I love you Jiaming

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***Abstract*—In this paper, we proposed a novel predictive modeling algorithms which is based on a designed spatial transformation. This model is capable of not only automated analysis but also providing analytical predicts on the upcoming abnormalities of time series signals. As an important application, the proposed algorithm has been applied on ECG signal and compared with benchmark ECG classifiers.**

I. Introduction

As a result of population aging, life stress increasing and accelerating pace of life, the incidence of fatal spontaneous disease such as cardiovascular disease has been increasing sharply, becoming one of the main mortality causes in worldwide[**?**]. Biomedical signals, as a non-invasive method, are investigated broadly by researchers to design automated analysis and real-time monitoring systems. In the past decades, various biomedical signal analysis systems are proposed. Whereas applying conventional classification algorithms on biomedical signals remains challenging, especially for applications of spontaneous disease detection. The main drawbacks of the existing systems are due to the following two features.

One important character of biomedical signal waveforms is its variability caused by distinct physical conditions of different individuals (i.e. gender, age, body-mass index etc.)[**?**][**?**]. Conventional classification algorithms fall short of generalization when applying on different patients' records.

To address this issue, some innovative patient-specific classification systems are proposed [**?**][**?**][**?**]. Hu et al. proposed a patient-specific mixture of experts (MOE) classifier by incorporating personalized annotations provided cardiologists in the local classifier [**?**]. This methods achieves patient-adapting capacity but requires further input from human experts. Following the design of MOE, de Chazal and B. Reilly proposed an improved patient-adapting classifier by reducing the requirement of manual annotations to as few as 10 beats for training adaptive local classifier. Based on 1-D convolutional neural networks (CNN), Kiranyaz et al. proposed a flexible algorithm which adjusts its parameters using information extracted from individual signal[**?**]. The classifier demonstrates consistent performance over different ECG records While this approach outperforms the aforementioned classification algorithms as it does not require expert further annotations, its performance reduces for some rare abnormal classes.

Another typical feature of signals for spontaneous disease is abnormality occurrence without obvious premonitory symptoms, which leads to the lack of effective therapeutic intervention beforehand and a high mortality rate of the disease. Therefore, a timely detection or prediction capacity is of great importance for automatic analysis systems.

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In order to overcome this unpredictability, systems with advanced warning or predicting capacity are proposed in some recent researches. In [**?**], Kiranyaz et al. proposed an abnormal beat synthesis approach to map normal beats to potential abnormal beats and thus generate analysis results in advance. The goal of normal-to-abnormal mapping is to model potential causes for spontaneous cardiac diseases. In our previous work[**?**], the specific spatial topology of normal and abnormal clusters was analyzed in order to model the trajectory of ECG samples evolving from normal status to abnormal. These two methods share a common concept of modeling the intermediate states from complete normal to abnormal state.

While the aforementioned systems demonstrated capacity of predicting upcoming abnormalities, it's hard to interpret the mechanisms of the systems and thus hindering the generalization of predictive warning to other applications of biomedical signals.

Having analyzed the symmetric encircled topology in our previous work, we proposed a novel spatial transformation based predictive modeling system to assist cardiologist take advanced therapeutic innervation. The system consists of four essential parts: data preparation, forming personalized normal cluster, tuning parameters of spatial transformation and predicting with transformed data. This paper is organized as follows: Section **??** briefly introduces the overview of data set deployed in this paper; Section **??** summarizes the overall workflow of the system including the formation of personalized normal cluster; Section **??** includes three proposed methods for designed spatial transformation; Section**??** demonstrates the results by deploying the system on benchmark ECG data; Section **??** concludes the system and proposes potential applications of this approach.

II. Data Preparation

The main goal of this stage is to extract informative features from biomedical signal, mapping the signal from its raw form to a single sample in the feature space. As an important biomedical signal for diagnosing cardiac disease, electrocardiogram (ECG) is widely used to design and test classifiers. In particular, the benchmark data MIT-BIH Arrhythmia database[**?**] (MITDB) is recommended by the Association for the Advancement of Medical Instrumentation (AAMI) [**?**] for reporting classification performance. Following the standardized AAMI recommended practice, the annotations of MITDB are further grouped into 4 major classes: class N(normal and bundle branch block beat types) class V(ventricular type), class S(supraventricular type) and class F(fusion of normal and ventricular types). In this paper, ECG lead A is adopted and the database is further split into test and training set by balancing the four major classes of ECG according to [?]. The data preparation for ECG signal is composed of signal preprocessing, segmentation, and feature extraction.