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A heart disease recognition embedded system with fuzzy cluster algorithm

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ABSTRACT

This article 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 indicated 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 field programmable gate array (FPGA) implemented a Xilinx Microblaze® Soft-Core Processor running at a 50 MHz clock rate.

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1. Introduction

The analysis of an electrocardiogram is performed by physicians and other health professionals in order to diagnosis many heart diseases. The analysis consists of extracting information from the peaks and time intervals of the signal waveforms. Few advanced electronic equipments can even conduct the analysis at patient's home, based on few extracted parameters [1].

Some heart diagnosis systems [2–7] are based on computer algorithms that use signal processing techniques for the interpretation of the electrocardiogram characteristics, thus allowing preliminary diagnosis of a cardiopathy. Ref. [2] proposes the multi-channel beat detection and segmentation, waveform models and unsupervised patient adaptation method used to detect ischemia. It demonstrates the use of segmentation for the data analysis in the signal processing. It uses the same ECG data bank and the same sensitivity and positive predictivity as in our work. Heuristic rules provided by cardiologists are used as knowledge base.

On the other hand, [3] introduces a cardiac arrhythmia classification system using fuzzy classifiers, that uses artificial intelligence algorithms and a knowledge base to classify arrhythmias. Ref. [4] detects specific points of the electroencephalogram (segment ST) using network-based fuzzy interferences and a MIT-BIH [8] knowledge base to classify the segment forms and thus provide the diagnosis of few cardiac illnesses. Those works provide detection mechanism by comparison of the signal with a databank.

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The importance of filtering on the ECG signal is provided by [9]. It also uses two combined research methods; the fast Fourier transform (FFT) and the wavelet threshold de-noising (WTD) to demonstrate the importance of real time processing. That work was validated in an field programmable gate arrays (FPGAs). Ref [10] shows an ECG signal classification system using neural network that was implemented in hardware. It demonstrated the portable hardware implementation using FPGA.

Ref. [11] presents a system that extracts and performs real time analysis of the QRS complex to indicate the presence of a cardiopathy that was also implemented in FPGA. ECG QRS complex detection using an adaptive lifting scheme (ALS) on a MIT-BIH database is also implemented in FPGA by [12].

Based on previous references, it can be observed that ECG data processing depends basically on four factors: data acquisition, filtering, detection algorithms and knowledge base, and they are required to implement a system to detect illnesses or provide a diagnosis from an ECG signal. It can be observed the demand of portable devices, based on FPGA as a validating mechanism.

The development of a portable heart diagnosis system capable of real time signal processing and analysis of an ECG is important to monitor high risk patients and to assist physicians to make decisions.

The development of an algorithm to extract the main ECG characteristics for embedded systems offers challenges such as time varying signals and physiological variables, including patient gender and age. The algorithm must also take into account the noise, generally generated by other electrical equipments in the vicinity and by the patients muscle movements [13]. The filter is among the most relevant component in an ECG signal processing [9], and it is used also to identify and to classify the signal. It is necessary the use of filters in the ECG input signal, so that the GK fuzzy cluster algorithm [14] can be conducted later. The cluster algorithm consists basically of adapting the rule sets technique. In other words it is the process of grouping a set of rules, real or abstract objects into sets of rules or similar objects [15,16]. The technique is adapted to identify points that describe the main features of an electrocardiogram signal. The signal processing becomes restricted to those points, thus reducing the number of data to be processed, which in turn simplifies the hardware implementation. Nevertheless, artificial intelligence techniques have been used to identify and to classify the ECG signal [10,17].

The fuzzy sampling algorithm extracts the most relevant aspects of the ECG signal [18], thus significantly reducing the amount of date to be analyzed, without loss of important information. It is a great advantage on an embedded system since it requires less computational effort.

By using the correlation technique [19,20], the ECG signal is compared with other previously sampled signals located in the system memory. The comparison provides the similarity factor between the ECG signal and the previously diagnosed data bank signals [21]. The comparison offering the largest factor is recognized as a possible patient diagnosis. Other metrics such as conventional Euclidean distance or Kullback–Leibler could also be used, but the results are similar.

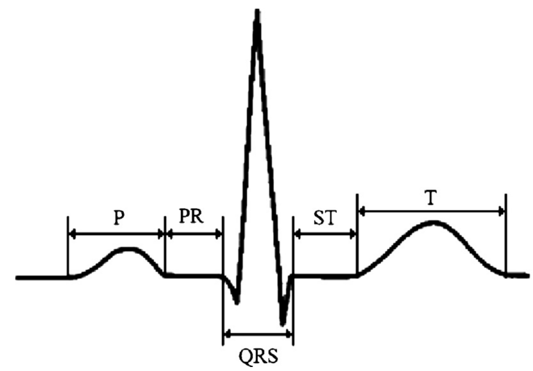

Fig. 1 – Typical electrocardiogram waveform with segment indication.

The partial algorithms on each stage, the filtering, the fuzzy cluster algorithm and the correlation were validated by using MathWorks® MATLAB® tools. The algorithm set, as indicated in Fig. 1, was completely implemented in C programming language. The programming code was developed according to the American National Standards Institute – ANSI in order to meet compatibility with a wide range of compilers and platforms [22]. The code implemented in a FPGA XILINX in order to be run by a Microblaze® processor. The soft-core processor performs the signal processing, runs the analysis and diagnosis the heart disease, thus charactering as in real time processing. The use of FPGA in medical applications, particularly ECG analysis, demonstrates that it is viable the hardware implementation of a real time heart disease detection system [23].

2. Methods

We have used the physionet.org – European ST-T Database (EDB) data bank [21]. It contains 90 ECG records from 79 patients. Each record consists of two signals of two hours long, each one sampled at 250 samples per second with a 12 bit resolution in a 20 mV interval.

The samples to be analyzed by the clustering process were taken by an ECG pattern detection algorithm that scans the signal to find a full cycle, which starts with a P segment and ends with a T segment, as shown in Fig. 1. The full cycle in an EDB signal is comprised of 213 samples.

The samples were resized after digitalization, referred to the calibration signals of the original analog recordings, in order to use a uniform reference of 213 samples per ECG cycle for all signals [24]. The basic ECG signal processing algorithm and analysis is comprised of three modules, as indicated in Fig. 2:

(1) Filtering process,
(2) Fuzzy cluster algorithm,

Fig. 2 – ECC Block diagram of system modules.

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