Pulse Waveform Classification Using ERP-Based Difference-Weighted KNN Classifier

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Abstract. Although the great progress in sensor and signal processing techniques have provided effective tools for quantitative research into traditional Chinese pulse diagnosis, the automatic classification of pulse waveform is remained a difficult problem. In order to address this issue, we propose a novel edit distance with real penalty-based *k*-nearest neighbor classifier by referring to recent progress in time series matching and KNN classifier. Taking advantage of the metric property of ERP, we develop an ERP-induced inner product operator and then embed it into difference-weighted KNN classifier. Experimental results show that the proposed classifier is more accurate than comparable pulse waveform classification approaches.

Keywords: pulse waveform; time series classification; edit distance with real penalty (ERP); *k*-nearest neighbor (KNN).

1 Introduction

Traditional Chinese pulse diagnosis (TCPD) is a convenient, non-invasive and effective diagnostic method used in traditional Chinese medicine (TCM) [1]. This diagnosis method requires practitioners to feel for the fluctuations in the radial pulse at the styloid processes of the wrist and classify them into distinct patterns which are related to different syndromes and diseases in TCM. Due to the limitation of experience and knowledge of different practitioners, the accuracy of pulse diagnosis could not be guaranteed. As a way to improve the reliability and consistency of diagnoses, in recent years techniques developed for measuring, processing, and analyzing the physiological signals [2, 3] have been considered in quantitative TCPD research [4, 5, 6, 7]. Since then, different pulse signal acquisition systems have been developed [8, 9, 10], and many methods are proposed in pulse signal preprocessing and analysis, including pulse signal denoising [11], baseline rectification etc. [14]. Moreover, a great progress have been made in pulse classification as a number of feature extraction and recognition methods have been studied for pulse signal classification and diagnosis [12, 13, 15, 16, 17, 18].

Although progress has been made, there are still problems in the automatic classification of pulse waveforms which involves classifying a pulse waveform as one of the traditional pulse patterns, e.g., moderate, smooth, taut, hollow, and unsmooth

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pulse according to its shape, position, regularity, force, and rhythm [1]. Since the intra-class variation in pulse patterns is inevitable, each pulse pattern may have more than one typical waveform. Because of the adverse effect of local time shifting and noise, pulse waveform classification suffers from the low accuracy. The developed pulse waveform classification methods, such as neural networks and dynamical time warping (DTW) [19, 20, 27], achieve accuracies mostly below 90%, and usually are only tested on small data sets.

In this paper, by referring to the development in time series matching techniques, i.e., edit distance with real penalty (ERP), we investigate novel approach for pulse waveform classification. We first propose an ERP-induced inner product operator, and using the difference-weighted KNN (DFWKNN) framework we further present a novel ERP-based classifier, i.e., ERP-based difference-weighted KNN (ERP-DFWKNN), for pulse waveform classification. We evaluate the proposed method on a pulse waveform data set which includes 2470 pulse waveforms. Experimental results show that the proposed method achieves an average classification accuracy of 90.36%, which is higher than several other pulse waveform classification approaches.

The remainder of this paper is organized as follows. Section 2 introduces the main modules in pulse waveform classification. Section 3 first presents a brief survey on ERP and DFWKNN, and then proposes ERP-DFWKNN. Section 4 provides the experimental results on pulse waveform classification. Finally, a conclusion is drawn in Section 5.

2 The Pulse Waveform Classification Modules

A pulse waveform classification system usually includes three major modules: a pulse waveform acquisition module, a preprocessing module, and a classification module (Fig. 1). The acquisition module is essential, for a good quality of acquired pulse signal will allow effective preprocessing and accurate classification possible. The preprocessing module is used to remove the distortions of the pulse waveform caused by noise and baseline wander. In the third module, different feature extraction and classification methods are used to classify the pulse waveform into distinct patterns.

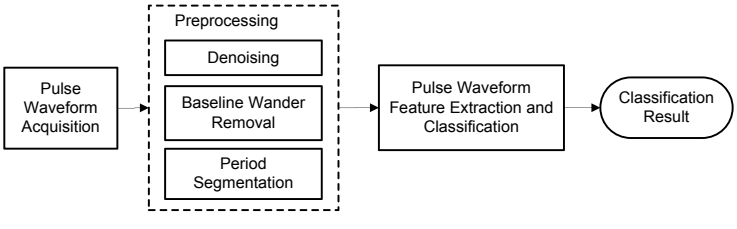

Fig. 1. Outline of pulse waveform classification modules

2.1 Pulse Waveform Acquisition

In this work, the pulse acquisition system was jointly developed by Hong Kong Polytechnic University and Harbin Institute of Technology. In pulse waveform