Dental Diagnosis from X-Ray Images using Fuzzy Rule-Based Systems

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ABSTRACT

In practical dentistry, dentists use their experience to examine dental X-ray images and to derive symptoms from patients for concluding possible diseases. This method is based solely on the own dentists’ experience. Dental diagnosis from X-Ray images is proposed to support for dentists in their decision making. This paper presents an application of consultant system for dental diagnosis from X-Ray images based on fuzzy rule. Fuzzy rule was applied in many applications and has important role in computational intelligence, data mining, machine learning, etc. Based on a dental X-ray image dataset, we use Fuzzy C-Means to classify them into clusters and construct the rule set. Fuzzy Inference System is then used to evaluate the rules by three validity indices. These rules accompanied with symptoms from patients help dentists in diagnosing dental diseases. This method is implemented and experimentally validated on the real dataset of Hanoi Medical University Hospital, Vietnam against the related algorithms.

KEYWORDS

1. INTRODUCTION

In the modern world, the health of human gets a special caring. Scientists try to find out the way for supporting clinicians in diagnosing disease. In 2012, Support Vector Machine (SVM) was used in diagnosis of osteoporosis from dental panoramic images by Kavitha, et al. (2012). Chattopadhyay et al. (2012) presented an application of Bayesian classifier for diagnosis of dental pain. Oad, DeZhi and Butt (2014) proposed a fuzzy rule-based approach to predict risk level of heart disease. Ramírez, Castillo and Soria (2010) used Fuzzy K-Nearest Neighbor (FKNN) algorithm for various medical problems including dental diagnosis. However, dentists use their experiences to diagnose diseases from dental X-ray images of a patient. Such the experts’ experience varies by different dentists. Thus, it is necessary to predict dental diseases from X-ray images and to support the dentists in diagnosing dental diseases. Computerized medical diagnosis systems are of great interest to clinicians for accurate decision making of possible diseases and treatments (Doi, 2014). One of the most typical approaches is fuzzy inference system (FIS) which determines a projection from a given input data set to an output data set using fuzzy logic (Guillaume, 2001 and Oad, DeZhi and Butt (2014)). However, forming such the rules requires much experience from experts in order to guarantee accurate diagnosis and avoid duplicate, conflict and meaningless rules (Grabisch, Nguyen and Walker, 2013). Another rule-based technique proposed (Hühn and Hüllermeier, 2009) is FURIA (Fuzzy Unordered Rule Induction Algorithm) which deals with uncovered examples by making use of an efficient rule stretching method.

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FURIA applies pruning modifications for optimizing the rule sets represented in a specific form and fuzzified by a greedy algorithm. A classifier output is given by using this method.

Fuzzy inference (Guillaume, 2001) is a process that determines exactly a projection from a given input data set to an output data set using fuzzy logic. This projection provides a basic in which we can make decisions or visual models. Fuzzy inference progress consists of three main parts: membership function, logic operators and rules in the form of “If…. then…” and works through five periods: 1) Fuzzification input variables; 2) Apply fuzzy operators (AND or OR) to these variables; 3) Infer results from given input; 4) Summary obtained results; and 5) Defuzzification. Fuzzy inference system (FIS) has been applied successfully in many different fields such as automatic control (Hosseini and Etemadi, 2008 and Lee, 1990), data classification (Wang and Lee, 2002), expert system (Togai and Watanabe, 1986) and computer vision (Ho et al., 2002), and stock market (Boyacioglu and Avci, 2010). FIS is also called as a fuzzy rule based system, a fuzzy expert system, a fuzzy model, a fuzzy combination memory, a fuzzy logic control set and a fuzzy system. There are three kinds of FIS: Mamdani FIS, Sugeno FIS and Tsukamoto FIS. The idea of applying FIS for the dental diagnosis problem is demonstrated as follows. FIS is a rule-based system, so that, it needs a rule set. At the beginning, we extract dental features from the training dataset to create a dental database. Fuzzy rules are then generated by the Fuzzy C-Means (FCM) method (Bezdek, Ehrlich and Full, 1984). Those rules are used to predict the diseases in the testing set by an inference mechanism of FIS.

The new contributions of this paper are: 1) Building a dental feature database from dental X-ray images of Hanoi Medical University; 2) Proposing a new FIS-based model to support diagnosing dental diseases via the obtained database; 3) Implementing this model and validating its performance by different criteria in comparison with FKNN. Such the contributions prove the roles of fuzzy systems to dental diagnosis problem.

The rests of this paper are organized as follow. Section 2 presents some background knowledge including the FCM method, an overview of FIS, and details of FKNN. Section 3 describes the new contributions namely mechanism of fuzzy control system, feature extraction methods and the rule generation progress. Section 4 shows experimental results and discussions. Finally, some conclusions and future works are drawn in Section 5.

2. BACKGROUND

In this section, we firstly overview about the Fuzzy C-Means (FCM), and then describes background knowledge of Fuzzy Inference System (FIS). Lastly, details of Fuzzy K-Nearest Neighbor (FKNN) are given.

2.1. Fuzzy C-Means (FCM)

Fuzzy C-Means (Bezdek, Ehrlich and Full, 1984) is based on an iteration process to optimize the membership matrix and the cluster centers. The objective function of FCM is:

\[ J = \sum_{k=1}^{N} \sum_{j=1}^{C} u_{kj} \times \left\| x_k - V_j \right\| \rightarrow \text{min} \]  

(1)
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