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Abnormal Brain Tissue Isolation Using Image Segmentation Methods

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Abstract

This paper describes a hybrid segmentation method for segmenting and isolating abnormal brain tissues or tumors in magnetic resonance imaging (MRI) images. A brain tumor refers to an abnormal proliferation of cells originating from brain tissue or surrounding structures. Nearby locations include the nerves, the pituitary gland, the pineal gland, and the membranes that cover the brain's surface. Brain tumor segmentation is a medical image analysis task involving separating brain tumors from normal brain tissue in MRI scans. Image segmentation methods are essential for accurately isolating abnormal brain tissue from MRI scans, enabling medical professionals and researchers to analyze and diagnose various neurological conditions. Different segmentation techniques were employed to segment and isolate the abnormal tissue in the brain. Thresholding methods were utilized to isolate the region of interest (ROI) using various threshold values (T). After experimenting with different values for the threshold, some values were chosen to be presented in this work as a sample of the method's performance. The K-Means method yields varied segmentation outcomes depending on the parameter settings and the number of clusters (K). Only samples (K=6) are presented in this work. A hybrid segmentation method is proposed, combining thresholding and K-Means to produce a novel segmentation approach. The proposed method yields very good results, albeit with some unwanted regions. In the final step, an opening morphological operation was applied to refine the segmentation and enhance the clarity of the identified regions.

Keyword: Segmentation techniques, Medical image processing, Brain tumor, Thresholding method.

عزل أنسجة الدماغ غير الطبيعية باستخدام طرق تجزئة الصور

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يصف هذا البحث طريقة تجزئة هجينة لتجزئة وعزل أنسجة الدماغ أو الأورام غير الطبيعية من صور بالرنين المغناطيسي (MRI). يشير ورم الدماغ إلى تكاثر غير طبيعي للخلايا ينشأ من أنسجة الدماغ أو البنى المحيطة بها. تشمل المواقع القريبة الأعصاب والغدة النخامية والغدة الصنوبرية والأغشية التي تغطي سطح الدماغ. تجزئة ورم الدماغ هي عملية مهمة لتجزئة وتحليل الصور الطبية التي تنطوي على فصل أورام الدماغ عن أنسجة الدماغ الطبيعية في فحوصات التصوير بالرنين المغناطيسي. تُعد طرق تجزئة الصور أساسية لعزل أنسجة الدماغ غير الطبيعية بدقة من صور الرنين المغناطيسي، مما يُمكن المتخصصين الطبيين والباحثين من تحليل وتشخيص مختلف الحالات العصبية. استُخدمت تقنيات تجزئة مختلفة لتجزئة وعزل الأنسجة غير الطبيعية في الدماغ. استُخدمت طرق تحديد العتبات لعزل منطقة العمل (ROI) باستخدام قيم عتبة مختلفة (T). بعد تجربة قيم مختلفة للعتبة، تم اختيار بعض القيم لعرضها في هذا العمل كعينة على أداء الطريقة. تُعطي طريقة K-Means نتائج تجزئة متفاوتة تبعاً لإعدادات المعلمات وعدد العناقيد (K). يُعرض في هذا العمل عينات فقط (K=6). يُقترح أسلوب التجزئة هجين يجمع بين طريقتي العتبة و K-Means لإنتاج نهج تجزئة جديد. تُعطي الطريقة المقترحة نتائج ممتازة، وإن كانت تتضمن بعض المناطق غير المرغوب فيها. في الخطوة الأخيرة، طُبقت عملية مورفولوجية افتتاحية لتحسين التجزئة وزيادة وضوح المناطق المجزئة.

Introduction

Brain tumor imaging analysis aims to extract essential clinical data and diagnostic features relevant to each case. Once the disease has been identified and localized, the information in the multidimensional picture data can help direct and track treatments, ultimately providing the understanding required for clinical diagnosis, staging, and treatment of the illness [1]. The imaging analysis process can be structured in sequential stages, each requiring specific techniques for effective data processing. Each step of the pyramid necessitates a unique technique for processing, extracting, labeling, and representing information. Furthermore, the information must be represented at a high level of abstraction to obtain relevant clinical knowledge or datasets for medical diagnosis and decision-making. A high-performance computing infrastructure, including fast processors, storage, a network, an image display unit, and software, is required to properly manage, process, view, and analyze obtained datasets. The creation and application of related procedures require a thorough understanding of the underlying issues and familiarity with the type of data obtained, the study's objectives, its scientific or medical significance, and other relevant factors. Segmenting images involves identifying and extracting relevant information and properties from various multidimensional image types. The primary goal of picture segmentation is to divide a picture into mutually exclusive sections, each of which must be spatially contiguous and have homogeneous pixels relative to a predetermined standard. Brain tumor segmentation is a crucial task in medical imaging, aiming to delineate tumor regions within brain scans accurately.

Many segmentation techniques face significant limitations due to the inherent complexity of brain tumor structures, particularly when it comes to identifying and classifying "abnormal tissue types," as Tumors necessitate segmentation because they are complex anatomical structures with non-rigid shapes. Fluctuate significantly in size and location, and exhibit high patient variability. When it comes to brain tumors, segmentation entails separating the various tumor tissues (edema, necrosis, and solid or active tumors) from the normal brain tissues (gray matter (GM), white matter (WM), and cerebrospinal fluid (CSF)). Most of the time, aberrant tissues in brain tumor investigations may be identifiable. However, it is not easy to segregate and characterize anomalies in a repeatable and precise manner. The ease of use and computational efficiency of segmentation techniques significantly influence their clinical acceptance [2]. The segmentation of tumor brain using image processing techniques has many benifites; the early detection and diagnosis is enabling the tumor braies identification; its also use in treatment planning surgical procedures, radiation therapy, and other treatment by

providing detailed of tumor size, location, and extent; segmentation process as well as help to monitoring disease progression, where the segmentation of regular tumor growth allows healthcare professional to know the tumor volume or shrinking over time, aiding in assessing treatment effectiveness and making necessary adjustment.

Related Work

Numerous researchers have explored methods to achieve better segmentation results. The quest for improved image segmentation has captured the attention of numerous researchers, resulting in a surge of innovative techniques. For instance, according to a study [3], neural networks are harnessed for the intricate segmentation task by leveraging local and global features. The approach is enhanced by incorporating a powerful CNN feature known as max pooling, which boosts the results. Researchers took a creative approach in a different investigation by defining the tumor boundaries more clearly, which improves the accuracy of tumor region identification. Meanwhile, in the study [4], a combination of K-means and Self-Organizing Maps (SOM) is highlighted for its effectiveness, where SOM adeptly pinpoints scattered pixels and K-means hones in on the firm clustering values, showcasing yet another layer of sophistication in the image segmentation tapestry.

In another study [5], effective segmentation unfolds through a meticulously crafted series of steps. Imagine combining K-means clustering with Fuzzy C-means (FCM) clusters! This synergy does not stop there; the resulting cluster undergoes further refinement with morphological operations, culminating in precisely thresholding those pesky tumor pixels. Exploring further, another study delves into the fascinating world of medical imaging [6], discussing various modalities, including MRI and CT scans. These modalities are not static; they can be segmented and classified. Here, traditional image processing techniques juxtapose with soft computing methods, sparking intriguing comparisons. Finally, in yet another research revelation, image segmentation takes the form of K-means clustering, which is aided by analyzing HOG features in conjunction with an SVM classifier to detect brain images. An intriguing scenario unfolds when brain MRIs are expertly preprocessed before being segmented using K-means—showcasing the blend of innovation and technology in medical imaging [7].

In a study [8], an intriguing fusion of K-means clustering with morphological operations has emerged. This combination produces more accurate segmentation of tumor regions, highlighting important features for analysis, unveiling the inner workings of these complex structures.

Moving to study [9], a novel segmentation method intertwines K-means Fuzzy C-means (KFCM) with Histogram Color Space Distribution (HCSD). Here, KFCM effectively segments tumor pixels and distinguishes them from adjacent non-tumorous pixels, whereas HCSD focuses on delineating the tumor pixel clusters. Such clever combinations reveal the intricate dynamics in identifying and classifying tumor cells [10]. In another fascinating exploration [11], researchers delve into the extraction of tumorous pixels, meticulously detecting them to ensure precise identification of tumor cell types in MRI images. Their methodology assesses the algorithm's performance using a comprehensive set of twenty relevant metrics. The fuzzy cluster values are juxtaposed with verified ground truth images, utilizing these twenty parameters to depict the results [12] comprehensively. Following this line of inquiry, three distinct approaches—hybrid techniques, learning-based methods, and atlas-based strategies have been employed for tumor pixel segmentation, with metrics such as the Dice and Jaccard serving as benchmarks for assessment [13,14]. Based on the results of previous studies and a review of the literature, a hybrid segmentation method is proposed in this work, which combines two segmentation methods that yield good results with less effort.

Tumor of the Brain

Abnormal brain tissue, or a tumor, is characterized by uncontrolled cell proliferation within the brain. In the brain. The brain's architecture is extraordinarily intricate, with multiple areas coordinating numerous nervous system operations. Any part of the skull, including the brainstem, sinuses, nasal cavity, base of the skull, and protective lining, can develop brain tumors. There are over 120 distinct types of brain tumors, classified based on the specific tissue from which they originate [15, 16].

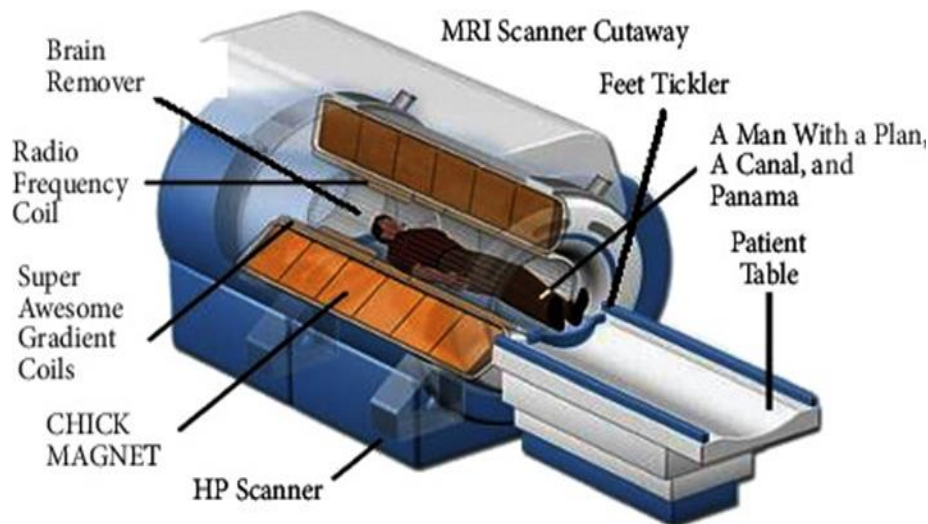


Figure 1: Architecture of an MRI machine.

Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) utilizes strong magnetic fields and radiofrequency energy to generate detailed images of the body's internal structures. Nuclear Magnetic Resonance (NMR) is the fluctuating magnetic field within the patient that causes the atoms to resonate. The human body is primarily composed of water (H_2O), which is significant for MRI due to its high hydrogen content, which is made up of one oxygen atom and two hydrogen atoms (H_2). Protons, or the nuclei of hydrogen, then align with a magnetic field of 0.2–3 Tesla. Since the atoms consist of protons, they absorb various quantities of energy from the varied fields provided by the scanner. The MRI machine generates a strong magnetic field, which causes the nuclei of hydrogen atoms to resonate. Precession is when they gradually revert to their regular spin after flipping spins when the field is switched off. An image is produced when the energy return generates a radio frequency that the scanner's receiver measures [17]. Using the scanner's settings, which create a contrast that enables tissue discrimination, the protons in various bodily parts will return to their usual spin at variable rates, allowing the scanner to distinguish between distinct tissues. MRI is a diagnostic tool that creates images of internal organs by detecting the signals emitted from hydrogen nuclei when they are subjected to a magnetic field and radiofrequency pulses (Figure 1[18]).

Methodology

In this work, two brain MRI images from Iraqi patients at Al-Emam Ali Hospital were used. Several image processing techniques were applied to segment the two images and extract the tumor region. Thresholding segmentation techniques with different threshold values were employed to segment the affected area; however, due to the difficulty in

distinguishing between the affected tissue and the normal region, this method was unsuccessful in isolating the ROI. K-Means techniques were also applied to ROI segmentation, using different numbers of clusters to achieve the desired goal. The best results for this technique are presented. To obtain more accurate results, a hybrid segmentation method combining thresholding and K-Means was applied. As a final processing step, a morphological operation was applied to obtain the ROI region accurately. In this section, the image processing methods used in this work will be briefly explained.

Approach

The segmentation and analysis of brain tumors using MR imaging are achieved through two primary methods. Generally, the segmentation procedure divides the image into distinct areas based on the properties of the pixels. Manual segmentation separates tumor tissues from normal tissues in MRI brain images. Brain tissue segmentation is crucial to identifying and treating brain disorders. This process is challenging due to factors such as noise, partial volume effects, intensity inhomogeneity, and the complex anatomical structure of the brain [19]. The following sections describe some of the segmentation methods employed in this study.

Thresholding

Thresholding is a straightforward shape extraction method that distinguishes foreground objects from the background based on pixel intensity. Assuming that brightness determines the shape to be extracted, an image thresholded at that brightness level will reveal the desired shape. Thresholding is sensitive to illumination variations; changes in lighting can affect the perceived brightness of the target shape [20]. For any thresholding technique to be effective, it must be able to adjust to changes in brightness levels. Simple thresholding is computationally efficient, making it an attractive option for many applications. An image can be produced using histogram equalization if the illumination level changes linearly [21]. Something is constant. However, noise can significantly impact the results of histogram equalization. Shadows and uneven lighting: noise can significantly impact the final image [22]. Consequently, this can undermine the effectiveness of thresholding techniques. If the total brightness cannot be managed, then threshold edge magnitude data can be used because this is unaffected by the overall brightness level due to the implicit differencing mechanism. Still, spaces may be found within a shape's observed perimeter and edge data that are not continuously available. The K-means image processing technique divides an image into several clusters based on the similarity of pixel values. The shapes must be separated if stacked on top, as one will occlude the other [23].

K-means

Based on the similarity of pixel values, an image can be divided into several clusters using the K-means image processing technique. The K-means technique divides the image into K clusters, where K is a user-defined parameter representing the desired number of clusters. Subsequently, the algorithm determines the mean value for each cluster by iteratively assigning each pixel to the cluster with the closest mean value [24]. This method continues until convergence, at which point K clusters with comparable pixel values are produced. This segmentation can be helpful for applications such as feature extraction, object recognition, and image compression. Color quantization is another application of K-means image processing, which reduces an image's color palette while preserving its overall aesthetic appeal. Minimal quality loss helps reduce file size and increase transmission efficiency. K-means is an effective method for analyzing and modifying images based on pixel values, making it applicable to various computer vision tasks [25].

Morphological operation

"morphology" refers to an object's form, structure, or the configurations and connections between its constituent pieces. Shape and morphology are closely related, and the morphology of digital items serves as a means to characterize or examine their shape, typically in a raster-based format. Digital or mathematical morphology is a relatively young field of study, as digital computers have made it feasible in recent years. Conversely, underlying mathematics is only set theory, a thoroughly researched region. Digital morphology is based on the concept that images are composed of pixels that form clusters into two-dimensional shapes. Mathematical operations can be applied to pixels to enhance specific properties of shapes, such as their ability to be counted or identified. The fundamental processes include erosion, which removes specified patterns from the image, and dilation, which adds pixels to the boundaries of shapes [26].

Opening morphology

An opening operation uses erosion immediately, followed by a dilatation image using the same structural element. Opening is a descriptive term that refers to the realization that the procedure tends to "open up" the tiny spaces or gaps between interacting elements in a picture. It is easiest to see this impact when the essential organizing element is used: a group of little objects is displayed, and some are putting their hands together. Following a simple opening, the items were improved. Isolated and may now be categorized or counted. The opening operation eliminates noise; some noise pixels in a grayscale image with thresholded noise are above the threshold, resulting in isolated pixels scattered randomly throughout the image. Isolated pixels will be eliminated in an opening by the erosion stage, in addition to borders of objects, with the majority of the boundary being restored by the dilation stage. Pixels while keeping the noise intact. This procedure eliminates erroneous black pixels without eliminating the white ones [27].

Results

Various image segmentation methods were employed to isolate abnormal brain tissues from normal tissues in two MRI images. Two MRI images were obtained from AL-Emam Ali Hospital in 2023, representing cases of brain tumors in two women aged forty. The following diagram represents the processing steps.

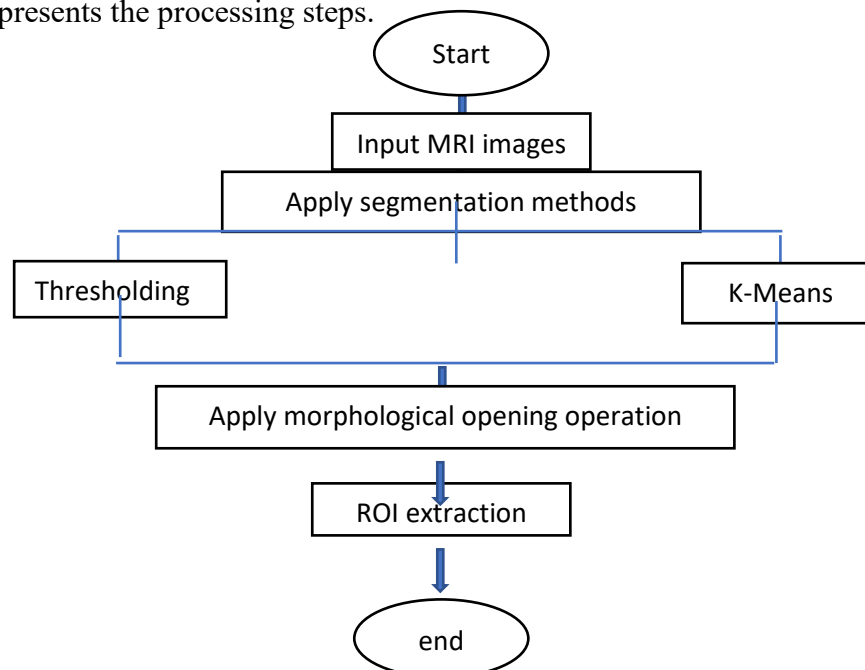


Figure 2: Illustrates the flowchart of work.

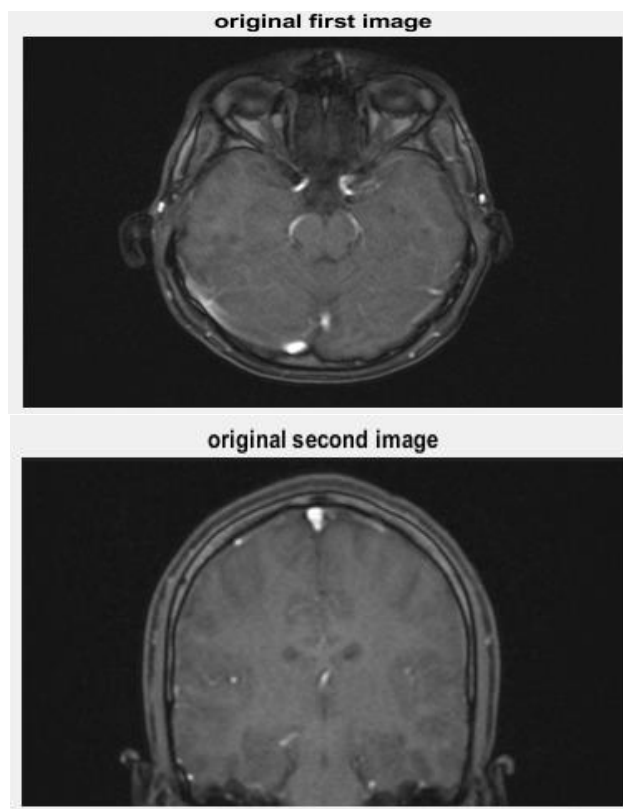


Figure 3: The original MRI brain images used in this work.

Thresholding method

Various threshold values were tested experimentally, with selected samples presented in this study. The results of the thresholding segmentation method with varying values ($T = 50$, 150, and 200) are shown in Figures 4 and 5.

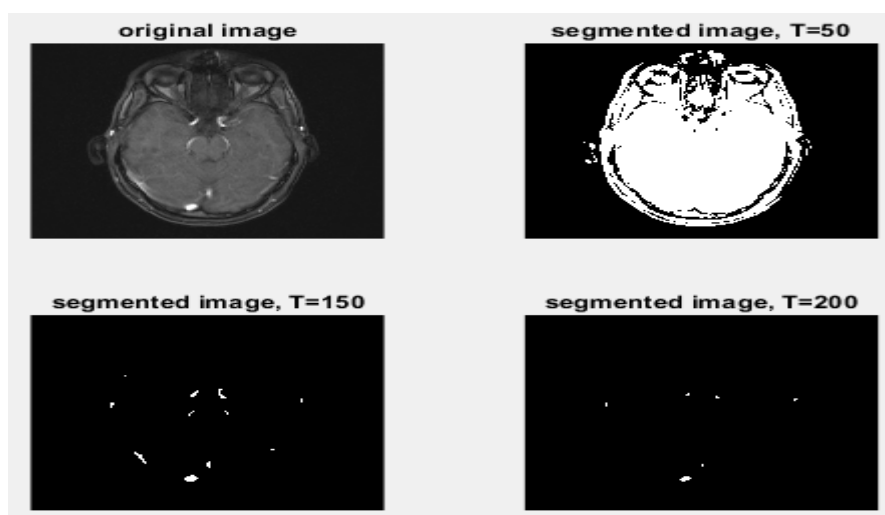


Figure 4: The results of using the thresholding segmentation method with various values of T on the first MRI image.

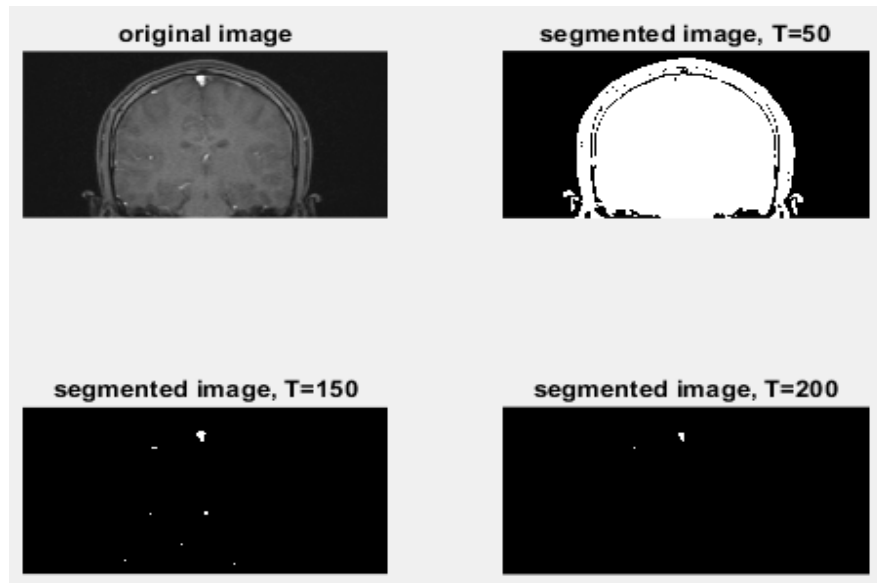


Figure 5: The results of using the thresholding segmentation method with various values of T on the second MRI image.

Figures 4 and 5 display the results of the thresholding segmentation technique with different threshold values (T). The results varied with the threshold values, and T=50 yielded ineffective outcomes. There were no features of brain tissue. Using T=150 and T=200 produced satisfactory results, effectively isolating the abnormal tissue from the surrounding areas. Using T=150 and T=200 produced satisfactory results, effectively isolating the abnormal tissue from the surrounding areas. However, other unwanted features appear.

K-Means method

When applying the K-Means method, various numbers of clusters were used experimentally, with selected results presented in this study. The K-Means segmentation method was applied to the brain image using six clusters (K=6), successfully identifying and separating the abnormal region from normal tissues, as shown in the figures.

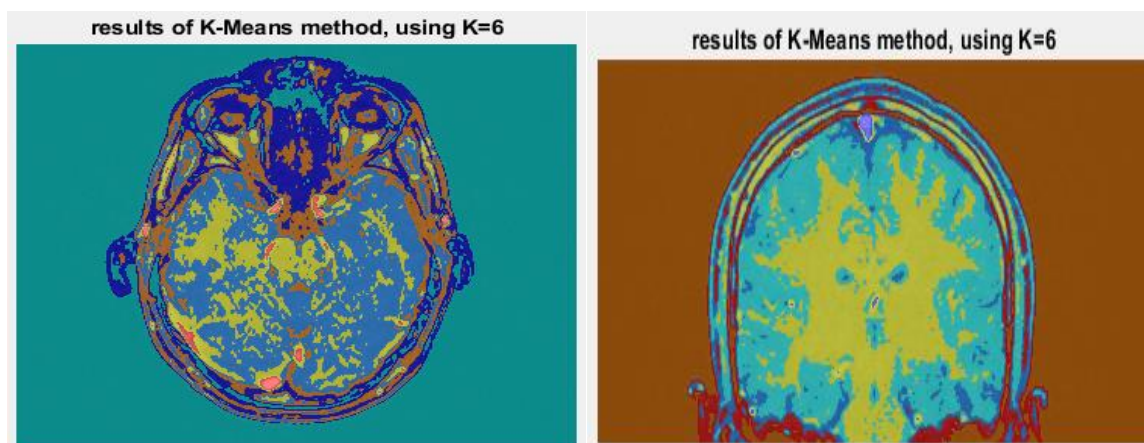


Figure 6: The results of using the K-Means segmentation method using six clusters (K=6) applied on MRI images.

The hybrid segmentation method combined thresholding ($T=$) and K-Means ($K=6$) methods. The results of hybrid methods are presented in Figure (7).

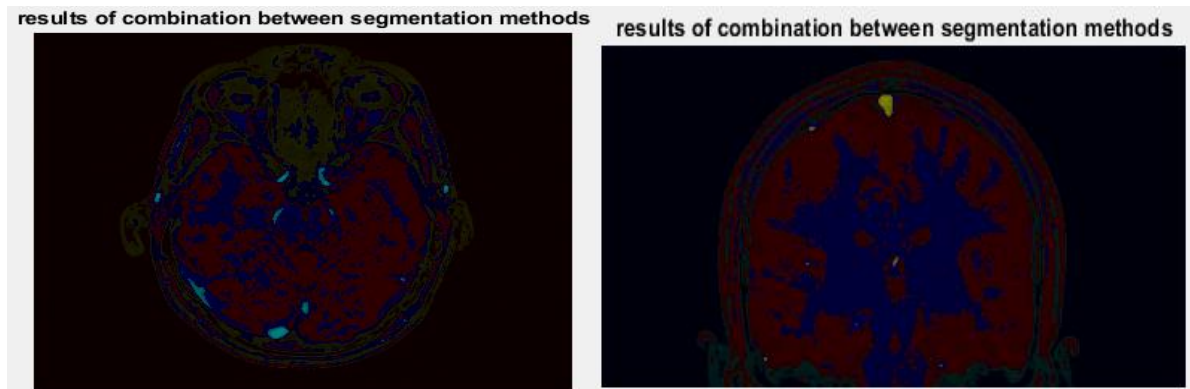


Figure 7: The results of hybrid segmentation on MRI images are shown.

The result of the hybrid segmentation method, as illustrated in the previous figures, shows that the area of abnormal tissue is isolated from the surrounding normal tissue. The hybrid technique successfully identified the ROI accurately. However, the ROI was not only deducted from the results of applying different segmentation techniques, but also from all the results. Even with practical methods for isolating the affected region, the tumor area was not exclusively identified; the results also included regions of healthy tissue.

Morphological operation

To overcome the unwanted features that appeared in the segmented images resulting from using the thresholding segmentation method (when using $T=150$) and segmented K-mean images ($k=6$), an opening morphological operation was applied

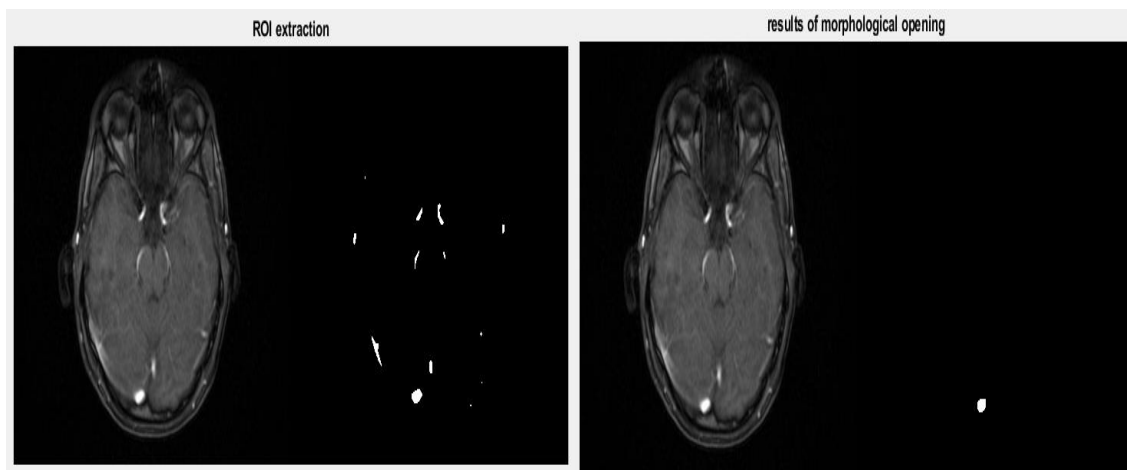


Figure 8: The segmented ROI by thresholding method ($T=150$) and results of using an open morphological process on the first MRI image.

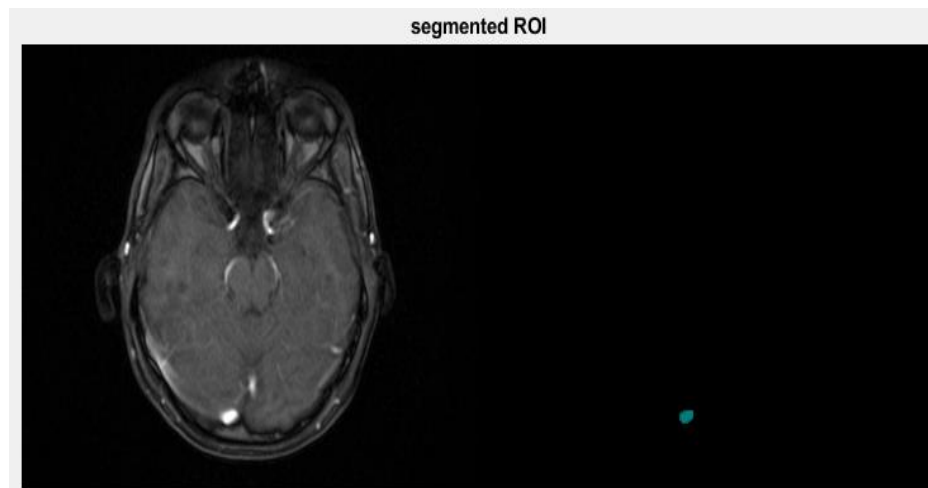


Figure 9: The segmented ROI of the First MRI brain image.

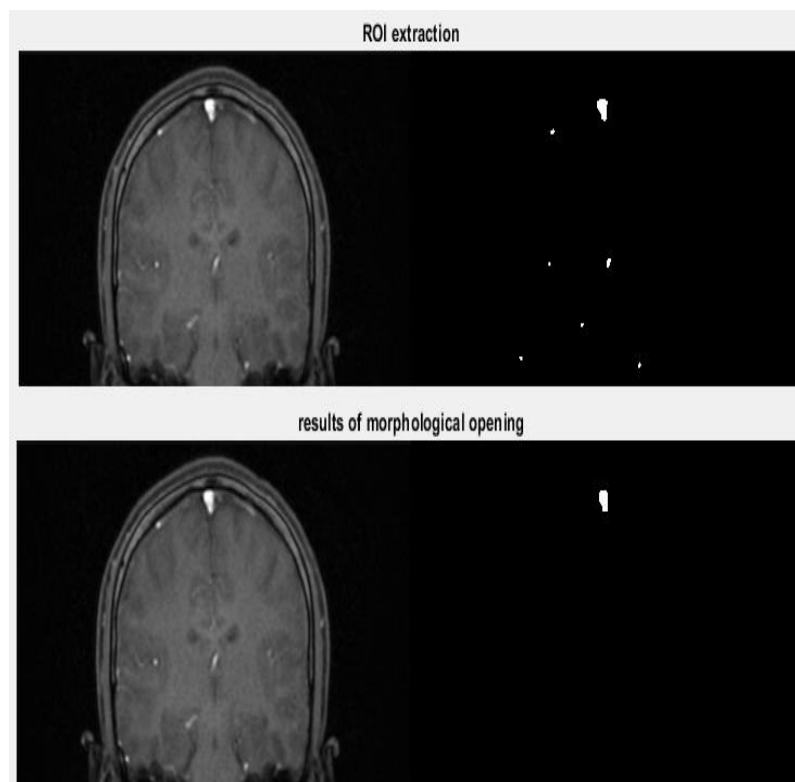


Figure 10: The segmented ROI by thresholding method ($T=150$) and results of using an open morphological process on the second MRI image.

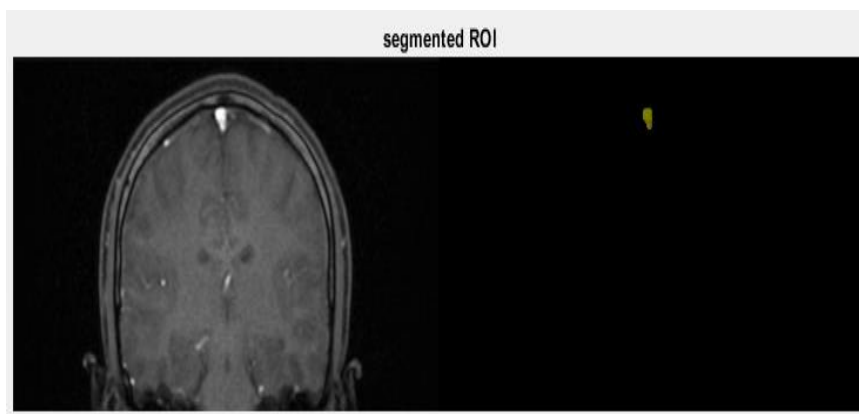


Figure 11: The segmented ROI of the second MRI brain image.

Figures (12 and 13): A comparison of the results obtained from the segmentation techniques used in this work.

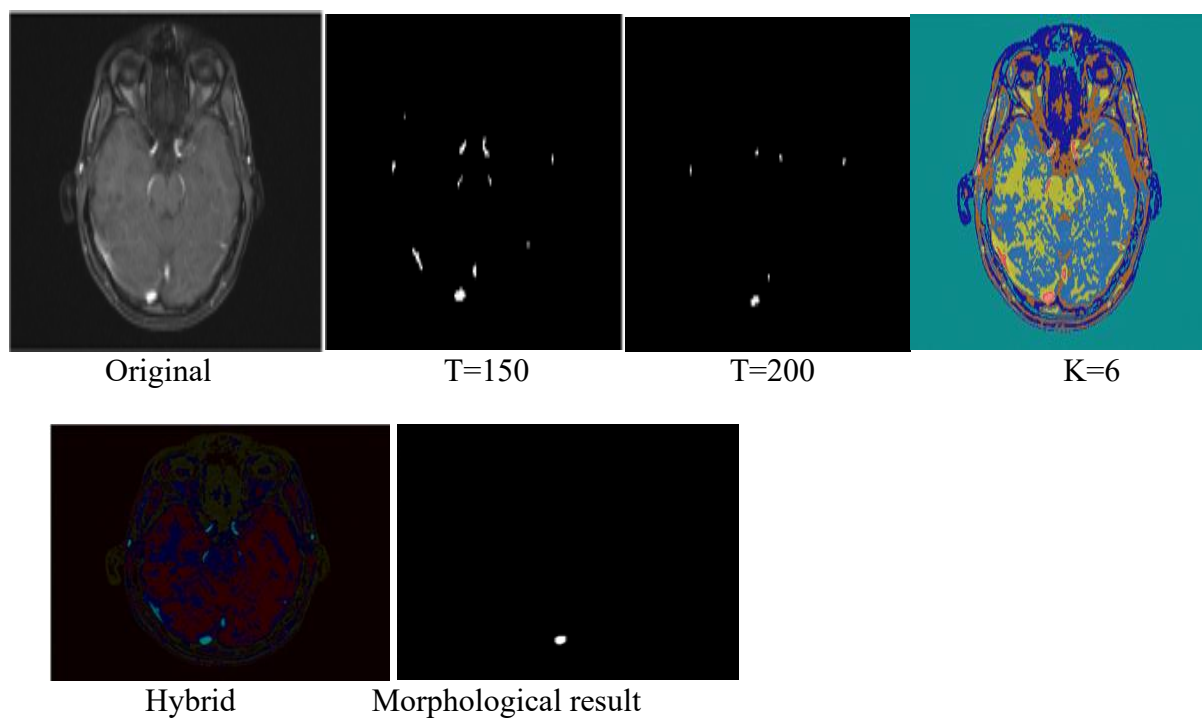


Figure 12: The comparison between the results of segmentation methods applied to the first MRI image.

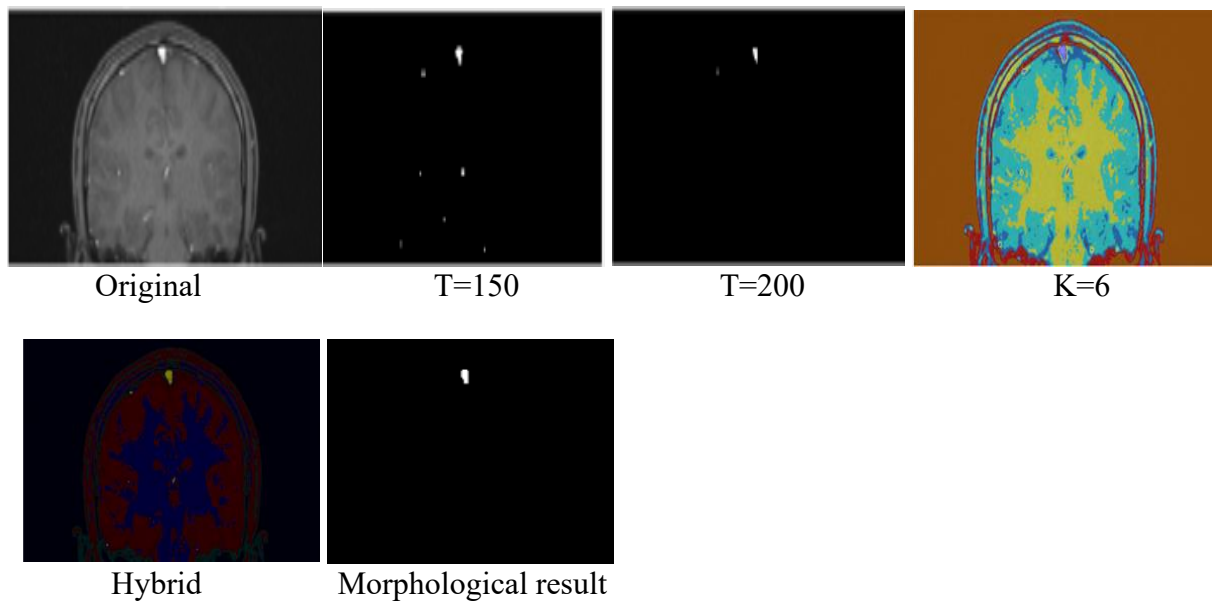


Figure 13: The comparison between the results of segmentation methods applied to the second MRI image.

Conclusion

Several segmentation techniques were employed in this work to detect and segment the abnormal region of the brain (ROI), yielding a range of quantitative results. The threshold segmentation method yielded results that closely aligned with the study's objective of accurately identifying abnormal regions, with acceptable results obtained using threshold values of $T = 150$ and 200 . These results identified abnormal brain tissues, although some normal regions were included in the ROI classification. After applying the K-Means technique with six clusters ($K = 6$), the results were satisfactory, demonstrating an accuracy rate of 75%. Then, the last two segmentation techniques were combined to create a hybrid segmentation method. Results of applying the proposed method to segment MRI images and isolate the tumor in the brain showed promising results, with the ROI clearly delineated, although some extraneous regions remained. Finally, the opening morphology method was employed to eliminate artifacts and clarify the ROI, and obtain the ROI with high accuracy. The results were evaluated by a specialist, who provided feedback supporting the efficacy of the proposed method in identifying and isolating the tumor area.

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