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Ontological fuzzy agent for electrocardiogram application

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Abstract

The electrocardiogram (ECG) signal is adopted extensively as a low-cost diagnostic procedure to provide information concerning the healthy status of the heart. However, the QRS complex must be calculated accurately before proceeding with the heart rate variability (HRV). In particular, the *R* peak needs to be detected reliably. This study presents an adaptive fuzzy detector to detect the *R* peak correctly. Additionally, an ontological fuzzy agent is presented to process the collection of ECG signals. The required knowledge is stored in the ontology, which comprises some personal ontologies and predefined by domain experts. The ontological fuzzy agent retrieves the ECG signals with *R* peaks marked for HRV analysis and ECG further applications. It contains a personal fuzzy filter, an HRV analysis mechanism, and a fuzzy normed inference engine. Moreover, the ECG fuzzy signal space and some important properties are presented to define the working environment of the agent. An experimental platform has been constructed to test the performance of the agent. The results indicate that the proposed method can work effectively.

Keywords: Ontology; Fuzzy inference; Agent; Electrocardiogram (ECG); Heart rate variability (HRV)

1. Introduction

Electrocardiogram (ECG) data are normally acquired for clinical diagnosis of cardiac function, and involve the electrical activity of the heart. The state of the cardiac heart is generally reflected in the shape of ECG waveform and heart rate. The ECG waveforms may differ for the same patient such that they are unlike each other, and at the same time alike for different types of beats (Osowski & Linh, 2001). Therefore, for effective diagnostics and classification, building a personal ontology is a good idea for ECG signals classification. An ontology is a collection of key concepts and their inter-relationships, collectively providing an abstract view of an application domain (Lee, Jian, & Huang, 2005). Beveridge and Fox (2006) presented a home monitoring mechanism through an intelligent dialogue system to apply to healthcare. Lee et al. (2005) presented a fuzzy ontology and applied it to news summarization. They also presented a novel episode-based ontology construction mechanism to extract a domain ontology from unstructured text documents (Lee, Kao, Kuo, & Wang, 2007), and an ontology-based intelligent healthcare agent for respiratory waveform recognition (Lee & Wang, 2007).

An agent is a physical or virtual entity that is capable of acting in an environment and communicating directly with other agents. An intelligent agent is more powerful than an ordinary agent, due to the reasoning and learning capabilities (Chen, Houston, Nunamaker, & Yen, 1996). Delen and Pratt (2006) designed and developed an intelligent decision support system for manufacturing. Hamdi (2006) presented a multi-agent customization system based on machine learning mechanism for web mining. Lee, Jiang, and Hsieh (2006) proposed a genetic fuzzy agent for meeting scheduling system. Wang (2005) applied the concept of agent-based control for networked systems in control theory to traffic and transportation management. Yan, Jiang, Zheng, Peng, and Li (2006) proposed a perceptron-based medical decision support system for the diagnosis of heart diseases. Grossklags and Schmidt (2006) studied how software agents affect the market behavior of human traders.

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An ECG signal can provide much information on the normal and pathological physiology of the heart activity. Thus, ECG is an important non-invasive clinical tool for the diagnosis of heart diseases (Israel, Irvine, Cheng, Wiederhold, & Wiederhold, 2005; Meau, Ibrahim, Narainasamy, & Omar, 2006). The accurate determination of the QRS complex, particularly accurate detection of the *R* peak, is essential in computer-based ECG analysis, but is often hard to achieve. Noise contamination because of baseline drifts changes, motion artifacts and muscular noise is frequently encountered (Benitez, Gaydecki, Zaidi, & Fitzpatrick, 2001). Therefore, many different approaches have been developed to enhance the accuracy of QRS detection. For instance, Benitez et al. (2001) presented a new robust algorithm for QRS detection using the first differential of the ECG signal, and the Hilbert transformed data to locate the *R* peaks. Friesen et al. (1990) developed a comparison of the noise sensitivity of nine QRS detection algorithms. Pan and Tompkins (1985) proposed a real-time algorithm for detecting the QRS complexes of ECG signals.

The ECG trace is highly informative. The most common digital application of the ECG trace is heart rate variability (HRV). Additionally, HRV is widely adopted to measure of the heart function, which helps to identify patients at risk for a cardiovascular event or death (American Heart Association Inc. & European Society of Cardiology, 1996). The recognition of the beats in ECG is a very significant subject in the intensive care units, where the recognition and classification of the ECG signals in real-time is essential for the treatment of patient. Osowski and Linh (2001) presented the application of the fuzzy neural network for ECG beat recognition and classification. Ozbay, Ceylan, and Karlik (2006) presented a comparative study of the classification accuracy of ECG signals by a fuzzy clustering neural network architecture. Tsipouras, Fotiadis, and Sideris (2005) proposed a knowledge-based method for arrhythmic beat classification and arrhythmic

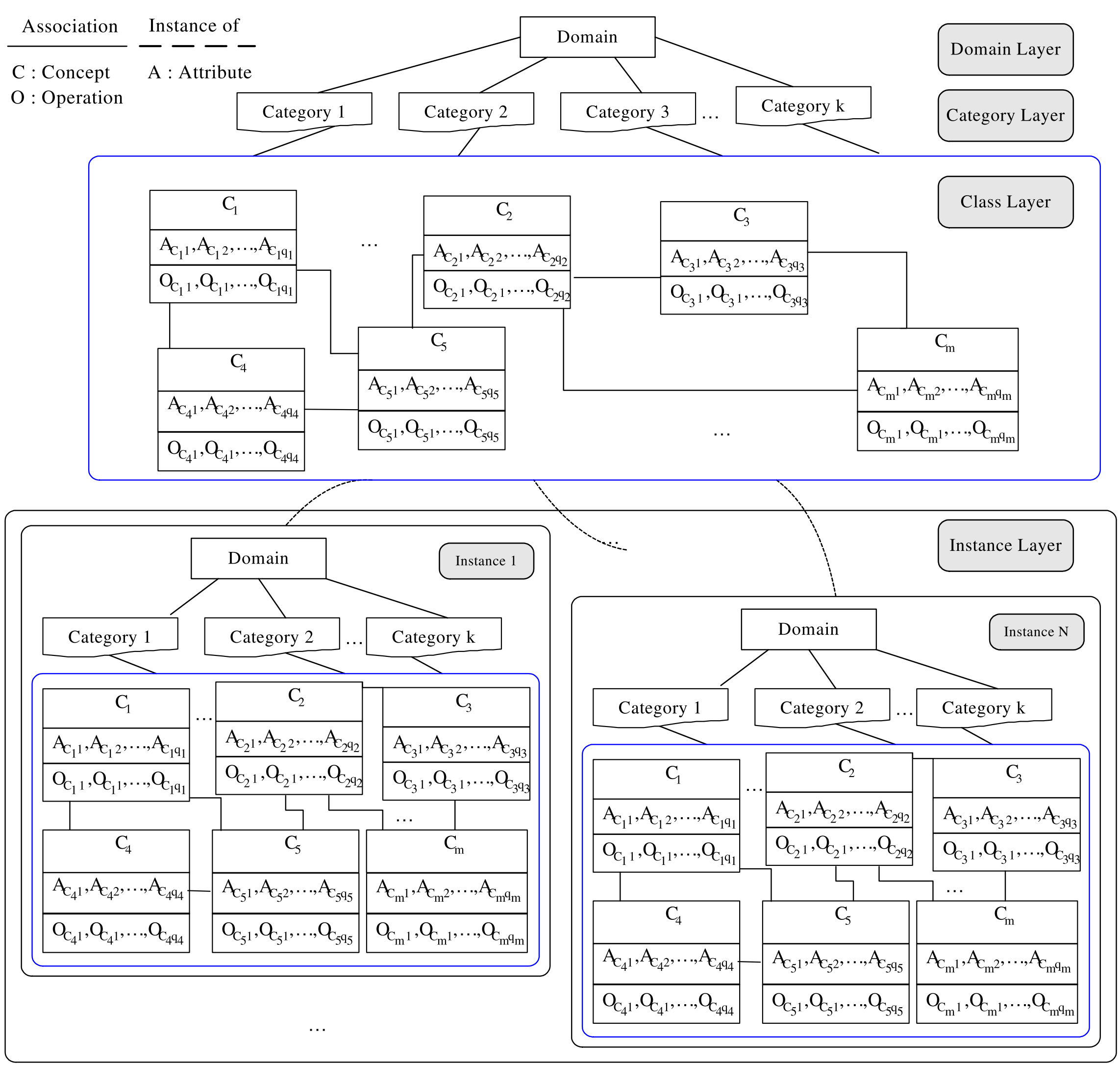

Fig. 1. The domain ontology architecture.