Temporal Analysis and Remote Monitoring of ECG Signal

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***Abstract*— The system "Temporal analysis and remote monitoring of ECG signal" is developed to assist patients and doctors in health care. An arrhythmia is an abnormal heart rhythm. It can cause the heart rate to be too slow or too fast. Enough blood is not provided by the heart to the body when arrhythmias are severe or last long enough. This can cause patient to feel tired, lightheaded or may make him pass out. It can also cause death. Before treatment, it's important for the doctor to know where an arrhythmia starts in the heart and whether it's abnormal. An electrocardiogram (ECG) is often used to diagnose arrhythmias. "Temporal analysis and remote monitoring of ECG signal" is meant to acquire ECG signal from patient and analyze it to detect and classify its anomalies and abnormalities. This is achieved by extracting amplitudes and durations of parameters of ECG waveform such as P wave, QRS complex, RR interval and PR durations. These parameters are compared with the normal values to determine the type of abnormality. Database of the patient is maintained for further use by the doctor. Under critical conditions, transmission scheme will ensure successful transmission of critical messages to doctors via Global system for mobile (GSM) network.**

Keywords: ECG, arrhythmia, GSM.

I. INTRODUCTION

Many developing countries suffer from an acute shortage of medical professionals, particularly specialists. India is one of the many countries facing severe shortages of trained medical professionals. One doctor has to serve many hospitals and hence they are not available full time in a single hospital. The available specialists and services are concentrated in big cities, while workers in rural health care, who serve most of the population, are almost completely isolated from specialist services. These patients have to travel long distances in order to be seen by a specialist cardiologist [1-2].

The ECG waveform that reflects the electrical activity of the heart, is widely used as a routine cardiac diagnostic tool. In conventional methods of ECG diagnosis, physician tries to find whether the ECG signal is different from normal sinus rhythm in terms of the morphology of each component, time intervals and heart rate [3-4]. Heart attack is usually considered as major heart disease but there are many other problems that compromise heart functions such as coronary artery disease, heart failure and arrhythmias. An arrhythmia is an abnormal heart rhythm. Some of the arrhythmias such as ventricular tachycardia and ventricular fibrillation are associated with sudden cardiac death. If arrhythmias persist in a patient, then medical care should be taken as early as possible in order to save patient's life. In the United States, each year more than 850,000 people are hospitalized for an arrhythmia [5].

II. THE ANALYSIS OF ELECTROCARDIOGRAM (ECG)

The normal ECG is composed of a P wave, a QRS complex and a T wave. The P wave and the QRS represent atrial and ventricular depolarization respectively. The T wave reflects the phase of rapid repolarization of the ventricles [1].

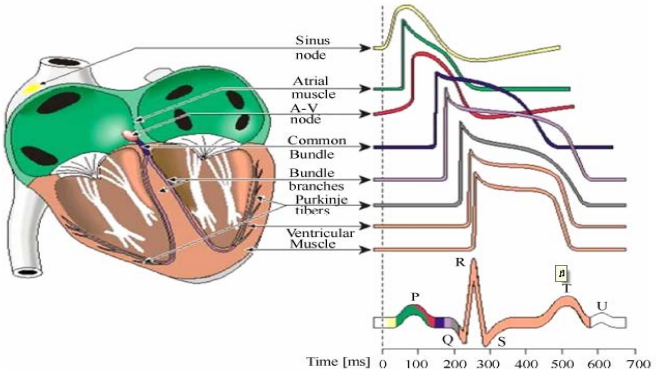

Fig.1. Typical representation of the ECG wave [8]

The P wave represents the spread of electrical impulse through the atrial musculature that is activation or depolarization. The PR interval reflects the time taken by the impulse to travel the entire distance from the SA Node to the ventricular muscle fibers. It represents the spread of the electrical impulse through the ventricular muscle that is

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depolarization. The S-T segment follows the QRS complex. The T wave represents the period of recovery for the ventricles [2].

Table 1.ECG reference model for a normal man [9].

Parameter	Reference Value
Heart Rate	60-100 beats per minute (BPM)
P wave	Duration < 0.12 s; Amplitude < 0.25mV
P-R interval	Duration 0.12 - 0.20 s
QRS complex	Duration 0.04 –0.12s; Amplitude 0.5–1mV
Q-T interval	Duration 0.39-0.42 s

An arrhythmia is an abnormal rate and/or rhythm of the heartbeat. It arises when the electrical impulses to the heart that coordinate heartbeats are not working properly, making the heart beat too fast/slow or inconsistently. [7][9].

Arrhythmias may occur because of the following reasons,

- Sinus node is not able to generate enough heartbeats.
- Abnormal rhythm of sinus node.
- Other area in the atria take over the function of the sinus node.

Abnormally fast heart rate is called as Tachycardia and abnormally slow heart rate is called as Bradycardia. In Bradycardia, the heart rate is too slow that is less than 60 beats per minute. Whereas in Tachycardia, the heart rate is too fast that is more than 100 beats per minute. When the electrical signal is slowed or disrupted as it moves through the heart, it is considered as a Heart block. Heart block is also a type of arrhythmia. A first degree AV node block occurs when conduction through the AV node is slowed. A first degree AV block is indicated on the ECG by a prolonged PR interval. First-degree heart block is not very severe [5].

III. System Description

The block diagram of the system is as shown in figure 2.

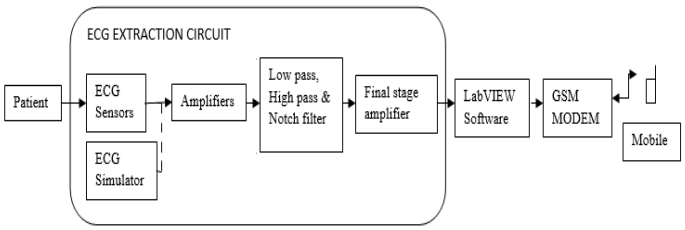

Fig 2. System Block Diagram

It consists of ECG extraction circuit which extracts the ECG signal of the patient using Ag-AgCl electrodes and preprocesses it. The amplified and filtered ECG signal is analyzed using LabVIEW software and results are stored in the form of report. An informative SMS is sent to the doctor's mobile under the abnormal condition via GSM modem SIM-900.

A. ECG signal analysis

Flowchart for ECG signal analysis is as shown in figure 3.

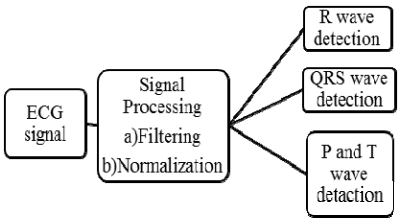

Fig 3. Flowchart of ECG analysis

The heart rate is calculated as follows,

Heart rate =(1/RR interval in sec.)*60 .

Analyais based on heart rate is explained with the help of flowchart as follows.

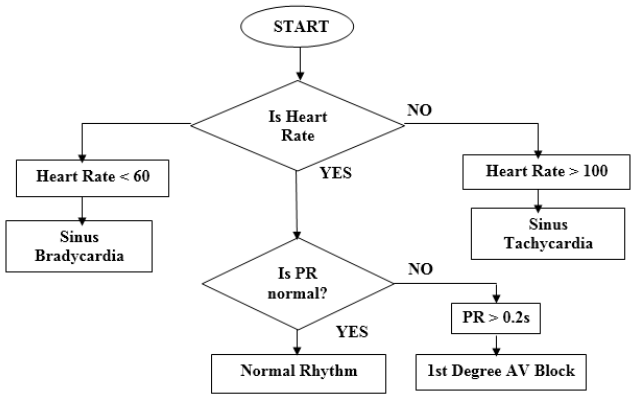

Fig 4. Analysis based on ECG

B. LabVIEW code

Acquired Sound VI is used to acquire ECG signal through audio port with the sampling rate of 11025 Hz. The acquired ECG signal has dynamic data type since it is acquired via sound port. The LabVIEW ASPT provides the WA Detrend VI converts the acquired ECG signal in waveform format and also removes the trend from the signal and make it suitable for further analysis.

Wavelet transform level =

$$\text{floor}\left(\log_2\left[\frac{\text{sampling rate}}{(2 * \text{threshold frequency})}\right]\right)$$

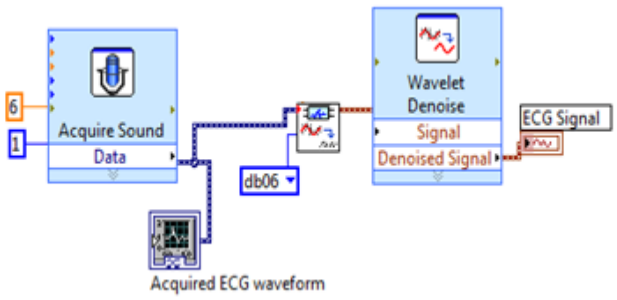

Fig 5. Code for Preprocessing of ECG Signal

The LabVIEW code for calculating heart rate is as shown in figure 6.

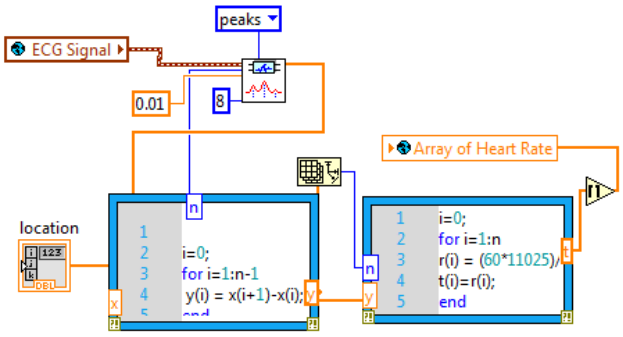

Fig 6. VI for Calculating Heart Rate

In order to communicate via serial port for sending SMS PL2303 prolific device driver has been installed. Port has been configured for baud rate 9600 bps with 1 stop bit. GPRS Execute Command VI with VISA VIs has been used in LabVIEW for communicating with GSM modem SIM 900 via serial port.

C. Decision Logic for identification of disease

The heart rate, PR interval and QRS interval are compared with their normal range. The normal heart rate lies in the range of 60 to 100 beats/minute. PR interval and QRS interval lies in the range 0.12-0.2 sec and 0.04-0.12 sec respectively. When heart rate is beyond 100 beats/minute with normal PR interval and QRS interval, it is considered as Sinus Tachycardia. When heart rate is below 60 beats/minute with normal PR interval and QRS interval, it is considered as Sinus Bradycardia. When PR interval is more than 0.2 sec with normal heart rate and QRS interval, it is considered as first degree AV block.

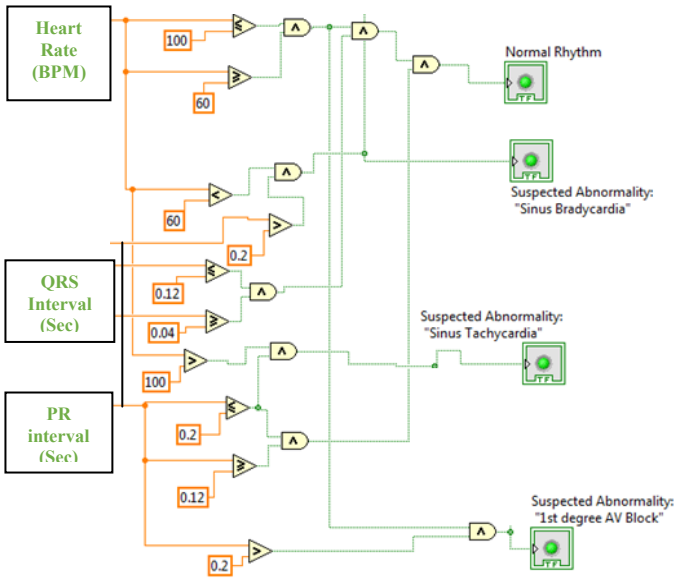

Fig 7. Decision Logic for identification of diseases

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RESULTS AND CONCLUSION

The ECG signal has been acquired from a person using the designed circuit through Ag-AgCl electrodes and it has been displayed on DSO which has heart rate of 80 bpm and amplitude of 1.1V as shown in figure 8.

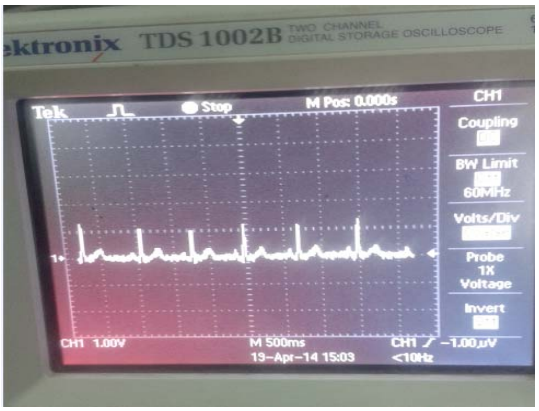

Fig 8. Acquired ECG signal on DSO

The acquired ECG signal from a person using the designed circuit and its LabVIEW analysis is as shown in figure 9.

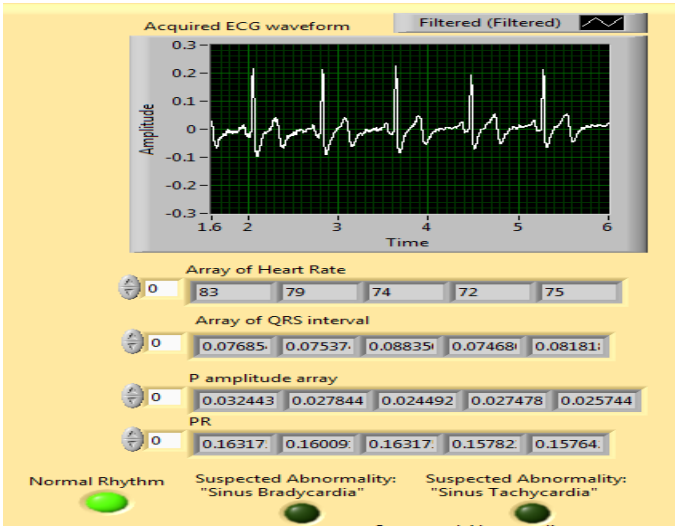

Fig. 9. ECG analysis results using LabVIEW

The analysis results has been verified with the observed values as follows.
Figure 10 shows cursor positions for observing PR interval. The observed value of PR interval is 2.03225 - 1.87096 = 0.161 sec.

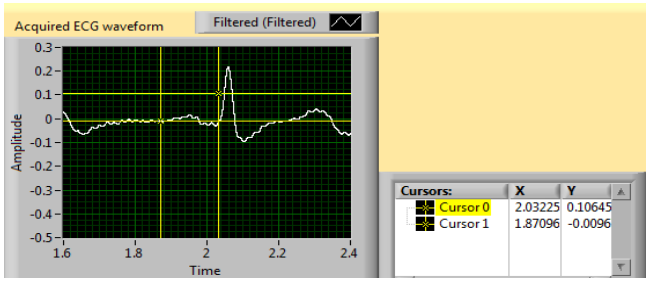

Fig. 10. Observed value of PR interval with a person as a subject

Figure 11 shows cursor positions of observing QRS interval. The observed value of QRS interval is 2.1-2.02580=0.0742 sec.

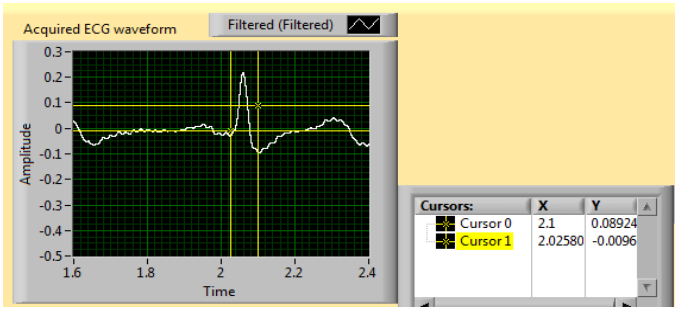

Fig. 11. Observed value of QRS interval with a person as a subject

In this way the observed values for PR interval and QRS interval have been noted for other abnormalities like Bradycardia, Tachycardia and 1st degree AV Block.

The analysis results and observed readings for the ECG signal have been noted and tabulated as shown in the table 2.

Table 2 Measured and Observed values of ECG parameters

	PR interval (seconds)		QRS interval (seconds)	
	Measured Interval	Observed Interval	Measured Interval	Observed Interval
Normal Person	0.163sec	0.161sec	0.076 sec	0.0742 sec
HR=30 BPM	0.270sec	0.274sec	0.070sec	0.072sec
HR=60 BPM	0.163sec	0.165sec	0.058sec	0.056sec
HR= 120 BPM	0.1087sec	0.1089sec	0.042sec	0.04sec
1st Degree AV Block	0.32 sec	0.30 sec	0.047sec	0.048sec

ECG signal analysis has been done with LabVIEW software with input collected from ECG simulator then filtered and amplified using designed circuit and the analysis report also been generated using LabVIEW as shown in figure 12.

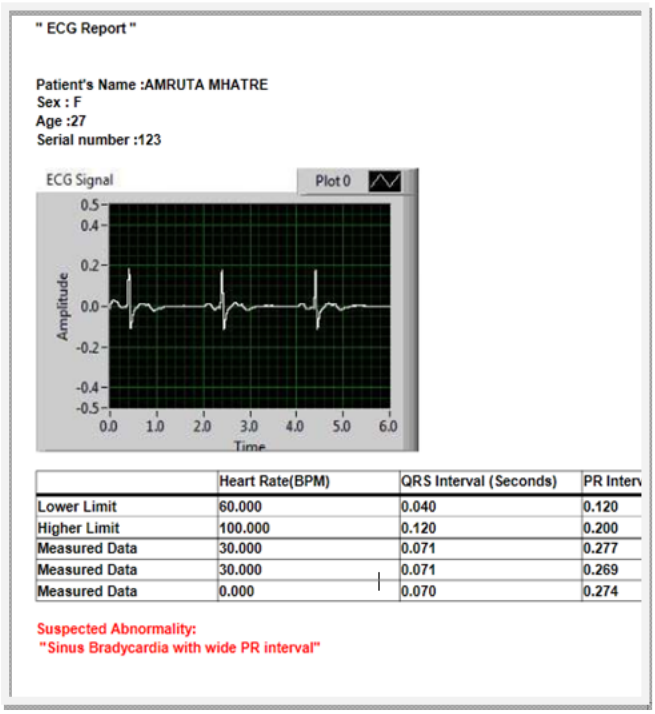

Fig 12. Generated Report using LabVIEW

The enitire set up was tested for abnormal conditions. When the heart rate went beyond its range of 60-100 BPM, the following message was transmitted by the system via SMS. Figure 13 shows the SMS received for abnormal ECG signal of heart rate 120 BPM

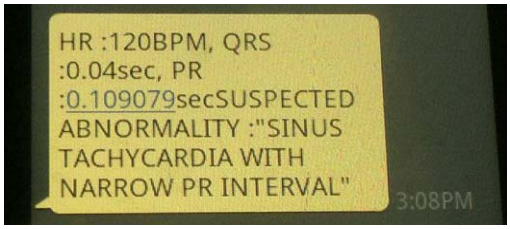

Fig. 13. SMS received for abnormal ECG signal

"Temporal Analysis and Remote Monitoring of ECG signal" is a smart measurement system for monitoring ECG signal. The system acquires ECG signal from patient and analyses the real time signal for the further detection of arrhythmia. In case of an emergency the system connects to the GSM service to transmit patient's data and rough estimate of the type of disease to the doctor's mobile. This system can have a widespread application in developing countries where the doctor to patient ratio is very less and where people cannot afford to travel long distance for continuous monitoring of health.

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