A Review of Brain MR Image Segmentation Techniques

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ABSTRACT *Traditionally tumors are one of the most deadly diseases commonly encountered in human beings. Early detection and corrective treatments can largely bring down the mortality rates improving the chances of survival. For the correct prognosis, proper visualization of each minute details of the anatomical structure of brain is required which is done by brain MR imaging technique. Brain MR imaging technique is highly preferred by the radiologists as fewer artefacts are encountered. Other notable benefits over other Imaging techniques is the higher contrast between the soft tissues. However, with the ever-increasing population, the availability of large quantum of MRI data set is the biggest problem as it cannot be manually analyzed. It's a cumbersome and error-prone procedure and hence the requirement of development of tools with minimum human interface. For the detection of brain anomaly on MR imaging, several steps like preprocessing of image, feature extraction, enhancement of image, segmentation and then classification are done. The results of classification concludes that the person is with anomaly or not. Despite continuous efforts and evolution in the field, achieving result reproducibility for segmentation and classification is a major challenge. This can be attributed to different locations shapes and image intensities of the different types of tumors. In the present study, different segmentation techniques are discussed along with their advantages and disadvantages.*

Keywords: *Artificial neural networks (ANNs),Clustering based segmentation, Edge-based segmentation, Hybrid segmentation, MRI image segmentation, Region based segmentation, Thresholding based segmentation.*

INTRODUCTION

MRI imaging is a technique which provides a lot of information about anatomical soft tissues and is generally used by radiologists. It gives detailed images in any direction. It's more significant use is in oncological, musculoskeletal and neurological imaging as it provides a greater contrast between body soft tissues as compared with Computer Tomography (CT). MR image segmentation plays an important role in detection of the anomaly and pre and post medication/surgical assessment and planning [1].

The difference between MRI and CT is that unlike CT it does not use ionizing radiation. It uses magnetic field for lining up the nuclear magnetization of hydrogen atoms of water in tissue [2]. Overlapping intensities with normal tissue are found for the brain tumors of different shapes, sizes textures and intensities [3]. Although lots of different methods have been developed, both automatic and semi-automatic, they face common hindrances like poor image contrast, noise, weak boundaries and inhomogeneity. This necessitates image segmentation before diagnosis [4]. Amongst various brain anomalies, brain tumors are the most common leading cause of fatality.

Although MRI has various parameters that can be adjusted to give different grey levels for different types of neuropathology and different tissues [5]. Still accurate brain tissues segmentation is required which paves a way for identification of many brain disorders. In the present review, we have focused on different image segmentation techniques and their varied usage for Brain anomalies.

RELATED RESEARCH

Historically, numerous MRI classification techniques have been worked on. A cohesion based self-merging (CSM) algorithm was developed by Koley, S. and Majumder, A. [6] which was used for segmentation of brain MRI for finding the exact region of braintumor. When compared with other merging techniques CSM has proven itself better and hence draws attention of researchers. As here, the noise interference was greatly reduced which in turn reduce the computational time and increses the chances of locating the tumor exactly.

Another approach of brain tumors segmentation in 3D magnetic resonance images was proposed by Hassan Khotanlou et al. [7]. This technique proved to be suitable for different kinds of tumors. After the brain segmentation, the selection of suspicious areas is done using fuzzy classification for tumor detection with respect to the approximate brain symmetry plane. A combination of deformable model along with spatial relations is used here for the tumor segmentation.

Particle Swarm Optimization (PSO) was proposed by Chandra, S et al. [8] which was based on clustering algorithm. In this algorithm, in the brain MR images, the centroids were identified as a number of clusters and each and every cluster grouped the brain tumor patterns together. The obtained results were then compared with those of Ada Boost and Support Vector Machine (SVM). The qualitative results of proposed model showed striking with the results obtained by SVM. Further, better results of the algorithm were obtained when the different values of PSO control parameters were selected.

Accurate brain tumor identification using MR images was done by Badran et al. [9] by using computer-based technique. The brain Tumor Classification in this case was done to differentiate the malignant tissue for the benign ones. In the proposed algorithm the image was first preprocessed, then segmented, further its feature extraction and classification were done. Finally, the tumor area was located using the region of interest technique.

An efficient system was developed by R. Mishra [10] in which brain tumor accurate diagnosis was done using artificial neural network. Firstly, MR data was used to extract features via wavelet packets, an artificial neural network were used for finding out the normal and abnormal spectra. The rich analysis provided by Wavelet packet in comparison to wavelet transform further adds to advantages of their proposed system.

A robust technique to segment brain tumor medical image was developed by Wen-Feng Kuo et al. [11]. This technique is a combination of watershed segmentation and Competitive Hopfield clustering network (CHCN) algorithm which minimizes unwanted over-segmentation. For improving the quality of watershed segmentation, a region merging method was used which was based on the use of region adjacency graph (RAG). Quantitative and qualitative validation of this technique was done on benchmark images to prove the process.

Another system for brain tumor diagnosis and region extraction was proposed by Qurat-ul Ain et al. [12]. Initial diagnosis of brain tumor MR Images was done by naive bayes classification. Thereafter, the boundary detection techniques and K-means clustering were applied for extracting exact brain tumor region. The proposed method envisaged more than 99% accuracy showing experimentally that proposed system is accurate in feature extraction.

Earlier researches using brain MR images, for the brain anomalies used classic methods of image processing in the algorithms (e.g. region growing, edge detection etc.) which were based on images gray intensities. Recently, human brain on MRI image classification is done by using supervised techniques such as Artificial neural networks k-nearest neighbour, and support vector machine(SVM) Also unsupervised classification techniques as fuzzy C-means algorithm and self-organization map (SOM) were also used to classify the normal vs pathological T_2 weighted MRI images.

Yan Li and Zheru Chi [13] developed unsupervised MRI segmentation method which was based on self-organizing feature map. Extra spatial information about a pixel region was included in this algorithm by the use of Markov Random Field (MRF) model. Improvement of MRF term was done by segmentation results without any extra data samples for the training set. Great potentials of MRF are shown by the cooperation of MRF into SOFM as it has shown the smoothness of the segmented regions.

Korbakis G, et al. [14] worked on the investigation efficacy of MR imaging technique for detection of pathology like cerebral infarction (CI) in subarachnoid hemorrhage (SAH). MRI-detected Cerebral infraction (CI) in SAH involving multiple vascular territories like age of Hematoma., integrity of blood brain barrier, site of hemorrhage, the local pH, patient's hematocrit etc. This study proves superiority of MRI over CT for cases with cerebral infarction (CI) with subarachnoid hemorrhage (SAH) as CT may under estimate the same.

Choi et al.[15] studied the differentiation between Hemorrhagic Infarct and Parenchymal Intracerebral Hemorrhage. It was found that advanced imaging techniques like MR imaging are helpful especially difficult cases, looking for arterial occlusion, perfusion deficit, and diffusion restriction remote from the site of hemorrhages. The correct pathological distinction between Hemorrhagic Infarct and Parenchymal Intracerebral Hemorrhage by the use of MR imaging helps in proper treatment considering the difference in acute and long-term management of both the diseases.

Lanzmann et al.[16] studied the measurement of Cerebral blood flow by the use of magnetic resonance imaging perfusion (MRP) techniques. This technique is usually used for patients with chronic arterial steno-occlusive disease, cervical atherosclerotic disease, primary brain neoplasms etc. In MRP, an exogenous tracer which commonly is gadolinium-based intravenous contrast, or an endogenous tracer like arterial spin labeling (ASL) is used. In this review the author proved that MR imaging provides vital information for patients with cerebral diseases.

Thus, the above related research has proven undoubted superiority of MR imaging technique in comparison to other imaging techniques especially when we are dealing with brain. In this review paper, various approaches of MRI brain image segmentation algorithms are summarized along with their advantages and disadvantages in section III. Conclusion and remarks are discussed in section IV.

TECHNIQUES FOR BRAINMR TISSUE SEGMENTATION

The commonly used segmentation techniques for brain MR tissuesare summarized in Fig 1.

A. Thresholding based segmentation

This approach is effective when the images have different intensities as in this method the image, based on the intensity values, is directly partitioned into different regions. So, pixels with values (color, gray intensity etc.)

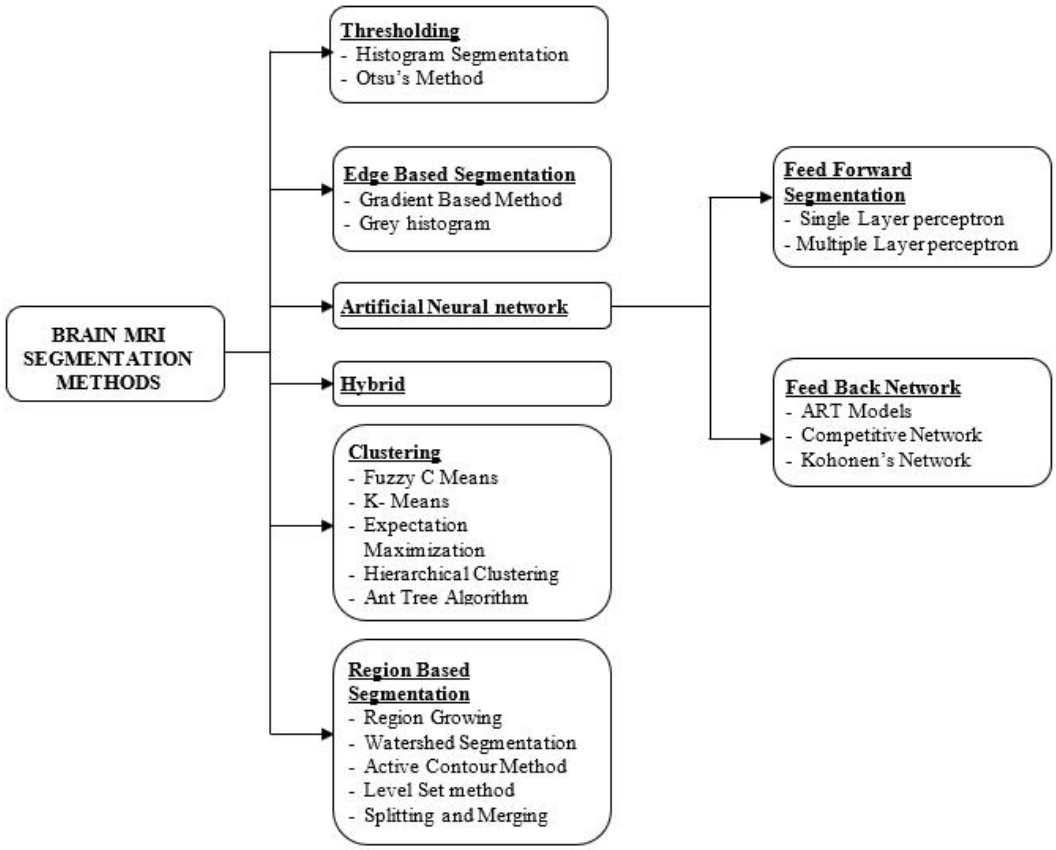

Fig1: Different Segmentation Techniques for Brain MR Images

lying between two threshold values of belongs to a region. The thresholding algorithm was given by [17] and has been widely used. While Global thresholding method selects one threshold value for the entire image giving faster computation time, applicable for images with uniform intensity and high contrast, Local thresholding divides the image into several sub images and thus calculating their threshold values taking moretime [18]. Histogram thresholding which worked on thresholding of histogram features and gray level thresholding, was mathematically defined by [19] in Eq 1.

$$g(x,y) = \begin{cases} 1, & if\ f(x,y) > T \\ 0, & if\ f(x,y) \leq T \end{cases} \quad (1)$$

Where,f (x, y) be the input image and 'T' be the threshold value andg (x, y) is the value of segmented image.

B. Edge-based segmentation

Rapid changes in intensity near edges is the basis for partitioning the image in edge based segmentation methods [17]. So, this technique works well when there is an abrupt intensity near change near edge and little image noise interference [20]. Hence in the edge detection methods, an equilibrium is

sought between the noise interference and detection accuracy. Common operators for edge detection used for gradient based method are canny operator, sobel operator, Laplace operator, & so on, but canny is most dependable [17], although is more time consuming.

C. Artificial Neural Network (ANN)

Segmentation technique which is based on Neural Network is ANN. Firstly, Image mapping is done in Neural Network. In this technique, each and every pixel is represented by Neuron [20], converting an image segmentation problem to an energy minimization issue. A training sample set was used to train the neural network for knowing the connection, weights between the nodes. The two basic steps in ANN are namely- feature extraction and image segmentation. As the determination of input data of neural network is done by feature extraction, hence making feature extraction a crucial step. [21]. Firstly, features are extracted from the images in such a way that they are a suitable input for segmentation.

The three basic characteristics of Neural Network Based Segmentation technique are better segmentation efficiency for non-regular data sets, fast computational capabilities and minimal expert intervention requirements during segmentation.Additionally, few basic drawbacksof the said technique are that prior information about segmentation should be available and it requires prior training which can sometimes require exceptionally long time.

D. Hybrid segmentation

Combined effects of both Region based and Edge Based segmentation techniques is used in Hybrid Segmentation which increasesthe segmentation accuracy when compared with Region based or edge-based methods separately. This process can extract features from both the processes namely region growing and edge based segmentation methods and oncombination of strength of these methodsgives better result. Hence,the decision of region growing is not only based onneighborhood similarity or pixel but also on the extracted edges [22, 23].

E. Clustering based segmentation

Clustering based segmentation techniques are used for dividing the image pixels in different clusters [24]. The process gives better results at a lower cost. One of the commonly used clustering technique is K- means clustering in whichallocation of each pixel is iteratively done to the nearest cluster. On the contraryin fuzzy c-means (FCM) clustering used for medical image segmentation gives better results [25, 26]. The standard FCM objective function for image partitioning into the different clusters [25] is given as below:

$$\int_p^{FCM}(\mu, v) = \sum_{i=1}^{L}\sum_{j=1}^{c}\mu_{j,i}^{p}\,\|s_i - v_i\|^2 \qquad (2)$$

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The membership functions are subjected to the following constraints

$$\sum_{j=1}^{c}\mu_{j,i}=1,\ \mu_{j,i} \in [0,1], \sum_{i=1}^{L}\mu_{j,i} > 0 \qquad (3)$$

Where, s= (s_1, s_2, s_3, s_4, ...s_t), t is the total no of pixels, u is the membership of the pixels s_t in the j_{th} cluster and v_f in f^{th} cluster centroid. ||(.)|| is the norm of a matrix and p is a weighted exponent on each fuzzy membership that controls the amount of fuzziness of the final segmentation.

F. Region based segmentation

Region based segmentation method finds the similarity of pixels within a sub region. These similarities are based on desired properties as color, intensity and texture. The basic principle behindregion-based segmentation are the similar characteristics of neighboring pixel within a particular region of the image.

Good results are obtained in Region growing technique where borders detection is difficult and the images are noisy [27].

CONCLUSION AND REMARKS

A wide range of image segmentation methods have been envisaged in the past several decades for the segmentation of Brain MRI images, but still remains a challenge for the radiologists. A segmentation method may give good results for one type of brain anomaly related MRI brain image but not for the other similar images. This makes it almost impossible to generalize the segmentation methods for different Brain MR Images. In the present review, we have focused on the pros and cons of various brain anomaly segmentation techniques.

REFERENCES

[1] Zhang Y, "A novel medical image segmentation method using dynamic programming", International conference on medical information visualization-bio Medical visualization, pp 69–74, 2007.

[2] Kekre H. B., Tanuja K. Sarode., Saylee M. Gharge, "Detection and Demarcation of Tumor using Vector Quantization in MRI images", IJEST, Vol1, No 2, pp 59-66, 2009.

[3] Mirajkar G., Barbadekar B., "Automatic Segmentation of Brain tumor from MR images using undecimated wavelet transform and Gabor wavelets", IEEE international conference on Electronics, circuits and systems, pp.702 – 705, 2007.

[4] Hall LO, Bensaid AM, Clarke LP, Velthuizen RP, Silbiger MS, Bezdek J, "A comparison of neural network and fuzzy clustering techniques in segmenting magnetic resonance images of the brain", IEEE Transactions on Neural Networks, Vol 3, No 5, pp 672–682, 1992.

[5] Tian D, Fan L, "A brain MR images segmentation method based on SOM neural network", 1st international conference on bioinformatics and biomedical engineering, pp 686–689, 2007.

[6] Koley S., Majumder A., "Brain MRI segmentation for tumor detection using cohesion based self merging algorithm",Proceedings of the IEEE 3rd International Conference on Communication Software and Networks (ICCSN), Xi'an, pp: 781 – 785, 2011.

[7] Hassan K., Olivier C., Jamal A., Isabelle B., "3D brain tumor segmentation in MRI using fuzzy classification, symmetry analysis and spatially constrained deformable models", Fuzzy Sets and Systems, Vol 160, No 10, pp. 1457-1473, 2009.

[8] Chandra, S.,Bhat R., Singh H, "A PSO based method for detection of brain tumors from MRI", Proceedings of the World Congress on Nature & Biologically Inspired Computing, Coimbatore, pp. 666 – 671, 2009.

[9] Badran E.F., Mahmoud E.G., Hamdy N, "An algorithm for detecting brain tumors in MRI images", Proceedings of the International Conference on Computer Engineering and Systems (ICCES), Cairo, pp. 368 – 373, 2010.

[10] Mishra R.,"MRI based brain tumor detection using wavelet packet feature and artificial neural networks", Proceedings of the International Conference and Workshop on Emerging Trends in Technology, pp. 656-659, 2010.

[11] Wen-Feng Kuo., Chi-Yuan Lin., Yung-Nien Sun., "Brain MR images segmentation using statistical ratio: Mapping between watershed and competitive Hopfield clustering network algorithms", Computer Methods and Programs in Biomedicine, Vol 91, No 3, pp. 191-198, 2008.

[12] Qurat-ul Ain., Irfan Mehmood., Naqi, M. Syed., Arfan Jaffar, M, "Bayesian Classification Using DCT Features for Brain Tumor Detection", Lecture Notes in Computer Science, Vol. 6276, pp. 340-349, 2010.

[13] Yan Li., Zheru Chi, "MR Brain Image Segmentation Based on Self-Organizing Map Network", International Journal of Information Technology, vol. 11, No. 8, 2005.

[14] Korbakis, G., Prabhakaran, S., John, S., MRI Detection of Cerebral Infarction in Subarachnoid Hemorrhage, Neurocrit Care, Vol. 24, No. 3, pp. 428-435, 2016.

[15] Choi PMC, Ly JV, Srikanth V.,"Differentiating between Hemorrhagic Infarct and Parenchymal Intracerebral Hemorrhage", Radiology Research and Practice, pp. 1-11, 2012.doi:10.1155/2012/475497.

[16] Lanzman B., Heit JJ.,"Advanced MRI Measures of Cerebral Perfusion and Their Clinical Applications", Top Magn Reson Imaging,Vol. 26 No. 2, pp. 83-90, 2017.

[17] Gonzalez Rafael C., Richard E. Woods, "Digital Image Processing", Pearson Education., 3rd Edition, 2007.

[18] Wirjadi O., "Survey of 3D image Segmentation Methods," Technical report, 2007.

[19] Srimani P.K., Shanthi Mahesh, "A Comparative study of different segmentation techniques for brain tumour detection", IJETCAS, pp. 192-197, 2013.

[20] Kang W.X., Yang Q.Q., Liang R.R, "The Comparative Research on Image Segmentation Algorithms", IEEE Conference on ETCS, pp. 703-707, 2009.

[21] Zhu C., Ni C., Li Y., Gu G, "General Tendencies in Segmentation of Medical Ultrasound Images", International Conference on ICICSE, pp. 113-117, 2009.

[22] Beveridge J.R., Griffith J., Kohler R.R., Hanson AR, and Riseman E.M., "Segmenting images using localized histograms and region merging", International Journal of Computer Vision, vol. 2, no. 3, pp. 311-347, 1989.

[23] Chu C.C. and Aggarwal J.K., "The integration of image segmentation maps using region and edge information", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 15, no. 12, pp. 1241-1252, 1993.

[24] Arakeni M. and Reddy G.R.M., "Efficient fuzzy clustering based approach to brain tumor segmentation on MR images", in Computational Intelligence and Information Technology. vol. 250, pp. 790-795, 2011.

[25] BezdekJ.C. and PalS.K., "Fuzzy Models for Pattern Recognition", IEEE press. New York, 1992.

[26] Chuang K.S., Tzeng H.L., Chen B., Wu J., and Chen T.J., "Fuzzy c-means clustering with spatial information for image segmentation", Computerized Medical Imaging and Graphics, vol. 30, no. 1, pp. 9-15, 2006.

[27] Shrimali V., Anand. R.S. and Kumar V. "Current trends in segmentation of medical ultrasound B-mode images: A review", IETE Technical Review, vol. 26. no. 1, pp. 8-17, 2009.