Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

PING CHENG

MSc (Northwestern Polytechnical University, 2012)
BEng (Northwestern Polytechnical University, 1998)

“Study on a Resource-Saving Cloud Based Long-Term ECG Monitoring System Using Machine Learning Algorithms”

Department of Electrical and Computer Engineering

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Engineering and Computer Science Building
Room 468

Supervisory Committee:
Dr. Xiaodai Dong, Department of Electrical and Computer Engineering, University of Victoria (Supervisor)
Dr. Wu-Sheng Lu, Department of Electrical and Computer Engineering, UVic (Member)
Dr. Yang Shi, Department of Mechanical Engineering, UVic (Outside Member)

External Examiner:
Dr. Yong Wang, Department of Obstetrics & Gynecology, Washington University School of Medicine

Chair of Oral Examination:
Dr. Dan Smith, Department of Geography, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

Electrocardiogram (ECG) records the electrical impulses from myocardium, reflects the underlying dynamics of the heart and has been widely exploited to detect and identify cardiac arrhythmias. This dissertation examines a resource-saving cloud based long-term ECG (CLT-ECG) monitoring system which consists of an ECG raw data acquisition system, a mobile device and a server. Three issues that are critically pertaining to the effectiveness and efficiency of the monitoring system are studied: the detection of life-threatening arrhythmias, the discrimination of normal and abnormal heartbeats to facilitate the resource-saving operation and the multi-class heartbeat classification algorithm for non-life-threatening arrhythmias.

The detection algorithm for life-threatening ventricular arrhythmias, which is critical to saving patients’ lives, is investigated by exploiting personalized features. Two new personalized features, namely, aveCC and medianCC, are extracted based on the correlation coefficients between a patient-specific regular QRS-complex template and his/her real-time ECG data, characterizing subtle differences in the QRS complexes among different people. A small set of the most effective features is selected for efficient performance and real-time operation using support vector machines (SVMs). The effectiveness of the proposed algorithm is validated in enhancing the performance under both the record-based and database-based data divisions. The classification algorithm achieves results outperforming the existing classification performances using top-two or top-three features.

A novel patient-specific arrhythmia detection algorithm, which discriminates the normal and abnormal heartbeats, is proposed using one-class SVMs. Conventionally, CLT-ECG systems are used to solve problems such as the portable problem and the difficulty of capturing the intermittent arrhythmias. However, CLT-ECG systems are subject to several practical limitations: battery power restriction, network congestion and heavily redundant ECG data. To overcome these problems, a resource-saving CLT-ECG system is studied, in which a novel arrhythmia detection algorithm closely related to the resource-saving rate is proposed and examined in detail. The proposed
arrhythmia detection algorithm explores two types of variations: waveform change index (WCI), reflects a change within one heartbeat; modified RR interval ratio (modRRIR), characterizes the successive heartbeat interval variation. The overall classification result is obtained from combining the results separately adopting WCI and modRRIR. The proposed algorithm is validated using the MIT-BIH arrhythmia database with a result outperforming others in the literature, as well as using the data collected from the ECG platform HeartCarer built in our research group.

Considering the multi-class classification in the cloud, a patient-specific and subject-oriented single-lead ECG heartbeat classification strategy is proposed to discriminate ventricular ectopic beats (VEB) and Supraventricular Ectopic Beats (SVEB). Two types of features are extracted: Intra-beat features characterize the distortion of the waveform within one heartbeat, while inter-beat features reflect the variation between successive heartbeats.

A novel fusion strategy consisting of a global classifier and a local classifier is presented. The local classifier is obtained using the high-confidence heartbeats extracted from the first 5 minutes data of a specific patient, while the global classifier is trained by the public training data. The advantage of the developed strategy is that fully automatic classification is realized without the intervention of physicians. Finally, simulation results show that comparable or even better classification performance is achieved, which validates the effectiveness of the proposed strategy.