ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

A Survey of Brain Tumour Segmentation and Classification For fMRI Data

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ABSTRACT

Trending in the recent days is the field of Medical Image Processing which is a rapidly growing and competitive field. Medical Image methodologies are utilized for Medical detection and treatment of diseases. One such critical and life endangering disease, is Brain Tumour which is an abnormal growth of brain cells inside the brain. Identification of brain tumour is a challenge due to the complications in the structure of brain. Functional Magnetic Resonance Images (FMRI) is beneficial for providing the detailed information about human soft tissue anatomy, which is in turn, is helpful in diagnosis of brain tumour. Basically, there are different stages which are involved in the detection of brain tumour such as image pre-processing, segmentation, feature extraction and classification. The intention of this research work is rendering a detailed overview for FMRI-based brain tumour segmentation and classification techniques. First, a concise introduction to brain tumours is furnished and then the imaging modalities of brain tumours are provided. Afterwards, Image pre-processing is conducted as a first step on FMR images of the affected patients to improve the features of brain cells. Second, introduction of state of the art methods of FMRI-based brain tumour segmentation is done. In addition, discussion on the assessment and establishment of the results of FMRI-based brain tumour classification are provided. As a last step, anon-subjective evaluation is submitted and developments in the futurity and to be in vogue are dealt for FMRI-based brain tumours segmentation and classification techniques.

KEY WORDS: FMRI image, pre-processing, segmentation, feature extraction and classification.

1. INTRODUCTION

Brain tumour is an unusual and uncontrollable development of brain cells. Functional Magnetic Resonance Imaging (fMRI) is a significant tool for medical diagnosis providing extensive knowledge about brain tumour anatomy, cellular structure. Functional magnetic resonance imaging (FMRI) is progressively applied in the preparation of patients at the preoperative stage to evaluate the relationship between the functionally active cortex and brain pathology. This is because the Inter-individual normal variations of anatomy make such evaluation not dependable only on the basis of structural imaging even though clear anatomical landmarks have been defined (Naidich, 2001; Belliveau, 1991). This issue is much more aggressive when normal anatomy is fogged by a tumor mass effect or when functional anatomy is changed due to cortical plasticity. FMRI has rapidly evolved from its first human application in 1991 (Belliveau, 1991) to animportant tool in the analysis of human brain functionality, highly in the scientific arena. In 2007, new Current Procedure Terminology (CPT) codes were constructed for FMRI by the American Medical Association, which signified the transitioning of FMRI as a worth full tool in a clinical environment (Pillai, 2010).

Brain image segmentation is defined as the procedure comprising of distinguishing the brain disease or abnormalities of the brain from the normal brain images. Doctors face extremely difficulty in the separation of the brain abnormality from the FMRI brain images, planning of treatment and diagnosing brain anomalies like tumour, and the study of anatomical structure. Thus the brain image classification has gained the status of a very important project. The classification of FMRI brain images can be performed by manual means, but it is inaccurate and its error rate is high. Also it is not easy for human to categorize it precisely since the time consumed is large and it is highly challenging. Therefore neural network techniques are brought into application for the classification of tumour images to reduce the burden of the manual effort. A single algorithm is not in place for categorization and sectionalisation of each medical image. Various parts of the body require different types of FMR images. Hence this research work makes use of various techniques for segmentation and categorization of fMRI brain images.

Neural network is the term used for the technique used for automatically classifying the functional magnetic resonance images (FMRI).It comprises of supervised feed-forward back-propagation neural network method that is utilized for the classification of the normal or abnormal images. Employment of artificial neural networks for brain image classification are being gruelling in terms of computation and also there is no guaranteed precision. (Jehan, 2002; Walaa Hussien Ibrahim, 2003; Vijay Kumar, 2010). Back propagation neural network technique is used for unmonitored segmentation and classification of MRI brain images.

The segmentation of brain abnormality employs different unsupervised neural network and different statistical methodologies. Various supervised techniques which are brought into application are Artificial Neural Network (ANN), and Support Vector Machine (SVM). Unsupervised techniques are auto organizing. Diverse techniques have been used in monitored neural networks like Back Propagation (BP), Learning Vector Quantization (LVQ), and Radial Basis Function (RBF). After using the PCA, there has been a reduction in the features of MRI. This methodology utilizes many databases. It is effective and has considerable robust behaviour (Walaa Hussien Ibrahim, 2003; Lalit, 2012). The Back Propagation Algorithm (BPA) is exploited for adjustment of the weights and minimization of the errors and provides the results with a reasonable accuracy. The basic principle behind BPA is to train a network on a set of input vectors and obtain good outcomes without having to train the network on all the possible input and output pairs (Walaa Hussien Ibrahim, 2003; Alberto Landi, 2009). The Radial Basis Function (RBF) network and Back Propagation network carry out similar function mapping. BP network is the global network whereas RBF network is the local network. RBF network is trained with supervision (Walaa Hussien Ibrahim, 2003; Lalit, 2012; Alberto Landi, 2009).

Literature Survey: The automated diagnosis of brain disorder with FMR images is gaining crucial importance in the medical field. This kind of diagnosis consists of two major steps: (a) Image classification and (b) Image segmentation. Image classification is the method of classification of the abnormal images into different groups on the basis of some similarity measure. The precision of this abnormality detection methodology must be highly accurate as this detection is extremely important for treatment planning. The second step involves image segmentation which is used to select the abnormal portion needed for volumetric analysis. The extracted size and shape of the abnormal portion helps in judging the effect of the treatment on the patient. Many research works with different reports for image classification and segmentation are discussed in this section.

Image pre – processing: Pre-processing of FMRI images is the foremost step in image analysis where improvement of the image and noise reduction methodologies is utilized to for the enhancement of the image quality. Image is fine-tuned in such a way that the minute details are enhanced and the image is noise-free. Brain tumor detection implements image enhancement and noise reduction techniques to provide optimum results. More prominent edges are received through enhancement and a sharp image like tumor is obtained. Noise reduction techniques help in reducing the blurring effect from the image.

Priyanka Balwinder Singh (Priyanka, 2013) made a proposal for Median Filter technique or de-noising the salt and pepper noise and Poisson noise from the images. A median filter functions in a way that, the output intensity value of the pixel being processed is obtaining by sliding a window along the image and the median intensity value of the pixels within the window becomes the output intensity. Median filter maintains edges in an image also with a reduction in random noise. Every pixel's value is set to median value of the pixels in the vicinity of the corresponding input pixels. This filter is then utilized for the removal of these noises and then the bounding box technique is employed to detect the position of the tumor.

Researchers Nobi and Yousuf (2011), have been involved in the development of Order statistics filters which allow for a simple and effective methodology to eliminate noise from the medical images. This technique employs the combination of both median filtering and mean filtering to decide on the pixel value in the no-noise image. It is also for the elimination of the Rician noise affecting the images.

Other works by Jaya, Thanushkodi, Karnan (2009) are on the proposals for weighted median filter. High frequency components are eliminated by the application of De-noising using weighted median filter and also salt and pepper noise from images are also removed without any disturbance towards the edges. Its application is also for the extraction of each pixel of a 3*3, 5*5, 7*7, 9*9, 11*11 windows of neighbourhood pixels and analysis of the mean grey value of foreground, mean value of background and contrast value.

Ramalakshmi and Jaya Chandran (2014), have been involved in the development of anisotropic filter for the removal of background noise and hence saving the edge points in the image. This mechanism involves concurrent filtering and contrast stitching. Choice of a Diffusion constant which corresponds to the noise gradient and smoothens the noise in the background by filtering a proper threshold value.

Feature extraction: Specific features from the pre-processed images of different abnormal categories are selected with the help of a technique termed as Feature extraction. This mechanism performs extraction of high-level features for the classification of targets. Features provide unique description such as size, shape, composition, position etc. Any pattern classification consists of Feature Extraction as a crucial step in its construction and it is purported towards the extraction of the relative information by which each class is characterised. Reviews have been published by Gaurav Kumar and Pradeep Kumar Bhatia on the different types of features, feature extraction methodologies and significance of utilizing these techniques in image processing systems (Gaurav Kumar, 2014).

The introduction of a bootstrapping-based feature extraction methodology for the detection of Alzheimer's disease in its early stage with the help of resting-state functional resonance images was done by Christian Sorg, Valentin Riedl, Afra Wohlschlager (2011). The diagnosis of Alzheimer in its primary stages is very important due to the below said reasons: Also easily curable Symptoms like depression, poor nutrition and drug side effects which may be easily cured are similar to those like early-stage Alzheimer. Further, in the current scenario, few medicines have been discovered which reduces the symptoms in a successful manner and thereby causes a delay in the advancement of Alzheimer, with the pre-condition that they have to be used as early as possible for curing effectively. Nevertheless, detection of Alzheimer in its early-stage is not very easy as the symptoms are not very extreme and can easily be replicated with effects of normal aging. Tests reveal that patients with early-stage Alzheimer's disease can be said apart from age-matched healthy subjects with an accuracy of 79% utilizing a support vector machine on the selected features.

The research works of Dua, Srinivasan (2008), propose a distinct non-voxel based technique using wavelet descriptor differentiation and principal components for the extraction of distinct features which decrease slice variability in fMRI data for the improved categorization of cognitive states. One example for a set of cognitive states is attempting to categorize between two persons with one reading a sentence and the other reading a picture. The selected feature vector is minor and accomplishes important classification with precision by the use of varied classifiers and under different Regions of Interest (ROI) restraints. Test results using this research work have proved the efficiency of the technique in comparison with other voxel-based methodologies.

Juan Manuel Ramírez Cortés, JingqiAo (2009), formulated PCA (Principal Component Analysis) based feature extraction technique to reduce the dimension of fMRI data. Thus the feature extraction aims at decreasing fMRI data's dimension. fMRI image classification needs feature extraction crucially, because fMRI is by itself high dimensional. Usually, one volume of fMRI consists of about 150,000 voxels, and more than 100 volumes will be inclusive in one experiment. This, in turn, relates to the fact that the raw dataset of one fMRI experiment will have more than ten million voxels. Memory and time limit make the processing of all these voxels as features for classification impossible in practice. Hence there is a necessity for transforming or utilizing only parts of these voxels to reduce fMRI data's dimension. The result of these feature extraction methods is much better in comparison to other feature selection methods.

Image segmentation: The aim of image segmentation is partitioning an image into regions (groups of pixels linked in space called classes or subsets) and objects taking into account one or more characteristics or features. Image segmentation has a key role in image processing due to its contribution to the excerption of suspicious regions from the medical images. Segmentation is based on the idea of segmenting an image into many clusters. The results obtained will make it possible for the identification of regions of interest and objects in the actual image.

Another new technique demonstrated by Gowri Srinivasa, Vivek, Oak, Siddharth Garg is the voting-based active contour segmentation of FMRI images of the brain. Stochastic active contour algorithm (STACS) which is applied to sectionalize the white matter from the rest of the image is again based on anactive-contour scheme—STACS, and hence possesses all the benefits active-contour schemes has. The statistics of the image drives the segmentation, which is carried out in three diverse planes of image capture, Andthen the combining of the segmentation results obtained from the three planes by a voting procedure in order to classify each voxel in theimage as white matter or not. The force computation is rewritten as a multi scale transformation, which again enhances the runtime of the algorithm.

The work on the development of the segmentation of FMRI using functional echo state neural network have been done by Ravichandran and ravindran (2006). This scheme demonstrates its focus on segmentation of fMRIwith efficiency using intelligent segmentation method. It uses Echo state neural network (ESNN) which is a measurement technique to segment the deviating profile. Electronic thermal effect and artifacts are some of the reasons that FMRI contains inherent noise. Statistical method is used to get the features of the FMRI. This supplies segmentation result with accuracy for the complicated profile of the fMRI.

The Auto-threshold Contrast Enhancing Iterative Clustering (ACEIC) segment-centric method is one of the schemes proposed by Pinaki, Mitra (2006). This is brought into use for functionally segmenting FMRI data. Simulated activation images are utilized and, it is proven that this segment based approach can render much success for knowledge discovery than traditional voxel-based techniques. The spatial coherence principle denotes the uniformity of behaviour of connected voxels in space. The presentation on ACEIC– a new algorithm based on the spatial coherence principle is done here for functional segmentation. With the availability of data that is a benchmark, it is established that the ACEIC method can accomplish accurately high segmentation than Probabilistic Independent Component Analysis – another prevalent technique used for fMRI data evaluation.

Image classification: Classification basically refers to the labelling performed on a pixel or a group of pixels. For a set of pixels, multiple features are utilized, that is, many images of a specific object are required. Image classification is defined as the labelling of images into one among a number of predefined groups. Image classification is significant since it is crucial for high-level processing such as brain tumour classification. Classification is the final step in the process of brain tumour detection and is used to group the image into normal or abnormal and then again, group them again based on the abnormality type depending on whether it is cancerous or non-cancerous. This research work assesses the different methods which are utilized in tumour detection from brain FMRI.

Yong Fan, Dinggang Shen, and Christos Davatzikos (2006), built up the Multivariate classification and Machine Learning methodology for the detection of Cognitive States from fMRI Images. The high inter-individual functional variability in brain activation patterns pose a major hurdle in the construction of classifiers that can detect with precision a particular cognitive state across different individuals using fMRI images. Multi variant classification and Machine Learning method deals with the issue. To enhance the generalizing capability and effectiveness of the classification, a hybrid feature selection method is utilized to select the most discriminative features, from the select regional features, which in turn are used to train a SVM classifier for decoding brain states from fMRI images. This scheme yields good results in comparison to other normally used fMRI image classification methods.

Pinaki, Mitra (2006) established the classification-based structure for knowledge discovery from fMRI data. It presents information about functional segments which are bunches of voxels representing a functional unit in the brain. The spatial coherence principle can also be brought into use for voxel-centric image classification issues. Spatially Coherent Voxels (SCV) is a new feature extraction technique which uses the spatial coherence principle to remove features which are unusable for classification. With a Substance Use Disorder dataset, it is proved that feature extraction with SCV can reach higher classification accuracies compared to traditional feature extraction techniques.

Ashish Panat, Anitapatil, Rohinichauhan (2014), have investigated and have proposed Gaussian Mixture Model (GMM) based classification for the evaluation of the fMRI dataset. The fMRI is a dominant player in the brain mapping research taking into consideration the safety of patients averting surgery or exposure to radiation. Statistical features selected from the fMRI are grouped using various classifiers like Gaussian Mixture Model and k nearest neighbor. The dataset is, in turn, grouped into Normal and with emotion as an output of both the classifiers. Then the comparison of the classification accuracy between both the classifiers is done. GMM classification results are dependable because of the stable behaviour of model even under high noise and extraction of the activation patterns with accuracy. Techniques like Correlation coefficients and de trending along with the GMM clustering method may be used for estimation of activation regions from fMRI data with authenticity. kNN (K-Nearest neighbor) is a technique performed with supervision with classes formulated before classification after deciding the classification which is unaffected by ‘highly correlated feature’ issue providing results with accuracy. The results indicate that the degree of accuracy of classification fMRI dataset using kNN classifier is more than that of GMM classifier.

Inference from existing solution: The important setbacks of FMRI data based pre-processing, feature extraction, image segmentation and classification techniques are as follows.

- Bootstrapping supplies plentiful and a well proven theoretical technique to have a comparison of various data sets with regard to their signal to noise ratio and to evaluate any minute changes in quality of data.
- These are non-voxel based schemes which use wavelet descriptor differentiation and principal components to select unique features, though with the precision of accurate selection is not large.
- The results of PCA based feature extraction method has been able to provide only 70% accuracy in the last report Pattern recognition of fMRI image using PCA method.
- Voting-based active contour segmentation technique accomplishes the best performance on each metric but again not able to detect it quite accurately.
- The Segmentation of FMRI using functional echo state neural network provides accurate segment result but the effectiveness is less.
- Auto-threshold Contrast Enhancing Iterative Clustering (ACEIC) segment result sare immensely accurate but the runtime of these are more.
- The results of Multi variant classification and Machine Learning method are better but accuracy is less compared to other classification methods.
- Classification-based framework for knowledge discovery provides highly accurate results but less efficient.
- The accuracy of Gaussian Mixture Model (GMM) based classification is less than KNN classifier.

Resolution proposed to solve these issues

There were some issues seen with the segmentation and classification from FMRI data based above techniques. One solution to have the inclusion of the image processing methods which helps in the Noise in the image samples being removed, which improves the classification accuracy or tumour classification results. Main features are selected and Feature selection or reducing dimensionality issue is hence solved, thus the chieffeatures areextraction for identifying classes. Then the technique of Image segmentation is applied which segments the image for tumour detection with accuracy.

This section provides a detailed assessment of the performance of proposed FNN classifier. The image datasets are collated and implementation is done (mat lab). After the application of image processing techniques the fuzzy neural network classifier is brought into use. The performance of several classifiers like local Independent projection-based classification (LIPC) classifier and KNN classifier are compared with proposed fuzzy neural network (FNN) classifier. Initially LIPC is analysed and the simulation results are taken for citation from (Ashish panat, 2014; Meiyan Huang, 2014). Widrow-Hoff learning rule with generalisation is used on to this multi-layered network with learning rate 0.5 and the value of activation function 0.5.The activation functions are then utilized for mapping onto a final resultant output. Benign images have values less than 0.5 and those of malignant have higher values. With the input data involving100 patients (78 abnormal and 22 normal) the numbers of normal images provided for training set is 83and that for abnormal images are 17. Table 1, table 2 and table 3 denote the results of the assessed performance of both classifiers. Comparison in terms of sensitivity, specificity and accuracy are shown in fig1. Sensitivity (true positive fraction) = TP/TP + FN Specificity (true negative fraction) = TN/TN + FP Accuracy = TP + TN/TP + TN + FP + FN (Lalit, 2012).

Table.1. performance evaluation of KNN

KNN	Normal	Abnormal	Total
Prediction	TP=13	FP=35	48
False negative	FN=9	TN=43	52
Total	22	78	100

Table.2. performance evaluation of LIPC

LIPC	Normal	Abnormal	Total
Prediction	TP=16	FP=30	46
False negative	FN=6	TN=48	54
Total	22	78	100

Table.3. performance evaluation of FNN

FNN	Normal	Abnormal	Total
Prediction	TP=18	FP=25	43
False negative	FN=4	TN=53	57
Total	22	78	100

Accuracy Comparison: The classifier FNN is more successful in producing accuracy rate shown in Fig.1that is much greater than the existing classifiers such as LIPC and KNN. The accuracy increases with the increase in the number of features. This technique volves with high accuracy rate in comparison with other available classification methods.

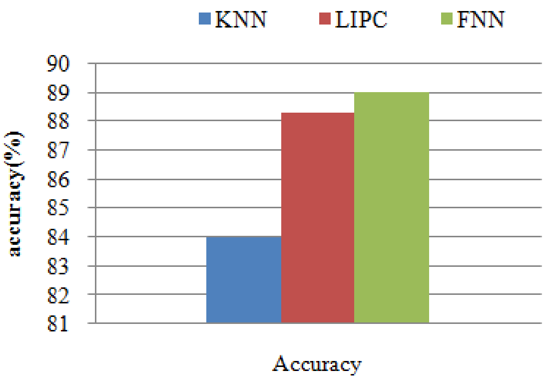

Figure.1.Accuracy Comparison

Sensitivity Comparison: The success rates of classifier FNN is great with respect to sensitivity shown in Fig.1in comparison to the classifiers such as LIPC and KNN which are available. The sensitivity increases with the increase in the number of features. This technique comes out with greater sensitivity rates in comparison toother classification methods.

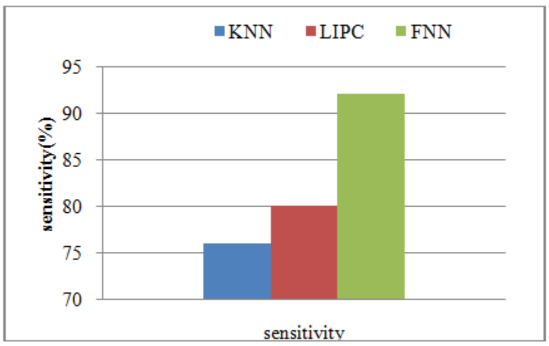

Figure.2. Sensitivity Comparison

Specificity Comparison: The classifier FNN is more successful in producing specificity rate shown in Fig.1that is much greater than the existing classifiers such as LIPC and KNN. The specificity increases with the increase in the number of features. This technique provides high specificity rate in comparison with other classification techniques.

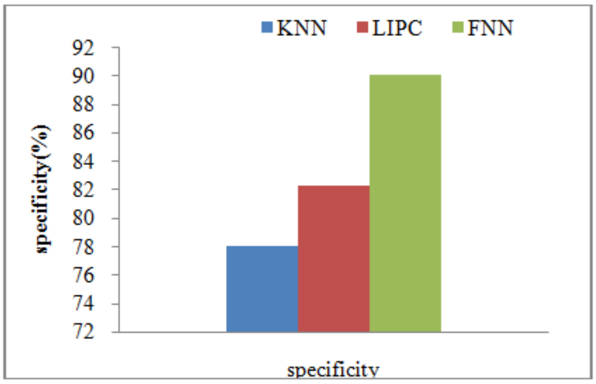

Figure.3. Specificity Comparison

2. CONCLUSION

This work provides a detailed description on the various image processing techniques for the detection of Brain tumour in FMRI image. Four techniques which assist in enhancing the performance, classification and accuracy, sensitivity, specificity of detecting the brain tumour in FMRI images were studied. They are Pre-processing, segmentation, feature extraction and classification respectively. First presented is a brief description of different image processing techniques in existence and also the detection rate and the accuracy rates of the methods are shown. Research in future are inclined towards the improvement of accuracy and also it can be progressed in the detection of the tumour and hence the growth can be studied. Fig 1, 2, and fig 3 show the performance study of different classification methods. This work will then be extensively done for Median Filter and neural network based algorithms to detect the types of tumour in MRI which will again be successful in providing more effective results.

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