Chapter 19
Embedded System for Heart Disease Recognition using Fuzzy Clustering and Correlation

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ABSTRACT

This chapter presents the viability analysis and the development of heart disease identification embedded system. It offers a time reduction on electrocardiogram – ECG signal processing by reducing the amount of data samples without any significant loss. The goal of the developed system is the analysis of heart signals. The ECG signals are applied into the system that performs an initial filtering, and then uses a Gustafson-Kessel fuzzy clustering algorithm for the signal classification and correlation. The classification indicates common heart diseases such as angina, myocardial infarction and coronary artery diseases. The system uses the European electrocardiogram ST-T Database – EDB as a reference for tests and evaluation. The results prove the system can perform the heart disease detection on a data set reduced from 213 to just 20 samples, thus providing a reduction to just 9.4% of the original set, while maintaining the same effectiveness. This system is validated in a Xilinx Spartan®-3A FPGA. The FPGA implemented a Xilinx Microblaze® Soft-Core Processor running at a 50 MHz clock rate.

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INTRODUCTION

According to the Center of Disease Control and Prevention – CDC of the United States of America, the leading cause of human death is attributed to heart illnesses, even surpassing deaths caused by cancer. More than 910 thousand U.S. citizens die every year from heart related illnesses and more than 70 million live and cope with some sort of heart condition, such as high blood pressure, strokes or angina (Carter M. (2006)). Seeking to reduce these figures, much research has been undertaken in order to make diagnoses faster, more accurate and with enough foresight to elevate the chances of patient survival through specific cardiopathy treatment.

In order to monitor patients’ cardiac signals, a device known as an electrocardiograph (galvanometer) is utilized which, in turn, presents these signals in the form of an electrocardiogram – ECG. An ECG is a record of the variations in electrical potential generated by the heart’s electrical activity. The diagnosis is based on the extraction of information about the peak of electrical waves and time intervals of the ECG signal. The procedure is safe, noninvasive (performed on the human body’s surface without breaking the skin), reproducible, easy to obtain, low in cost and offers important indicators for analyses and diagnoses of cardiac anomalies (Brazilian Society of Cardiology (2003)). ECGs are a representation of an analog signal whose magnitude in the abscissa axis corresponds to time (normally in seconds), while the ordinate axis corresponds to electrical potential in volts (mV).

The problem herein under investigation is the possibility of application and implantation of a real system, or rather, of a device which utilizes signal processing techniques in order to obtain the most relevant characteristics of an electrocardiogram signal with greater precision and simplicity. Through such improvements, it may be possible to attain cheaper and simpler hardware with less processing, while still enabling accurate diagnoses.

In order to verify the efficacy of this research’s proposal, a databank of real electrocardiogram signals was acquired, in which each signal presents the main characteristics of an electrocardiogram with some kind of cardiopathy. The databank was obtained through PhysioNet (Taddei, A. (1993)), which is a cooperative public service project for complex physiologic signals research. The project is financed by the National Center for Research Resources and the National Institutes of Health. PhysioNet offers free access via the Internet to multiple physiologic signal databases and open-source related software (Goldberger, AL. (2000)).

The general objective of this chapter is to present processing techniques for signals inserted in an embedded system, implanted in hardware, which serves to receive an electrocardiogram signal and carry out processing, while also reducing the quantity of samples, until generating a possible diagnosis. We further divide system implantation, in relation to the ECG, into acquisition, treatment, filtering, fuzzy clustering and correlation. The system is always aiming to produce accurate and fast diagnoses at a low cost with portable algorithms for the proposed implementation.

The entire process, starting from the acquisition to the probable diagnosis, is demonstrated in Figure 1 and Figure 2.

Figure 1 shows two blocks: ECG acquisition and Filters. The ECG block represents the leads. These leads are signals obtained through sensors placed on strategic points of the human body in order to capture electrical signals generated by the heart. For greater certainty in the diagnosis, normally 12 leads are analyzed in the electrocardiogram, detailed in item 2 of this chapter. However, it is known that with just two leads it is possible to generate a diagnosis (Negreiros de Andrade, PJ. (2008)). The second block separates the noise from the signal to be analyzed and removes the DC level. The DC level corresponds to the average obtained from the 213 signal...
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