METHODS OF EXTRACTING SUB-CORTICAL STRUCTURES FROM HUMAN BRAIN SCANS – A SURVEY

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Abstract

The DGM - Deep Grey Matter in the human brain is responsible for various activities such as memory, cognition, learning, etc. The problem in any of these functions indicates neurological diseases like Alzheimer's disease (AD), Cerebral palsy, etc. The image of DGM helps to study the functions of various organs. To extract the structure of DGM, many algorithms are applied. This paper presents automatic and semi-automatic segmentation techniques. The commonly used techniques are categorized into Atlas-based, Learning-based and intensity-based. The performance of such algorithms is compared with the existing tools like FreeSurfer, LesionTOADS and FIRST. The Quantitative metrics like Jaccard and Dice are also used to validate the performance of a technique.

Keywords: Human brain, Segmentation, Hippocampus, Alzheimer's disease.

1. Introduction

For the purpose of accurate diagnosis doctors often use the images captured in medical imaging techniques which help them inspect and visualize anatomical structures of various human organs. Also, it is an inevitable tool for diagnosis and treatment of diseases [1]. Magnetic Resonance Imaging and Computed Tomography have now become the most important medical imaging technologies. To understand the structure of a particular human organ, the clinical experts segment them manually. But, the drawback of this manual segmentation is that it is time consuming. To overcome this problem, many computer-aided techniques have been developed.

Atlas based and intensity-based methods are the most conventional methods. Accuracy of most of the methods depend on the type of an image. Nowadays most of the techniques are proposed to apply on any type of images and produced good segmentation accuracy. The Recent computer-based methods to segment hippocampus from MRI of human brain for the diagnosis of memory related diseases are presented in this review article. The techniques used, datasets and the performance of the methods are described.

1. Review of Literature

Template and Neural network-based methods

Ting Guo et al. [2] developed a method which segments hippocampus of preterm neonates.

This is achieved by a protocol called MAGet. This method is able to perform segmentation at early in life also. An intermediate library is generated to reduce the registration. The method needs minimum number of input atlases to create a template. Three types of validations are performed to study the accuracy of segmentation. First, Monte Carlo validation is done with 187 atlases. Second, the method is applied to images of 125 infants to evaluate the growth of hippocampus. Third, linear regression is applied to calculate the volume of hippocampus during gestation age.

A neural-network-based method was proposed by Amod Jog et al. [3] to segment whole brain structure from T1W and T2W images. A forward model is built to produce a test image. This method produced good results with run time

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approximately 45s and Dice value 0.94. A 3D deep learning technique was developed by Benjamin Thyreau et al. [4] for bilateral hippocampus segmentation. The output generated by FreeSurfer tool is taken as an input to this deep learning method. This method uses various training sets for experiment and segmentation time is <30s per subject.

Clustering based techniques

The Expectation Maximization (EM) is applied to combine intensity modeling and multi-atlas segmentation in [4]. In this method, intensity-homogeneity is removed from the target image using low pass filtered template. Fedde van der Lijn proposed a method [5] which uses location and appearance of hippocampus as an atlas image. Gaussian scale space is applied to model the appearance of a structure. The appearance model enables to segment the structure of hippocampus with fuzzy intensity distributions.

The method is proposed by graph-cuts in combination with atlas-based algorithms [6] to segment the structure of hippocampus from T1W MR Images. The morphological operation is applied to make false positive rate low. A generative model is proposed based on specific atlases [7]. In this model, subject-specific atlas is estimated with registrations in a probabilistic framework to generate longitudinal MRI scans.

Atlas based segmentation methods

Manhua Liu et al. [8] derived a framework to classify hippocampus for diagnosis from structural MRI. A multi-model and 3D-connected network is designed for hippocampus segmentation. For each input image, a bounding cube is formed by cropping the images of MRI. The multi model feature is automatically learnt thus improving segmentation accuracy. This method is evaluated with T1W MRI datasets collected from ADNI. FIRST tool is used to produce rough segmentation. The method is applied to 449 subjects and good results are obtained. The measures such as volume error and positive predicted value are calculated.

Random forest method [9] is used in hippocampus segmentation. This method detects the feature of hippocampus and so the manual feature selection is avoided. The training voxels are defined from the training images and the dilation operation is performed to the slices containing hippocampus. The final segmentation is done by the voting rule. The standard metrics such as precision, recall and error are measured for accuracy.

An automatic segmentation method is developed using Label Fusion method [10]. In this method, a curve is for asymmetry index. The range of asymmetry index is set between -0.1487, -0.0624. Every time a subject is entered, Dice index and atlas set proportion are recorded. Then, within-subject coefficient is calculated. A hybrid method is developed by Fan Li e al. [11] by constructing DenseNets, which is used to learn features of hippocampus such as shape and intensity. Features of the left and right hippocampus are combined to classify disease. The dataset is obtained from ADNI database. The method is found to produce better result, and helps diagnosing diseases.

Details about some of the automatic and semi-automatic methods, repository of datasets and the type of images are given in Table 1.

Conclusion

In this paper, the literature of various segmentation methods was discussed. From these reviews, it is evident that every method has its limitations. The method that works well for one image may not be equally effective in the case of another type of image. The novelty of the methods and type of images taken for experimentation were also discussed.

S.No	Segmentation techniques	Dataset collected from	Segmented brain Structures	MRI type
1	Multiple-Atlas based (2010)	IBSR, ADNI	Hippocampus, thalamus, putamen, amygdala, pallidum and caudate from IBSR dataset Hippocampus from ADNI dataset	T1W
2	Atlas registration and appearance model (2012)	Rotterdam scan study	Hippocampus and cerebellum	T1W
3	Graph-cuts and atlas based	Samsung Medical Center, South korea	Hippocampus	T1W
4	Atlas-Bayesian longitudinal approach	MIRIAD and ADNI	Hippocampus	T1W
5	Random forest classifier	ADNI	Hippocampus	T1W
6	Label Fusion Method	Hospital of the university of Pennsylvania	Hippocampus	T1W

References

1. Dolz, L. Massoptier and M. Vermandel. Segmentation algorithms of subcortical brain structures on MRI for radiotherapy and radiosurgery: A survey. IRBM pp. 200–212, 2015.

2. Ting Guo, Julie L.Winterburn et. al., Automatic segmentation of the hippocampus for preterm neonates from early-in-life to term-equivalent age, NeuroImage: Clinical, Volume 9, 2015, Pages 176-193.

3. Amod Jog, Andrew Hoopes et. al., PSACNN: Pulse sequence adaptive fast whole brain segmentation, NeuroImage, Volume 199, 2019, Pages 553-569.

4. Benjamin Thyreau, Kazunori Sato et. al., Segmentation of the hippocampus by transferring algorithmic knowledge for large cohort processing, Medical Image Analysis, Volume 43, 2018, Pages 214-228

5. Fedde van der Lijn, Marleen de Bruijne, Tom den Heijer et. al., Automated Brain Structure Segmentation Based on Atlas Registration and Appearance Models, IEEE Transactions On Medical Imaging, Vol.31, pp. 276-286, 2012.

6. Kichang Kwak,Uicheul Yoon,Dong-Kyun Lee et. al., Fully-automated approach to hippocampus segmentation using a graph-cuts algorithm combined with atlas-based segmentation and morphological opening, Magnetic Resonance Imaging, vol. 31, pp.1190-1196, 2013.

7. Juan Eugenio Iglesias, Koen Van Leemput, Jean Augustinack et.al., Bayesian longitudinal segmentation of hippocampal substructures in brain MRI using subject-specific atlases, NeuroImage, vol.141, pp. 542–555, 2016.

8. Manhua Liu, Fan Li et. al., A multi-model deep convolutional neural network for automatic hippocampus segmentation and classification in Alzheimer's disease, NeuroImage, volume 208, 2020, Pages 1-16.

9. P. Inglese, N. Amoroso, M. Boccardi et. al., Multiple RF classifier for the hippocampus segmentation: Method and validation on EADC-ADNI Harmonized Hippocampal Protocol, Physica Medica vol. 31, pp.1085–1091, 2015.

10. Peter N. Hadar, Lohith G. Kini et. al., Clinical validation of automated hippocampal segmentation in temporal lobe epilepsy, NeuroImage: Clinical vol. 20, pp. 1139–1147, 2018.

11. Fan Li, Manhua Liu et.al., A hybrid Convolutional and Recurrent Neural Network for Hippocampus Analysis in Alzheimer's Disease, Journal of Neuroscience Methods, Volume 323, 2019, Pages 108-118.