Enhanced Brain Tumor Detection through MRI Imaging

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Abstract- Brain tumors are severe forms of cancer originating from uncontrolled and abnormal cell division. The medical industry has witnessed recent advancements in advanced learning, particularly in medical imaging, facilitating the diagnosis of various diseases. The prominence of medical imaging is growing, driven by computerized, definitive, rapid, and systematic diagnostics capable of producing images surpassing human visual capabilities. In humans, brain tumors stand as the primary cause of cancer-related deaths, posing significant dangers and leading to various diseases if not treated appropriately. Recognition plays a crucial role in the early detection of malignant tumors. This study introduces an algorithm utilizing image preprocessing techniques, segmentation, localization, feature extraction, and classification to alert clients to tumor information. The Computerized Brain Tumor Detection Set, designed for MRI scan images, employs a GUI tool aiding doctors and professionals in discerning tumor features' shape, size, and highlighting.

Introduction [1]

The human brain, a remarkably sensitive organ, regulates fundamental bodily functions and features, as noted by the National Brain Tumor Society. Brain tumors account for 85% to 90% of all primary central nervous system (CNS) tumors. Worldwide, an estimated 308,102 people were diagnosed with a primary brain or spinal cord tumor in 2020. It is estimated that 5,230 children under the age of 20 will also be diagnosed with a CNS tumor in the United States in 2023. While brain tumors are less common compared to other cancers like breast or lung cancer, they stand as a primary global cause of death, with an estimated 18,020 adults projected to succumb to brain cancer this year.

Beyond the immediate health implications, a brain tumor exerts a lasting psychological impact on patients even after successful recovery. The core objective of this research is to establish a transparent environment fostering collaboration between medical staff and patients, ultimately yielding improved outcomes. This openness enables patients to comprehend their treatment options, providing them with peace of mind, while affording clinicians the time for thoughtful consideration and work in managing the situation.

Brain tumors result from abnormal tissue growth within the brain or spinal cord, compromising brain function. These tumors are categorized into low-grade (grades 1 and 2) and high-grade (grades 3 and 4) forms. The severity of brain tumors varies, with some being minor and slow-growing, devoid of cancer cells – characteristics indicative of a benign brain tumor. Benign tumors typically remain localized in a specific area of the brain without spreading, while malignant brain cells harbor rapidly growing cancer cells that can extend to other regions of the brain and spinal cord, potentially leading to fatal consequences. The World Health Organization (WHO) classifies brain tumors into benign tumors of grades 1 and 2 or malignant tumors of grades 3 and 4, with the latter referred to as malignant tumors.

Various techniques, such as computed tomography and EEG, can be employed to detect brain tumors, but magnetic resonance imaging (MRI) stands out as the most effective and widely utilized method. MRI utilizes a powerful magnetic field and radio waves to generate detailed images of internal organs, offering superior insights compared to CT or EEG. In this project, the focus is on detecting brain tumors through MRI imaging [2], with the primary objective of aiding clinical diagnosis. To achieve this goal, the project aims to provide an algorithm that ensures the reliable detection of tumors in brain MRI images. This involves combining multiple procedures to establish a robust and trustworthy method for identifying the presence of tumors in the brain.

Motivation

A brain tumor refers to an abnormal cell growth within the brain or the central spinal canal, and some tumors have the potential to become cancerous, necessitating early detection. The precise cause of brain tumors remains unclear, and the set of symptoms is not definitively outlined, leading individuals to endure potential risks unknowingly. Brain tumors can manifest as either malignant (containing cancer cells) or benign (lacking cancer cells), appearing as solid lumps when diagnosed through diagnostic medical imaging techniques.Two main types of brain tumors exist: primary brain tumors and metastatic brain tumors. A primary brain tumor originates in the brain and tends to remain localized, while a metastatic brain tumor forms elsewhere in the body and spreads to the brain. Symptoms associated with a brain tumor vary depending on the tumor's location, size, and type, with common indicators including headaches, nausea, vomiting, and issues related to balance and walking. Diagnostic imaging modalities such as CT scans and MRIs play a crucial role in the detection of brain tumors.

Medical imaging extensively employs various techniques, including X-rays, computed tomography, and magnetic resonance imaging, to identify lesions. Image processing is crucial for discerning and distinguishing the intricate details of the human body's internal structures. Among these techniques, magnetic resonance imaging stands out as the most suitable 3D non-invasive method for detecting brain tumors. Its exceptional image quality enables clear delineation of brain structure, precise identification of tumor size, and accurate determination of its location.

Problem Statement and Objective

This paper centers on extracting and simplifying MR brain images of tumors for universal understanding. The primary goal is to present valuable information in an accessible format, particularly for medical staff treating patients. The paper seeks to establish an algorithm capable of extracting tumor images from MR brain images. The resulting images aim to convey details such as tumor size, dimensions, and position, with the boundary offering pertinent information for diverse cases. This comprehensive data serves as a foundation for medical staff in determining optimal treatment procedures. Ultimately, this research utilizes Convolutional Neural Network to ascertain the presence of a tumor in a given MR brain image.

Here the objective is to identify tumors in brain MR images, providing crucial assistance in clinical diagnosis. The algorithm developed ensures robust tumor detection by combining various procedures, focusing on image preprocessing techniques like segmentation, extraction, and classification. The resulting images deliver essential information, including the tumor's position, dimensions, and size, aiding staff in making informed decisions for diverse cases and guiding appropriate therapeutic approaches.

Literature Survey

Survey of Existing System [1,3]

The prevailing system commonly encountered comprises:

1. Neurological Examination: This entails a series of tests designed to assess the functioning of the patient's nervous system, encompassing both physical and mental alertness.
2. Brain Scan: A brain scan involves capturing an internal structure image of the brain, akin to a digital camera photographing. A specialized machine captures the scan, compiling images of the brain from different angles using computer technology. Some scans utilize a contrast agent or dye to enhance the distinction between normal and abnormal brain tissues, aiding doctors in their analysis.
3. MRI (Magnetic Resonance Imaging): Utilizing a magnetic field and computer technology, MRI is a scanning device that produces images of the brain on films without the use of x-rays. It provides multi-planar images, allowing doctors to construct a three-dimensional image of the tumor. By detecting signals emitted from both normal and abnormal tissues, MRI yields clear images of nearly all types of tumors.
4. CT or CAT scan (Computed Tomography): Integrating advanced X-ray and computer technology, CT provides a comprehensive view of soft tissues, bones, and blood vessels. The images generated by CT can identify certain types of tumors and also reveal signs of swelling, bleeding, as well as bone and tissue calcification. Typically, iodine serves as the contrast agent employed during a CT scan.

Related Work

- **Brain Tumor [4]**

  A brain tumor is an uncontrolled mass or proliferation of abnormal cells within the brain. While there are 120 different types of brain tumors, they are primarily categorized into two groups: benign and malignant.

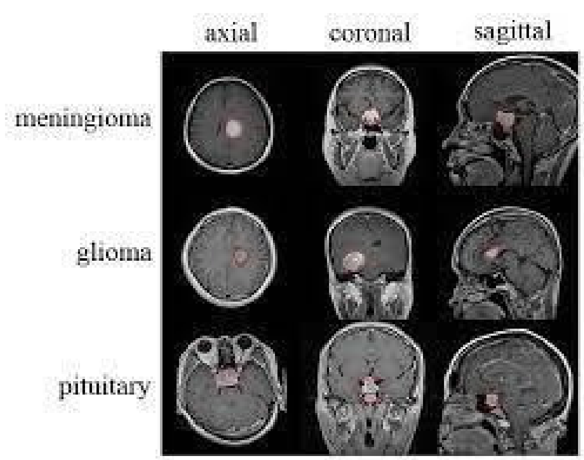


Fig. 1 [4]

- **MRI Machine [5]**

MRI, short for Magnetic Resonance Imaging, is commonly utilized for the examination of the soft tissue within the human body. The components of the machine include magnets, radio waves, gradients, and computers. With the human body consisting of approximately 60% water, and water possessing magnetic properties due to its oxygen-hydrogen composition, the hydrogen acts as a miniature magnet sensitive to magnetic fields. When the body is placed in the MRI machine, it generates a magnetic field around it, and the gradient adjusts this magnetic field in a specific section to examine a targeted part of the body, such as the brain.

As a result of the magnetic field affecting water molecules, they begin to move, with some moving more than others. The MRI machine detects this movement, and the information is relayed to a computer. The computer, equipped with image software, translates this data to produce three-dimensional images that doctors can analyze.

Project Components

- **Deep learning**

In recent years, deep learning has garnered significant attention across various domains, spanning decision-making, business, healthcare, marketing, and sales. Particularly in the medical field, both machine learning and deep learning have demonstrated promising outcomes in diverse applications, encompassing the diagnosis of illnesses through medical images, deployment of surgical robots, enhancement of hospital performance, and more [6].

One notable application involves utilizing deep learning to detect brain tumors from MRI scan images. The proposed methodology for constructing the classifier is outlined in the following steps:

i. Conduct Exploratory Data Analysis (EDA) on the brain tumor dataset.
ii. Develop a Convolutional Neural Network (CNN) model.
iii. Train and Evaluate the model on the dataset.

To commence the process, an initial step involves performing Exploratory Data Analysis (EDA). The brain tumor dataset comprises two folders, "no" and "yes," containing ninety-eight and one hundred fifty-five images, respectively. These folders are loaded into the current working directory, and utilizing the imutils module, the paths for all images are extracted and stored in a list named "image_paths."

The subsequent step involves iterating through each path, extracting the directory name (acting as a label, either "no" or "yes"), and resizing the images to 224 x 224 pixels. The cv2 module's read() function is employed to convert the brain tumor image into pixel information during this process.

- **CNN** [7, 8, 9]

Before delving into constructing the classifier architecture, let's gain an understanding of what a Convolutional Neural Network (CNN) entails. A CNN is a deep neural network widely employed for visual image analysis, particularly adept at tasks such as image classification, recognition, and segmentation. The CNN comprises two main components [8]: Convolution Layer for executing feature extraction tasks, and the final fully connected layer, utilizing the output from the convolution layer to predict the image's class.

To enhance the dataset and address small input data concerns, TensorFlow offers an Image Data Generator for data augmentation. Data expansion proves highly beneficial in situations with limited input data, employing diverse transformations to augment the dataset's size. Various transformations, including rotation, horizontal and vertical flips, and zoom, are provided. The use of fill_mode and rotation_range transforms ensures the filling of out-of-bounds pixels with the "closest" pixels and introduces a rotation of 15 degrees

- **Dataset**

Given the limited size of the dataset for brain tumor detection, training deep neural networks becomes challenging. To overcome this limitation, we leverage the capabilities of transfer learning to achieve optimal predictions. Transfer learning involves utilizing features from pre-trained models, eliminating the necessity to train an entirely new model from the ground up. In the Brain Tumor project, the VGG16 model, originally designed for cardiac condition analysis, is employed. Keras offers various pre-trained models, and the VGG16 model is illustrated below.

- **Tensorflow**

TensorFlow, a Python library, is employed for developing machine-learning models. Although machine learning itself is a complex undertaking, leveraging machine learning models has become more accessible and less challenging, thanks to frameworks like Google's TensorFlow. These frameworks streamline tasks such as data acquisition, model training, prediction generation, and refining future outcomes.

TensorFlow enables developers to construct data flow graphs, which delineate the flow of data through a graph structure or a sequence of processing nodes. Each node on the graph signifies a mathematical operation, while each link or edge connecting nodes represents a multidimensional data system or tensor.

- **Android Studio**

Android Studio functions as an integrated development platform (IDE) designed for Android app development. Built upon IntelliJ IDEA, a comprehensive Java software development platform, Android Studio seamlessly combines coding and developer tools. Facilitating app development within the Android operating system, it employs a Gradle-based build system, emulator, code templates, and GitHub integration.

Within Android Studio, each project encompasses one or more options containing source code and application files. These options encompass Android app modules, library modules, and modules within the Google App Engine, offering versatility in the development process.

Limitations of Existing System

These methods are mainly traditional methods to detect the tumor present in the brain. Also, an old method includes a human to verify whether the tumor is present in the brain or not. There is a high chance of human error involved in this process. Also, a patient needs to visit a doctor to know whether their MRI reports are normal or not. Proposed system will solve all of these problems.

Proposed System

Introduction: The algorithm comprises crucial techniques for image processing. The fundamental concept of the proposed algorithm revolves around a series of morphological operations, applied after passing through a high-pass filter, to obtain a clear image of the tumor. The quality and clarity of the tumor image are determined by this set of morphological operations. To implement the algorithm, a graphical user interface (GUI) will be developed using the Python Flask library, and the backend will be coded using Python. The chosen algorithm for this process is Convolutional Neural Network (CNN).

Architecture:

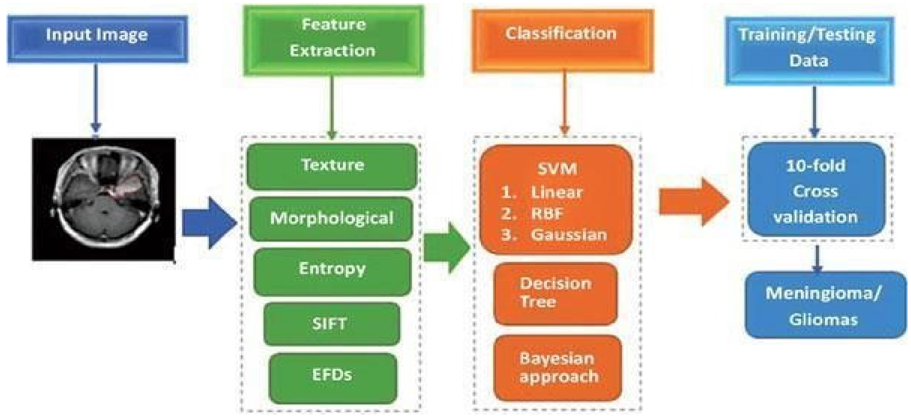


Fig. 2

The system's framework will operate on the Convolutional Neural Network (CNN) model. CNN, a category of deep neural networks, is widely employed for analyzing visual imagery. Contemporary models for various image-processing tasks, such as image classification, segmentation, and object detection, prominently feature convolutional neural networks. To venture into the realm of Image Processing or enhance the prediction accuracy of custom CNN models, familiarity with renowned CNN architectures is essential to stay competitive in this dynamic and demanding landscape.

Framework: In Android Studio, we employed tflite, a tool facilitating the conversion of a TensorFlow model into a tflite model suitable for use in Android Studio. Initially, in Android Studio, we designed a user interface using XML. Subsequently, we integrated the tflite model into Android Studio.

The functioning of the proposed system is designed to operate as follows: when a user uploads their MRI images within the application, it will determine and indicate whether a brain tumor is present or not.

Algorithm and Process Design:

1. User will see an android app.
2. There is an upload an image button.
3. User can click on that button.
4. From there, user can choose their MRI image.
5. System will show the result.

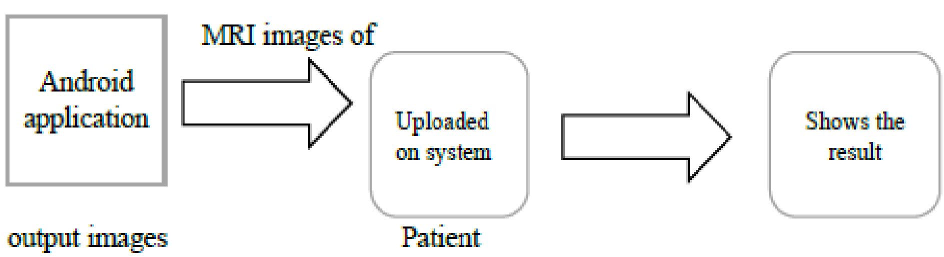


Fig. 3 [10]

Considered Design Constraints:

- User Interface Constraints: - The system is designed to be user-friendly, with a straightforward and easy-to-use interface. Individuals possessing basic computer operational skills should find it comprehensible, as it offers intuitive functionality.
- Hardware Constraints: - The system is expected to function smoothly on standard home desktops and laptops and has the potential for extension to mobile phone applications.
- Software Constraints: - The software is web-based, ensuring compatibility across various platforms.
- Communications Constraints: -The system's functionality relies on access to CT scan images for brain tumors.
- Data Management Constraints: -The system is engineered to interface with other components according to their specifications.
- Operational Constraints: The system exhibits versatility and is not confined to any particular operating system; it performs effectively on Windows, Mac, and other platforms.

Details of Hardware and Software

Hardware Requirement –

Processor: i3 processor Ram: 4 GB

Storage: 3 GB

Graphics: integrated graphic card

Software Requirement -

Software: python, java

Editor: VS code studio, android studio

Library: OpenCV, TensorFlow, os, tflite

Programming language used: Python, java

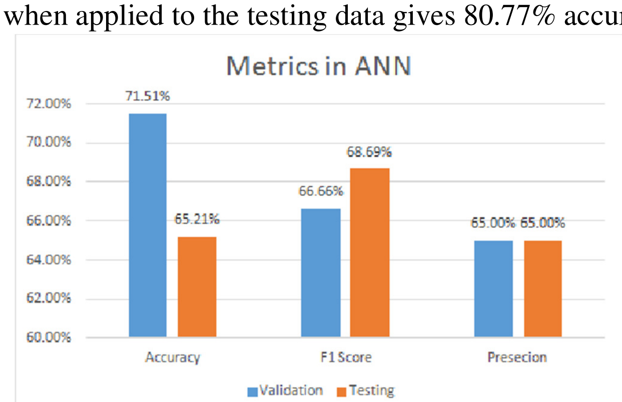
Experiment and Result for Validation and Verification

As we open our app we will see an interface in which we can there is having two buttons. The first button is to select an MRI image button. You need to click on that button. As you click on it you will be redirected to your gallery. From your gallery select your MRI image. After selecting click on predict button. After doing so you will see a text displaying whether a tumor is present or not.

This figure represents the accuracy and loss obtained when the ANN model is applied to the training and validation dataset When the ANN model is applied to the training

Data for fifty epochs training accuracy obtained is 97.13% and a validation accuracy of 71.51 %. The same when applied to the testing data gives 80.77% accuracy.

Fig. 4



Screenshots of Mobile Application:

Fig. 5

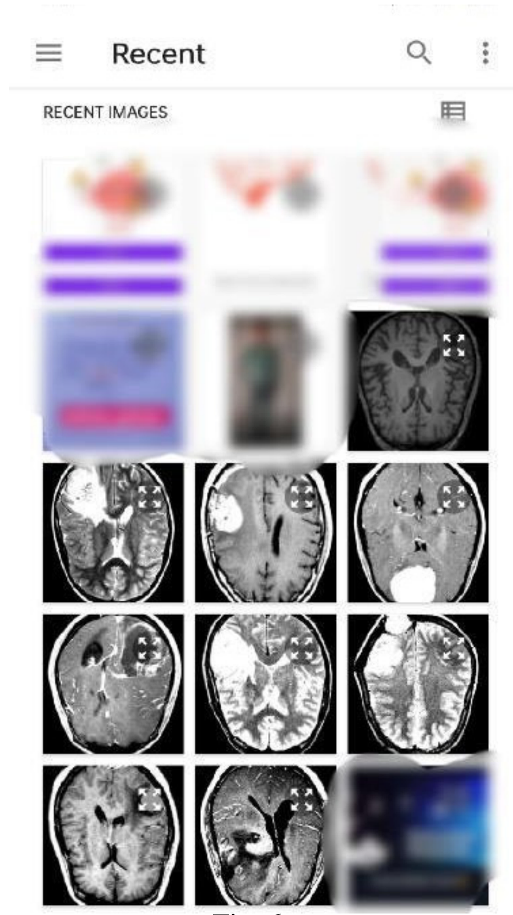


Fig. 6

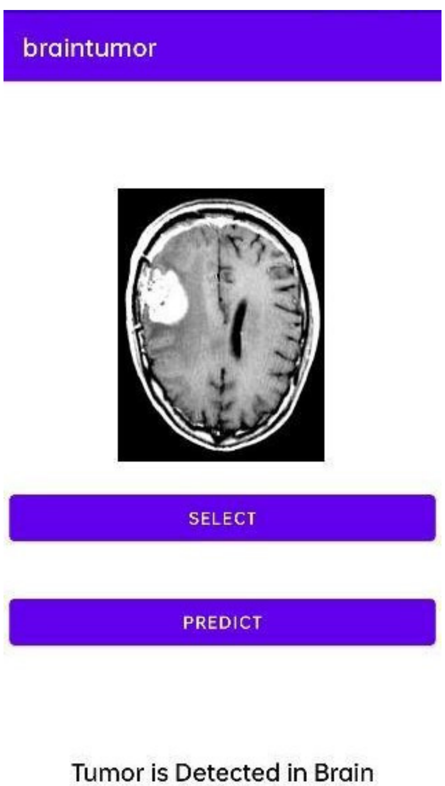


Fig. 7

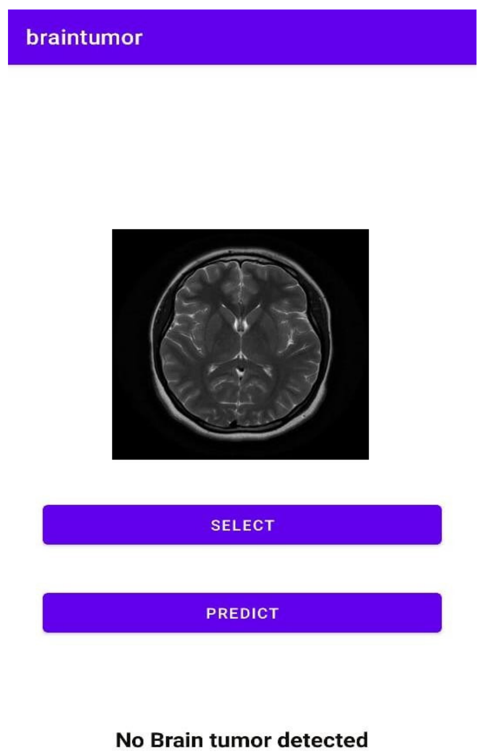
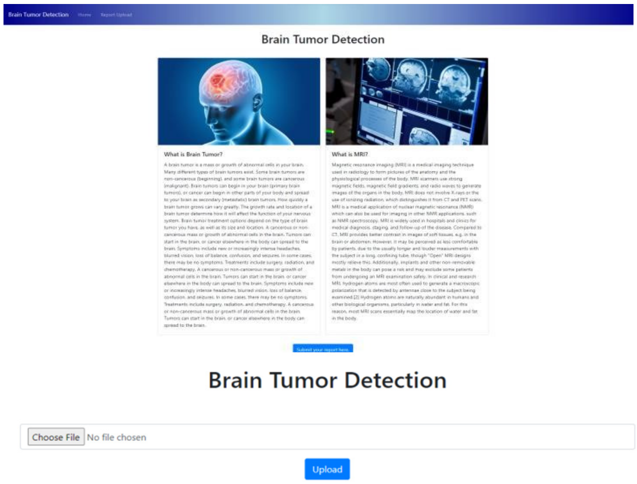
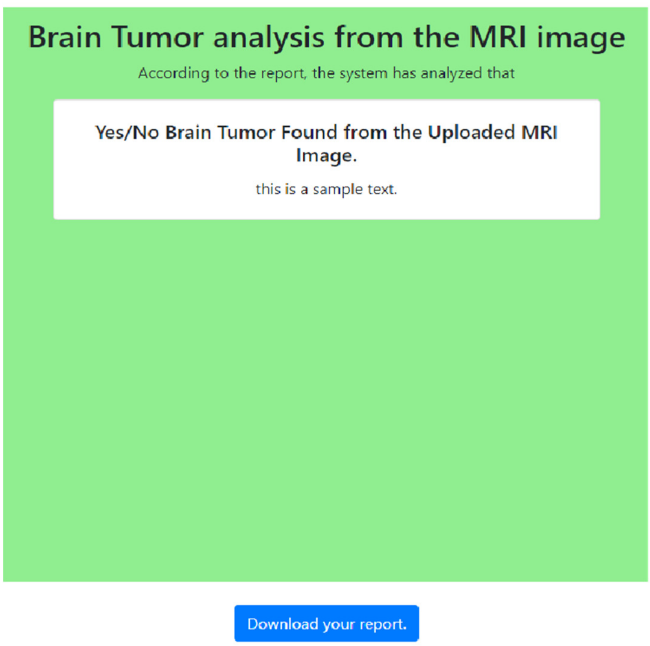
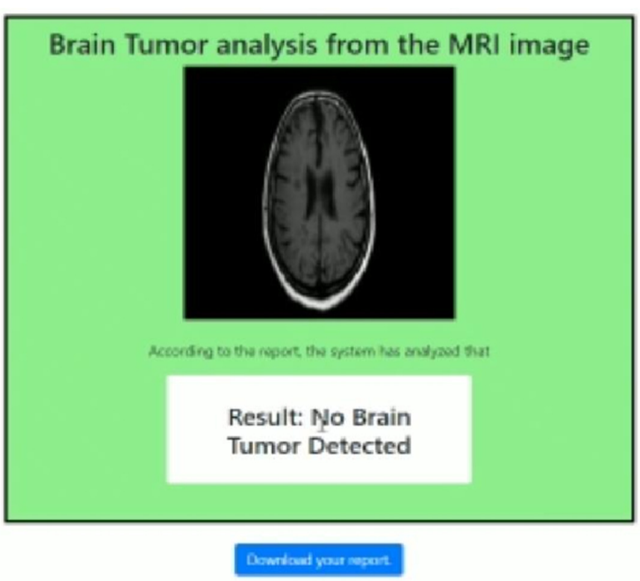


Fig. 8

Screenshots of Web Application: Fig. 9







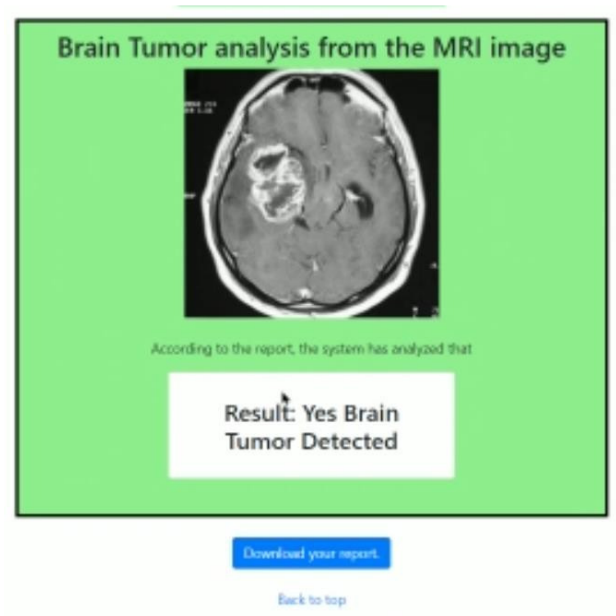


Fig. 10

Analysis

System requirements define what the system must achieve without specifying the method of accomplishment. The requirements presented in this document are both comprehensive and coherent. There are two user categories for this software:

1. Patients - Patients can utilize the software to visualize the size of the tumor, providing a straightforward understanding of its dimensions and location.
2. Doctors - Doctors employ the software for extracting tumors from MRI scan images of the brain and for visualizing the tumor.

Functional Requirements

- Selecting the MRI scan images of the brain.
- Extracting only tumor region from the scan images.
- Finding the boundary of the tumor.
- Creating a GUI for easy access to the program.

Non-Functional Requirements

- Availability- The software for the Extraction of brain tumors from MRI scan images can be available in all the systems that have MATLAB installed.
- Reliability- This software attempts to ensure appropriate content but assumes no responsibility for external manipulations.
- Performance- The CPU time of the proposed software varies from 4 seconds to 6 seconds and the PSNR value from 25db to 26db

Conclusion and Future Work

Conclusion

The mobile application and webpage effectively identify the presence or absence of tumors in sample MRI images. The accuracy of the sample dataset obtained from Keras reaches a level of 90%. However, challenges arise in this project, as non-MRI images may also erroneously indicate the presence of tumors due to the presence of additional pixel data resembling MRI samples. Despite this, the system remains highly effective in determining the presence or absence of tumors in the majority of the sample dataset, with very few instances showing errors.

Future Scope

Experimental findings indicate that the proposed method necessitates a substantial training dataset for enhanced accuracy in results. In the realm of medical image processing, acquiring medical data is a challenging endeavor, and there are instances where datasets might be unavailable. In such scenarios, the proposed method must exhibit sufficient reliability to enable accurate identification of tumor areas in MRI scans. An additional enhancement to the suggested method could involve amalgamating weakly trained algorithms capable of detecting irregularities with minimal training data, coupled with self-learning algorithms. This integration aims to augment algorithm accuracy and reduce computation time.

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