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Reliable Smartphone Based Wireless Healthcare Monitoring System For Post Operative Heart Surgery Patients On Driving Conditions

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ABSTRACT

In the last decade the healthcare monitoring systems have drawn considerable attentions of the researchers. The prime goal was to develop a reliable patient monitoring system so that the healthcare professionals can monitor their patients, who are either hospitalized or executing their normal daily life. In this article, a biomedical sensor network is used for more cost efficient solutions for supervision/monitoring patients during and after surgery, as well as when the patient is at home or regular activities. Cardiac arrest is parroted as the major contributor to unanticipated death rate around the globe. In some patients the cardiac problems may re-occur, when they start doing their monotonous work. Decrease in heart rate of a postoperative patient will afford drowsy feeling and increase in heart rate will lead to death and huge accidents. This proposed research work examines the relationship between abnormal heart rate and fatigue of a post-operative person in driving state and alerts the patients in case of abnormality detected.From the investigations it is found that if the measured pulse rate is inferior than the threshold the person is subjected to fatigue or if it is greater than threshold then the patient is wide-open to have a second order attack.

Key words: Biosensors, Electrocardiogram, Biomedical signal processing, Noise measurement, Signal processing algorithms, Security.

INTRODUCTION

Innovations in mobile and electronic healthcare are revolutionizing the involvement of both doctors and pa- tients in the modern healthcare system by extending the capabilities of physiological monitoring devices[1]. Expansion of health information technology and consumer e-health tools and services, such as telemonitoring plat- form and mobile health applications have created new opportunities for individuals to participate actively in their healthcare, and provides the opportunity for re- mote monitoring of clinically relevant variables in nonclinical settings. These devices can be integrated into routine care of acute and chronic diseases and provides essential information for management to both the healthcare providers and patients. Studies show that a well-informed patient improves quality of life and patient outcome because they are more likely to participate in healthy behavioral changes[2].

Heart disease is the leading cause of death for both men and women. Prime study of deaths shows heart infirmities have supplanted communicable diseases as the biggest killer in rural & urban India. Heart diseases have emerged as the most important killer in both urban and rural areas of the country. About 25 per cent of deaths in the age group of 25- 69 years occur because of heart diseases. In urban areas, 32.8 per cent deaths occur because of heart ailments, while this percentage in rural areas is 22.9. If all age groups are incorporated, heart diseases account for about 19 per cent of all deaths. It is the foremost cause of death amongst males as well as females. It is also the prominent cause of death in all regions though the numbers vary. The percentage of deaths triggered by heart disease is the uppermost in south India (25 per cent) and nethermost (12 per cent) in the central region [3]. The maiden results relate to an investigation of 1,30,000 deaths that occurred between 2011 and 2013. Data connecting to another 270,000 deaths is being examined currently.

The post-operative patients can develop complications once they are discharged from hospital. Hence the ECG of such patients needs to be monitored for some time after their treatment. This helps in spotting the improper working of the heart and take safety measures. Certain of these lives can often be saved if desperate care and cardiac treatment is delivered within the so-called golden hour. So the need for guidance on first hand medical attention becomes inexorable. Hence, patients who are at risk require that their cardiac health to be monitored recurrently whether they are indoors or outdoors so that emergency cure is possible[4].

Heart Rate (HR) is naturally conveyed as beats per minute. From few try-outs conducted it is obvious that the spectrum of HRV speckled expressively during the conditions of fatigue driving [5]. In general it is frequently recognized that commencement of drowsiness is supplemented with declining breathing frequency. HRV analysis provides information on sympathetic nerve and para sympathetic nerve activity [6]. Inside the power spectra of HRV, a high frequency (HF) peak seems at 0.15-0.4Hz and a low frequency (LF) peak at 0.04-0.15Hz. The HF imitates the degree to which RR intervals are conceited by parasympathetic activity and the LF is exaggerated by sympathetic activity [7]. HRV is also used efficiently for assessing sleep stages. HRV during REM sleep is portentously greater than in stages 2 and 4 of non-REM sleep [8].When a person deviates from waking into drowsiness/sleep stage, the LF to HF power spectral density ratio (LF/HF ratio) drops, whereas the HF power upsurges associated with this status change. So the performance of a person in driver state can be investigated with changes in heart rate[9-10].

Related work

The SWS include a wide range of wearable devices and sensors such as accelerometers and gyroscopes, smart fabrics and actuators, wireless communication networks and power supplies, and data capture technology for processing and decision support [12]. Having a wearable device decreases the restrictions placed on their motility and daily activities which allows monitoring in the envir- onment of the patients directly home but also at work.

The most used and well-known sensor accelerometers are electrochemical sensors that measure acceleration of objects in motion along reference axes and provide basic step and activity counts used as a quantitative assess- ment of physical activity [11,13]. This data can be used to obtain velocity and displacement by merging the data with respect to time . Triaxial accelerometers, which monitor vibrations in three planes, can detect movement and posture, such as upright or lying down, according to the magnitude of acceleration signals along sensitive axes [14,15]. Gyroscopes are also another popular type of sensor. A gyroscope is a mechanical device that measures 3-D orientation based on the principles of an- gular momentum. A spinning rotor tends to maintain its orientation allowing the changes in orientation to be calculated by integrating the angular velocity [14].

Placement of SWS is versatile and provides flexibility and comfort for patients, which is one of the keys for patient acceptance. There are many devices already on the market for fitness and wellness that use consumer- facing applications which can be easily incorporated into clinical practice. Most sensors can either be worn or placed on clothes. Some wearable devices can be placed on the almost any part of the body: wrist, ankle, waist, chest, arm, legs, etc. These sensors can detect many dif- ferent variables such as speed, distance, steps taken, floors climbed and calories burned [16]. Implementation of a real-time waist-mounted tri-axial accelerometer unit detects a range of basic daily activities, including walking and posture [17,18]. Other possibilities for wearable sen- sor placement include gloves, rings, necklace, brooches, pins, earrings, and even belt buckles.

These models have been used to monitor blood oxygen saturation (SpO2), heart rates, and record hand posture while manipulating objects, such as eating or dressing [19,20]. A newly mar- keted device measures body temperature through the use of an ear probe which detects infrared radiation from the tympanic membrane [21]. Another approach which could be more convenient for patients is the placement of sensors in clothing, such as a vest or shoe. Smart Vest is a wearable physiological monitoring sys- tem for parameters such as, heart rate, blood pressure (BP), body temperature, galvanic skin responses, and can even perform electrocardiograms (ECG) [22]. There are also experimental designs, with promising preliminary results, demonstrating that sensors (heart rate, acceleration, and respiratory activity) can be incorporated into a regular t-shirt rather than a bulky vest, which adds another layer of convenience [23]. Placement in the shoe can provide a more convenient method to measure differences between mean foot extreme and gait stride time for healthy gait and those with physical disorders, as well as proved highly capable of detecting foot orientation and position [24-26].

Methods of early detection shown in previous research are based on continuous monitoring of several physiological parameters such as EEG, eye movements, pupillary reaction, muscular tone and behaviour .Also employing neural networks are time consuming and also design process is too complex[27-30]. We have also performed drowsiness detection using eye image processing and yawning state as a combined technique but there was much delay in processing the images.

So we propose a method of a non-invasive system that determines drowsiness from heart rate to monitor the caution of a post-operative patient in driving condition and provides an alert if the value outstrips the predefined threshold. This proposed system measures heart rate of an individual from his ECG obtained from various bio sensors. This invention acquires ECG signal through non-intrusive ECG sensors that are wrapped on to the steering wheel from which it calculates the time interval for the driver's pulses and converts the time interval into a pulse rate. When a driver is sleepy while driving, the pulse rate is gradually decreasing. This projected system persistently monitors the time interval for the pre-set amount of the driver's pulses and translates the time interval into a pulse rate. If the measured pulse rate is lesser than the pre-set threshold pulse rate, the system will provide an immediate alert to the person in prior. The other case if the pulse rate is higher than threshold it will detect it as abnormality and provide an immediate alert to the person in advance thereby reducing critical accidents.

Proposed reliable healthcare monitoring system

In the last decade the healthcare monitoring systems have drawn considerable attentions of the researchers. The prime goal was to develop a reliable patient monitoring system so that the healthcare professionals can monitor their patients, who are either hospitalized or executing their normal daily life activities. In this work we present a mobile device based wireless healthcare monitoring system that can provide real time online information about physiological conditions of a patient. Our proposed system is designed to measure and monitor important physiological data of a patient in order to accurately describe the status of her/his health and fitness. In addition alarming and reminding messages about the patient health status can also be sent to patient mentors for necessary medical diagnosis and advising. The proposed system consists of sensors, a data acquisition unit, smartphone, and the LabVIEW program. The system is able to display, record, and send patient's physiological data. Moreover, the proposed WHMS also supports Internet connectivity so that the healthcare professionals can monitor and access patients' data from anywhere of the world at any time.

The patient is equipped with biomedical sensors, which transform the changes in the monitored physiological quantities into electronic data that are measured and recorded. The LabVIEW program assists monitoring and displaying the data. The patient's temperature, heart beat rate, muscles, blood pressure, blood glucose level, and ECG data can be monitored by our present system. Our careful design of the hardware and software components of the system is able to fulfil any further requirement of the users. The overall concept is explained through the flow diagram as shown in the Figure.1. Usually the Bio-signals are acquired from sensors. That converts the bio signal into electrical signal to the system.

We cannot use electrodes to envisage the signals as they will provide more physical turbulences to driver. Mostly a type of electrolyte gel is glued on the skin before employing the electrodes which makes allergies to persons in driving conditions. So our system uses a non-invasive method of picking up an ECG where each half of steering wheel is wrapped with electrically conductive fabric (ECF) as two ECG electrodes. For its tractability, it can be effortlessly mutilated to fit the curve of steering wheel deprived of causing discomposure to the drivers. These electrodes are bendable, biocompatible and do a waterless signal gaining without the use of any electrolyte gel or any bonding agent.

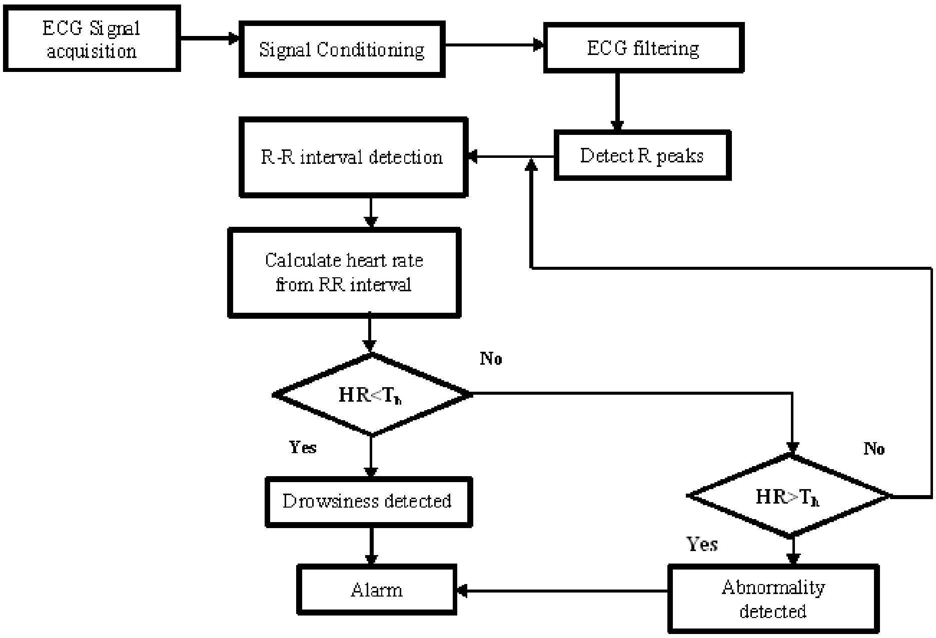

Fig. 1: Flow diagram of the Proposed Drowsiness Detection System using HRV

Table 1: Methods of analysing heart rate directly from ECG chart

Methods	Steps involved
The Cardiac Ruler method	Place the commencement point of a cardiac ruler over an R wave. Look at the number on which the next R wave falls and that becomes the heart rate for that patient
The Six Second Tracing method	Obtain a six second tracing (30 five mm boxes) and count the number of R waves that appear within that 6 second period and multiply by 10 to obtain the HR/min.
The 300 method	Count the number of large boxes between 2 R waves and divide this number into 300 to obtain the HR/min.
The 1500 method	Count the number of small boxes between two R waves and divide this number into 1500 to obtain the HR/min.

ECG signals acquired are very small electrical signals in the incidence of higher noise components. The electrical signal is very weak (normally 0.0001 to 0.003 volt) in amplitude. These signals are within the frequency range of 0.05 to 100 Hz. If they are not amplified a greater gain is needed to convert the weak differential signals into characteristic signals, causing the circuit to douse easily. So here the signal conditioning includes both amplifying and filtering.

ECG Noise Filtering

Once after getting the ECG signal the next step is to denoise the signal and extract the noise free signal. Baseline wandering, or inessential low-frequency high-bandwidth components, can be caused by respiration and body movements. It can cause problems to analysis, especially when examining the low-frequency ST-T segment. The cut-off frequency should be selected so as to ECG signal information remains unembellished while as much as possible of the baseline wandering is removed and so the lowest-frequency component of the ECG should be acquired. This is generally thought to be definded by the slowest heart rate. The heart rate can fall to 40 bpm, implying the smallest frequency to be 0.67 Hz. Again as it is not meticulous, a sufficiently lower cutoff frequency of about 0.5 Hz should be used. Power line interference from power lines can cause 50/60 Hz sinusoidal interference, possibly essorted by some of its harmonics. Such noise can cause complications interpreting low-amplitude waveforms and spurious waveforms can be

Table 2: Various Signal Analysing methods to obtain heart rate from ECG

Different Techniques	Methods applied
Time domain analysis	1.Standard deviation of Normal to Normal intervals2.Mean NN interval 3.Mean heart rate
Frequency domain analysis	1.Power Spectral density2.Fast Fourier Transform (FFT)
Wavelet transform	The wavelet transform simply accomplishes the convolution process of the signal and the basis function.
Autocorrelation	Autocorrelation function is applied on signal energy and Peak detector is applied on autocorrelation function.
Thresholding of Energy Signal	Firstly, time indexes of samples higher than the threshold are found. After that, the algorithm computes differences between time indexes

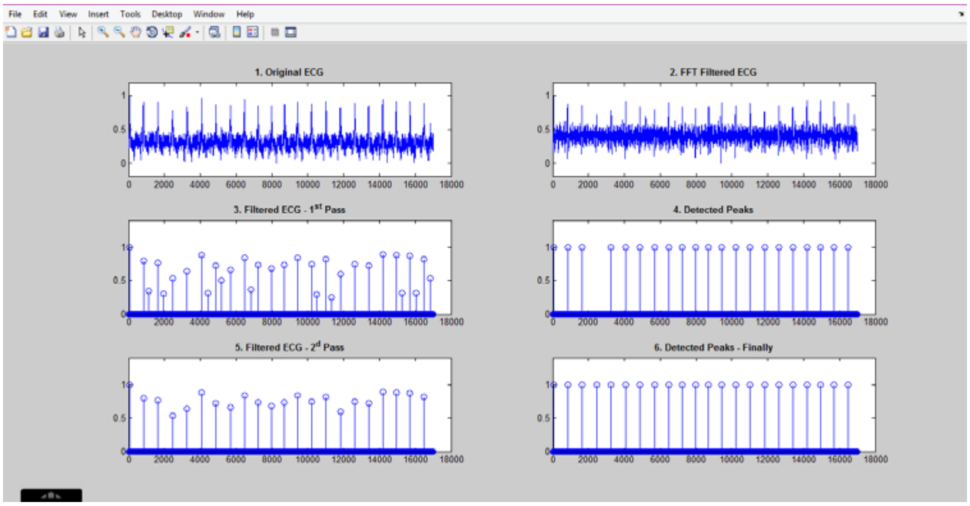

Fig. 2: Results of obtaining peaks through FFT

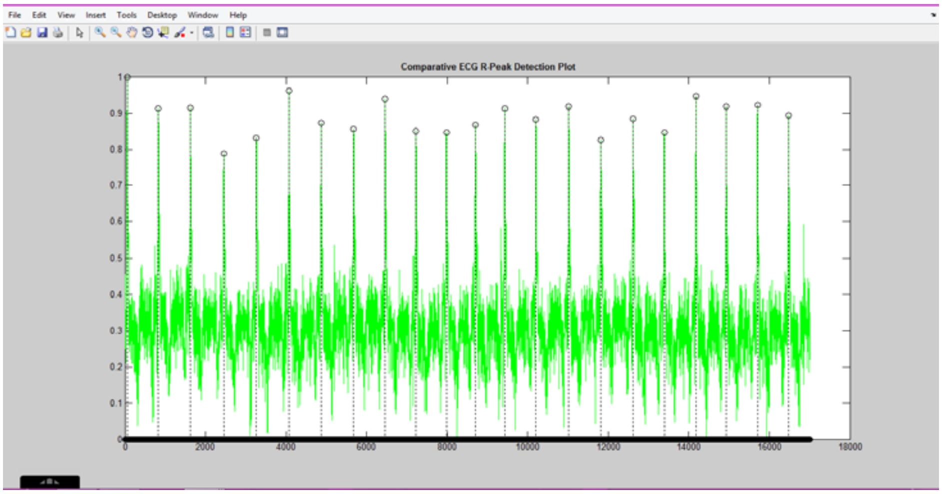

Fig. 3: R peak detection plot

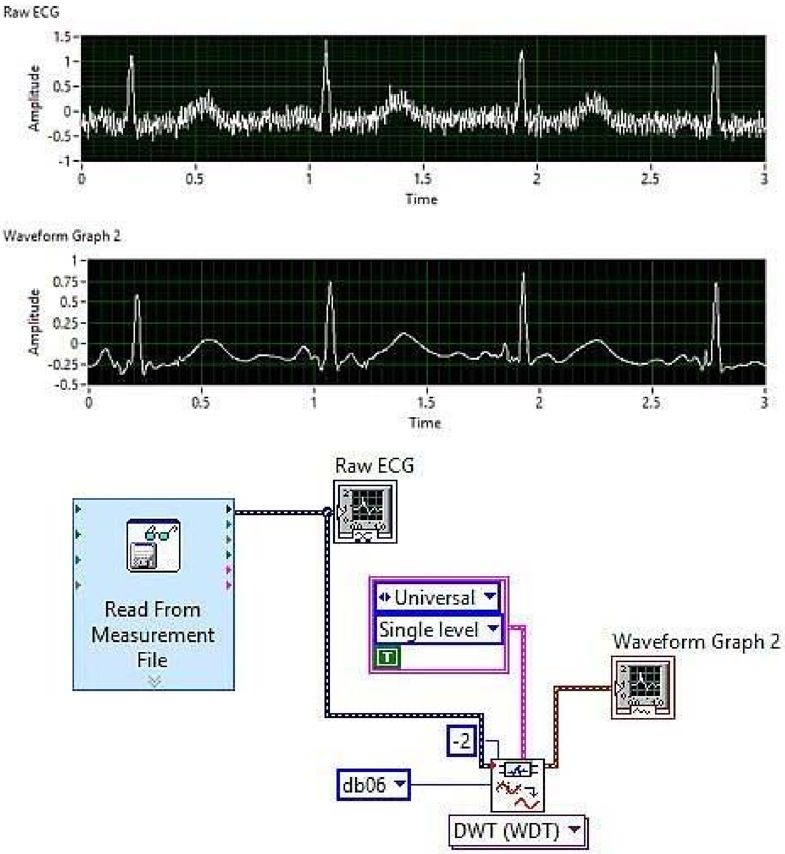

Fig. 4: Noise free ECG signal

Table 3: Experimental results of the proposed system

S.No	Average Heart rate (BPM)	Symptoms
1	62	Normal
2	72	Normal
3	115	Sinus Tachycardia
4	58	Sinus Bradycardia
5	77	Normal
6	45	Sinus Bradycardia
7	78	Normal
8	66	Normal
9	57	Sinus Bradycardia
10	74	Normal
11	59	Sinus Bradycardia
12	101	Sinus Tachycardia
13	103	Sinus Tachycardia
14	76	Normal
15	78	Normal

pioneered.

R peak detection

After noise removing process, the ECG signal is extracted. An ECG signal is a standard waveform that contains P wave, QRS complex and T wave. Amplitudes of P, Q, R, S, T waves are 0.25 mv, 25% of R wave, 0.16 mv, 0.35 mv and 0.01 to 0.05 mv respectively. The PQ interval (also known as the PR interval) is the amount of time from the beginning of the P complex to the QRS complex. This signifies the extent of time between the commencement of atrial contraction and the start of ventricular contraction. The normal duration is lasts nearly 0.16 seconds. Likewise, the QT interval is the time amongst ventricular retrenchment and ventricular repolarization. This is measured from the commencement of the Q wave to the termination of the T wave and typically lasts 0.35 seconds and also T wave is only visible up to a range of 50 to 75%. So our system focuses on QRS complex wave and RR interval since QRS complex wave is the most central, visual part and less affected by noise.

Our proposed work is concentrating only on RR intervals where RR interval is the time between QRS complexes. From RR interval, we are going to calculate heart rate of the driver. Different methods are used to calculate heart rate from ECG.Heart rate in beats per minute can be calculated by 60 divided by the average R-R interval. The different methods of analysing heart rate from ECG chart are stated below in Table 1.

All the above discussed methods in Table 1 require ECG waveform chart with precise output and it is not suitable for analysing heart rate in real time. So we have also analysed digital processing algorithms for the estimation of heart rate form ECG signal. The perspective analysis of those steps involved and its corresponding outputs are stated in Table.2.

After determining the average heart rate, decision is taken based on our threshold whether the heart rate of the person is less than the lowest threshold value (Heart rate <60) then the driving person is subjected to drowsiness or if it is more than the highest threshold value (Heart rate > 100) it will be considered as abnormal heart rate , normal heart rate is 72 per minute respectively. The last stage comprises a buzzer which acts as an alarm for notification for any detection of any abnormality, a custom pre-recorded voice message playback, stating the condition being experienced.

EXPERIMENTAL RESULTS

We have performed an analysis using Matlab software by taking a noisy ECG signal and determined R peaks from it. Figure 2 contains six subfigures where the first part contains the uneven ECG signal from which it is difficult to extract the R peaks. So our first step is to remove low-frequency component and flatten it. The hint is to apply direct fast Fourier transform (FFT), remove low frequencies and restore ECG with the help of inverse FFT. The result of FFT processing is shown in second part of Figure 2.

Our second step is to find local maxima by applying windowed filter that sees only maximum in his window and ignores all other values. On this step we use window of default size. The next step is to remove small values and preserve significant ones. Even though the result is good in general case we cannot be sure we have all the peaks. So the final step is to adjust filter window size and repeat filtering. The R peaks found are shown in the last part. Comparative ECG R peak detection plot is shown in Figure 3.

Since using Matlab the delay in processing the ECG signal is higher we have performed the same type of analysis using LabVIEW. An analysis was performed using LabVIEW and as a first step we have obtained ECG of a person in driving condition and obtained noise free ECG signal by applying FFT is shown in Figure 4.

Successive RR intervals calculation was required to predict the exact heart rate of a person. We have used ECG simulator to produce the typical ECG waveforms of different leads. The ECG simulator empowers us to investigate and study normal and abnormal ECG waveforms without actually using the ECG sensors and DAQ board. Active filters remove the noise in ECG signal and the ECG graph collector collects the input signal and returns the most recent data, up to the specified maximum number of sample per channel. The maximum value of the peaks is processed into the waveform peak detector which defines the peak value for the particular given width and after that the peak value was divided by width and multiplied by 60 for the measuring heart rate in beats per minute. We have used waveform peak detector and the output of peak detector was used to calculate the heart rate. The result depicts the time measured between two QRS complexes are 0.9 seconds, from which the number of beats per second is calculated as 1.11 beats / second. Applying a scalar and appending a constant will determine the conversion into seconds/minute which results in 66.7 beats per minute.

At present, PhysioNet includes databases of multiparameter cardiopulmonary, neural and their biomedical signals from healthy subjects and patients with a diversity of situations with major public health implications, including impulsive cardiac death, congestive heart failure, epilepsy, gait disorders, sleep apnea and aging. First step is the acquisition of ECG signal from the data base that is obtained by appending a scalar constant that derives the signal from original file.. After pre-processing we have set up the upper limit, lower limit frequency and sampling rate, through arbitrary constants in LabVIEW palette for generating QRS complex of the signal. Our system generates alert message when the monitored physiological data of patients are outside the normal set ranges. Our proposed system, also analysed heart rate variability from ECG of different subjects obtained from the MIT-BIH database and during tired conditions we have observed the gradual decrease in heart rate. The statistics taken from the above results are shown in the below **Table 3**. Subjects with a heart rate lesser than 60 are prolonged to affect with sinus Bradycardia and have experienced drowsy feeling.

CONCLUSION

The relationship between heart rate and drowsiness detection system was analyzed using Matlab and LabVIEW as realizing tools. People under stress will have decreased heart rate. Our proposed analysis will provide a good solution to those post-operative patients an immediate alert when they are subjected to abnormalities in driving state. Results shown in output figures specify heart beat is not regular and the person is subjected to abnormalities. When a significant variation with a lower pulse rate is observed then it is classified as drowsiness and buzzer provides an alarm. MIT-BIH database provides samples of different subjects and the results tested using LabVIEW. We are also in the state of developing a real time model with two states. The data for the analysis may be taken from a wearable ECG Sensors wrapped on to the steering wheel .If the driver is found to be drowsy, a first level warning will be delivered to the driver. Even after that the driver remains in the drowsy state then a next level warning will be issued to the traffic control rooms and ambulance located at nearby remote centres through GPS and GSM modules installed.

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