INTEGRATING NEURO-SYMBOLIC AI FOR ACCURATE BRAIN TUMOUR DETECTION IN MRI IMAGING

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Introduction:

Brain tumors are a significant health issue worldwide, causing high mortality rates. Detecting them early is essential for effective treatment and improved patient outcomes. Magnetic Resonance Imaging (MRI) is the most reliable imaging method for diagnosing brain tumors because it offers exceptional soft tissue contrast and provides intricate images. However, interpreting MRI images to identify brain tumors is challenging and varies from person to person, necessitating the involvement of qualified radiologists. Manual interpretation is time-consuming, prone to variations among observers, and may lead to diagnostic errors and treatment delays. Recent advancements in artificial intelligence (AI) and machine learning (ML), especially in medical image analysis, offer promising opportunities to address these challenges.

Convolutional Neural Networks (CNNs) have become essential in medical imaging, providing powerful tools for identifying features and patterns. However, traditional CNNs often lack transparency and clarity, which is crucial in medical contexts where trust and understanding of results are paramount. This lack of interpretability poses a significant challenge, especially as decisions made using these tools directly impact patient care. Neuro-symbolic AI, a cutting-edge field of research, combines the learning process of neural networks with the logical capabilities of symbolic AI. This hybrid approach offers applications across multiple domains. Neuro-Symbolic AI bridges this gap by merging symbolic thinking with neural networks, which improves the interpretability and trustworthiness of AI-powered diagnostic systems. Neuro-Symbolic AI enables physicians to not only diagnose brain tumours more accurately, but also understand the reasoning behind diagnostic decisions, by combining data-driven insights derived from neural networks with the logical inference skills of symbolic reasoning.

Our study focuses on the potential of Neuro-Symbolic AI for brain tumour detection, with the objective of creating a more accurate, transparent, and practically relevant diagnostic system. We intend to investigate the benefits and drawbacks of introducing symbolic

reasoning into neural network-based diagnostic models by comparing various methodologies within the Neuro-Symbolic AI framework. In this work, we undertake an in-depth evaluation of the use of Neuro-Symbolic AI for brain tumour diagnosis, evaluating many techniques such as direct CNN application, hybrid models such as hybrid CNN-Symbolic (CNN → Symbolic) and hybrid Symbolic-CNN (Symbolic → CNN). Our study intends to enhance the cutting-edge in AI-assisted medical imaging by describing the harmonious interaction of neural networks and symbolic reasoning in the context of brain tumour detection, opening the way for more effective and interpretable diagnostic tools in neurology

Objective:

To implement a deep learning model for accurate brain tumor segmentation and classification in MRI images. This model will leverage recent advancements in convolutional neural networks (CNNs) and potentially explore transformer-based architectures.

To Integrate symbolic reasoning into the system to provide interpretable explanations for its decisions. This could involve incorporating knowledge graphs, rule-based systems, or other symbolic AI techniques.

To Evaluate the performance and interpretability of the integrated system on a large dataset of labeled MRI images. Compare the system's performance with existing state-of-the-art methods and assess the effectiveness of its explanations for clinical decision.

Methodology:

1. Data Collection and Preprocessing:
   - Acquire a large dataset of labeled MRI images.
   - Develop preprocessing pipelines to enhance image quality.
2. Deep Learning Model Development:
   - Design and train a deep learning model for tumor segmentation and classification.
   - Experiment with different CNN architectures and hyperparameters to optimize performance.
3. Symbolic AI Integration:
   - Select appropriate symbolic AI techniques and knowledge representation methods for interpretability.
   - Integrate the symbolic module into the system to explain the model's reasoning and feature importance.
4. Evaluation and Refinement:
   - Evaluate the performance of the integrated system on the test dataset using standard metrics like accuracy, sensitivity, and specificity.
   - Analyze the interpretability of the explanations provided by the system.
   - Refine the system based on the evaluation results, focusing on improving both accuracy and interpretability.

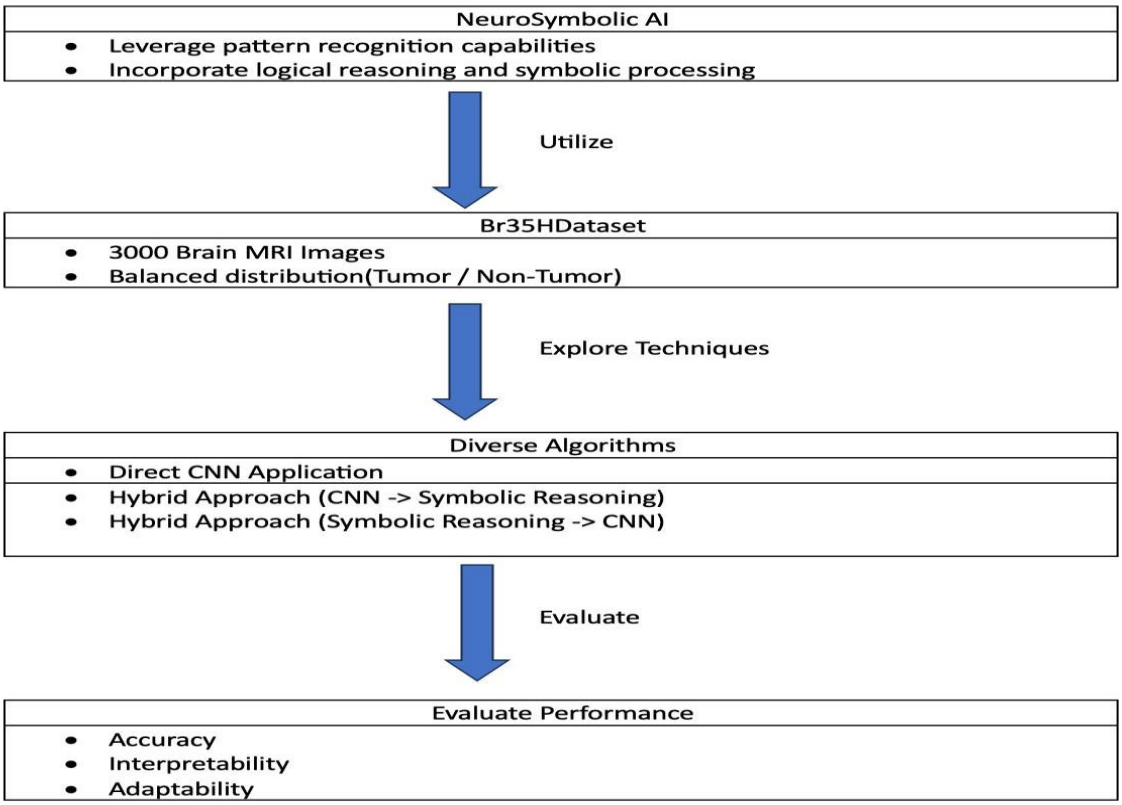

Figure-: Flowchart of the project.

Result And Conclusion:

The integration of Neuro-Symbolic AI in the diagnosis of brain tumors is a revolutionary method that will have a significant impact on medical picture analysis. Considering brain imaging are so complex and are affected by different tumor properties as well as patient-specific circumstances, creative methods are required. The implementation of three models, namely the Convolutional Neural Network (CNN), Hybrid CNN-Symbolic Model (CNN → Symbolic), and Hybrid Symbolic-CNN Model (Symbolic → CNN), in brain tumor MRI dataset showcased the potential of combining symbolic reasoning and CNN-based feature extraction for brain tumor detection. The Hybrid CNN-Symbolic Model (CNN → Symbolic) achieved the highest accuracy of 98.50%, surpassing both the standalone CNN and Hybrid Symbolic-CNN models. This highlights the benefits of incorporating symbolic reasoning after CNN layers, allowing the model to capture symbolic relationships in the data and improve tumor detection performance.

WHAT IS THE INNOVATION OF THE PROJECT:

This project innovatively combines convolutional neural networks (CNNs) with symbolic reasoning for brain tumor detection in MRI images. It explores two hybrid models—CNN followed by symbolic reasoning (CNN → Symbolic) and symbolic reasoning guiding CNN (Symbolic → CNN)—to enhance both accuracy and interpretability. Advanced techniques, including transformer-based architectures and knowledge graphs, are employed to provide clear diagnostic explanations. The system is evaluated on a large MRI dataset using

standard performance metrics and interpretability assessments, ensuring clinical relevance. Iterative refinements based on these evaluations aim to improve diagnostic accuracy and transparency, setting a new standard in AI-assisted medical imaging.

Scope of Future Work:

The future scope of this project involves further enhancing the interpretability and accuracy of Neuro-Symbolic AI models for medical imaging. Future research can focus on refining the integration between CNNs and symbolic reasoning to provide even more detailed and transparent explanations for diagnostic decisions, including why the model reached a positive or negative diagnosis. This could involve developing advanced reasoning frameworks that not only highlight relevant features but also articulate the logical steps taken by the model. Additionally, expanding the application of this hybrid approach to other types of medical images and conditions could significantly improve AI-driven diagnostics across various medical fields. Integrating real-time feedback from radiologists into the model's learning process could also lead to continuous improvement and higher clinical acceptance, ultimately contributing to more reliable and interpretable AI-assisted healthcare solutions.