Non-invasive Wearable Healthcare Monitoring Device

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ABSTRACT - Cardiovascular diseases are the one of the leading causes of death in recent times. Studies show that in the United States, in the year 2008, over 616,000, i.e. about 25% of total deaths were due to heart diseases in the United States [11].In According to the 2016 Global Burden of Disease report, released on September 15, 2017, heart disease remains to be the leading cause of death in India, killing 1.7 million Indians the year 2016.

In recent times, the healthcare industry has seen tremendous growth due to advancement in technology and increased awareness in the society. Healthcare industry is much diversified and is full of opportunities in every sector.

But despite these advancements, various issues and challenges in timely detecting and monitoring of vital parameters of the patient needs to be addressed. For a patient having risk of cardiovascular diseases,continuous monitoring of ECG, respiratory rate, pulse rate etc. needs to be monitored at all times. There is a need for a system which can take data about vital parameters of the body such as Electrocardiogram (ECG) signals, Seismocardiogram (SCG) signals, and display on the screen. Since these greatly depend on the state of motion of the concerned person, it is therefore very important to also gather the real time motion along with SCG and ECG data.

We have developed the data acquisition system which will not only monitor ECG but also the SCG in addition to the posture of the patient. Integration of the motion data with the ECG and SCG signals helps us yield better results and gives proper direction to the healthcare professionals who will be responsible for analysing the results.Thus the vital parameters which are being monitored here can be of great help in generating an early warning alarm for any cardiovascular-related disease. It can also be recommended as a primary test recommend to any patient who is suffering from any trivial symptoms (such as chest of pain) of cardiovascular diseases. The system uses BMD-101 for ECG, MPU-9250 for SCG and body motion. These sensors get the data and send it through serial communication to a laptop and displays on the screen. Through this device, monitoring of the vital parameters of a human body becomes extremely feasible and convenient not only the patient but also for the doctor.

KEYWORDS-

Electrocardiogram,Seismocardiogram,Atrial rate, Ventricular rate, Aortic,Pulmonic,Tricuspid,Mitral

INTRODUCTION

The logarithmic growth in the world population is profound and pervasive. Unfortunately this growth rate is not in resonance with the growth of the number of physicians or medical professionals. Yet, we are seeing a constant decrease in the mortality rate and an increase in the life expectancy. This is attributed to the technological advancements in the field of healthcare and medicine. It has shown drastic improvement in facilities by the use of more sophisticated and accurate equipments. Hence in this paper we aim to use these technological advancements and contribute our bit in the betterment of healthcare facilities and systems.

Cardiovascular diseases (CVDs) have now become the leading cause of mortality in India[9]. This is closely related to the problem of unequal access to medical care in India, as mentioned by Debasis Barik et.al [10]. Presently, we have the technology to monitor the vital parameters of a human body, but not the ability to utilize it. In Urban areas, the major issue is population. Healthcare centers here may be equipped with the most advanced technology but accounting to the large population (thus more number of patients), there is a lack of trained professionals who are able to operate these equipments and foster to the needs of the patients. An average cardiac patient hence spends more time in standing in long queues to get the essential tests done, and in waiting for diagnosis of the test, than in getting treated.

The population of a rural area is generally manageable but scenario is still worse. This is because the healthcare centres here are not equipped with the essential paraphernalia that are required to monitor basic body parameters such as the ECG, SCG, etc. Most of the traditionally available equipments such as ECG with 12 electrodes is very bulky and expensive. A majority of the vital health monitoring systems available in the market are so sophisticated that they are available only in top-notch hospitals, let alone rural areas. Hence not all patients have the luxury of being diagnosed with the help of such equipments, thus worsening their state of health.

These shortcomings call for a need to develop a convenient, easy to access and inexpensive system which will measure the essential body parameters of a person anytime, anywhere and convey the data to the Doctor, without actually moving the subject physically to the health care centre. We aim to make one such wearable device which will measure the ECG and SCG of a person and integrate it with the state of motion of his body . These are the two most vital parameters which can essentially detect the onset of the cardiovascular abnormality in the person. The reason why measuring of ECG and SCG is not very common in the existing health monitoring wearable devices is that these signals are highly dependent on the state of motion of the concerned person. Each posture has different threshold values. For instance, the ECG signals captured of a healthy person while he is running may be indicative of a chronic disease for a person at rest. Hence acquiring the ECG/SCG signals alone is not sufficient. It has to be integrated with the current motion of the body in order to be able to accurately interpret the results. To accomplish this, we have developed a data acquisition system to integrate the three sensors (ECG,SCG and motion) to get their real time readings simultaneously.

LITERATURE REVIEW

The work by Nurul A. Abdul-Kadir et.al[1] deals with the acquisition of ECG signal from BMD 101 module and uploading the data to cloud. The work specified in [2] by Tingyu Wang et.al collects the ECG data from BMD101 and they tested the system on 450 people consists of all age group, gender, and job and finally plotted the graph between heart rate and age group. Zimu Li et.al[3] developed the ECG acquisition system and transmitting it wirelessly to the server. Prasan Kumar Sahoo et.al [4] carried out a combined analysis of SCG and ECG for cardiac-related health monitoring system**.**

METHODOLOGY

To acquire the Seismocardiogram (SCG) signals and the motion of the body, MPU-9250 has been integrated. BMD-101 has been integrated in order to acquire the Electrocardiogram (ECG) signals. These parameters are being monitored in real time and and the data is being shown in MATLAB.

1) ELECTROCARDIOGRAM (ECG)

Information about BMD101- BMD101 is NeuroSky's 3rd generation bio-signal detection and processing SoC device. BMD101 has analog front-end circuitry and dynamic powerful digital signal processing unit. It efficiently acquires Electrocardiogram signals ranging from uV to mV and passes to signal conditioning circuits.The Low-Noise-Amplifier and (16-bit)ADC are the two main components of the BMD101 from the analog front end. Because of the BMD101's extremely low system noise and programmable gain, it can detect bio-signals and convert them into digital words using a 16-bit high resolution ADC.[5]

Fig 1: ECG BMD-101

ECG acquisition System - Three electrodes are attached to body as shown in figure-2 and connected to BMD101. BMD receives low amplitude differential analog signals from the SEP and SEN electrodes and converts the analog signal into 16 bit digital data.It is then directly transmitted to microcontroller by TX and RX.After checking the checksum bits, the stream of data packet is parsed according to the data payload format as specified in the datasheet.The acquired data is then converted into usable ECG data and sent to PC via serial communication.The ECG data is then acquired from the corresponding COM port and displayed real-time on Matlab GUI.

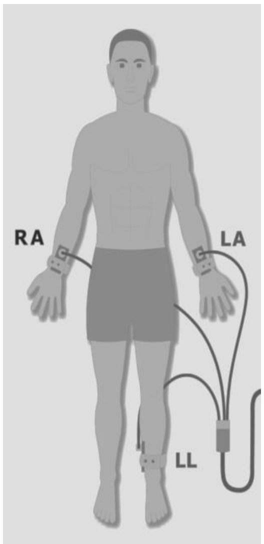

Fig-2: Placement of ECG electrodes

2) SESIMOCARDIOGRAM (SCG)

a) Seismocardiogram is a measurement of mechanical vibrations created due to cardiovascular functions. SCG can be measured only when the subject is still. This is because there is a high probability that gets masked by various body movements and locomotion, thus giving false results. Irrespective of the subject's posture, about 30 seconds of motionless behaviour is sufficient for a stable estimate of the average SCG waveform[7]. The mechanical aspects involved in the heart contraction and blood ejection are accounted for, in the SCG, while the sequential electrical events occurring in the heart are represented in the ECG.A three axis accelerometer can be used as a SCG sensor.

b) **Acquisition System-** A three axis accelerometer sensor (MPU9250) is placed on the chest wall and vibration along z-axis or normal to chest is measured.The SCG signal can be acquired from Aortic, Pulmonic, Tricuspid and Mitral valves,which was proposed in the paper[8]as shown in the figure-3 .The MPU9250 directly sends the data to microcontroller via I2C communication.Then it is send to PC via USB serial communication and corresponding data is shown on the MATLAB.

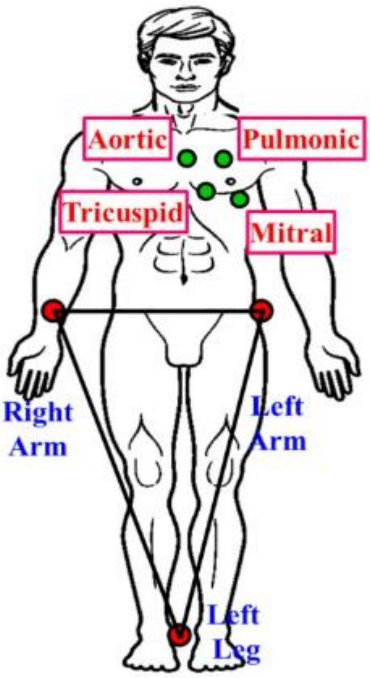

Fig-3: Locations of SCG sensors as mentioned in [2]

3) MOTION SENSING

a)**Information about MPU-9250**- MPU-9250 is a 9-axis Motion Tracking device that combines a 3-axis gyroscope, 3-axis accelerometer and 3-axis magnetometer. MPU-9250 features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs, three 16-bit ADCs for digitizing the accelerometer outputs, and three 16-bit ADCs for digitizing the magnetometer outputs with signaling conditioning circuits separately in all the three cases.When the device is placed on a flat surface, it measures 0*g* on the X-axes and Y-axes and +1*g* on the Z-axis.The full scale range of the accelerometer digital output can be adjusted to ±2*g*, ±4*g*, ±8*g*, or ±16*g*. [6]

Fig 4: MPU-9250

b) **Acquisition System-** The module is mounted on the body and acquires real-time acceleration data of all the three axes with the orientation data. These outputs are then processed and analyzed in a microcontroller to predict whether the body is in motion or not. Whenever some motion has occurred it will cause some change in the sum of linear or angular acceleration. When this change is greater than threshold values it implies that the body is motion.The magnitude of linear acceleration is given by

$$|\mathbf{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Where ax,ay,az are the accelerations in the three axes.

The final result, along with the other parameters is then shown on the matlab GUI. This helps us decide whether the SCG and ECG signals were procured in motion or motionless state. The SCG and ECG values are then compared with the threshold values of that particular state of motion or rest of the subject, and the verdict on the poor or good health of the subject is made.

RESULTS

1)SEISMOCARDIOGRAM- To SCG data was acquired from aortic valve as shown in the figure-5 .The data rate of 100Hz.The subject was in standing position (motionless state).During the process the motion of the subject was monitored by MPU-9250 to ensure subject is in motionless state.The real-time output was then communicated serialand plotted on matlab as shown in the figure-6.

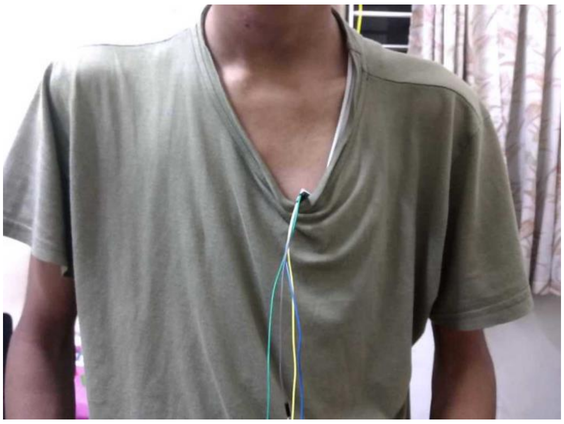

Fig-5:Placement of MPU-9250 for Seismocardiogram signal

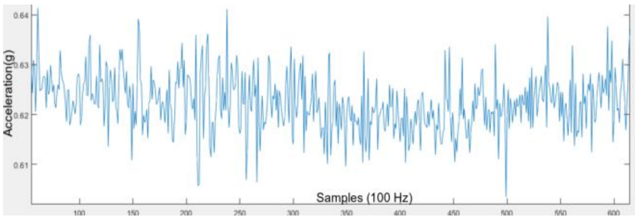

Fig-6 : Seismocardiogram signal shown on matlab

2) MOTION- The 3-axis accelerometer sensor has been attached on the chest of the subject as shown in Figure-7(b). The magnitude of acceleration is acquired and calculated at 100 HZ. A number of samples have been taken and the results of each test case plotted as a graph.Figure-8 shows a concerted graph of acceleration magnitude versus the various samples, while the subject was standing (motionless).The magnitude of acceleration in this case ranges between 1.02g and 1.05g, along with sudden spiked samples, which can be ignored.Figure-9 represents the graph when the subject is in any state motion state that it is jogging,jumping, bending etc and this case Figure-7(c) placement was used.To detect precisely sitting, sleeping, jogging,running and standing Figure-7(a) MPU-9250 placement was used.

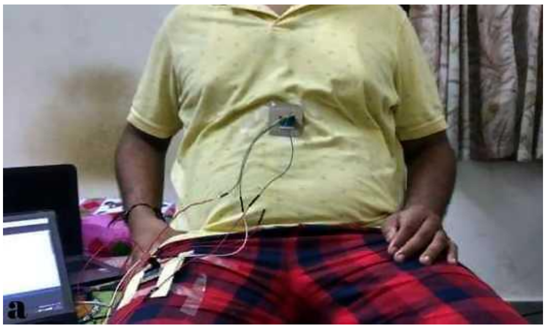

Fig-7: a) Two MPU-9250 was used to detect sitting position

Fig-7: b)MPU-9250 is placed on chest

Fig-7: c)MPU-9250 is placed on hand

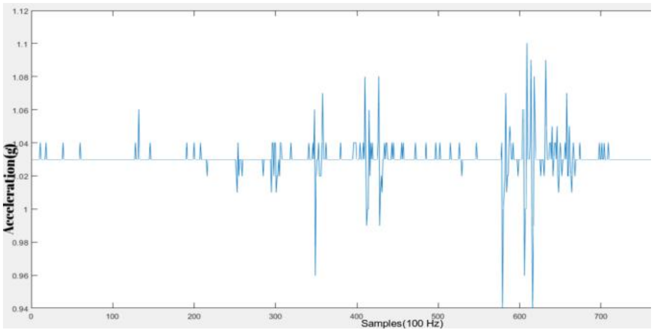

Fig-8:Magnitude of acceleration during motionless state

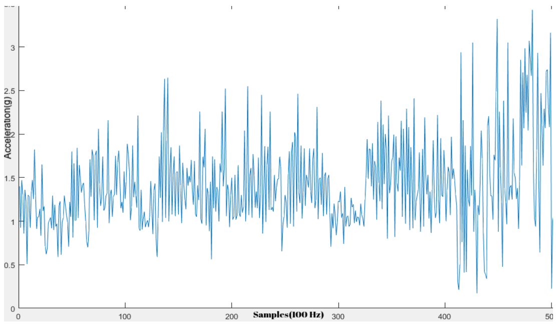

Fig-9: Magnitude of acceleration during any motion state

The analysis helped us to determine not only the abstract state of motion or rest but also enabled to accurately classify the motion. The exact state of the body i.e, whether the subject is at rest, standing, sitting, or sleeping; and if in motion, then is he running or walking, could be detected precisely after the analysis of each component of acceleration separately. For acquiring this, two accelerometers have been used. One is placed on the chest and other on one of the thighs. The relative motion between these is quantified to determine the exact state.

Further experiments will be carried to study the behavior of SCG and ECG signals depending on motion of the body.

3) ECG- For the purpose of acquiring the ECG data, the subject is made to rest in a comfortable sitting position.Three electrodes are attached to the body of the subject as shown in the figure-10. The SEP and SEN electrodes are placed on the two hands and the leg is taken as reference by connecting the ground electrode to it. The data is acquired from BMD 101 with data rate of 25 Hz and is simultaneously plotted on matlab(See figure-11). During the whole process, accelerometer sensor was attached and monitored, in order to ensure that the subject is in motionless state. According to the plot, the heart rate is approximately 60 bpm which we know is the normal heartbeat of a healthy person. As seen from the graph, for every QRS complex there exists one P wave.This implies that atrial and ventricular rates are equal, thus indicating the absence of any disease.

Fig-10: Subject was tested for ECG signal

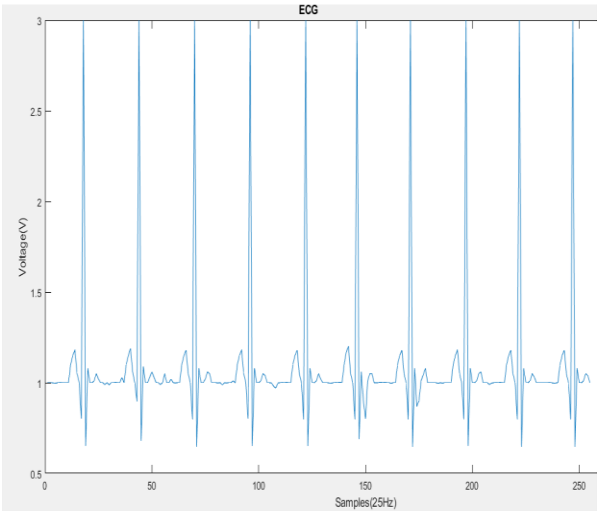

Fig-11: Ecg signal plotted in Matlab

APPLICATIONS

This health monitoring system has been primarily developed to be used in hospitals where monitoring of all vital cardiovascular parameters of the patients by the doctors is not possible.This is a very common scenario in rural areas where the hospitals are not well equipped with sophisticated machines and instruments. This system is exceptionally useful for old aged people as they require constant monitoring of the vital parameters at all times. The real time data can be sent to their family members and the concerned doctor so that immediate action can be taken if the readings show some deviation from those of a normal, healthy human being.

FUTURE SCOPE

Presently we have tested on discrete sensors but in future we shall fabricate each sensor on a single substrate so that the system size become more compact. This real time data can then be directly uploaded on the cloud, thereby, making it instantly accessible to all the concerned individuals including the patient's family and the healthcare professionals. Further, to enhance the security and privacy of the system, it can be integrated with GPS and session login features can be added. With cloud integration, the medical professionals will have an easy access to the detailed medical history of every patient under treatment. This will help them undergo a thorough, in-depth analysis of patient's health. In addition, an early warning system can be introduced for the critical patients, wherein even a slight deviation from the normal reading would raise an alarm. This would also prove to be immensely beneficial in many deadly illnesses where early detection is essential.

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