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A cooperative semi-supervised fuzzy clustering framework for dental X-ray image segmentation

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ABSTRACT

Dental X-ray image segmentation (DXIS) is an indispensable process in practical dentistry for diagnosis of periodontitis diseases from an X-ray image. It has been said that DXIS is one of the most important and necessary steps to analyze dental images in order to get valuable information for medical diagnosis support systems and other recognition tools. Specialized data mining methods for DXIS have been investigated to achieve high accuracy of segmentation. However, traditional image processing and clustering algorithms often meet challenges in determining parameters or common boundaries of teeth samples. It was shown that performance of a clustering algorithm is enhanced when additional information provided by users is attached to inputs of the algorithm. In this paper, we propose a new cooperative scheme that applies semi-supervised fuzzy clustering algorithms to DXIS. Specifically, the Otsu method is used to remove the Background area from an X-ray dental image. Then, the FCM algorithm is chosen to remove the Dental Structure area from the results of the previous steps. Finally, Semi-supervised Entropy regularized Fuzzy Clustering algorithm (eSFCM) is opted to clarify and improve the results based on the optimal result from the previous clustering method. The proposed framework is evaluated on a real collection of dental X-ray image datasets from Hanoi Medical University, Vietnam. Experimental results have revealed that clustering quality of the cooperative framework is better than those of the relevant ones. The findings of this paper have great impact and significance to researches in the fields of medical science and expert systems. It has been the fact that medical diagnosis is often an experienced and case-based process which requests long time practicing in real patients. In many situations, young clinicians do not have chance for such the practice so that it is necessary to utilize a computerized medical diagnosis system which could simulate medical processes from previous real evidences. By learning from those cases, clinicians would improve their experience and responses for later ones. In the view of expert systems, this paper made uses of knowledge-based algorithms for a practical application. This shows the advantages of such the algorithm in the conjunction domain between expert systems and medical informatics. The findings also suggested the most appropriate configuration of the algorithm and parameters for this problem that could be reused by other researchers in similar applications. The usefulness and significance of this research are clearly demonstrated within the extent of real-life applications.

1. Introduction

Dental X-ray image segmentation (DXIS) is an indispensable process in practical dentistry for diagnosis of periodontitis diseases. It has been said that DXIS is one of the most important and necessary steps to analyze X-ray dental images in order to get valuable information for medical diagnosis support systems and other recognition tools (Said, Fahmy, Nassar, & Ammar, 2004). In the view of medical systems, segmentation aims to determine isolated teeth or different parts such as stump, gums, etc. (Said, Nassar, Fahmy, & Ammar, 2006).

An X-ray dental image consists of three main parts (Scott, 1977) (Fig. 1a): (i) *Teeth area*: often has high values of grayscale and is what we have to clarify from the image; (ii) *Dental structural area*: has medium values of grayscale and consists of gums, bone, and other periodontitis structure; (iii) *Background area*: has the smallest value of grayscale among all and shows the background of a teeth structure. The structure of X-ray dental images makes the segmentation more complicated than traditional image segmentation (Zhou & Abdel-Mottaleb, 2005). In the other words, the connection between various parts of an X-ray dental image and low quality of the image due to noises, low contrast, errors on image scanning, etc. degrade the

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Fig. 1. (a) An X-ray dental image; (b) blank holes in missing teeth.

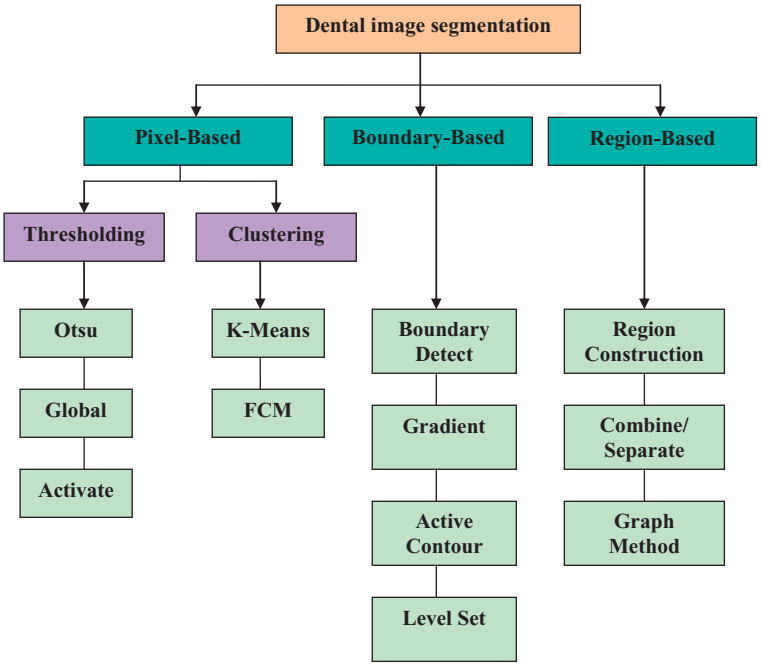

Fig. 2. A classification tree of the DXIS methods.

segmentation performance. For instance, the blank holes in missing teeth in Fig. 1b cannot be processed by conventional image thresholding techniques (Kondo, Ong, & Foong, 2004). Thus, specialized data mining methods for DXIS have been investigated to achieve high accuracy of segmentation (Nomir & Abdel-Mottaleb, 2005).

A classification of various techniques for DXIS was introduced in (Rad, Rahim, & Norouzi, 2014). In the classification tree in Fig. 2, *thresholding* is the simplest technique among all. It divides histogram of an image into two separate regions according to a threshold T. The classification is performed by assigning a label to each pixel: either "Main part" (Teeth and dental structure areas) or "Background part". A typical thresholding method is Otsu (Otsu, 1975). Bhandari, Singh, Kumar, and Singh (2014) employed cuckoo search algorithm and wind driven optimization for multilevel thresholding using Kapur's entropy. This algorithm was used to obtain the best solution or best fitness value from the initial random threshold values, and to evaluate the quality of a solution, correlation function is used. Ayala, dos Santos, Mariani, and dos Santos Coelho (2015) proposed a beta differential evolution (BDE) algorithm for determining the $n-1$ optimal n-level threshold on a given image using Otsu criterion. Bhandari, Kumar, and Singh (2015a) introduced a modified artificial bee colony (MABC) algorithm based satellite image segmentation using different objective functions to find the optimal multilevel thresholds. Bhandari, Kumar, and Singh (2015b) developed another technique for color image segmentation using Cuckoo Search algorithm supported by Tsallis entropy for multilevel thresholding toward the effective colored segmentation of satellite images. Oliva et al. (2015) proposed a new algorithm for multilevel segmentation based on the Electromagnetism-Like which is used to find the optimal threshold values by maximizing the Tsallis entropy. Zhou, Tian, Zhao, and Zhao (2015) presented a novel image segmentation algorithm that combines improved Firefly Algorithm with Two-Dimensional Otsu to solve the problems of time consuming, low accuracy and easy to produce false segmentation image. However, a major disadvantage of the thresholding group is the determination of threshold T for detecting the main part of a dental image especially on noise images (Xu, Xu, Jin, & Song, 2011). Even though evolutionary algorithms have been utilized for such the determination, the complexity of computational models makes them hard to apply in real situations.

In the *boundary-based techniques* such as the Level Set method (Rad, Mohd Rahim, Rehman, Altameem, & Saba, 2013), a surface is covered by a curve so that image characteristics such as edges and