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HYBRID APPROACH FOR MRI SEGMENTATION USING DEEP LEARNING AND MACHINE LEARNING

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ABSTRACT

Accurate MRI segmentation is a crucial part of modern medical diagnostics and is essential for early disease diagnosis and effective treatment planning. Vision Transformers (ViT), Kernel-Based Convolutional Neural Networks (CNN), and Multi-Class Support Vector Machines (M-SVM) are all presented in this study as part of a novel hybrid approach to MRI segmentation that improves accuracy and efficiency. Our method employs ViT, which rapidly extracts high-level features from MRI patches, in combination with kernel-based convolutional neural networks, which are well-known for their ability to capture intricate patterns in image data. The M-SVM then refines the classification process, separating the pixels into distinct classes that are suggestive of different tissue types, and the segmentation phase begins without any problems. In addition to increasing the accuracy of MRI segmentation, initial findings suggest that this novel method might set an innovative standard for the analysis of medical images. This research has the potential to be an important development in medical imaging, which would significantly advance the current state of the art in healthcare technology by improving the accuracy with which diagnoses are made and the effectiveness of treatment plans.

Keywords: MRI Segmentation, Vision Transformers (ViT), Kernel-Based Convolution Neural Networks (CNN), and Multi-Class Support Vector Machines (M-SVM)

1. INTRODUCTION

Image segmentation is a process of dividing an image into multiple segments or regions to simplify the image and make it easier to analyze. In medical imaging, image segmentation is used to identify and isolate specific structures or regions of interest, such as tumors, blood vessels, or organs[1] The Benefits of using image segmentation and deep learning for brain tumor classification include the ability to automatically extract meaningful features from brain magnetic resonance (MR) images, which offer significantly better performance than traditional machine learning techniques . Deep learning-based techniques automatically extract powerful and discriminative deep features from brain MR images, which can improve the accuracy of the classification . Additionally, deep learning models can handle high inter and intra shape, texture, and contrast variations, which is a challenging problem for traditional machine learning techniques [2]. Traditional deep learning methods for multimodal medical image segmentation, such as fully CNNs, suffer from a deficiency of long-range dependencies and bad generalization performance. This means that fully CNNs may not be able to capture all the relevant information in the input images and may not perform well on new, unseen data. Combines the strengths of CNNs and Transformers to achieve better performance and generalization in multimodal medical image segmentation. Specifically, the CNNs are used to extract local features from the input images, while the Transformers are used to model long-range dependencies and capture global context. The benefits of this approach include improved accuracy, faster convergence, and better generalization to new data. The authors demonstrate the effectiveness of HybridCTrm on two benchmark datasets and compare it with a fully CNN-based network, showing that HybridCTrm outperforms the fully CNN-based network on most evaluation metrics.[3]. The Multi-Class Support Vector Machine (M-SVM) is essential for improving MRI segmentation. It essentially divides pixels into different classes, expressing various tissue types as determined by MRI patches, and serves as the final level of refining. This categorization is essential because it enhances the high-level characteristics found by Vision Transformers and the patterns found by Kernel-Based CNNs, allowing for an accurate and thorough segmentation. Additionally, the M-SVM assists in reducing classification mistakes and noise, potentially improving the whole segmentation process' accuracy and dependability and enabling more precise diagnoses and treatment plans.

2. LITERATURE SURVEY

Traditional methods in medical image analysis include feature-based methods, such as texture analysis and shape analysis, and machine learning-based methods, such as support vector machines and deep learning - Deep learning-based methods have shown great success in various medical image analysis tasks, but they require large amounts of labelled data and may not generalize well to new data [4].

Traditional methods like Dermoscopy are dependent on the expertise of dermatologists, and some computer-aided diagnosis methods may not be accurate or reliable [5]. Previous research on multimodal medical image segmentation using deep learning methods. The authors note that traditional deep learning methods, such as fully CNNs, have limitations in capturing long-range dependencies and generalizing to new data. Therefore, recent research has focused on combining CNNs with other architectures, such as Transformers and kernel-based CNNs, to improve performance. Additionally, some studies have explored the use of support vector machines (SVMs) for classification and segmentation tasks. The authors highlight the importance of multimodal imaging, which provides additional information and improves the discriminative power of the network. Overall, the related works section provides a brief overview of the current state of research in multimodal medical image segmentation using deep learning methods [3].

3. IMAGE SEGMENTATION

Image segmentation is a critical task in medical image analysis, as it involves identifying and separating different regions or structures within an image. In the context of multimodal medical image segmentation, the goal is to assign labels to each pixel of the input images from different modalities. This allows for more accurate and detailed analysis of the images, which can aid in diagnosis, treatment planning, and monitoring of various medical conditions. Deep learning methods, such as CNNs and Transformers, have shown great promise in achieving accurate and efficient image segmentation, particularly in the context of multimodal imaging. By combining these architectures and leveraging the strengths of each, researchers can develop more powerful and effective models for multimodal medical image segmentation.

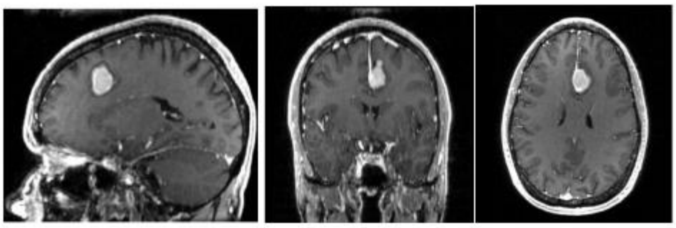

Figure 1: MRI Brain Tumor image Slices in different dimensions

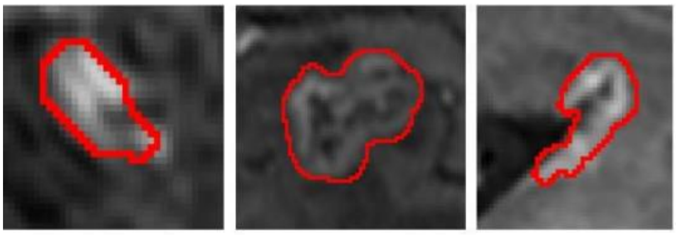

Figure 2: MRI Brain Tumor image Structure Examples

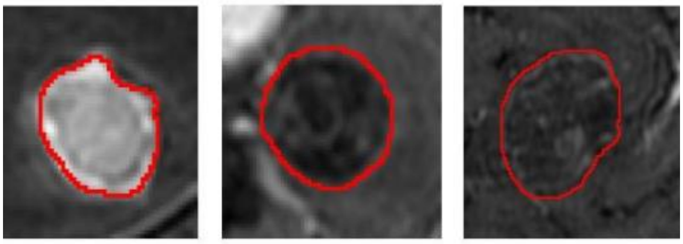

Figure 3: MRI Brain Tumor image various Appearances

4. VISION TRANSFORMERS

Vision Transformer (ViT) is an upgraded variant of the Transformer model that was originally developed for natural language processing tasks. ViT is a deep learning model that uses a self-attention mechanism to integrate information from different parts of an image. It splits the image into small patches, which are considered sequence tokens, and then flattens them to generate low-dimension embedding's linearly. Finally, the sequence output is passed as an input to the Transformer encoder. ViT is used for image classification tasks, such as identifying skin diseases like Melanoma. It is preferred over traditional Convolutional Neural Networks (CNNs) because it can handle variable-sized information and allows the positional embedding's of the image. ViT also takes less time in training and does not require convolution layers, making it more efficient.

CNN and TRANSFERMERS with M-SVM

In the Hybrid approach CNNs and Transformers are used together to address some of the limitations of traditional CNN-based methods for medical image segmentation. CNNs are very good at learning local features from image data, but they may not be as effective at capturing long-range dependencies between different modalities. Transformers, on the other hand, are designed to capture long-range dependencies, but they may not be as effective at learning local features. By combining CNNs and Transformers in a hybrid architecture, the HybridCTrm approach is able to leverage the strengths of both types of networks. The CNNs are used to extract local features from each modality, while the Transformers are used to capture long-range dependencies between different modalities. This allows the network to better integrate information from multiple modalities and produce more accurate segmentation results.

First, Vision Transformers and Kernel-Based Convolutional Neural Networks are utilized to identify complicated patterns and details in MRI data, functioning as intelligent eyes capable of detecting detailed details in images.

The Multi-Class Support Vector Machine (M-SVM) is then applied. Consider is that classifies these small information into separate categories, such as different tissue kinds or disease signs. It achieves this by finding the correct boundaries which divide these groups in the most logical way. This procedure is similar to drawing the best possible lines on a map to clearly distinguish distinct terrains. This aid in obtaining a more exact interpreting of the MRI images, making sure the difference between various regions is as precise as possible. This not only helps in spotting finer details in images, but also in more consistently diagnosing conditions. The method tries to improve how we evaluate medical images, probably improving the accuracy of diagnoses and treatments.

5. METHODOLOGY

HYBRID Approach for Medical Image Segmentation

Data collection

The initial step is to import the medical imaging dataset. This is the basic data that can be used for further analysis, processing, and classification can be performed.

Pre-processing

There are two stages within the pre-processing phase:

The first step is collecting all of the required medical images for the dataset. Alternatively, the data can be extended to improve the feature set through a process known as "data augmentation."

Feature Extraction

Here, the algorithm uses two powerful methods for feature extraction from the image data:

Convolution Neural Networks (CNNs) that use a kernel function. In order to recognize patterns and textures at a finer scale, these networks must first extract local features from the image data.

Vision Transformers: Vision Transformers process image data in parallel to capture long-range dependencies between various characteristics or modalities contained in the images.

Segmentation and Classification

The Multi-Class Support Vector Machine (M-SVM) is used once features have been extracted. In part of the classification process, this essential part classifies the features obtained from the previous step into their respective categories. It's possible that these groups stand in for different kinds of tissue or disease indicators. In essence, it ensures accurate and reliable classification by constructing optimal hyper planes in a high-dimensional feature space. As a result, the precision of the segmentation is greatly enhanced, allowing for more solid diagnoses to be made.

Post-processing

The algorithm then enters a post-processing stage once the classification and segmentation steps have been completed. As part of this stage, you will be doing: Reconstructing the individual segments into a whole image is called "image reconstruction. “Accuracy, sensitivity, specificity, and other metrics are calculated by the algorithm to evaluate segmentation performance.

Visualization and Analysis

The segmented images and categorization regions are displayed at this stage. We also perform in-depth analyses of the segmented data, which may be useful in medical care and research.

Finalization

Finally, the segmented image and its related classification metrics are provided as the finished segmentation's output.

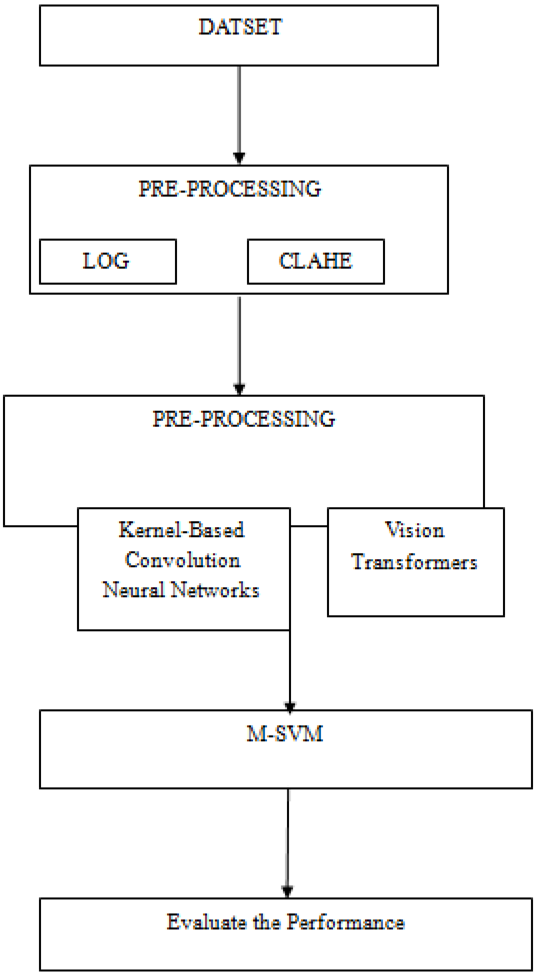

Figure 4: Architecture of CNN and TRANSFERMERS with M-SVM

Algorithm:

- Read MRI image.
- Apply pre-processing techniques:
- Apply Log filter for edge enhancement and noise reduction.
- Apply CLAHE for contrast enhancement.
- Feature Extraction using Kernel-Based Convolutional Neural Networks:
- Define window size and matrix size for feature extraction.
- Choose pixel from the image with distance d, angle θ, and process using defined kernel functions to extract patterns and textures.
- Feature Integration using Vision Transformers:
- Utilize transformers to integrate features extracted from CNNs, capturing long-range dependencies and complex patterns.
- Classification using Multi-Class Support Vector Machine (M-SVM):
- Utilize M-SVM to classify the integrated features into distinct categories (like different tissue types or disease markers).
- Evaluate the performance using appropriate metrics and validate the results on different datasets.

6. RESULT ANALYSIS

This study work experiment is done with the Python language, Medical Segmentation Decathlon (MSD) [36] data set, from which we took Task01_BrainTumour: There are 750 labels in total, and they are split into two groups: Glioma (dead or active tumour) and edoema. It is a regular MRI scan that is done in a hospital.

The Performance of the proposed work was calculated by the various measures. They are

Sensitivity = TP/TP+FN

Specificity= TN/TN+FP

Accuracy = TP+TN/TP+TN+FP+FN

Table 1: Performance Analysis of Existing Work and Proposed Work

Measures	K-Means	SVM	CNN	Proposed Work
Sensitivity	84.6	83.1	89.4	95.3
Specificity	86.4	84.3	91.7	94.6
Accuracy	85.3	83.6	90.6	94.8

Error Rate: The number of instances that a decision model has erroneously labelled a pattern. Error rate of proposed method compared to prior work is shown in Figure.

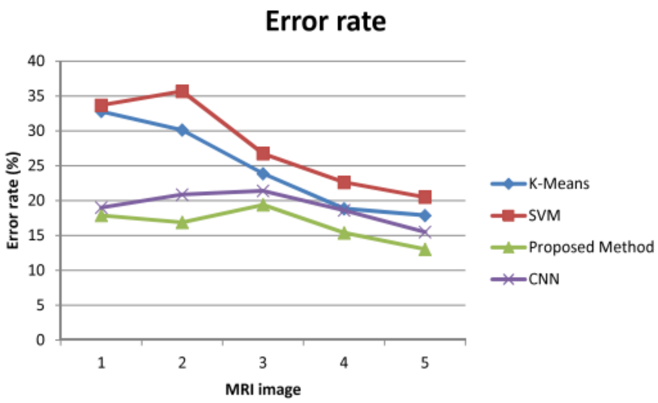

Figure 5: Error Rate of Proposed work versus Existing Work

7. CONCLUSION

In this study, we developed a method for improved medical picture analysis by combining Vision Transformers, Kernel-Based Convolutional Neural Networks, and Multi-Class Support Vector Machines (M-SVM). We used LoG and CLAHE for pre-processing to improve image quality, allowing for more precise segmentation and classification. Collectively, proven to be an effective tool for analysing complex MRI patterns, which in turn prepares the way for quicker, more precise diagnoses. This novel method has great promise for the future of medical image processing, as it may lead to improved diagnosis accuracy.

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