AI-DRIVEN BRAIN TUMOR DETECTION, SEGMENTATION AND PERSONAL GUIDANCE USING LLM

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Abstract - *Brain tumour detection is a critical task in medical diagnostics, requiring accurate and timely identification to ensure effective treatment. This project presents an automated system for detecting and segmenting brain tumours from MRI images using deep learning and image processing techniques. A pre-trained convolutional neural network model is employed to classify MRI scans as tumour-positive or tumour-negative. Tumor regions are then segmented using morphological operations and the watershed algorithm for precise visualization. Additionally, the system integrates a Generative AI assistant (Google Gemini via Lang Chain) to provide patients with personalized medical advice, treatment suggestions, and lifestyle precautions based on the detection results. The system also includes a webbased platform for user registration, secure login, and admin-controlled account activation, ensuring controlled access.Experimental results demonstrate accurate tumour detection and effective integration of AI- driven guidance, highlighting the potential of combining deep learning and generative AI for enhanced medical diagnostics.*

KEYWORDS: Brain Tumour Detection, MRI, Deep Learning, Image Segmentation, Generative AI, Google Gemini, Lang Chain, Web-Based Medical System.

1. INTRODUCTION

Brain tumours are abnormal growths of cells within the brain that can lead to severe health complications if not detected early. Accurate diagnosis of brain tumours is crucial for effective treatment planning and improving patient survival rates [5], [7].

Magnetic Resonance Imaging (MRI) is a widely used non-invasive imaging technique that provides high-resolution visualization of brain tissues, making it the preferred modality for brain tumour detection [2], [5]. However, manual examination of MRI scans is time-consuming, highly dependent on expert radiologists, and susceptible to human error, particularly in early-stage tumour identification [4], [7].

Recent advancements in deep learning and medical image processing have enabled automated brain tumour detection and segmentation, significantly improving diagnostic accuracy and efficiency [1], [6], [9]. Convolutional Neural Networks (CNNs) have demonstrated strong capability in learning complex spatial features from MRI images, allowing accurate classification of tumour and non-tumour regions [3], [8], [10].

In addition to classification, tumour localization and segmentation play a vital role in understanding tumour shape, size, and spread. Image processing techniques such as morphological operations and watershed algorithms are widely used for precise tumour region segmentation and visualization [2], [9].

Furthermore, the integration of Generative Artificial Intelligence (AI) models enables intelligent interaction with patients by providing personalized medical guidance, treatment suggestions, and precautionary recommendations based on detected tumour conditions [6], [10].

By combining MRI-based tumour detection using CNNs, automated segmentation techniques, and AI-assisted recommendation systems into a web-based platform, the proposed system offers a comprehensive solution for early diagnosis, enhanced clinical decision support, and improved patient awareness while maintaining administrative control over user management [1], [5], [9].

1.1 MRI-Based Brain Tumour Detection and Automated Segmentation

Magnetic Resonance Imaging (MRI) plays a vital role in the detection of brain tumours due to its high spatial resolution and excellent soft-tissue contrast. In the proposed system, MRI scans uploaded by users are first pre-processed to remove noise, normalize intensity levels, and enhance image quality. These preprocessing steps ensure that the relevant tumour features are preserved for accurate analysis.

A Convolutional Neural Network (CNN) is employed to automatically analyse MRI images and classify them as tumour-positive or tumour-negative. CNNs are well-suited for this task as they can automatically learn hierarchical features such as edges, textures, and complex tumour patterns directly from the image data. Once a tumour is detected, image segmentation techniques are applied to precisely identify the tumour region.

Morphological operations combined with the watershed algorithm are used to segment the tumour area from surrounding brain tissues. This segmentation process highlights the size, shape, and location of the tumour, assisting in better visualization and clinical interpretation. Automated detection and segmentation significantly reduce manual effort, minimize diagnostic errors, and enable faster decision-making in medical workflows.

1.2 Motivation and Problem Overview

Brain tumours are among the most life-threatening neurological disorders, and their impact on patient survival largely depends on early and accurate diagnosis. Despite the availability of advanced imaging techniques such as Magnetic Resonance Imaging (MRI), the conventional process of analysing brain scans is heavily dependent on expert radiologists, making it time consuming, costly, and susceptible to human error, especially in cases involving subtle or early-stage tumours.

The growing number of MRI scans in clinical environments further increases the burden on medical professionals, often leading to delayed diagnoses. In addition, accurately identifying the exact tumour boundaries is challenging due to variations in tumour size, shape, intensity, and location across patients. These challenges highlight the need for an automated, reliable, and efficient system capable of detecting and segmenting brain tumours with high precision. Motivated by these limitations, the proposed approach leverages deep learning, image processing techniques, and AI-driven guidance to assist in early tumour detection, improve diagnostic accuracy, reduce clinical workload, and provide accessible, patient-centric support through an intelligent web-based platform.

2. PROPOSED SYSTEM

The proposed system is a web-based platform designed to automate brain tumour detection, segmentation, and patient guidance using deep learning and generative AI. It addresses the challenges of manual MRI analysis, which is time-consuming, prone to human error, and requires specialized expertise. The system integrates several modules to provide a seamless workflow for both users and administrators.
The user module allows patients to register and log in securely. Once authenticated, users can upload brain MRI scans for analysis. Uploaded images are pre-processed using grayscale conversion, Gaussian blurring, and noise reduction to enhance feature extraction. A pre-trained Convolutional Neural Network (CNN) model then predicts the presence of a tumour, providing probabilistic results for tumour detection. To assist with visualization, the system employs image segmentation techniques, including morphological operations and the watershed algorithm, to highlight tumour regions in the MRI scans. The segmented images help both patients and healthcare professionals understand the tumour's location and extent.
Additionally, the system integrates a Generative AI assistant using Large Language Model (LLM) such has Google Gemini via Lang Chain. Based on the detection results, the AI generates personalized advice, recommended treatments, and lifestyle precautions for the patient, enhancing informed decision-making.

The admin module manages user accounts, allowing administrators to view registered users and activate accounts as necessary, ensuring controlled access to the system.

Overall, the proposed system provides an end-to-end solution that combines automated tumour detection, visual segmentation, and AI-driven medical guidance. It aims to improve diagnostic efficiency, support early intervention, and empower patients with actionable information, reducing the dependency on manual interpretation and enhancing overall healthcare delivery.

2.1 System Architecture

The system architecture of the proposed AI-driven brain tumour detection system is designed in a modular and layered manner to ensure efficiency, scalability, and ease of maintenance. The architecture begins with the User Interface Layer, which provides a web-based platform for users to register, log in, and upload MRI brain images securely. This layer ensures user-friendly interaction and proper input validation before data is sent for processing. Once an MRI image is uploaded, it is forwarded to the Application Processing Layer, where the core analysis takes place. The first stage in this layer is MRI Image Preprocessing, which removes noise, normalizes intensity values, enhances contrast, and resizes images to a standard format suitable for deep learning models. This step improves image quality and ensures consistent input for accurate analysis.

The pre-processed images are then passed to the CNN Based Tumour Detection Module, where a trained Convolutional Neural Network analyses the MRI scan to determine whether a brain tumour is present. If a tumour is detected, the image is further processed by the Tumour Segmentation Module, which uses image processing techniques such as morphological operations and the watershed algorithm to accurately extract and highlight the tumour region.

Following detection and segmentation, the system interacts with the AI Guidance Module, which leverages a Large Language Model (LLM) to generate personalized guidance, precautionary advice, and general treat men related information based on the analysis results. This enhances patient awareness and provides supportive insights while emphasizing that professional medical consultation is essential.

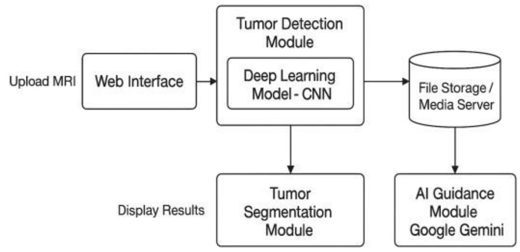

Fig -1 : System Architecture of the AI-Driven Brain Tumour Detection and Guidance System

2.2 Data Flow and Processing Module

The data flow in the proposed system begins with the user uploading a brain MRI scan through the web-based interface. Once uploaded, the image is forwarded to the preprocessing module, where noise reduction, resizing, intensity normalization, and contrast enhancement are performed to improve image quality and ensure consistency across different MRI inputs. The pre-processed image is then passed to the deep learning module, where a Convolutional Neural Network (CNN) analyses the scan to determine the presence or absence of a brain tumour. If a

Tumour is detected; the image is further processed using image segmentation techniques, including morphological operations and the watershed algorithm, to accurately extract the tumour region from surrounding brain tissues. The segmented output highlights the tumour's location, size, and shape for better visualization. Based on the detection and segmentation results, the system interacts with a Generative AI model to generate personalized guidance, precautionary advice, and general treatment related information for the user. Finally, all results, including classification outcomes, segmented images, and AI-generated recommendations, are displayed on the user dashboard, while relevant data is securely stored in the database for future reference and administrative monitoring.

2.3 MRI Image Preprocessing

MRI image preprocessing is a crucial step in the proposed system, as the quality of input images directly affects the accuracy of tumour detection and segmentation. Raw MRI scans often contain noise, intensity variations, and irrelevant background information that can degrade model performance. To address these issues, the uploaded MRI images are first converted into a standardized format and resized to a fixed resolution suitable for the Convolutional Neural Network (CNN).Noise reduction techniques such as median filtering or Gaussian filtering are applied to remove unwanted artifacts while preserving important structural details. Intensity normalization is then performed to reduce variations caused by different imaging conditions and scanners, ensuring uniform pixel distribution across all images. Contrast enhancement techniques, including histogram equalization, are used to highlight tumour regions and improve the visibility of brain tissues.

2.4 CNN-Based Brain Tumour Detection

Convolutional Neural Networks (CNNs) are employed in the proposed system to automatically detect the presence of brain tumours from pre-processed MRI images. CNNs are highly effective for medical image analysis due to their ability to learn spatial hierarchies of features such as edges, textures, and complex tumour patterns directly from image data without the need for manual feature extraction. The pre-processed MRI images are fed into the CNN model as input, where multiple convolutional layers extract low-level and high-level features relevant to tumour identification. Each convolutional layer is followed by activation functions such as ReLU and pooling layers that reduce spatial dimensions while retaining important information. This helps in minimizing computational complexity and preventing overfitting. The extracted feature maps are then passed through fully connected layers, which perform classification to determine whether the MRI scan indicates a tumour-affected brain or a normal brain

3. IMPLEMENTATION DETAILS

The implementation of the proposed system integrates deep learning, image processing, and Generative AI within a unified web-based framework. The system is developed to ensure seamless interaction between MRI image acquisition, tumour detection, segmentation, and personalized guidance delivery. Python-based frameworks are used for model development and image processing, while the web application enables secure user interaction and result visualization. Each module is implemented independently yet works cohesively to provide accurate, efficient, and user-friendly brain tumour analysis..

3.1 Project Planning and Requirements Gathering:

Project planning and requirements gathering constitute a crucial phase in the implementation of the proposed AI powered brain tumour detection system. During this stage, the primary objectives of the project were clearly defined, focusing on accurate MRI-based tumour detection, precise segmentation, and AI-assisted personalized guidance through a web-based platform. A detailed study of existing brain tumour detection methods and clinical challenges was carried out to identify system limitations and establish realistic project goals. Functional requirements such as user registration, MRI image upload, automated tumour detection, segmentation visualization, AI-generated guidance, and administrative control were identified. In addition, non-functional requirements including system accuracy, reliability, data security, scalability, and user friendly interface design were considered. Technical requirements such as dataset selection, deep learning frameworks, image processing techniques, and Generative AI integration were also finalized during this phase. Proper planning and systematic requirement analysis helped in designing a structured architecture, reducing development risks, and ensuring that the final system meets both technical and user expectations effectively.

3.2 System Design and Architecture:

The system design and architecture of the proposed AI powered brain tumour detection system are structured to ensure modularity, scalability, and efficient data processing. The architecture is divided into multiple interconnected modules, including the user interface, preprocessing unit, CNN-based tumour detection module, segmentation module, AI guidance engine, and database management system. Each module is designed to perform a specific function while seamlessly interacting with other components.

The user interface allows users to securely register, log in, and upload MRI images for analysis. Uploaded images are passed to the preprocessing module, where noise removal, normalization, and enhancement are performed. The processed images are then analysed by the CNN model to detect the presence of a brain tumour. If a tumour is identified, segmentation techniques are applied to extract and highlight the tumour region. The AI guidance module generates personalized precautionary and advisory information based on the analysis results. All data and outputs are securely stored in the database, while the administrator module manages user activities, system monitoring, and access control, ensuring a reliable and efficient system workflow.

3.3 Frontend Development:

The frontend of the proposed system is designed to provide a simple, intuitive, and user-friendly interface that enables seamless interaction between users and the brain tumour detection platform. The frontend allows users to register, log in securely, and upload MRI brain images for analysis. Clear navigation and responsive design principles are followed to ensure accessibility across different devices and screen sizes. The user interface displays tumour detection results, segmented MRI images, and AI-generated personalized guidance in a visually clear and understandable format. Forms and validation mechanisms are implemented to guide users during image upload and prevent incorrect inputs. The frontend also includes an administrator dashboard that enables efficient user management and system monitoring. Overall, the frontend development focuses on usability, clarity, and effective visualization of medical results, ensuring a smooth and engaging user experience.

3. 4: Backend Development:

The backend of the proposed system is responsible for handling core functionalities such as data processing, model execution, user management, and secure communication between system components. The backend is developed using a server-side framework that manages user authentication, MRI image uploads, and interaction with the deep learning and image processing modules. Once an MRI image is received, the backend triggers the preprocessing pipeline, executes the CNN-based tumour detection model, and applies segmentation techniques to generate analytical results. All user data, MRI images, and processed outputs are securely stored in the database, ensuring data integrity and privacy.

4. RESULTS AND PERFORMANCE ANALYSIS

The proposed AI-driven brain tumour detection and guidance system was tested using MRI brain scan images to evaluate its performance in tumour classification, tumour region segmentation, and user-level result presentation. The system produces end-to-end outputs through a web-based interface, including detection status, segmented tumour visualization, and AI-generated precautionary guidance. The experimental results show that the integrated CNN model effectively identifies tumour presence, while the segmentation module successfully highlights the tumour region. The overall workflow provides accurate results with clear visualization and user-friendly interaction.

4.1 Tumour Detection Output

The tumour detection module uses a pre-trained Convolutional Neural Network (CNN) to classify uploaded MRI scans as tumour-positive or tumour-negative. After successful analysis, the system displays the classification result to the user through the dashboard interface. As shown in Fig. 2, the system clearly presents the detection status as “Tumour Detected”, enabling users to immediately understand the outcome of the MRI analysis. This automated detection reduces dependency on manual interpretation and supports faster decision-making.

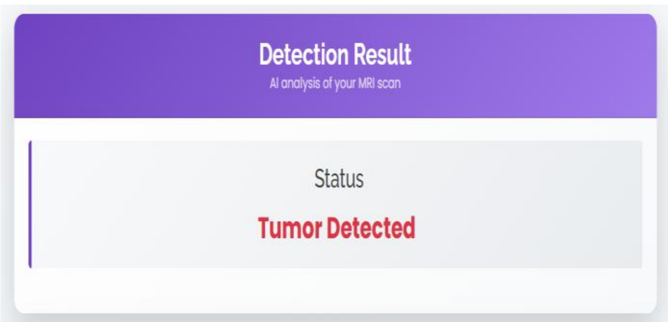

Fig. 2: CNN-based tumour detection result displayed on the web interface (Tumour Detected).

4.2 Tumour Segmentation Visualization

After tumour detection, the system performs tumour region segmentation to identify the exact location and shape of the tumour. Morphological operations and the watershed algorithm are applied to extract the tumour area from the surrounding brain tissues. The segmentation output provides a clear visual representation of tumour boundaries, improving interpretability. As shown in Fig. 3, the system displays both the uploaded MRI scan and the corresponding segmented tumour image, allowing users and clinicians to observe the tumour's position and size effectively. This segmentation stage enhances diagnostic support by providing additional visual evidence along with classification.

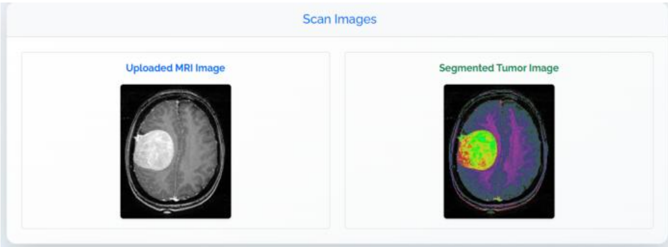

Fig. 3: Uploaded MRI image and segmented tumour region generated using morphological and watershed-based segmentation.

4.3 AI-Generated Guidance and Precautionary Output

To improve patient awareness and provide supportive assistance, the system integrates a Generative AI assistant using a Large Language Model (LLM). Based on the detection results, the AI generates personalized medical guidance, including suggested follow-up actions, precautionary measures, and lifestyle advice. As illustrated in Fig. 4, the system provides structured recommendations such as consulting a neurologist, avoiding strenuous activities, and monitoring symptoms. This feature enhances user understanding and ensures that the system not only detects tumours but also provides meaningful guidance in an accessible format. However, the system also emphasizes that professional medical consultation is required for final diagnosis and treatment.

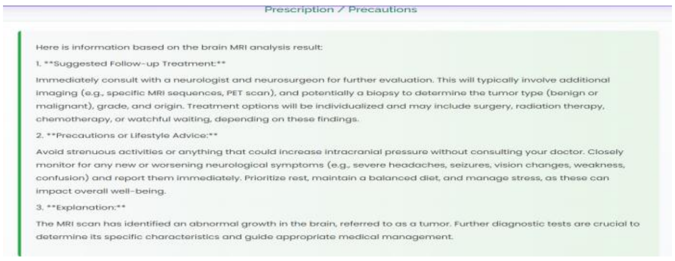

Fig. 4: AI-generated prescription, treatment suggestions, and lifestyle precautions based on MRI analysis.

4.4 Overall System Output and User Experience

The proposed system demonstrates efficient performance by providing results in a complete pipeline—from MRI upload to tumour detection, segmentation, and AI-guided recommendations—within a short time. The web interface ensures smooth interaction, clear visualization of outputs, and easy accessibility for users. The integration of detection results (Fig. 1), segmentation visualization (Fig. 2), and guidance generation (Fig. 3) proves that the system delivers an end-to-end solution for brain tumour analysis. This makes the platform suitable for supportive diagnostic assistance, patient awareness, and early intervention workflows.

5. CONCLUSION

This project successfully presents an AI-powered system for brain tumour detection, segmentation, and personalized guidance using deep learning and Generative AI techniques. By leveraging MRI images, Convolutional Neural Networks effectively automate the detection of brain tumours, reducing reliance on manual analysis and minimizing diagnostic errors. The integration of image processing techniques enables accurate segmentation and clear visualization of tumour regions, aiding better clinical interpretation. Furthermore, the inclusion of AI-assisted guidance provides users with meaningful insights, precautionary information, and general recommendations in an accessible manner. The proposed web-based platform ensures ease of use, secure data handling, and efficient interaction between users and administrators. Overall, the system demonstrates the potential of combining deep learning and AI technologies to enhance early diagnosis, improve healthcare efficiency, and support informed decision-making in brain tumour management.

6. FUTURE ENHANCEMENT

The proposed AI-powered brain tumour detection and guidance system can be further enhanced in several ways to improve accuracy, scalability, and clinical usefulness. Future work may include extending the system to support multi-class tumour classification to identify different tumour types and grades. Incorporating advanced deep learning architectures such as 3D CNNs and transformer based models can improve feature extraction from volumetric MRI data. The segmentation module can be refined using state-of-the-art techniques like U-Net variants for more precise tumour boundary detection. In addition, integrating real-time clinical data, radiology reports, and patient history can enable more personalized and context-aware AI guidance. Deployment of the system in hospital environments with cloud-based infrastructure, along with mobile application support, can further enhance accessibility and usability. With proper clinical validation and regulatory compliance, the system can evolve into a reliable decision-support tool for assisting medical professionals in early brain tumour diagnosis and patient care.

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