An Explainable AI for Detection and Classification of Microwave Brain Stroke

Lalitha K[1], Sai Kiran Oruganti[2]
[12]Lincoln University College, Malaysia
pdf.lalitha@lincoln.edu.my

Abstract: Stroke is a serious neurological condition that requires timely diagnosis and localization for appropriate therapy. Microwave imaging provides a promising non-invasive and portable alternative for head stroke localization and classification. This work proposes a method to solve this complex problem by presenting a wavelet convolutional neural network (CNN), which combines multiresolution analysis with CNN to learn distinctive patterns in the scalogram for accurate classification. An explainable artificial intelligence approach is proposed to explain the model and to point out distinguishing properties for classifying stroke types. Grad-CAM visualization is utilized to enhance interpretability and boost physician confidence. The experimental analysis shows an improvement of localization accuracy and sensitivity.

Keywords: microwave Imaging; explainable artificial intelligence; brain stroke classification; wavelet

Introduction

Stroke is one of the leading causes of mortality worldwide. Early diagnosis is essential because treatment effectiveness depends strongly on rapid medical intervention. Brain strokes are generally classified as ischemic strokes and hemorrhagic strokes. Microwave sensing technology is developing rapidly, and it is increasingly applied in biomedical applications with great potential to advance medical care. Microwave brain imaging has evolved as a complementary approach to fulfill several demands in stroke diagnosis, including early diagnosis and localization of stroke, bedside imaging, and continuous monitoring for treatment evaluation. At the same time, the emergence of artificial intelligence (AI) is allowing major progress in the biomedical field.

The basic idea of microwave medical imaging is the contrast of tissues due to their various dielectric constants. The resulting backscatter signals are utilized to reconstruct images by using algorithms. Deep learning has recently improved medical image analysis performance. However, many deep learning systems behave as black-box models. Explainable artificial intelligence techniques improve transparency by highlighting the important regions influencing predictions. This work proposes an explainable microwave imaging framework for stroke localization.

Related work

Microwave imaging techniques such as radar and tomographic reconstruction have been used for medical diagnosis. Traditional machine learning approaches including Support Vector Machines and Random Forests require handcrafted features and provide limited performance [1][2][3]. Deep learning models improve feature extraction capability, while explainable AI techniques such as Grad-CAM, SHAP, and saliency maps enhance interpretability [4][5]. However, limited work has focused on explainable microwave stroke localization and classification [6]. The confidence of deep learning output is enhanced by GRAD-CAM based explainable AI technique. But it requires reconstructed microwave image using DMAS algorithm [7][8][9]. This proposed work localizes and classifies stroke directly from raw S-parameters.

Method, Experiments and Results

The proposed system consists of microwave signal acquisition, preprocessing, image reconstruction, CNN-based localization, and explainability analysis as illustrated in Fig.1. Antennas send microwave signals and record reflections and transmissions at different frequencies and places. Modern systems routinely acquire hundreds of measurements in one scan. Reconstruction techniques replicate the propagation of electromagnetic waves in tissue with varying dielectric characteristics, by solving Maxwell's equations. These models predict the effect of differences within the breast on the observed signals.

Finally, computational techniques reconstruct spatial maps of dielectric characteristics. Common reconstruction methods include delay and sum beamforming, confocal microwave imaging and inverse scattering tomography. If the reconstruction process produces several scattered signals that converge to the same spatial position, that region may correlate to a dielectric anomaly, possibly a tumor.

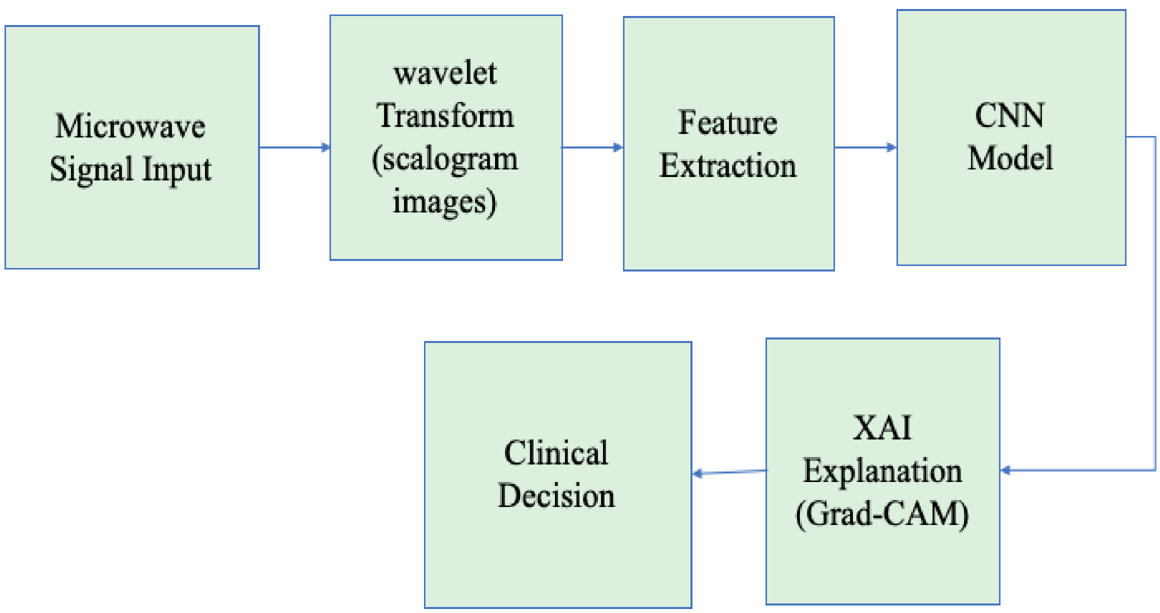

Fig.1. Block diagram of Explainable AI system for stroke detection and Classification

The microwave antenna array surrounds the head phantom and captures scattered electromagnetic signals. Signal preprocessing includes Gaussian filtering, normalization, and denoising. Wavelet technique ia applied for construction of scalogram images. A CNN model performs stroke localization, while Grad-CAM provides visual interpretation of stroke regions. The architecture extracts deep features from reconstructed microwave images and classifies stroke regions with high accuracy.

Discussions

Grad-CAM is used to visualize the regions contributing to stroke localization as depicted in Fig2. The generated heatmaps improve transparency and help clinicians understand model decisions. Explainable AI improves trustworthiness and reduces black-box behavior in healthcare systems.

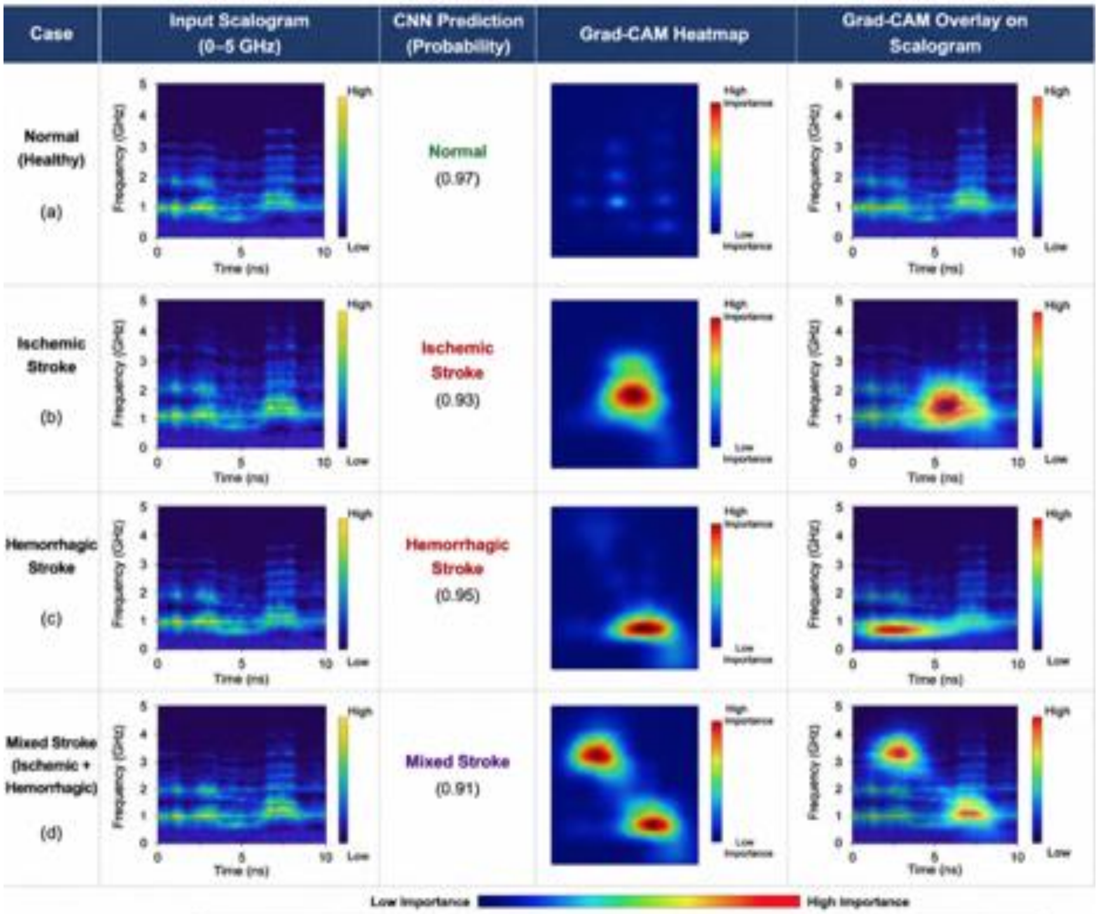

Fig.2 GRAD-CAM visualization for stroke classification

The model is trained using simulated microwave brain datasets containing healthy, ischemic, and hemorrhagic stroke samples. The following training parameters are adopted for this deep learning model.

• Optimizer: Adam
• Learning rate: 0.001
• Batch size: 32
• Epochs: 100

The proposed explainable CNN achieved superior localization performance compared with conventional machine learning approaches.

Performance comparison:

• SVM Accuracy: 84.2%

• Random Forest Accuracy: 87.6%
• Conventional CNN Accuracy: 92.4%
• Proposed Explainable CNN Accuracy: 96.3%

Grad-CAM visualization successfully highlighted stroke-affected regions and improved clinical interpretability.

Conclusions

This paper presented an explainable deep learning framework for microwave head stroke localization. The proposed system combines microwave imaging, convolutional neural networks, and explainable AI techniques for accurate and interpretable diagnosis. Experimental results demonstrate improved localization accuracy, sensitivity, and transparency compared with conventional approaches. The proposed system currently depends on simulated datasets and requires further clinical validation. Variations in antenna placement and patient anatomy may affect localization performance.

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