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Optimization of Image Analysis Algorithm for the Diagnosis of Brain Tumors

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Abstract: Image analysis is the best diagnostics tool for carcinoma cell diagnosis. Symptomatic clinical correlation with pathological findings amalgamated with Image analysis is the best way to diagnose cancerous cells and their nature. The worldwide brain tumor recorded cases have risen in recent years which is a huge challenge for clinicians to detect the tumor in the early stage of development. Though, plenty of research has been conducted on brain MR image segmentation and features extraction, but the existing approaches comprise certain limitations. These approaches are not restricted to massive time consumption, the lower rate of accuracy along with the more computational cost is also challenging for current scenario. In this research, a novel and optimized image analysis algorithm for the diagnosis of brain tumors has been presented. This optimized image analysis algorithm is rooted in the combined artificial neural network (ANN) as well as particle swarm optimization (PSO) approach. The obtained results have been recorded enhanced in terms of accuracy as well as sensitivity in comparison to the existing brain tumor detection methods. Using the combined approach i.e., ANN and PSO methods, the accuracy, sensitivity as well as recorded time was optimal. The proposed optimized image analysis algorithm takes very less time in operation i.e., only 0.8 seconds which is minimal in comparison with earlier methods. The measured accuracy and sensitivity for the proposed optimized image analysis algorithm on white matter (WM), gray matter (GM), and tumor MR images are found 98%, 97%, and 99% as well as 97.5%, 98.4%, and 99.22%, respectively.

Keywords: *Artificial Neural Network (ANN), Carcinoma, Diagnostics, MR Images, Particle Swarm Optimization (PSO), Segmentation, Tumor.*

1. Introduction

Brain tumor analysis is a very critical procedure as well as demands high skill, huge care, and attention from clinicians. Brain tumor has been categorized in the highly dangerous illness category by the world health organization (WHO). Worldwide clinicians face many issues in manual diagnosis procedures such as more time in screening and the complexity to identify tumors in the developing stage. Brain tumors have been categorized in various stages for providing the required diagnosis to the patients. These tumors may be categorized into various stages from 0 to IV. Stage 0 means that atypical cells are existing, but do not spread to nearby tissues which are referred to as cancer *in situ* and it can become a reason for carcinoma development further. Stage I to III shows that carcinoma is present. Further, Stage IV depicts that the carcinoma has been spread in other parts of the body, particularly distant organs. The medical MR image analysis in computer-based diagnosis tools requires the separation of the tumor as well as non-tumor images in the initial step [1].

Because of the ambiguous characteristics of the medical images, the effective classification of the tumor, as well as non-tumor images, is very challenging to categorize. In this current modern era, brain tumor cases are increasing globally which produces a huge amount of images every day. At present, magnetic resonance imaging (MRI) is one of the advanced and widely accepted non-invasive clinical screening procedures. This is used to obtain brain images to identify any kind of transformation in the brain cells of the patients due to abnormal tissues. The MR images help clinicians for identifying the detected tumor in the images or no tumor images in the real-time diagnosis process of patients. As the human mind does have a convoluted architecture, correct brain segments are critical for recognizing tumors, ascites, dead cells,

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white matter (WM), as well as gray matter (GM), to give appropriate therapy [2]. Since most brain architectures have been characterized by the borders of various tissue classifications, a strategy to divide cells into different groups is indeed a crucial milestone in the statistical morphogenesis of the brain. Brain tumor effectiveness, as well as early diagnosis, has become a gigantic problem at present, owing to multifarious reasons namely the complicated structure of the human brain, as well as its shape and dimensions. Various tools and approaches are being employed by clinicians for effective screening of patients to determine the stage of the tumor categorized from Stage 0 to IV. These days brain tumor image analysis is becoming more interesting for research owing to the technological advancement in the area of clinical image processing. As per a recent study conducted by the National Brain Tumor Foundation (NBTF), brain tumor-identified cases have increased globally at a rapid pace which is a mammoth concern for oncologist [3].

Though various researchers have developed various frameworks and algorithms for effective and faster segmentation and feature extraction from brain MR images. However, due to the rapid increment in brain tumor cases globally, there is an urgent need to develop new frameworks and algorithms to overcome the issues related with false positive and false negative cases. According to the WHO as well as the NBTF survey [4] brain tumor has been classified in the highly dangerous disease category. Therefore, more advanced and less time taking clinical tools are to be required for the effective diagnosis operation of the patients. The main objective of the proposed research is to develop an optimized image analysis algorithm for the effective as well as highly accurate diagnosis of brain tumors in minimal effort and time. The proposed algorithm is based on the joint ANN as well as PSO algorithm which provides more optimal and desired outcomes in comparison to the conventional methods.

2. Literature Review

C. E. Zimmerman *et al.* discussed the skull MRI segmentation strategy in their research. Numerous neurological disorders, as well as ailments, need quantitative assessment of skull MRI, which depends on the correct fragmentation of tissues of concern. Because of their capacity to self-learning as well as generalize over huge volumes of datasets, deep learning and deep-rooted categorization techniques for skull MRI are in trend and acquiring popularity. Deep learning structures are increasingly outperforming prior novel conventional machine learning models whenever they develop. This research paper seeks to offer an outline of contemporary deep learning and deep-rooted brain MRI categorization algorithms. To start the proposed research, we'll go through the existing deep training frameworks for segmenting anatomical mind regions as well as diseases. The results speed, as well as attributes of deep learning algorithms, are then presented as well as reviewed. This paper provides a critical evaluation of the existing situation as well as predictions for upcoming changes as well as trends [5].

H. Sajedi *et al.* discussed research on brain MR imaging techniques in their paper. The human-aged forecast is a fascinating as well as a useful topic in a variety of professions. It may be dependent on a variety of factors, including a person's face, DNA methylation, breastplates radiography, knee radiographs, teeth images, and so forth. The majority of maturity assessment studies have relied heavily on photographs. Because image processing, as well as machine learning technologies, have advanced, researchers were begun to apply methods to age assessment problems. The algorithms may be employed across a variety of sectors, particularly medicinal prescription. Brain Aged Estimation (BAE) had gotten a lot of press throughout recent times because it might be extremely useful towards the early detection of neurological disorders including Alzheimer etc. To calculate the generations of the head, BAE is usually applied to MRI scans. There is indeed a link between faster aging as well as increased brain shrinkage, according to investigations predicated on skull MRI [6].

I. Oksuz *et al.* discussed another technique for brain MRI scans. The greatest widely utilized diagnostic neuroimaging modalities for detecting neurological illness is skull MRI. The ability to construct strong image processing methods for downstream activities such as classification is dependent on the reliability of the diagnostic images. Another of the most common issues in medical practice is the existence of image distortions that can result in poor diagnostic image clarity. In this study, researchers suggest employing deep CNN to identify motion-related

head MRI aberrations as well as a remnant U-net structure to repair them. Utilizing an MR-rooted corruption technique, researchers first create synthesized artifacts. Secondly, to identify artifacts, researchers employ a detecting technique centered on a CNN model [7].

Z. Zhang *et al.* presented another technique for 3D brain image segmentation. The utilization of functional skull MRI to identify neurological illness is among the most frequent diagnostic scanning techniques. The ability to construct strong image analytics methods for regression tasks like classification is dependent on the clarity of radiology. The existence of image aberrations that can contribute to inferior diagnostic image clarity is among the key difficulties in therapeutic practice. Researchers proposed throughout this study that motion-related head MRI artifacts be detected utilizing multilayer convolutional neural networks as well as corrected utilizing a leftover U-net structure. After that, researchers apply a multilayer convolutional neural network-based identification technique to find artifacts. A residue U-net network taught on faulty information is used to rectify the artifacts seen [8].

Various researchers have proposed various frameworks as well as algorithms to increase the sensitivity and accuracy of MR image segmentation as well as feature extraction, but due to rapid technological developments, there is a larger need to investigate as well as to improve new frameworks and algorithms in the upcoming days to solve the existing difficulties.

3. Methodology

3.1 Design:

A brain tumor is a very thorny disease and rapidly spreading worldwide. Early detection of brain tumor is only the solution for effective diagnosis in the beginning phase and help the patient to recover sooner. Brain tumor accurate recognition has become a gigantic challenge for clinicians at present because of the fast increment in tumor patients globally [9]. Though, clinicians identify brain tumors based on manual as well as available computing approaches. However, the manual procedures do not provide fast and accurate results to initiate proper and required diagnosis immediately [10]. Also, manual procedure as well as other available computing approaches used in brain tumor recognition at present takes very much time in the screening of the patients. Due to these issues, in this work, a novel image analysis algorithm based on the artificial neural network (ANN) and particle swarm optimization (PSO) is presented for brain tumor segmentation and classification for effective diagnosis of the patient [11]. Figure 1 shows a flow chart of our proposed image analysis algorithm for the diagnosis of brain tumors. The working operation of the proposed approach is as follows. For performance evaluation of the proposed approach multiple brain images i.e., normal images as well as various pathological images have been used as input MR images. Once the system initializes and input images are entered, the pre-processing phase begins. In this phase, various image enhancement operations are done, for instance, image resizing, as well as image orienting along with the desired color correction of the image. As soon as the image pre-processing operation is completed, then all the images are processed for the next phase i.e., images noise detection as well as image enhancement. For image noise detection and enhancement, multiple filters are employed i.e., a Mean filter and Median Filter to get noise-free images, and these images are further used as training samples for brain tumor detection procedure. In the next process, the training sample images are processed for the image segmentation phase. The main aim to segment the images is to simplify as well as transform image representation for easy analysis of the images. For the segmentation of the images novel optimized ANN and PSO algorithm is employed to perform the segmentation operation quickly and more accurately. The PSO [12] is a computational technique that is utilized for the optimization of any given issue in multiple iterations for trying to enhance an applicant's way out in response to any specified quality measurement. It resolves a difficulty by generating a populace of possible responses, referred to as particles, as well as shifting them throughout the searching area using a simplified algebraic formula based on their location as well as momentum. After the image segmentation procedure, image feature extraction is performed as means of the principle component analysis (PCA) [13]. The PCA approach is used to analyze obtained datasets that comprise a large number of features as well as allows for the multi-dimensional dataset's effective visualization in real-time. Once the image feature extraction operation is completed, then performance measurement operation is done i.e. identification of

non-tumor and tumor from the images. Further, the identified tumor is categorized into multiple stages for instance Stage 0, Stage I, Stage II, Stage III, and Stage IV, which would help clinicians to initiate the proper diagnosis of patients immediately.

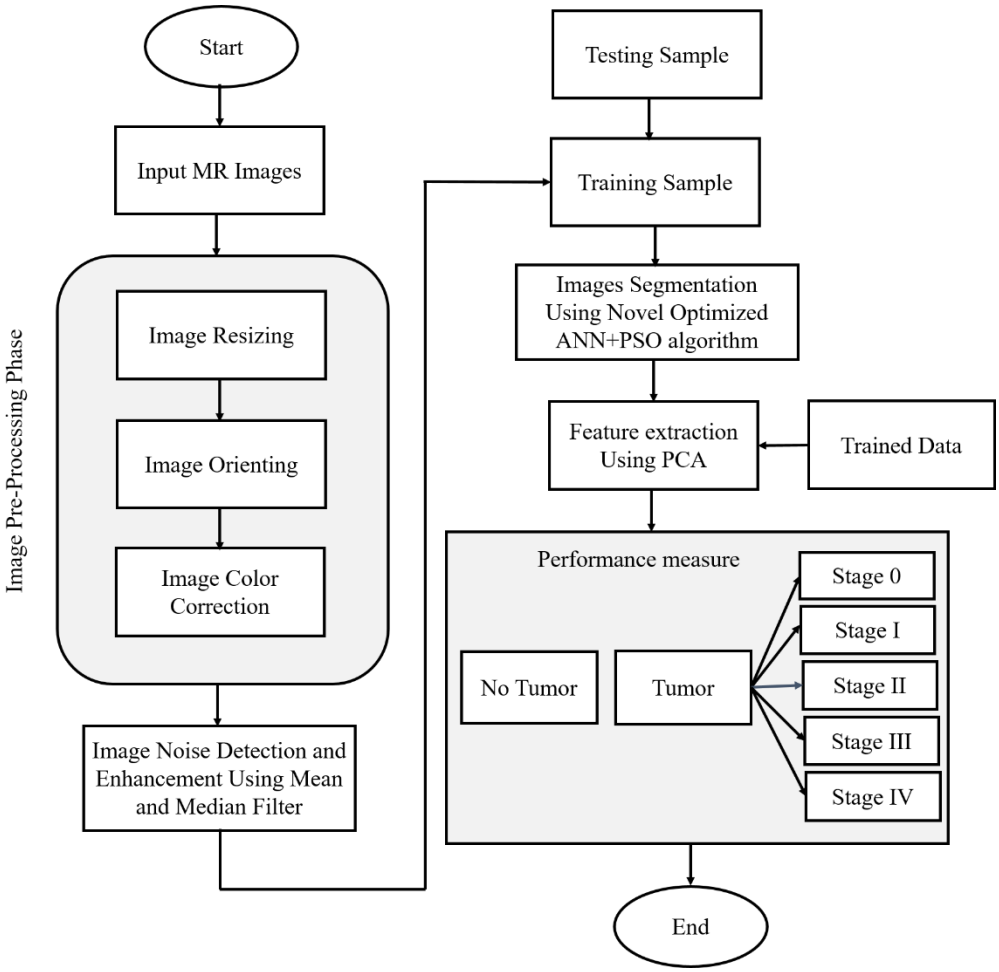

Figure 1: Flow chart of our proposed image analysis algorithm for the diagnosis of brain tumors.

3.2. System Configuration:

The proposed optimized image analysis algorithm which is based on the ANN as well as PSO has been implemented and validated on a personal computer (PC) in MATLAB R2022a. This selected PC configuration is as follows: 12th Gen Intel processor I5, Graphic Card: GeForce RTXTM 3060 Ti, with integrated RAM of 16GB DDR5 up to 4800 MHz clock speed and Windows 11. The entire implementation and validation of this optimized image analysis algorithm have been done with a high level of accuracy for performance measurement and all the results as recorded in real-time for the analysis. MATLAB software provides various tools such as image processing, neural networks, digital signal processing, etc.

3.4 Data Collection:

The datasets used in the proposed method have been taken from worldwide used datasets namely the Kaggle [14]. The Kaggle datasets contain a huge number of brain tumor images as well as non-brain tumor images. The Kaggle offers a platform to the users for exploration and publishing the datasets to develop new models or protocols as well as helps to collaborate with other researchers. Table 1 shows the datasets used for the training and validation of the proposed algorithm. The chosen images include both males as well as female images with tumors as well as no tumor images. For iteration 1, the total number of selected images for males and females was 228. For iteration 2, the total number of selected images for males and females was 220. For iteration 3, the total number of selected images for males and females was 212. For iteration 4, the total number of selected images

for males and females was 241. And for iteration 5, the total number of selected images for males and females was 209. The overall number of images selected for the entire training and validation was 1110.

Table 1 Datasets used for training and validation of the proposed algorithm.

S. No.		Male images taken (Training and Validation)		Female images taken (Training and validation)		Total Images taken (Training and Validation)
	Iterations	Images having tumor	Images having no-tumor	Images having tumor	Images having no-tumor	
1	Iteration 1	55	67	51	55	228
2	Iteration 2	67	54	54	45	220
3	Iteration 3	51	59	49	53	212
4	Iteration 4	67	65	50	59	241
5	Iteration 5	45	47	60	57	209
6	Total	285	292	264	269	1110

3.4 Data Analysis:

The data analysis has been conducted for conducting effective training and validation of the proposed novel and optimized image analysis algorithm for brain tumor diagnosis. The entire chosen image datasets from Kaggle have been classified initially into different classes i.e., Males as well as Females for both the training and as well as validation. For effective evaluation and to acquire highly accurate results, the entire datasets have been arbitrarily classified into the tumor as well as non-tumor images. The entire training and validation of the proposed optimized image analysis algorithm are completed in multiple iterations and the results are recorded from iteration 0 to iteration 5 for the validation of the proposed algorithm for comparative analysis. For iteration 1 selected images were 228, for the second iteration total images were 220, for the third iteration, the total images were 212, for the fourth iteration the total images were 241 and the iteration 5 the total images were 209. The total image datasets used in the entire training and validation in all iterations were 1110 images of the brain tumor and non-brain tumor images.

Before the image segmentation procedure using the proposed ANN and PSO-based optimized images analysis algorithm the entire 1110 image dataset was translated to perform the effective pre-processing and noise removal procedure using highly efficient filters i.e., Mean and Median filter combinations. This procedure removes the noise as well as other dark-colored rings from the selected images and later the skull stripping is done. After that, the entire images were segmented for further feature extraction procedures. The non-tumor images obtained later, the skull stripping may be denoted by the Iseg. All the tissues of MR images, for instance, grey matter (GM) as well as white matter (WM) were separated into distinct segments. Effective image segmentation is very essential for the separation of the GM and the WM tissues from the tumor-segmented image Iseg for applying the filtration process [15]. The two different variables namely p and q have been chosen which are described in the following equations.

$$\nabla I_{Seg}(p,q) = \frac{\partial I_{Seg}}{\partial p}\,\hat{\imath} + \frac{\partial I_{Seg}}{\partial q}\hat{\jmath} \quad (1)$$

$$I_{Seg} = \begin{cases} GM; & When\ I_{Seg} = 0 \\ WM; & When\ I_{Seg} = 1 \end{cases} \quad (2)$$

The outcome of the GM, as well as WM segmentations pictures, can be demoted as I_{GX} and I_{WX}. In the case of the orthogonal transformation of the polynomial, the selected picture I_{Seg} can be evaluated utilizing the illustrated equation:

$$I_{Seg} = Sin\left(\frac{I_{S(i)}^3}{100}\right)^2 + \left(0.05 * rand\left(|I_{Seg}|\right)\right) \quad (3)$$

4. Results and Discussion

The brain tumor is a hazardous disease and continuously becoming a massive problem faced by patients all around the globe. The WHO [16] reported that early and accurate detection of the brain tumor may reduce the death percentage worldwide and help doctors for providing required

therapy and treatment on time as per the detected tumor stage i.e., proper categorization between Stage 0 to Stage IV [17]. The previously developed model is less effective and takes massive time and effort from the doctors in patient screening which is a mammoth issue [18]. This research presents a novel and optimized image analysis algorithm for brain tumor segmentation. This optimized algorithm is based on the ANN and PSO algorithm for more accurate segmentation operation of the MR images. For the testing and validation and performance measure of the proposed optimized image analysis algorithm based on ANN and PSO, MATLAB R2022a software was adopted. In the training and validation of the proposed optimized image analysis algorithm, there have been selected multiple brain tumors and non-brain tumors have chosen for WM, GM, and tumor for detection as well as quantification of pathology in brain MR images using ANN and PSO. The proposed optimized image analysis algorithm is compared with the manual analysis approach and results are recorded in terms of various performance parameters such as accuracy, sensitivity as well as processing time consumption in real-time training and validation in various iterations. Figure 2 shows the pathology in Brain MR Image samples for the experiment. Figure 3 shows MR Image's segmentation using the manual method (a) GM (b) WM (c) tumor.

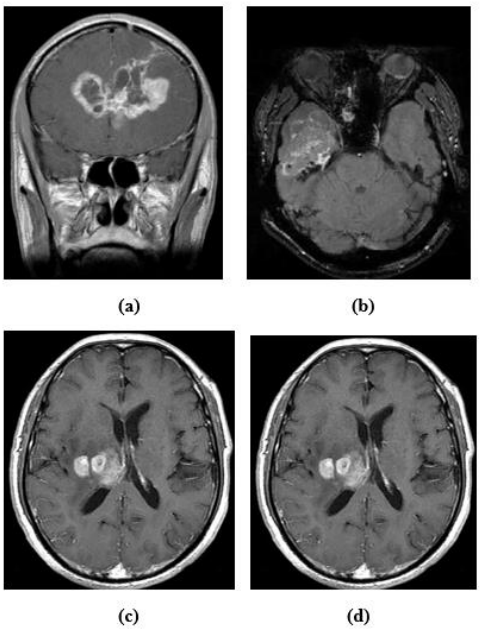

Figure 2: Pathology in Brain MR Image samples for the experiment.

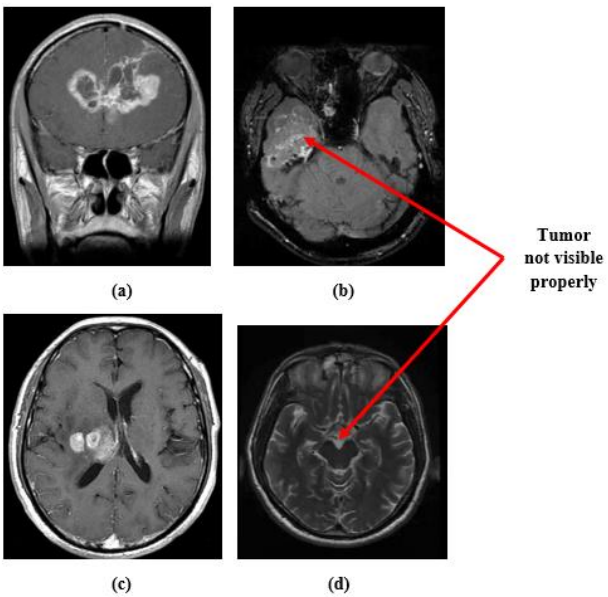

Figure 3: MR Image's segmentations using the manual method (a) GM (b) WM (c) tumor.

Statistical metrics are used to assess the effectiveness of the proposed optimized image analysis algorithm for tissue classification in an effective manner. The statistical metrics are used to determine the effectiveness of normal as well as pathological tissue categorization. In this research, an optimized and advanced image analysis algorithm for the detection and quantification of pathology in brain MR images using ANN and PSO has been proposed to increase the categorization accuracy level. The results have been recorded and validated with more care for reducing the possibility of any error. The entire training and validation procedure has been conducted in multiple iterations to record the results on different image datasets for performance measures of the proposed optimized image analysis algorithm for image segmentation and brain tumor classification procedure. Figure 4 illustrates MR Image's segmentation using the proposed method (a) GM (b) WM (c) tumor. Figure 5 illustrates the accuracy in the percentage of existing techniques vs. the proposed algorithm. The measured accuracy for the proposed optimized image analysis algorithm on WM, GM, and tumor MR images is 98%, 97%, and 99% which is optimal and higher in comparison to the existing approach [19]. Figure 6 illustrates the sensitivity in the percentage of existing techniques vs. the proposed scheme. The sensitivity of the proposed optimized image analysis algorithm vs. the existing approach on WM, GM, and the tumor MR images, is 97.5%, 98.4%, 99.22%, 80.50, 82.55, and 86.77, respectively. The recorded results show that the proposed optimized image analysis algorithm performs better as compared to the existing approach.

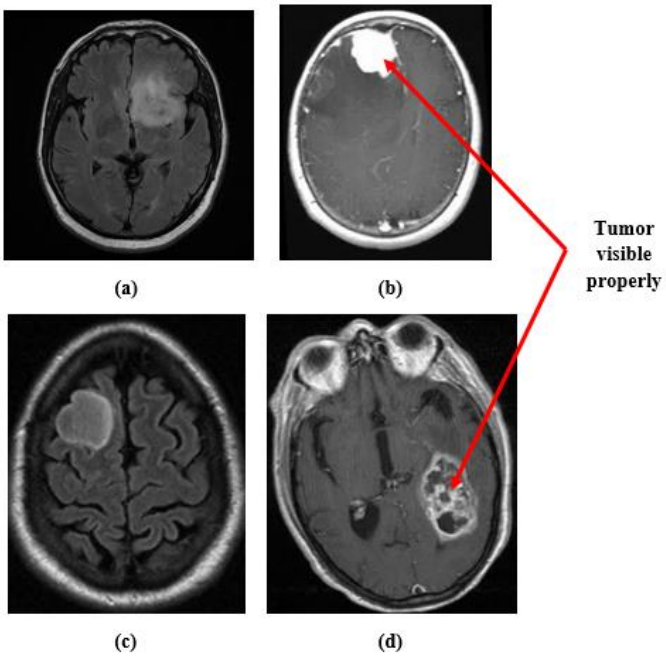

Figure 4: MR Image's segmentation using the proposed method (a) GM (b) WM (c) tumor.

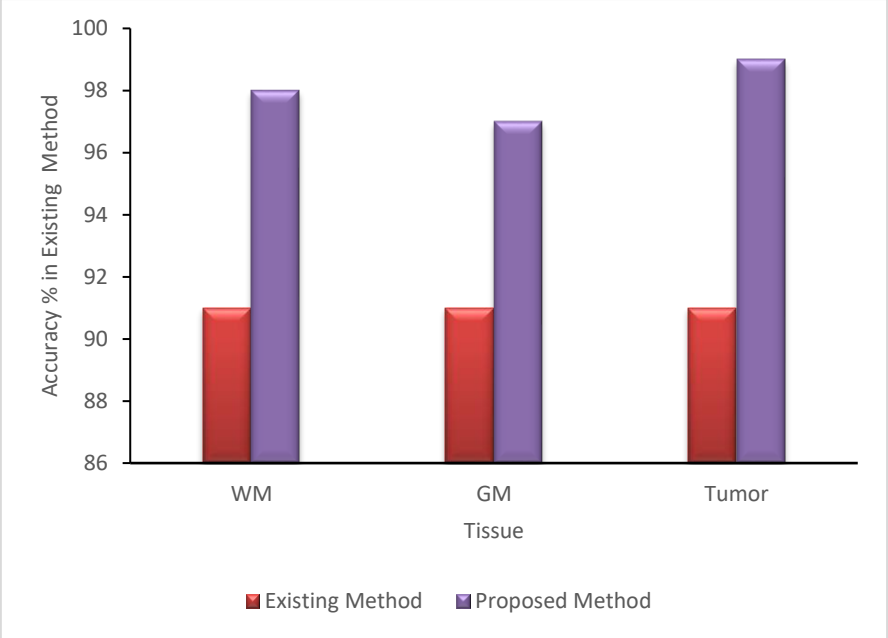

Figure 5: Accuracy in the percentage of the existing method vs. the proposed method [19].

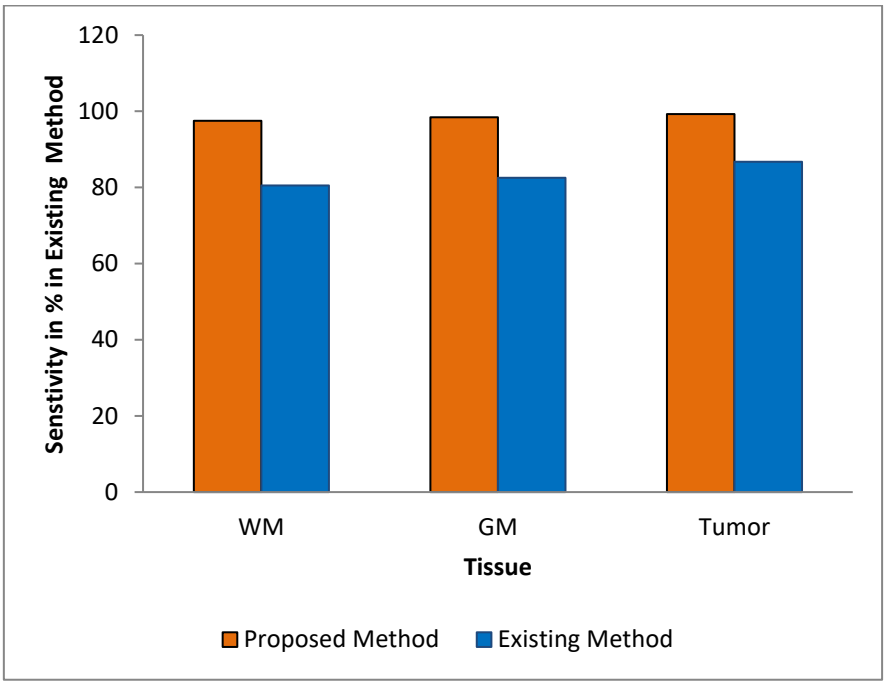

Figure 6: Sensitivity in the percentage of the existing method vs. the proposed method [19].

Table 2: Shows comparative analysis of execution time for proposed and existing methods.

S. No.	Methods	Time consumption
1	R. Ranjbarzadeh *et al.* [20]	84 seconds
3	Proposed optimized image analysis algorithm	0.8 seconds

Table 2 shows a comparative analysis of execution time for proposed and existing methods. The existing method presented by R. Ranjbarzadeh *et al.* in [20], demonstrates that it takes time in

execution of 84 seconds. While the proposed optimized image analysis algorithm based on ANN and PSO method consumes very minimal time i.e., only 08 seconds which is far less compared to the existing method.

5. Conclusion

Though substantial research has been done previously on brain MR image segmentation and feature extraction, however, the earlier brain tumor analysis algorithms have some disadvantages, such as high computing costs and reduced feature extraction and segmentation accuracy. In this research, a novel and optimized image analysis algorithm is proposed for faster and more accurate brain tumor analysis. The proposed optimized image analysis algorithm is based on the ANN and PSO approach and performs very well in comparison to earlier methods. The proposed optimized image analysis algorithm consumes very minimal time during operation i.e., only 0.8 seconds which is reduced in comparison with earlier methods. The recorded accuracy as well as the sensitivity of the proposed optimized image analysis algorithm on WM, GM, and tumor MR images are found 98%, 97%, and 99% as well as 97.5%, 98.4%, 99.22%, respectively. Though, various researchers have introduced multiple methodologies as well as techniques for brain tumor analysis, effective brain tumor segmentation, and feature extraction of MR images. However, there is also an urgent need to develop more effective and fast methods in the future for brain tumor diagnosis owing to the very fast increment in brain tumor patients worldwide. The present algorithm model will provide a gateway for rapid screening with a high accuracy rate, less time consumption, and cost-effective solution.

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Conflict of Interest:

The authors declare that they have no conflict of interest among them.

Data Availability Statement:

In this research work, all the brain tumor images dataset has been utilized from the Kaggle. Kaggle is one of the widely utilized database by the research all across the globe as it is open access for all the platforms and contains plenty of the datasets for the research community. Kaggle is an online community platform for data scientists and machine learning enthusiasts. Kaggle allows users to collaborate with other users, find and publish datasets, use GPU integrated notebooks, and compete with other data scientists to solve data science challenges.

The link of the website is attached herein:
https://www.kaggle.com/

Highlights:

- In this research, a novel optimized image analysis algorithm is presented for the diagnosis of brain tumor.
- The proposed algorithm is based on the ANN and PSO approach.
- The obtained results are pragmatic and improved in terms of accuracy as well as sensitivity and time taken in images analysis.
- The proposed algorithm takes very less time which is only 0.8 seconds.

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