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Segmentation of Brain Tumour in Magnetic Resonance Images in Time Domain - Study of Previous Work

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Abstract:
There are different image segmentation techniques that are used in detecting brain tumour. Most cells in body grow and then divide to form new cells as they are needed to keep the body healthy and working properly. Medical imaging faces a big challenge of detecting brain tumour through magnetic resonance images (MRI). MRI is used to analyze body organs to replace surgery.

1. Introduction

Brain tumour is one of the dangerous diseases that have affected lives of many. MRI and computed tomography (CT) scan of brain are the common test performed to detect brain tumour. Accurate tumour detection is needed for the treatment and minimizing of errors in tumour detection. Sometimes brain cells grow uncontrollably because of different reasons, resulting in abnormal growth of brain cells. The outcome of abnormal cell growth is an increased pressure on the brain skull or damage of nerves [1]. Brain tumours are of two types:

1.1. Meningioma

These types of tumours do not expand rapidly, they don't affect the neighbouring tissues. These tumours are less dangerous and can be treated easily.

1.2. Gliobla-Stoma

These are fast growing tumours and can spread into surrounding brain. These are grade 3 and 4 tumours that need urgent treatment. This tumour is more dangerous and requires surgery and radiotherapy, also known as malignant tumours. Malignant means disease which is serious.

Magnetic resonance imaging was invented by Paul C. Lauterbur in September 1971. He used MRI to examine human body. MRI results in good contrast of tissues resulting in better quality of image as compared to other techniques [2]. An MRI scan is made up of gray level intensity values. These values depend on concentration of cells in particular area.

1.2.1. Difficulties in Segmentation of Brain MRI

Segmentation of MRI when done by medical experts manually consumes time. Tumour tissues of different patients are o different shape and intensities; as a result it faces many problems in detection.

i. Noise: random noise that is present in MR images result in faults in tumour segmentation [3].
ii. Intensity in homogeneity: non uniformity during data collection results in shading effect [4].

As a result there is a strong demand of automated tumour detection and segmentation process.

2. Image Segmentation

Image segmentation is the process of partioning a digital image into two or more segments. The goal of segmentation is to convert an image into something that is more meaningful and easier to analyse. Automated detection of brain tumour using MRI helps in reducing the time taken for detection. The image segmentation has following steps:-

- Image acquisition: it is the process of obtaining an image using MRI scan and these scanned images are displayed in a two dimension matrix having pixels as its elements. Images are stored in Mat-lab and displayed as a gray scale image 256*256.

- Pre-processing: this step is used for noise removal. Generally, this work is done using gray scale values and filters. This step removes blurriness of an image.
- Image enhancement: it helps in increasing the contrast of an image to make it clearly visible.
- Thresholding: it helps in converting the input gray scale image into binary format. This method is based on a threshold value
- Morphological operations: after converting the image into binary image, morphological operations are used to separate tumour part of the image.

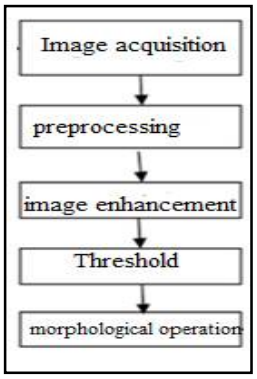

Figure 1: Steps in segmentation

The image segmentation and detection approaches were studied under following categories

i. Thresholding approach
ii. Graph based approach
iii. Region growing approach
iv. Clustering approach

2.1. Thresholding Based Methods

A Thresholding procedure attempts to determine an intensity value called threshold. Segmentation is achieved by grouping all pixels with intensity greater than the threshold into one class and all other pixels in another class. It helps in segmenting light objects in darker background [5]. Any pixel(x, y) is a part of object and its intensity value is greater than or equal to threshold value.

There are two types of thresholding used:

→ Global Thresholding: In global thresholding, a single threshold is used for all the image pixels. When the pixel values of the foreground and background are fairly consistent in whole image then global thresholding can be used [6]

→ Adaptive Thresholding: In adaptive thresholding, different threshold values are used for different local areas. The limitation of threshold method is that it cannot be used in spatial features of an image like shape. [5]

2.2. Region Growing Based Methods

Region growing is one of region-based image segmentation method. It is also classified as a pixel-based image segmentation method. It is considered that pixels that are close to one another and have similar intensity values belong to the same object. The main goal of segmentation is to partition an image into regions. Partitioning into regions is often done by using grey values of the image pixels. The first step in region growing is to select a set of seed points. Seed point selection is based on gray scale range criterion. The initial region begins as the exact point location of these seeds. The regions grow from these seed points to adjacent points depending on properties of pixel. Region extends from the seed pixel by adding in neighbouring pixels that are similar. When one region stops growing we simply choose another seed pixel which does not yet belong one of the regions and start again. The process is continued until all pixels belong to some region.

Segmentation algorithms based on region consist of following method

→ Region growing: it puts pixels in an image as a group into sub regions [7]. Region growing process consists of four steps.
- Select a group of seed pixels in an image.
- Select a set of gray level intensity.
- Growth of a region by attaching seed pixel with nearby pixels having similar properties
- Control growth of region when no more pixels that are similar to seed pixel are present.

→ Region split and merges: here image is divided into detached regions and merge the regions [5].

Region growing methods used so far are:

- Texture feature FCM [8]: good results in terms of accuracy, effectively extract tumour region from brain MR images.
- Seed based region growing [9]: here comparison was made between number of pixels of the raw MRI brain images and seed based region growing (SBRG) segmented abnormalities etc.

- The main disadvantage of region growing approach is that it needs a seed point at the starting point of the segmentation process. This needs user interaction. Due to the differences in image intensities and noise, region growing can effect in holes and over segmentation.

2.3. Graph Based Methods

2.3.1. Graph Based Segmentation

It represents the problem in form of graphs where nodes are the pixels and edges are used to join some neighbouring pixels. One of the methods of graph segmentation is minimum spanning tree. The main goal of graph based segmentation is to get the intensities in particular range. Disadvantage of this method is it requires a large dataset and a small tumour size for graph structure. Also, tumour with low contrast enhancement is not detectable. This method is only appropriate in finding low grade glioma**.** [10].

Graph matching includes following two concepts.

2.3.2. Graph Isomorphism

Graph isomorphism is a technique used to find whether two objects are the same. If two graphs are isomorphic, they have equal in terms of vertices and edges, the degrees for corresponding vertices must be same, the equal no. of connected components.

2.3.3. Sub Graph Isomorphism

Sub graph isomorphism is used to find out if one object belongs to a group of different objects or not. The number of common sub graph that belongs to two graphs shows the similarity of those graphs.

2.4. Clustering Based Methods

Clustering is a method which helps to group similar data as one and separates dissimilar data from similar one. Euclidean distance is used to measure between data points. Lesser the distance greater is the similarity. Fuzzy c-means (FCM) is one of the methods of clustering which helps one data to belong to two or more clusters. Each data element is given a membership level. The membership level depicts the strength of the association between a particular data element and a cluster.

Dunn introduced a new technique of image segmentation known as fuzzy c mean (FCM) clustering algorithm [11]. Some of fuzzy c mean methods are:

→ Fuzzy c mean [12]: this method help in improving the segmentation performance but poor contrast noise and non uniform intensity variations can affect results.

→ Fuzzy possibistic c means [13]: the method uses hybrid segmentation method which is combination of region and boundary information of image to segment the tumour.

More methods that have been used for segmentation and detection are:

- Watershed segmentation: this method has been used in combination with active contour or edge detection [14]. It leads to less computational over heads and accuracy but fails by giving over segmented results.
- Graph cuts: graph cuts used in combination with other techniques and overcome the problem of overlapping of tissues. Disadvantage lies in detection of lower grade glioma only[14]
- K means: this is an unsupervised clustering method which takes less time for detecting tumour [15].
- Entropy based segmentation**:** It uses entropy as the basis to measure the uniformity of pixels within a region. Entropy is the grey level of any individual pixels. Difficulty in this method is that the selection of number of grey levels is crucial.
- Support vector machine: SVM is based on decision planes that define decision boundaries. Drawback of SVM is in size and speed during training and testing phase. The working of SVM is degraded in testing phase. It needs high memory for large scale tasks [16].
- Mathematical morphology, DWT k means: it is applied for improving quality of image using morphological operations, wavelet transform is used to decompose MRI and k means is applied to extract tumours from brain.

3. Features for Brain Tumour

There are different types of features of MRI image, whose extraction takes place using various feature extraction techniques. Features that can be extracted are:

→ Shape Features - circularity,, Area, Perimeter, Shape Index

→ Intensity features – Mean, Variance, Standard Variance, Median Intensity, Skewness, and Kurtosis

→ Texture features - Contrast, Correlation, Entropy, Energy, Homogeneity, cluster shade, sum of square variance.[24]

These three kinds of features are extracted, which describe the structure information of intensity, shape, and texture. Different types of features are as follows:

- Size: there are numerous studies to build estimation model of growth and size of the tumour. This feature helps in differentiating between malignant and benignant tumour[17]
- Colour: this is one of essential feature which can be used in detection of brain tumour [18].

- Wavelet packets: many researchers develop the features of image in form of wavelets which help in giving better signal.
- Edge: this feature helps in detecting the boundaries of an image part.
- Contrast: it plays an important role in differentiating tumorous and non tumorous part of brain MRI [19].
- Statistical: features like mean, median variance etc are used to find segment an image based on intensity levels.[20]
- Morphological features: shape is essential feature to detect tumour.
- Entropy: tumour part has more energy and entropy as compared to normal tissues. So this feature can be used to find out tumour regions.
- Inhomogenity: the tumour part becomes less uniform and less homogeneous as compared to parts which does not have tumour. Homogeneity reflects the uniformity of the elements of an object and express how similar they are.
- Smoothness: it is one of the texture feature method which helps us to detect smooth and non smooth tissues for tumour detection [20].

4. Classification

Image classification is used to put data into different categories according to their numerical values of image features. Classification consists of two parts: *training* and *testing.* Classification system consists of database that contains patterns which are used to compare detected object and predefined pattern to put in particular class. Image classification is needed in various applications like medical imaging, artificial intelligence, biometry, robot navigation, and remote sensing. There are different types of classification techniques used in image processing [21]:

- Artificial Neural network: ANN Classification is used as a learning tool for separating samples. Samples having same features are categorized into one category. Having it automated provides speeding up of the system, and the faster we can be in treating the patients. It involves human like thinking and they can handle noisy or missing data. They can work with large no. of variables and provide good accuracy results. Performance and accuracy depends upon the network structure and number of inputs.

ANN is capable of performing logical functions used in MATLAB. It efficiently handles noisy inputs and computation rate is high.

- Decision tree: DT calculates class membership by partitioning a dataset into uniform subsets. Hierarchical classifier permits the acceptations and rejection of class labels at each intermediary stage. This method consists of 3 parts: Partition the nodes, locating terminal nodes and allocating class label to terminal nodes. DT is simple and computational efficiency is good. [25]
- Support Vector Machine: The SVM algorithm was invented by Vladimir N. Vapnik in 1963. It helps in pattern recognition. It represents data as points in spaces so that data of separate categories is divided by visible gap that is as wide as possible. They are suitable for binary tasks.[21]

5. Ground Truth Validation

Ground truth is a dataset that uses measurements that is known to be more accurate as compared to the measurements from the testing system. Ground truth database is used in areas, like satellite imagery, machine learning, remote sensing, etc in lots of cases the effect of image processing algorithms cannot be evaluated by device or existing objective indicators, ground truth is often generated manually by human experts in the corresponding fields. Segment the region of interest, but doctor is not around to confirm if the ROI is correct. Thus the ground truth image database is presented for the convenience. [22]. For example, there are databases in [22], including medical databases,face databases, fingerprints databases, gesture databases,eyes detection, object and shape detection, and so on.

Methods used for validating the ground truth are:

5.1. True Positive Rate

When the process of tumour detection is done in an image, the correctness of a class is done on the bases of the amount of genuine positives which means the amount of things accurately marked tumours e.g. positive class may be non-tumour separated by the number of components having a place with the positive class.

5.2. Specificity and Sensitivity

Sensitivity and specificity are terms which are used to calculate the work done by the system. The results are used in considering the estimation of work done. The sensitivity and specificity of a quantitative test are reliant on the cut-off quality above or underneath which the work is positive value.

6. Comparison of Image Segmentation Techniques

- Accuracy of segmentation in [26] was done by applying different techniques to some samples of MRI images. Comparison on basis of accuracy was as follows.

Segmentation Method	Degree of Accuracy of the Segmentation (out of 10)
Otsu's method	8.1
Mean Shift	6.1
K-means	6.0
Fuzzy c-means	5.2
Expectation maximization	4.5
Discrete Topological Derivative	4.2
Continuum Topological Derivative	3.9
Iterative thresholding	3.8
Two Seed Region Growing	2.2
One Seed Region Growing	2.2

Table1. Accuracy comparison of different segmentation techniques

- Comparison of k mean and fuzzy c mean as shown in [23]. Working on iris data set

The matlab function k mean used for k mean clustering to partion the points in form k clusters. This partioning minimizes the overall sum of clusters. K mean return an n by 1 vector idx containing cluster indices of each point. K mean uses Euclidean distance for its calculation. For the given dataset for 3 clusters the total sum of distance is 7897.88 and total time elapse is 0.443755.
Similarly applying FCM to same dataset, the function takes the desired number of clusters and returns cluster centres and membership grade for each data point. The process stops when maximum number of iterations is reached. The results are total distance 6058.6899 and total time elapsed is 0.781679.which showed k means is better than FCM.

time	k mean : 0.443755.
	FCM: 0.781679
distance	k mean : 7897.88
	FCM: 6058.6899

Table 2: comparison of k mean and FCM

7. Conclusion

To detect a brain tumour accurately in an MRI, it is essential to use segmentation method. Information is given in form of images from various sources, these are used in diagnosis of tumours and treatment purpose. The available data uses computation processing to make the decision. Nowadays, speed of computation is no longer an issue for researchers. As a result, there is need to focus on improvement of outputs from images obtained using detection system to get an accurate picture of the brain tumor.
In this current paper, review of previous work done in field of brain tumour detection is done. Through this review we obtained the conclusion about automation of systems that can be used in detection of brain tumour from MRI images. This is one of the active research area that has been done so far. However, currently there is no clinically accepted automated method.

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