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Automatic Segmentation Approach Based Data Aggregation for the Classification of Brain Tissues

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Abstract. The paper presents a study and an evaluation of a novel unsupervised segmentation technique based aggregation approach and some of possibility theory concepts. Firstly, the MPFCM (Modified Possibilistic Fuzzy C-Means) algorithm is used to extract information from each of MR images modalities. In second step, an obtained data are combined with an operator in order to exploiting the uncertainty and ambiguity in the images. Finally, the segmented image is constructed using a decision rule. The efficiency of the proposed method is demonstrated by segmentation experiments using simulated MR images with different noise levels.

Keywords: aggregation, possibility theory, segmentation, MPFCM, MR images.

1. Introduction

Magnetic resonance (MR) imaging has been widely applied in biological research and diagnostics, primarily because of its excellent soft tissues contrast resolution, non-invasive character, high spatial resolution and easy slice selection at any orientation. In many applications, its segmentation serves a significant role on the following areas : (a) identifying anatomical areas of interest for diagnosis, treatment, or surgery planning paradigms; (b) preprocessing for multimodality image registration ; and (c) improved correlation of anatomical areas of interest with localized functional metrics [1]. Fully automatic brain tissue classification from magnetic resonance images (MRI) is of great importance for research and several clinical study of much neurological pathology. The accurate segmentation of MR images into different components, such as gray matter (GM), white matter (WM) and cerebrospinal fluid (CSF), is a vital role both in image analysis and computer vision.

In medical imaging domain, segmenting MR images has been found a difficult task due to the limited spatial resolution, noise and intensity in homogeneities variation, partial volume effects and a remarkable amount and largest set of data to be processed. To handle these difficulties, an enormous number of approaches have been reported in the literature, including fuzzy logic methods [3], neural networks [4], markov random field methods with the maximum expectation [5], statistical methods [5], and data fusion methods [6]. Here, the evaluation of a full automatic and robust approach for the segmentation of the human brain tissues using a multispectral aggregation technique is presented. This approach consists of the computation of fuzzy tissue maps generated by each of the three modalities of MR images T1, T2 and PD as an information source, the creation of fuzzy maps by a combination operator and a segmented image is computed in decision step.

The rest of this paper is organized as follows : In section 2, review of related research is briefly cited. Section 3 summarize the fuzzy clustering algorithm employed in the proposed method. In section 4, we describe the principals of possibility theory reasoning. The proposed process is detailed in section 5. Simulation results qnd discussions are introduced in Section 6. Finaly, the conclusion is summed up in Section 7.

2. Review of Related Research

Copious number of works of fuzzy information fusion field is found in the literature. Let us review some

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of them. Waltz [11] presented three basic levels of image data fusion named as : pixel level, feature level and decision level, espacialy to three processing architectures. Some concepts of Dempster-Shafer evidence theory have been outlined by I. Bloch [2], which can very useful for medical image fusion for classification, segmentation or recognition goals. Examples were given to indicate its ability to take into account a various of situations. Registration-based methods are considered as pixel-level fusion, such as MRI-PET (Positron Emission Tomography) data fusion[12]. Some techniques of knowledge-based segmentation can be stated as the feature-level fusion such as the methods proposed in [16].

One of belief functions, uncertainty theory and Dempster-Shafer theory are often used for decision-level fusion such as in [14]. I. Bloch [17] proposed an unified framework of information fusion in the medical field based on the fuzzy sets, allow to represent and process the numerical data as well as symbolic systems. V. Barra and J. Y. Boire [9] have discussed a general framework of the fusion of anatomical and functional medical images. The purpose of their research is to fuse functional and anatomical information obtained from medical imaging, the fusion process is realized in possibilistic logic frame, which allows for the management of uncertainty and imprecision inherent to the images. A new class of operators based on information theory and the whole process is finally illustrated in two clinical cases : the study of Alzheimer's disease by MR/SPECT fusion and the study of epilepsy with MR/PET/SPECT. The obtained results was very encouraging.

V. Barra and J. Y. Boire [15] proposed a new effective scheme of information fusion to segment intern cerebral structures. The information is provided by both expert knowledge and MR images, and consists of constitution, morphological and topological characteristics of tissues. The fusion of multimodality images is described in [13]. In [8], the authors have presented a framework of fuzzy information fusion to segment automatically tumor areas of human brain from multispectral magnetic resonance imaging (MRI); in this method three fuzzy models are used to represent tumor features for different MR image sequences and the fuzzy region growing is exploited to improve the fused result.

Maria del C. and al [10] proposed a new multispectral MRI data fusion technique for white matter lesion segmentation, in that an approach is detailed and compared with thresholding mathod in FLAIR images. In [19], Hongwei Zhu et al. have proposed an adaptive fuzzy evidential reasoning scheme for segmenting multi-modality MR brain images. Recently, The authors in [20] have presented a new framework of fuzzy information fusion using T2-weighted and proton density (PD) images in order to improve the quality of brain tissue segmentation.

3. The MPFCM Algorithm Clustering

Typically, clustering is a process of partitioning an unlabeled data set $X=\{x_1, x_2, x_3, \ldots, x_n\}\in \Re^p$ into 1<c<n non-overlapped, consistent regions called classes with respect to some characteristics, by assigning labels to the vectors in *X*. A cluster contains similar patterns placed together. One of the most widely used clustering methods is the MPFCM (*Modified Possibilistic Fuzzy C-Means*) algorithm [21]. The MPFCM algorithm uses both the information of pixels and their neighborhoods, membership and typicality for classification. The MPFCM clustering algorithm minimizes the objective function :

$$J(U,T,V,X)=\sum_{i=1}^{C}\sum_{k=1}^{N}(au_{ik}^{m}+bt_{ik}^{\eta})D_{ik}+\sum_{i=1}^{C}\gamma_i\sum_{k=1}^{N}(1-t_{ik})^{\eta} + \beta\sum_{i=1}^{C}\sum_{k=1}^{N}(au_{ik}^{m}+bt_{ik}^{\eta})S_{ik} \quad (1)$$

where m>1 is the weighting exponent, $\lambda\in[3,5]$ is the typicality exponent D_{jk} is the Euclidean distance between data x_j and cluster center v_i, $S_{ik}=\sum_{w=1}^{n_w}\|x_w-v_i\|$ where xw is a neighbor pixel of x_k in a window around xk and nw is the number of neighbours in this window., $[U]_{CxN}$ is the fuzzy matrix where $\forall k,\sum_{i=1}^{C}u_{ik}\le 1$. $[T]_{CxN}$ is the typicality matrix where $\forall k,t_{ik}\le 1$, a>0, b>0 are user defined constants and the parameter γ_i is given by :