**JADAVPUR UNIVERSITY**

**BRAIN MR IMAGE SEGMENTATION USING RBF NEURAL NETWORK**

BY

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**To whom it may concern**

I hereby recommend that the project **“BRAIN MR IMAGE SEGMENTATION USING RBF NEURAL NETWORK”** has been

carried out by **SHRUTI PATHAK** (Registration No.: 163613 of 2022 - 2023, Class Roll No.: 002210503021, Exam Roll No.: MCA ) under my guidance and supervision and be accepted in partial fulfillment of the requirement for the degree of **MASTER of COMPUTER APPLICATION** in **DEPARTMENT of COMPUTER SCIENCE and ENGINEERING**, **JADAVPUR UNIVERSITY**, during the academic year 2023-2024.

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**CERTIFICATE OF APPROVAL**

This is to certify that the project entitled “**BRAIN MR IMAGE SEGMENTATION USING RBF NEURAL NETWORK**” is a bonafide record of work carried out by **SHRUTI PATHAK**  in partial fulfillment of the requirements for the award of the degree of **MASTER of COMPUTER APPLICATION** in the **DEPARTMENT of COMPUTER SCIENCE & ENGINEERING**, **JADAVPUR UNIVERSITY**. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein but approve the project work only for the purpose for which it has been submitted.

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Signature of Examiner 1 Signature of Examiner 2

Date : Date :

**DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC PROJECT**

I hereby declare that this thesis work holds literature survey and original research work by the undersigned candidate, as a student of **MASTER OF COMPUTER APPLICATION.**  All the information in this document have been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all the material results that are not original to this work.

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**1 ) Introduction :**

**In medical image analysis, image segmentation is a fundamental task, especially when it comes to brain MRIs (Magnetic Resonance Imaging). It is essential for several applications, including surgical planning, brain tissue classification, and tumor identification. Among the numerous segmentation methods available, the Radial Basis Function ( RBF ) [1] algorithm has gained significant attention and proven to be effective in handling the complexity and variability of brain MRI data.**

In medical imaging, image segmentation is crucial, particularly when analyzing magnetic resonance imaging (MRI) scans of the brain. Since MRI offers detailed information on the brain, it is a valuable diagnostic and research tool for a wide range of neurological conditions. However, in order to extract useful information from these complex images, it is necessary to correctly segment the relevant brain structures.

The act of dividing an MRI scan of the brain into distinct areas or structures, such as white matter, gray matter, cerebrospinal fluid, and anatomical regions like the cortex, ventricles, or tumors, is known as brain MRI segmentation.

Accurate segmentation of brain MRI scans causes many problems due to the inconsistencies and differences between brain structures, images, and the images obtained. To address these issues and produce dependable segmentation results, researchers and specialists have created a wide range of computational approaches, ranging from conventional image processing techniques to sophisticated machine learning and deep learning. It also provides an overview of commonly used segmentation techniques, highlighting their strengths, limitations, and future directions in the brain.

In conclusion, The Radial Basis Function (RBF) algorithm emerges as a reliable tool for brain MRI segmentation, adeptly handling data complexities. Its kernel functions efficiently model intricate relationships, ensuring accurate delineation of brain structures. RBF's effectiveness in capturing tissue boundaries and accommodating intensity variations bolsters medical image analysis. From surgical planning to neurological research, RBF facilitates diagnosis, treatment planning, and advances in neuro-imaging, promising continued enhancements in MRI utilization.

In this article, we investigate a distinctive approach using the Radial Basis Function (RBF) algorithm for brain MR image segmentation across various volumes with noise. Our exploration aims to discern the algorithm's efficacy amidst diverse conditions, offering insights into its robustness and adaptability in real-world applications.

**1.1) Literature Survey**

**1.2 ) Image Segmentation :**

Image segmentation is a widely used method in digital image processing and analysis. Its goal is to separate the image into distinct sections or areas, usually using pixel attribute measurement. These concepts can influence how the foreground and background are separated, or they can group pixels together according to color or shape consistency. For instance, image segmentation is frequently used in medical science to recognize and classify pixels or 3D voxels that represent malignancies in the patient's brain or other organs.

To put it another way, image segmentation is the process of breaking apart an image into separate, recognizable areas or objects according to attributes like color, texture, shape, or brightness. The purpose of image segmentation is to simplify the image representation and transform it into a useful and identifiable form. In this process, each pixel is assigned a label so that pixels with similar characteristics can be placed in the same category.

Recent advances in image segmentation have concentrated on increasing accuracy through the integration of preparatory information from atlases and 3D community data. However, the segmentation process now takes longer and is more complex as a result of this advancement. Future research should prioritize the development of accurate and noise-tolerant methods while focusing on accelerating the segmentation process. This computational efficiency is crucial for real-time operations such as computer-assisted surgery.

Furthermore, the evolution of image segmentation techniques has led to the exploration of deep learning approaches, which leverage neural networks to automatically learn and extract features for segmentation tasks. These methods show promise in achieving higher accuracy and efficiency, paving the way for advancements in medical imaging and other fields requiring precise image analysis.

Segmentation can be done in two different ways:

**Similarity:** In this way, the similarity between the image pixels is analyzed and segmentation is done. This is usually done through the initialization process. Machine learning algorithms such as clustering rely on image segmentation methods.

**Discontinuity:** This method involves creating segments based on changes in pixel density throughout the image. Line, point, and edge detection techniques use these techniques to obtain interpolation results that can be further processed to produce the final segmented image.

**1.3 ) Brain MRI Segmentation :**

**The brain, which is the body's central nervous system, controls speech, memory, cognition, and movement function in addition to acting as a warning system for body control. The rise in brain diseases caused by many factors like high stress, fast-paced lifestyle, stress on the brain and emotions, frequent injuries and the elderly has become more alarming in recent years. The health of people is gravely threatened by these circumstances.**

**Brain illnesses are commonly diagnosed in medicine using magnetic resonance imaging (MRI) equipment. The shape and function of the brain's tissues can be electronically visualized with magnetic resonance imaging (MRI), a cutting-edge medical procedure. Doctors can benefit from non-invasive, non-radiation, but more precise and superior solutions with comparable tissues by using this technique.**

In general, brain image segmentation methods are categorized as intensity-based [2], machine learning [3], hybrid [4] etc. These methods are both progressive and collaborative. Segmenting (i) healthy brain tissues, (ii) brain sub-structures, and (iii) tumor and intra-tumor regions is the overall goal of the method. Conversely, a progressive approach makes the procedure more complex.

Tesla MRI [5] is generally used to identify any blockages in the heart's blood arteries as well as brain tumors, aneurysms, etc. A Tesla MRI produces substantially sharper images in less time by using magnetic fields that are twice as strong as a standard MRI.

**1.2.A ) Need of Brain MRI Segmentation :**

There are several reasons why a brain MRI—which produces incredibly precise images—might be necessary. If doctors asked for an MRI of the brain, its not indicate to the worst case such as brain tumor or some other deadly condition. But the reality is that brain MRI is a diagnostic tool for a wide range of disorders involving the brain and spinal cord.

## i ) Cysts or Tumors :

In addition to helping diagnose brain disorders, magnetic resonance imaging (MRI) scans can find small cysts [6] that CT scans might miss. In certain instances, doctors may administer an intracranial injection of a specialized contrast agent prior to the scan in order to enhance the visibility of various brain regions. Doctors are able to spot tumors and cysts that are challenging to detect with other procedures thanks to the better and more detailed images provided by this modern technology.

**ii )** Stroke:

When a blood artery in the brain becomes blocked or starts to bleed, a stroke [7] occurs. Within minutes, brain tissue begins to degrade due to this disturbance of oxygenated circulation. Brain MRI is a useful diagnostic technique for determining whether a cerebral hemorrhage or stroke has caused brain tissue damage. It helps medical professionals to evaluate damage and decide quickly on the best course of action. Medical professionals can identify the next steps required for successful therapy by using information from brain MRIs.

**iii ) Traumatic Brain Injury** and Abnormalities **:**

The severity of traumatic brain injuries [8] can vary, and a brain MRI is an important tool to accurately diagnose the location and extent of the injury. It offers crucial details regarding the impact of the damage, such as brain swelling or hemorrhage. Doctors can evaluate brain MRI results to identify treatment plans based on the severity of injury, such as cerebral palsy, birth defects, etc.

**iv ) Multiple Sclerosis :**

The degenerative disease known as multiple sclerosis (MS) [9] affects the brain and central nervous system, leading to an immune system attack on the tissue surrounding the nerves. To quantify the severity and course of multiple sclerosis, as well as to confirm a diagnosis, doctors frequently use brain MRI scans.

**v ) Aneurysms or Hemorrhages :**

Brain MRI is important for identifying aneurysms [10] and bleeding in the brain. A ruptured aneurysm can lead to serious consequences such as brain damage, stroke, and even death. By performing an MRI of the brain, doctors can detect aneurysms and measure their size and location, allowing timely intervention to prevent rupture.

In addition, an MRI scan of the brain can detect blood and abnormal blood flow in the brain. Disruption of normal blood flow can cause insufficient oxygen to the brain, lead to stroke or brain damage. Using a brain MRI, doctors can identify these problems and create an appropriate treatment plan to restore blood flow and reduce the risk of further complications.

**1.2.B ) Challenges in Segmenting Brain Structures :**

**a ) Different shapes :** Brain tumors can occur anywhere in the brain and take different forms and uses. This variability makes it difficult to predictive model without prior knowledge, especially for small tumors.

**b ) Intensity inhomogeneity:** This is due to uneven use of homogeneous tissue and spatial density variations in each dimension, which brings the challenges in segmentaion.

**c ) Bias field:** The bias field [11] is caused by the defects in the acquisition sequences or radiofrequency coil imperfections, which also makes problems when segmenting.

**d ) Imbalance Data:** It is a main problems in Brain segmentation is the inconsistent information on MR images. This uncertainty is due to regional differences between healthy and abnormal brain regions.

**e ) Data scarcity :** Insufficient data poses problem for supervised segmentation methods in the analysis of medical images, especially in the context of the brain. Limited training data often leads to overfitting and have difficulty generalizing to new, unseen data.

**1.3 ) Technique of Brain MR Image Segmentation :**

1.3.1 ) Intensity-Based Approaches :

A ) Thresholding : Thresholding [12, 13] is a simple image segmentation approach that uses reference histograms to determine a specific value, called the threshold to distinguish between different classes. By specifying these thresholds, the segmentation process categorizes the pixels falling from the threshold, resulting in a segmented image.

Thresholding is fast and computationally efficient method but sensitive to noise and intensity inhomogeneities. Although it use to separate background from the brain tissue in brain image segmentation.

B ) Region-Based : Region-based [14] methods help extract connected regions from an image based on predefined criteria such as pixel or voxel matching. This approach usually involves three steps: (i) select initial seed points, (ii) identify points in objects or regions, and (iii) select content-related points that start with similar results. In recent studies, regional methods have been widely used in the classification of brain tissue and show their effectiveness in this regard.

The main disadvantage of the region based method is its sensitivity to the initialization of seed point. By selecting a different seed point, the segmentation result can be completely different.

C ) Clustering : Clustering methods [4] are unsupervised segmentation techniques that group pixels/voxels with similar intensities in an image without relying on training data. These methods use the available image data to train themselves. segmentation and training happen in parallel by iterating between data clustering and estimating tissue class properties. The popular clustering methods are *k-means* clustering [15] and *fuzzy C-means* clustering [1, 16].

a ) *K-means* Clustering : *K-Means* clustering [15] is an unsupervised learning algorithm that divides unlabeled data into different clusters. It is center-based and its main purpose is to minimize the distance between data points and groups. It clusters the data into different groups and discover the categories of groups in the unlabeled dataset itself without the need of any training.

***K-Means* Clustering Algorithm has the following disadvantages :**

i )It requires to specify the number of clusters (k) manually in advance also it can not handle noisy data and outliers.

ii ) It is not suitable to identify clusters with non-convex shapes. Get better result only on spherical-like shape clusters.

iii ) *k-means* algorithm doesn’t let data points that are far-away from each other share the same cluster even though they obviously belong to the same cluster.

**b ) *Fuzzy C-Means* Clustering :**

***FCM* [1, 16] is a data clustering technique that assigns data points to N groups based on membership.** In other word, *FCM* is a machine learning algorithm that can associate data points with multiple clusters with different membership classes. The *FCM* algorithm works by assigning the membership value to each data point to indicate how many items belong to each category. *FCM* allows for partial membership or ambiguity, unlike *K-means*, which assigns specific values to a group. This means that each data source can have different members in different groups.

Advantages of Fuzzy Clustering :

Flexibility: *Fuzzy C-Means* clustering allows for overlapping clusters, which can be useful when the data has a complex structure or when there are ambiguous or overlapping class boundaries.

**Robustness:** *Fuzzy C-Means* clustering can be more robust to outliers and noise in the data, as it allows for a more gradual transition from one cluster to another.

**Interpretability:** *Fuzzy C-Means* clustering provides a more fine distinction for understanding the structure of the data, as it allows for a more detailed representation of the relationships between data points and clusters.

1.3.2 ) Machine Learning :

A ) Traditional Machine Learning : Any fundamental algorithmic structure to solve given problem will come under Traditional Machine Learning [17]. These algorithms learn from the data, where choice of algorithm and features ( inputs ) to be fed into algorithm are made by subject matter experts. Traditional ML models expects all inputs are in the format of structured data like numbers. Traditional ML models can be used to solve classification, regression, clustering, dimensionality reduction problems.

Some common types of traditional machine learning techniques used in brain MRI segmentation are: Support Vector Machines (SVM) [18], k-Nearest Neighbors (k-NN) [19], Naive Bayes [20], Artificial Neural Networks (ANN) [21].

B ) Deep Learning : Deep learning [22, 23] is a technique that separates a feature hierarchy from input data using multiple-layer neural networks. It is a well-liked technique, as opposed to manual feature extraction in standard machine learning, which automatically extracts features from images. Various deep-learning algorithms have been employed to achieve various objectives.

Neural nets that perform the task of segmentation typically use an encoder-decoder structure. There are so many deep learning methods such as :- U-Net [24], SegNet [25], DeepLab [26] etc.

Besides, deep learning based segmentation is performed using 2D, 3D, 2.5D. Deep learning using 2D images requires brain image slices or extracted 2D patches from 3D images as an input for the 2D convolutional method [27]. The second category of deep learning-based tumor segmentation approaches uses 3D MR images for segmentation to overcome the limitation of neglecting contextual information in 2D CNN [28]. But in this 3D approach has limitations related to network intensiveness and memory consumption. To overcome network complexity and memory consumption of the 3D based-segmentation methods, Wang et al. [29] suggested a cascade of 2.5D CNN voxel-wise architecture for sequential segmentation of brain tumors from MR images.

1.3.3 ) Hybrid Segmentation Approaches :

Brain MRI segmentation problems need to be continuously investigated and new methods introduced. Selecting the most appropriate technique for a given application can be difficult and often requires a combination of techniques to achieve accurate segmentation. Therefore, the hybrid or combined segmentation method [4] has gained great popularity in many brain MRIs. There are three sub category of Hybrid Segmentation Approaches :- a ) contour-based and machine learning, [30] (ii) metaheuristic, and machine learning [31] and (iii) deep learning and machine learning [32].

Several examples of hybrid brain MRI segmentation methods have been developed. Kapoor et al. [33] Segmentation of multiple brain tissues in adults in 2D MRI using a combination of Contour-Based and Machine Learning. Masutani et al. [34] Combining model-based region growth with local quality information for accurate segmentation of cerebral vessels. An unsupervised brain MRI segmentation is developed by Xue et al. [35] by combining minimum error global thresholding and a spatial-feature-based *FCM* clustering to segment 3D MRI in a “slice-by-slice” manner.

The main disadvantage of the hybrid (combined) segmentation method is its complexity, usually compared to the individual method. This challenge requires more time and more parameters to be adjusted for specific applications. Therefore, the design of the hybrid segmentation method must be carefully considered to ensure efficiency and high-quality segmentation results.