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Object extraction from T2 weighted brain MR image using histogram based gradient calculation

Ghulam Gilanie [a], Muhammad Attique [a], Hafeez-Ullah [b,c,*], Shahid Naweed [a], Ejaz Ahmed [c], Masroor Ikram [b]

[a] Department of Computer Science and Information Technology, The Islamia University of Bahawalpur, Pakistan
[b] Department of Physics and Applied Mathematics, Pakistan Institute of Engineering and Applied Sciences, Nilore, 45650 Islamabad, Pakistan
[c] Department of Physics, Bahauddin Zakariya University, Multan, Pakistan

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ABSTRACT

Several segmentation methods have been reported with their own pros and cons. Here we proposed a method for object extraction from T2 weighted (T2) brain magnetic resonance (MR) images. The proposed method is purely based on histogram processing for gradient calculation. The proposed method utilizes the histogram filtering technique as a pre-processing. The primary brain areas; gray matter (GM), white matter (WM), and cerebrospinal fluid (CSF) are extracted out efficiently from 2D and 3D images. The method has been successfully implemented on human brain MR images obtained in clinical environment.

1. Introduction

There are several image processing steps; enhancement, segmentation, classification and etc. (Attique et al., 2012a). Nowadays, still diagnosis is mostly based on the set of luminance values acquired by different medical imaging modalities such as X-ray, MRI, ultrasound, and optical coherence tomography (Atif et al.; Hafeez-Ullah et al., 2011. These techniques are used for the analysis of biological tissues and pathological assessment with their own pros and cons (Attique et al., 2012a), in addition, 2D and 3D images can be acquired with various imaging modalities to represent tissue structures spatially (Zacharaki et al., 2009; Ullah et al., 2010; Veksler et al., 2008; Vlasova et al., 2006). MR imaging is the latest medical imaging modality that provides data about human anatomical structures to deal with soft tissues and is becoming important part of daily healthcare environment for the diagnosis of diseases. It also provides excellent tissue contrast, and high spatial resolution (Zhang et al., 2001). Often however, for further analysis and to extract hidden information, the segmentation of these images is required for better visualization of different regions.

Medical image segmentation has core importance to implement high level operations such as tissues recognition and classification. Segmentation of this type of imaging data is still a problem that demands to be probed (Liévin et al., 2001; Vassilieva, 2009). Segmentation of medical structures is compulsory in computer assisted surgery or diagnosis system. Medical imaging methods take part in focusing organs and tissues during surgery process (Caulfield and Fu, 2007; Hajar Hamidian et al., 2010). The visible and palpable tumor mass seen by different medical imaging modalities like CT and MRI is usually complicated to identify automatically with existing image processing methods, but still same is achieved manually by clinicians using computer aided drawing software (Carranza et al., 2007; Chia-Chi Teng and Kalet, 2010).

Segmentation of basic brain MR regions supports in visualization to identify various diseases, morphological and volume estimation, tissue classification and etc. (Ahmed and Mohamad, 2008; Zhang et al., 2001). Various methods of segmentation are edge based, thresholding, watershed and region growing etc., which are distinguished on the basis of their application and modality (Arlazarov et al., 2002; Sezgin and Sankur, 2004) using which image is acquired. These produce identical results on same imaging modality but vary in execution time and number of extracted objects. Some of the existing segmentation methods are computationally complex and some of them corrupt the histogram of image. Sometime combination of developed techniques achieves the goal of segmentation. Some of the limitations of these methods include the need for supervision/subjective aspects of method, search initialization, high computational cost and complexity.

* Corresponding author at: Department of Physics and Applied Mathematics, Pakistan Institute of Engineering and Applied Sciences, Nilore, 45650 Islamabad, Pakistan. Tel.: +92 619210091, mobile: +92 344 718 1418; fax: +92 619210068.
E-mail address: hafeezullah79@gmail.com (Hafeez-Ullah).

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Inhomogeneity and image noise corrupt the histogram of the image, making separation of different tissues difficult (Dzung L. Pham et al., 1998; Sharma and Aggarwal, 2010). Due to these artifacts various segmentation methods that ignore the spatial characteristics such as thresholding, edge based methods generate undesired results (Harikrishna Rai, 2009; Ming et al., 2009). So this field demanding some alternate methodologies with enhancements. From the literature various histogram based segmentation work is presented. Single rough threshold is selected from the histogram and re-estimate it using Gaussian distribution (Panning et al., 2009). Wrong selection of initial threshold may yield strange results in this method. Histogram is utilized to estimate variable ranges with density estimator and region growing is used for segmentation by utilizing these ranges (Krstinic et al., 2009). Due to the utilization of histogram ranges are calculated efficiently however region growing methods are costly in terms of computation. Dempster Shafer evidence theory based mass estimation function is used to estimate homogeneity histogram and incorporates fuzzy homogeneity vector for segmentation (Salim Ben Chaabane et al., 2009). Sometime the histogram based segmentation divides the image in two classes and somewhere histogram is used to estimate membership function for segmentation (Anjos and Shahbazkia, 2008; Otsu, 1979; Ridler and Calvard, 1978). Conte et al. (2011) proposed a segmentation method especially for wrist MRI images by integrating region growing and level set segmentation. They develop the method in a way to extract some specific region of interest (ROI) from the whole image. The developed method of segmentation works well for the estimation of a ROI having sharp edges completely. The main drawbacks with this method are the operator involvement for seed selection and extraction of single selected object under observation. Region growing based segmentation methods are computationally complex as compared to histogram based segmentation methods (Attique et al., 2012b).

Mayer and Greenspan (2009)) use multiple methods approach to segment out brain primary regions. First of all they use Adaptive Mean Shift (AMS) for mode list selection then using iterative mode pruning procedure they further reduce the mode space and finally they use voxel weighted clustering method (K-Mean) to segment out the brain primary regions. Mode list depends upon the window size. K-Mean is sufficient for the segmentation of brain MRI images with defined number of classes to segment out the basic primary regions. Since K-Mean by-self is iterative in nature the integration of other iterative processes for preprocessing is an extra overhead.

Another segmentation method is reported by Kalaiselvi and Somasundaram (2011) that utilizes the Fuzzy C-Mean (FCM) algorithm for brain MRI image segmentation with fixed centriod values analyzed from image histogram. The main drawback with these FCM based segmentation algorithms is that they are iterative in nature that makes the whole process of segmentation computationally complex (Attique et al., 2012b). Shan et al. (2002) reported a segmentation method to remove non-brain tissues (sinus, dura, marrow and etc.) and segment out the brain tissues (Gray Matter and white Matter) as a whole from the T1 weighted (T1W) images utilizing the histogram analysis based multi-level thresholding and morphological operator. While our study deals specifically with the brain MRI images and extracts out the all primary regions in single phase. We utilized the image histogram to estimate the gradients (intensity ranges for primary brain regions) to extract out brain primary regions.

Fouquier et al. (2012) proposed a knowledge based segmentation method for the segmentation of functional brain regions (internal regions) from brain MRI images. They used the spatial relationship and prior anatomical model to decide and segment the required regions in some specific order. The main draw back with knowledge based segmentation methods are that they require learning or training from huge volume of subjects belonging to all age sets for their successful results or outputs. Whereas our proposed segmentation method deals with primary regions only for segmentation without requiring the prior anatomical knowledge rather it estimates these primary regions automatically from the image histogram.

It selects gradient from the histogram for each brain region. Initially it selects the highest peak from the histogram and probes for two significant valleys around it. Both of the valleys provide range/gradient for a specific brain region. With this gradient selection from histogram we improve the efficiency of image segmentation. The pixels that come under each gradient symbolize an object and these pixels are extracted from the image to form a separate object. The extracted objects retain their original intensity levels.

Although intensity in-homogeneities or shading artifacts are present in magnetic resonance images due to non-uniformities in the radio frequency and other factors which affect the segmentation process. To deal with in-homogeneity, segmentation process is performed in two steps. First in-homogeneity is estimated and removed to make the region homogeneous then segmentation process is performed secondly (Pham and Prince, 1999). In the text several techniques have been reported for the correction of intensity in-homogeneity. Ahmed et al. (2002) modified the Fuzzy C Mean (FCM) clustering algorithm where the labeled voxels are classified on the behalf of their neighborhood voxels. Pham and Prince (1999) proposed Adaptive Fuzzy C Mean (AFCM) algorithm for the correction of in-homogeneity (both scalar gain field and vector gain field) and segmentation. The main drawback with these FCM based segmentation algorithms is that they are iterative in nature that makes the whole process of segmentation computationally complex (Attique et al., 2012b).

Basically the aim of our research work is to deal brain MRI images with homogeneous regions to provide a new and efficient method for segmentation. However to estimate and correct the intensity in-homogeneity, the way adapted by Sled et al. (1998) might be used that corrects the intensity in-homogeneity by estimating a gain field that further enhances the image histogram which is beneficial for histogram processing based segmentation methods.

The experiments and results provide adequate demonstration of the achievements of the proposed method. The results indicate that proposed method is capable of delineating the brain anatomical structures, yielding more visually probable images; facilitates the radiologist to visualize, analyze and or interpret each region separately to diagnose various pathologies related to various regions e.g. WM lesions and hydrocephalus (CSF related disease) more precisely than the regions are analyzed inside the original image. The suggested method can potentially be used with other medical imaging modality to segment out anatomical tissues/regions.

2. Materials and methods

2.1. Image acquisition

Total 48 subjects (31 males and 17 females) with average age of 34 years, which include normal, abnormal, volunteers and patients having brain related diseases, were scanned to acquire T2 brain MR images. Out of them, total 29 subjects (19 males and 10 females) have been examined to derive criteria for histogram filtration and segmentation as shown in Table 1. Rest of the 19 subjects (12 males and 07 females), were used to obtain and verify the results produced by proposed segmentation method. The images have been obtained on a Philips Achieva 1.5 Tesla MRI, with twenty 0.5 mm. The experimental work has been performed under institutional laws of Bahawal Victoria Hospital (BVH) Bahawalpur, Pakistan. These laws were validated by institutional review and