University of Macau

ABSTRACT

ECG QRS COMPLEX DETECTION WITH PROGRAMMABLE HARDWARE

by Ieong Chio In

Thesis Supervisor: Dr. Vai Mang I, Dr. Mak Peng Un
Master of Science in Electrical and Electronics Engineering

Electrocardiogram (ECG) auto diagnosis is a hot topic in Biomedical Engineering field. Researchers attempt to employ electronic device to recognize ECG characteristics and provide preliminary diagnosis advice to patients for saving valuable time of both doctors and patients.

QRS Complex is the most striking waveform of ECG. The frequency of QRS Complex occurrence corresponds to the heart rate and the detection of QRS Complex can help determine the occurrence of other waveforms. Many efforts of researches have been spent on QRS Complex detection in last decades, and in recent years, modern QRS Complex detection algorithms based on Wavelet transform or Mathematical Morphology are reported. However, most of the algorithms are not real-time algorithms. They are computation intensive and based on Von Neumann type computer. Moreover, the hardware implementation of the modern QRS Complex algorithms are seldom reported in published literatures.

This thesis proposed the algorithm and architecture of ECG QRS Complex Detection system based on Field Programmable Gate Array (FPGA). FPGA is a reprogrammable and reconfigurable integrated circuit, which can map design into hard-wired circuit for high performance computation. The algorithm and architecture include Morphological filtering, Quadratic Spline Wavelet transform and Modulus Maxima Pair Recognition.

The challenges of this research are: 1) ECG signal is non-stationary. They are different from person to person, and they are often noise contaminated. 2) The ECG QRS Complex Detection algorithm should be suitable to be map into FPGA with digital circuit. Circuit architecture for realization in FPGA has to be investigated with the constraints of timing and resource consumption, etc. Algorithm and circuit architecture co-design has to be performed.

The advantage of the FPGA-based ECG QRS Complex Detection system is significant, including high performance, small size, low power consumption, and feasibility of transformation to Application Specific Integrated Circuit (ASIC). The ECG QRS Complex Detection system facilitates the parallel processing characteristic of system, so that the data throughput is up to 35.231 MSa/s which is very high. By testing the system with the records of MIT/BIH Arrhythmia database, the overall accuracy is 97.29%.

KEYWORDS: Field Programmable Gate Array (FPGA), Electrocardiogram (ECG), QRS Complex Detection, Mathematical Morphology, Quadratic Spline Wavelet transform, State Machine