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FPGA Implementation of Disease Detection System

Amana Yadav, Naresh Grover

Abstract: ***Nowadays Cardiovascular diseases are very trivial in every part of world. People are suffering from many such diseases; so a time to time check-up of their heart is very important and it is good if a person get to know about these diseases in advance. Heart checkup is again a very crucial task; hence to overcome this problem, a single system is needed, to know about few diseases depending upon electrocardiogram (ECG) of the patient under observation and few body parameters. Here to detect the disease in early stage, a new Field Programmable Gate Array (FPGA) based technique has been proposed using different ECG features along with few body parameters. This novel technique will diagnose diseases depending upon temperature, Systolic Pressure, Weight, Diastolic pressure, SPo2, and Sugar etc. MIT-BIH database was used to get ECG signals and for simulation and to display the results Xilinx version 8.2 was used.***

Keywords: ***Electrocardiogram (ECG), QRS complex, Cardiac Arrhythmia, MIT-BIH, FPGA.***

I. INTRODUCTION

The ECG is an indispensable clinical means and is widely used to detect the cardiac problems. It calculates the contractile electrical activity of the heart originate over the cardiac rhythm using different electrodes placed at several places on the body surface [1]. ECG is an exclusive signal which provides the important information of a particular person depending on the physical composition and morphology of the heart. Hence ECG can be used to distinguish every person and to find out the diseases [2].

The normal range of heart rate is about 70 beats/ min. Any variations come in this range leads to Arrhythmia, and it is broadly classified Bradycardia and Tachycardia depending on R-R interval [3]. Once the features of each heart beat have been the extracted, the cardiac arrhythmias can easily be classified and it is widely used by numerous physicians in various applications [4].

A normal ECG signal consists of a P, T wave and a QRS interval is represented in Fig.1.

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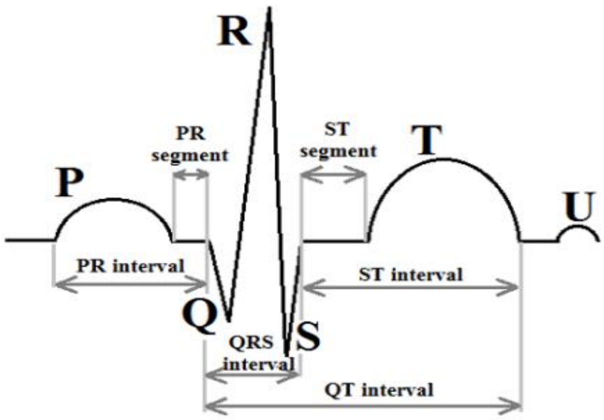

Fig.1. ECG signal made of a P wave, a QRS complex and a T wave [5]

Arrhythmia classification and disease detection using electrocardiogram (ECG) signals has become an important topic of research. A significant research has already been done in the field to health monitoring of a human being but this process is still ongoing to find out more innovative ideas. From past few years, many researchers have been contributed to develop a method for ECG arrhythmia classification based on Wavelet Shrinkage [6], nearest neighbor classifier using filter banks [4], wavelets [5], a local fractal [7], SVM [support vector machines] and PCA based classifier [8]. Few more methods to detect cardiac abnormality based on electrocardiogram (ECG) using Gaussian mixture model (GMM) [9], using ECG morphology and dynamics [10] and based on Hermite and support vector machines (SVMs) [11] have also been presented. A feature extraction has also been done using a convolutional neural network (CNN) [12].

The already existing techniques given in the literature for arrhythmia classification used the R peak detection method to extract the features of ECG signals. These R peak detection methods are accurate but take more time to detect QRS complex.

Many researches have also been done in the field of FPGA implementation of ECG signal analysis. Bo Zhang et al. [13] reported an FPGA implementation of a system to detect the QRS interval using integer Haar wavelet. VHDL (Hardware Design Language) was used to describe the implementation and was verified on an FPGA Cyclone EP3C5F256C6. In [14] and [15], the Pan-Tompkins algorithm was designed on the FPGA-Based system to detect QRS interval for automated ECG analysis. Stojanovi'c et al. [16], reported a novel FPGA based system for QRS interval detection using the Integer Haar Transform (IHT).

The whole system was implemented in FPGA Cyclone EP1C12Q240 chip and the accuracy obtained from on-chip detection is about 95%. In the same way [17], the authors used the same method to detect the QRS interval and presented a telemonitoring system which is based on FPGA to detect cardiac Arrhythmia.

The techniques given in the literature have only classified the type of arrhythmia but in our work we have designed a system which detects the type of diseases.

The main aim of the proposed work is to implement a system based on FPGA, which detects the disease like Heart Attack, Type 1 Diabetes and Dysataunomia using ECG feature and several body parameters like temperature, Systolic Pressure, Weight, Diastolic pressure, SPo2, and Sugar etc . The proposed system execute detection of disease in two simple steps, first ECG features and arrhythmia have been classified and then in the later stage disease has been identified using the type of arrhythmia and several body parameters. This algorithm was developed using Verilog HDL. MIT-BIH database has been used as a reference for ECG signals.

The paper is arranged as follows:

In Section 2, the represents the proposed methodology and a disease identification technique in detail. Section 3, shows the experimental results to represent the standard of the work. Proposed method used MIT-BIH arrhythmia database to assess the technique. At the end, Section 4 represents the conclusion of this work and shows the future scope also.

II. RESEARCH METHOD

For implementation of proposed disease detection system on FPGA, several steps have been used. These steps are explained below in details, where MIT-BIH data base was used as a reference to get ECG signal. This signal is then passed through pre-processing and filter block to remove the noises and then its time domain and frequency domain features have been identified. These entire features and several other body parameters like temperature, Systolic Pressure, Weight, Diastolic pressure, SPo2, and Sugar etc. have been given to the decision circuit which provided the decision about the type of disease based on these inputs. This system has been implemented to detect the diseases like Dysautonomia, Type 1 Diabetes and Heart diseases. The normal range of BP (blood pressure) in human beings is 120/80mmHg (mili-meter mercury) and normal range of QRS complex is 0.04 - 0.12 sec [18].

Fig.2. shows the block diagram of FPGA implementation of diseases detection system.

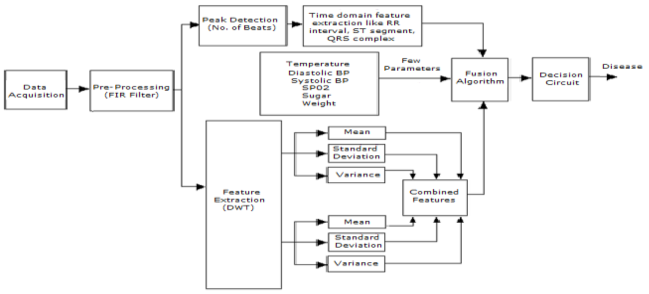

Fig.2. Block diagram of Disease Detection System

The detailed explanation of each stage is as follows:

A. Preprocessing and Filtering

Some external noises get mixed with obtained ECG signal from the patients, which makes the signal corrupted, Hence Removal of these noises is necessary. So to remove these noises, Bandpass filter (BPF) stage is required which highlights the QRS complex and reduces the effect of P and T waves.

B. Peak Detection and Time domain Feature Extraction

After the filtering the ECG signals, all the peaks have been detected using peak finding logic, for detection of these peaks thresholding has been applied. To detect Q and S peaks, negative peaks have been identified on both sides (left and right) of the R Peaks respectively. In the time domain feature extraction block, features of different signals have been extracted, which lies near the R peak. In this stage we obtained different intervals like RR interval by measuring the gap between two continuous R peaks, then ST interval, QT interval, and PR segment in the same way.

C. Features Extraction

The approximation coefficients and detailed coefficients are computed from the decomposed signal, which represents the original signal [19]. The original signal can be represented by using these obtained coefficients of the ECG signal. Then we calculated some features like Mean, Variance and Standard deviation of the coefficient of wavelet. These features are further used to show the time and frequency distribution of the ECG signals.

D. Additional Parameter

By using these features, obtained from previous stage and all the peaks of ECG signals along with different intervals, type of arrhythmia have been classified. But few additional parameters are required to find the type of disease. Those additional parameters are temperature, Systolic Pressure, Weight, Diastolic pressure, SPo2, and Sugar etc. which we have been used in the given work.

E. Fusion algorithm

In this stage an algorithm has been designed to take the decision, about the type of diseases depending on time domain and frequency domain features and few body parameters. Here Neural network was used to classify the arrhythmia like Left bundle branch block (LBBB), Right bundle branch block (RBBB), Bradycardia, Ventricular Tachycardia and 1st Degree Ant. After that the type of disease was detected based on the several body parameters given in the table 1. Figure 3 shows the correlation between three diseases and related body parameters. Diseases which have been identified using this algorithm are Type 1 diabetes, Heart Attack and Dysautonomia.

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Table- I: Disease detection table depending on parameters

Disease / Parameters	Heart Attack	Dysautonomia	Type 1 Diabetes
Temperature	–	≥ 106 deg F	–
Blood Pressure	≥ 160/96 mmHg	< 100/70 mmHg	≥ 140/90 mmHg
Pulse Oximetry (SPo2)	< 80 to 90%	90 to 96%	< 96 %
ECG	–	0.01-0.03 sec QRS Interval	0.121-0.35 sec QRS Interval
Sugar	< 7 mmol/L	–	BM 4 to 7 AM< 8.5 mmol/L
Weight	≤ 30 BMI	–	≥25 to 29.9 BMI

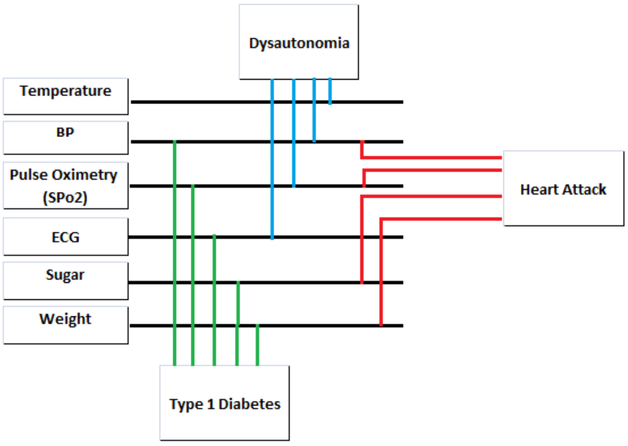

Fig.3. Correlation of body parameters and diseases

III. RESULTS AND DISCUSSIONS

The MIT-BIH arrhythmia database is considered to analyze the specified disease detection process. The acquired ECG signals from this MIT-BIH record contains long and sharp P and T waves, and compact QRS intervals [20]. The reported work has been done on Xilinx version 8.2 using Verilog Hardware Description Language (Verilog HDL) code and also simulated with test bench. The complete work has been verified on various ECG signals gained from the MIT-BIH arrhythmia database.

Disease detection process was of three steps where in the first step R peaks have been obtained then time domain features and DWT features of various patients have been detected and calculated. After that depending on the few parameters like temperature, Systolic Pressure, Diastolic pressure, SPo2, Sugar and Weight, diseases of that specific patient have been obtained and verified on Xilinx. The results of detected disease on different patients are given below.

After simulating this proposed disease detection method on Verilog the results obtained are as follows:

Fig. 4 and 5 shows the Top view of disease detection system which took 5 inputs for body parameters, 3 additional inputs for clock, reset and enable and 3 outputs for different disease.

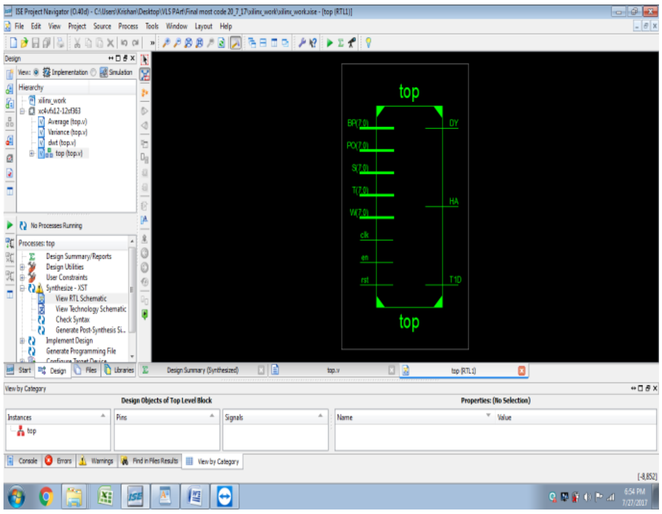

Fig.4. Top model of the Disease Detection system

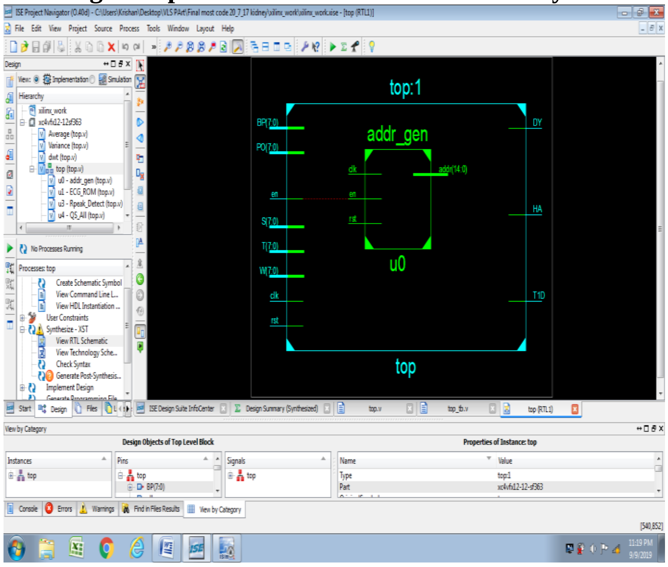

Fig.5. Top model of the Disease Detection system

Fig. 6 and 7 show the internal structure and architecture details of given disease detection system.

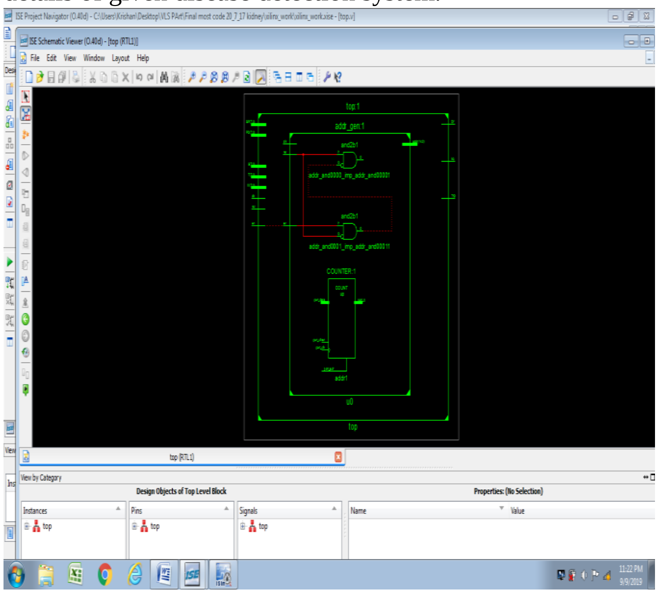

Fig.6. Internal Structure of the Disease Detection system

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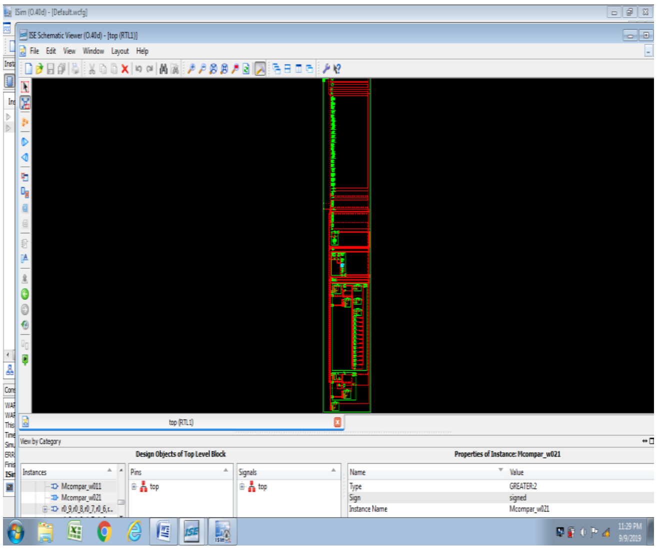

Fig.7. Overall architecture of the Disease Detection system

This Fig. 8 represented the hardware requirement and different delays for the system.

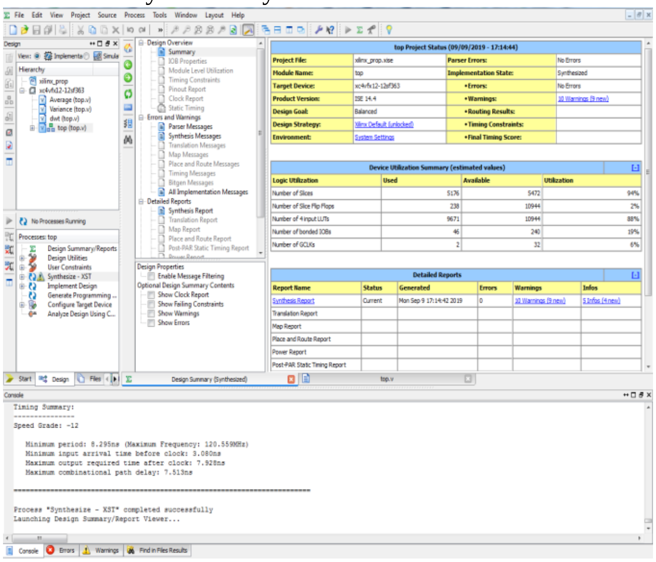

Fig.8. Hardware description

It has been observed from the result shown in Fig. 9 that patient is having heart problem.

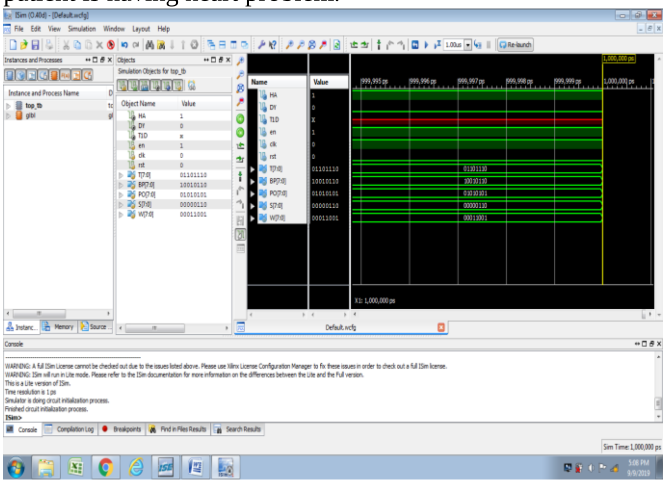

Fig.9. Result obtained from patient 100

It has been observed from the result and shown in Fig. 10 that patient is having type-1 diabetes.

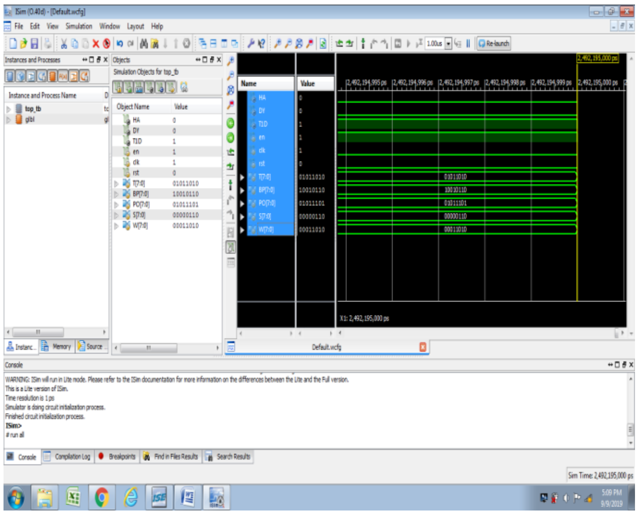

Fig.10. Result obtained from Patient 101

It has observed from the result shown in Fig. 11 that the patient is normal.

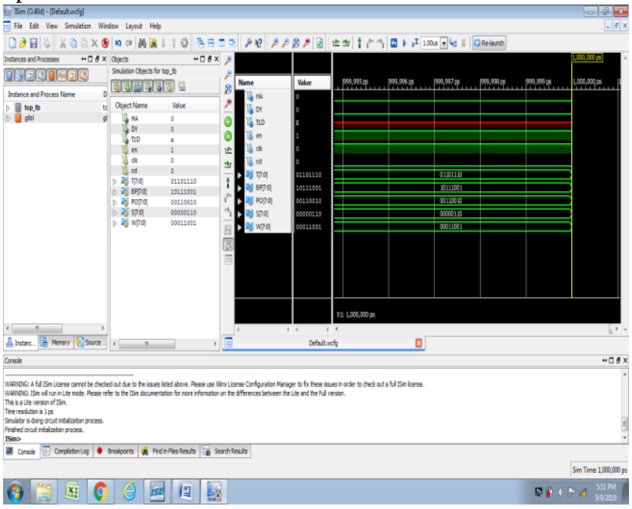

Fig.11. Result obtained from Patient 105

Fig. 12 shows that the patient is having type 1 diabetes.

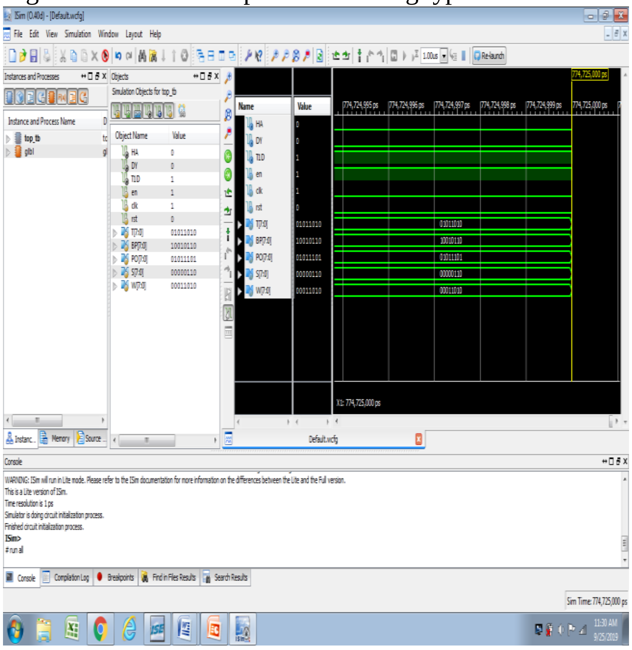

Fig.12. After changing the parameter obtained type-1diabetes from the patient 102

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Fig.13 shows the implementation of developed disease detection system on FPGA. Here heart attack has been identified.

Fig.13. FPGA Implementation of Disease Detection System.

IV. CONCLUSION

To diagnose the cardiac disease it is very important to analyze the ECG parameters which are very essential to diagnose the cardiac disease. A novel method has been implemented on FPGA to detect the time domain features and DWT features of various patients and then based on these features and other body parameters detect the type of disease. The results received after implementation of proposed method have been shown and discussed. The reported work has been synthesized and tested on Xilinx version 8.2 using Verilog Hardware Description Language (Verilog HDL) code and on Sparton-6 FPGA platform. The given work has been verified on various ECG signals gained from the MIT-BIH arrhythmia database. For prior and accurate detection of more disease at the output, given technique can be modified further. This technique can also be further processed to detect the disease for real time ECG signals.

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