, paving the way for AI-assisted diagnostic tools in clinical settings.

IV. Challenges and Limitations In Existing Systems

Despite advancements in deep learning for multiple sclerosis (MS) detection, several challenges persist. Accurate segmentation using U-Net is hindered by variations in MRI scan quality, lesion appearance, and imaging protocols. EfficientNet, while effective in classification, struggles with limited labeled datasets and potential overfitting. Integrating both architectures requires extensive computational resources and optimized hyperparameter tuning. Additionally, distinguishing MS lesions from other neurological abnormalities remains difficult, impacting model reliability. Lack of large, multi-center datasets affects generalization, and manual annotations introduce variability. Addressing these limitations requires improved preprocessing, attention mechanisms, and hybrid approaches for enhanced segmentation and classification accuracy.

V. BLOCK DIAGRAM

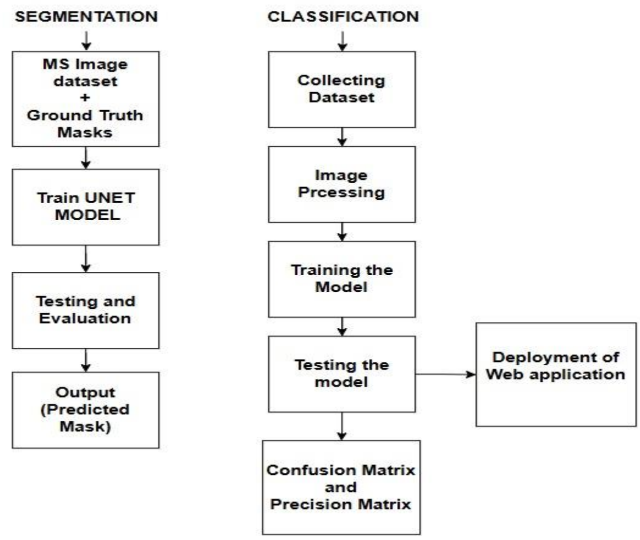

Fig 1. Block Diagram

VI. Proposed Solution

This project combines classification, and semantic segmentation to improve multiple sclerosis (MS) detection, we propose a hybrid deep learning model combining U-Net for segmentation and EfficientNet for classification. U-Net effectively extracts MS lesions from MRI scans using its encoder-decoder architecture with skip connections, enhancing lesion localization. The segmented output is then processed by EfficientNet, which classifies MS cases based on MRI dimensions (Axial and Sagittal) while optimizing computational efficiency. Attention mechanisms are integrated to focus on critical lesion areas, improving accuracy. Additionally, transfer learning on large multi-center datasets enhances generalization, ensuring a robust, scalable, and automated MS detection system for clinical applications.

VII. Methodology

A. *Disease Classification*

Disease classification in the proposed system includes classifying MRI images into three classes: Normal, MS Axial, and MS Sagittal. Each of these classes refers to a specific Multiple Sclerosis condition and proper classification is essential for the diagnosis and planning of treatment.

- Normal:
  CS Axial– This category includes MRI scans of individuals without multiple sclerosis, viewed in the axial plane, providing a horizontal cross-section of the brain for detecting abnormalities.
  CS Sagittal – Represents normal MRI scans taken in the sagittal plane, offering a side view of the brain, helping in identifying structural changes and ensuring accurate differentiation from MS-affected scans.

- MS Axial: – This category includes MRI scans showing MS lesions, characterized by demyelination, inflammation, and neurodegeneration, aiding in early detection and treatment planning.

- MS Sagittal: – MRI scans of MS patients in the sagittal view, allowing detailed visualization of lesion distribution along the brain and spinal cord, improving diagnostic accuracy and classification efficiency.

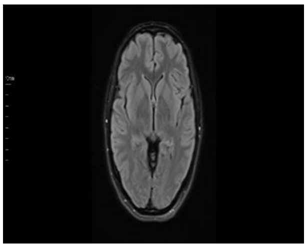

Fig.2.1. Control Axial

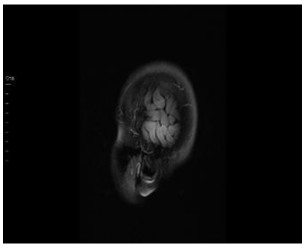

Fig.2.2. Control Sagittal

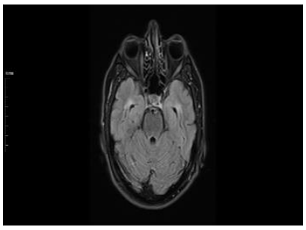

Fig.2.3. MS Axial

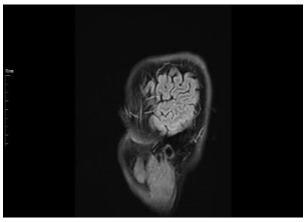

Fig.2.4. MS Sagittal

B. *Data Collection*

The model uses MRI datasets with four classes: Control Axial, Control Sagittal, MS Sagittal and MS axial, each containing a balanced set of 500 training and 20 testing images for comprehensive evaluation. U-Net, trained on a specialized MS lesion dataset, performs semantic segmentation to accurately delineate lesion boundaries. Simultaneously, EfficientNet is used for classification tasks, identifying the presence and progression of MS with high precision.

C. Data PreProcessing

Multiple sclerosis detection, the preprocessing of the images is adapted to the requirements of U-Net for segmentation and EfficientNet for classification. For U-Net, the MRI scans are resized to 128x128 and normalized so that the intensity values are constant, thus the model inputs remain stable. The augmentation techniques like rotation and contrast adjustments are used to enhance robustness. Images for EfficientNet are resized to 224x224 and augmented by transformations including rotation in the 15° range, shear in the 0.2 range, zoom in the 0.2 range, horizontal flipping, and width/height shifts in the 0.1 range to increase generalization. All these preprocessing steps are carried out before dividing the data into training and testing sets, hence allowing better model performance and reliability in both segmentation and classification tasks.

D. Operation Flow

1. Semantic Segmentation using U-Net

U-Net model, a convolutional neural network that is specifically tailored for biomedical image analysis, to perform the task of multiple sclerosis segmentation. The training is performed on the ISBI dataset, which consists of 1,000 MRI scans of MS patients paired with their corresponding ground truth masks. The U-Net architecture, consisting of an encoder-decoder structure enhanced by skip connections, captures both fine structural details and larger contextual patterns effectively. After training, the model produces segmentation masks, which are evaluated against the ground truth to determine accuracy. This approach ensures precise lesion identification, supporting MS diagnosis, tracking disease progression, and informing treatments

2.Classification using EfficientNet

For multiple sclerosis classification, an EfficientNet model is trained using a pre-trained network with customized classification layers. These layers include global average pooling, fully connected dense layers, and a SoftMax activation function to categorize MRI scans. The training process is conducted on the augmented dataset, followed by evaluation on the test set. A confusion matrix is used to assess predictions, while precision, recall, and F1-score metrics measure classification performance, ensuring accurate differentiation between normal and MS-affected brain scans.

3. Web Application

Web application integrating the Django framework and EfficientNet for Multiple Sclerosis (MS) prediction follows a structured workflow. Django, a high-level Python web framework, handles the backend by managing user authentication, request processing, and database interactions. The frontend, built using HTML, CSS, and JavaScript, allows users to upload MRI scans for analysis. Once an image is received, the request gets routed to a deep learning model that uses EfficientNet. It's a convolutional neural network famous for its higher performance and efficiency. The model parses the MRI scan and analyses features used to predict if the MS is present or not After the prediction is generated, Django formats the results and renders those on the frontend. The entire system is optimized for scalability and efficiency, thereby ensuring accurate and rapid MS detection to assist in clinical decision-making.

VIII. RESULTS AND DISCUSSION

A balanced test set was used for the evaluation of the classification model, ensuring fair performance across categories. EfficientNet were trained on MRI scans to classify MS from normal cases. The performance metrics that include accuracy, precision, recall, and F1-score were computed to measure the effectiveness of classification. EfficientNet is higher in general accuracy due to optimized architecture; further, analysis in the confusion matrix showed the issue was distinguishing between early MS lesions and normal structures of the brain. However promising the results seem, some classification errors still happen, particularly borderline cases. Large datasets and model resembling or advanced augmentation might be seen for future improvement, enhancing the overall robustness and generalization.

A. Semantic Segmentation output using UNET

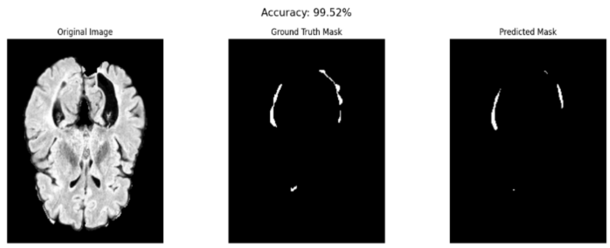

Fig 3.1 Segmented image of Multiple Sclerosis

B. Classification Results using EfficientNet

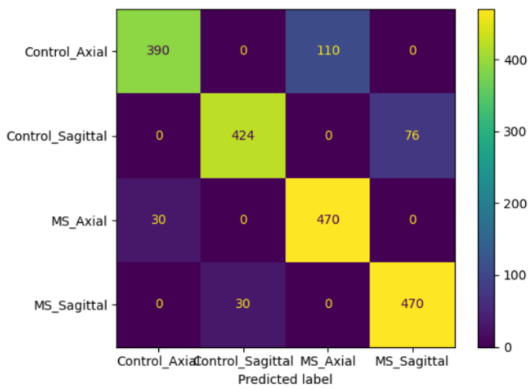

Fig 5.1 Confusion Matrix of EfficientNet

	PRECISION	RECALL	F1 SCORE	SUPPORT
Control_Axial	0.93	0.77	0.84	500
Control_Sagittal	0.93	0.87	0.90	500
MS_Axial	0.81	0.94	0.87	500
MS_Sagittal	0.88	0.94	0.91	500
accuracy			0.88	2000
macro avg	0.89	0.88	0.88	2000
weighted avg	0.89	0.88	0.88	2000

Table 1. Precision Metrics using Inception EfficentNet

C. Web Application

Fig 5.2 Login Page

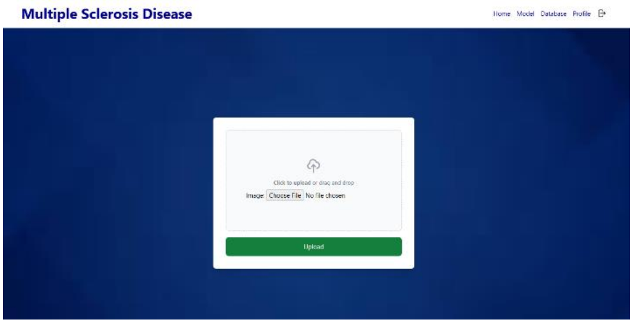

Fig 5.3 Picture Upload

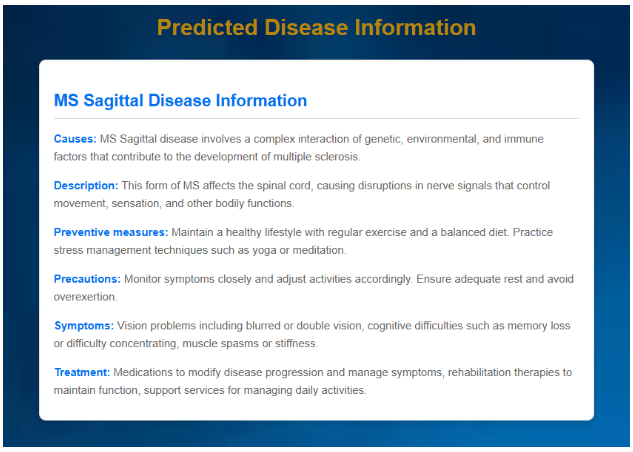

Fig 5.4 Predicted Output

CONCLUSION

EfficientNet demonstrated superior performance in multiple sclerosis classification, achieving an average accuracy of 88%, outperforming other models and proving highly effective. For lesion segmentation, U-Net achieved over 99% accuracy when compared to ground truth masks, ensuring precise localization of MS-affected regions in MRI scans. The integration of automated segmentation and classification techniques can significantly improve early MS detection, facilitate disease progression monitoring, and enhance clinical decision-making efficiency. The application of deep learning models in this field can help in optimizing the diagnostic accuracy, improving the workflow of neurologists, and further enhancing patient care and outcomes.

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IX. References

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