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Proposal of a new PPG-based watch-like device for Heart rate and BP measurement with GPS facility

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***Abstract*—** PPG signal may be considered as an important diagnostic platform for measurement of different physiological indices for cardiovascular disease. PPG detects volumetric changes in arterial vessels that cause a change in the light absorption, reflection and therefore the light intensity detected by the photo detector. Our proposed research topic primarily deals with performing data acquisition of raw PPG signal from a Spo2 sensor based blood pressure measuring system. The PPG signal thus acquired will be processed for different noise removal using suitable filtering and smoothening methods. Thereafter analysis of the PPG signal could be done with the help of signal processing method for feature extraction like Spo2 value, Pulse rate, Heart Rate Variability, Blood flow rate, Arterial stiffness, Augmentation index etc. all of which contribute to arterial pressure can be calculated from the PPG waveform itself. All these physiological parameters extracted from PPG signal would result in an overall analysis of patient's cardiovascular condition. Each of the parameter calculated from the real time PPG signal would be then clinically standardized and finalized for remote transmission wirelessly resulting in immediate diagnosis in case of emergency. The measured HR and BP can be displayed on a LCD watch or ring-like proposed instrument and using GPS, MCU and ITTT website, an auto message can be sent to his/her family member during any emergency stating the condition BP, HR and location of the person.

***Keywords*—** PPG signal, arterial vessels,Spo2 sensor, NODE MCU (ESP8266) noise removal, pulse rate, heart rate variability, blood flow rate, arterial stiffness, augmentation index, arterial pressure.

I. INTRODUCTION

A pulse oximeter is a device that can measure and display the pulse rate and Spo2 level in blood. Using a pulse oximeter, which employs a Photo-detector, Red and near-IR light emitting diodes (LEDs- 660 & 940 nm for measuring the light that scatters through blood perfused tissue), Oxygen Saturation level can be achieved. Oxygen is transported in the blood by hemoglobin and depending on whether haemoglobin is bound to oxygen, it absorbs light at different wavelengths. Oxygen saturation can be defined as the ratio of oxygenated hemoglobin to the hemoglobin in the blood.

Photoplethysmography (PPG) is a non-invasive method to measure the heartbeat that uses the ability of light to reflect and penetrate in human tissue. With every pulse the blood vessels increase in thickness and the body will therefore absorb more light as the light will have to travel through more tissue. PPG detects volumetric changes in arterial vessels that cause a change in the light absorption, reflection and therefore the light intensity detected by the photo detector.

In this paper a new watch/band like device has been proposed which can continuously monitor, measure and display heart rate (HR) and blood pressure (BP) and status of the health condition on a LCD mounted on it. In case there is any abnormality in HR or BP level, using a GPS System, an auto message can be sent to his or her family member stating the emergency situation and his/her current location.

II. BACKGROUND OF WORK

In the work of [11] PPG signal is taken as a diagnostic tool for measurement of different physiological indices like Augmentation index, Stiffness Index etc. along with heart rate calculation from PPG peaks, pulse period etc.

Adequate amount of blood supply to all the organs in the body is of paramount importance. Various diseases result in reduced amount of supply to the organs. The measurement of blood flow will therefore help in early diagnosis of diseases, arterial thickening etc. There are several extensively used techniques for measuring the blood flow. They can be categorized into two types- invasive (surgical) techniques and non- invasive (through the skin) techniques [1]. With each heartbeat, a pulse radiates out to peripheral circulation which causes changes in the diameters of the arteries because of the changes in the blood volume [2]. Existing methods of blood flow measurement include

invasive techniques like-Electromagnetic Blood Flow Meter, Dye Dilution Method, Fick's method, Thermal convection method [3] and non-invasive techniques like Doppler Flow-meter [3]. The laser Doppler imaging technique of blood flow measurement makes use of the laser source which moves in a raster pattern over the skin to build up a laser Doppler image. This method has the advantage of being non-invasive but suffers from disadvantages of limited laser penetration, low resolution and longer measurement time [4]. Adequate amount of blood supply to all the organs in the body is of paramount importance. Various diseases result in reduced amount of supply to the organs. The measurement of blood flow will therefore help in early diagnosis of diseases, arterial thickening etc. The proposed methodology for measuring blood flow/HR is a non-invasive method which makes use of the optical technique called Photoplethysmography (PPG).

III. OBJECTIVES

- ✓ Acquiring a PPG signal from a Spo2 sensor based blood pressure measuring system and pre-processing it before it is taken to PC for analysis.
- ✓ Signal analysis including feature extraction like Spo2 value, Heart Rate, Blood flow rate, Arterial stiffness, Augmentation index, Aging Index calculation will be performed using software.
- ✓ Extracted features from the real time PPG signal would be clinically standardized.
- ✓ Saving the result of analysis of PPG signal for remote health monitoring.
- ✓ Displaying HR, BP and status of the health condition on the LCD mounted on the instrument.
- ✓ Sending a message in case of emergency stating the condition, BP, HR and current location of the person using GPS, ITTT.

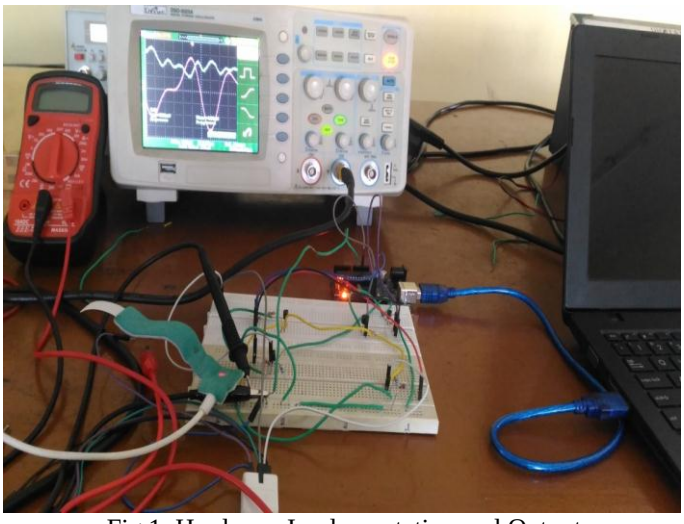

Fig.1. Hardware Implementation and Output

IV.MAIN BLOCK SCHEMATIC REPRESENTING OFFLINE PPG SIGNAL PROCESSING

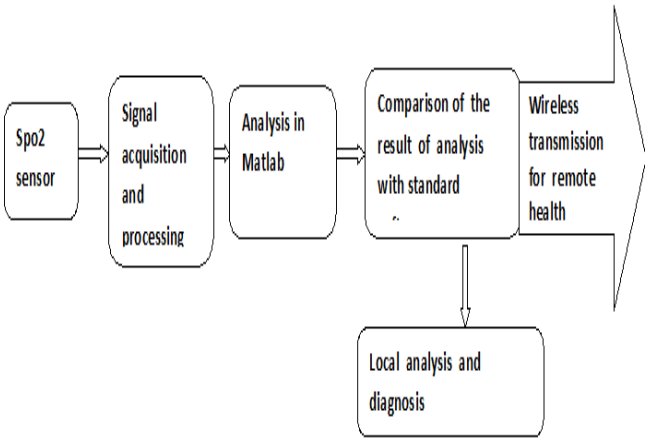

Fig. 2

V. FLOW CHART

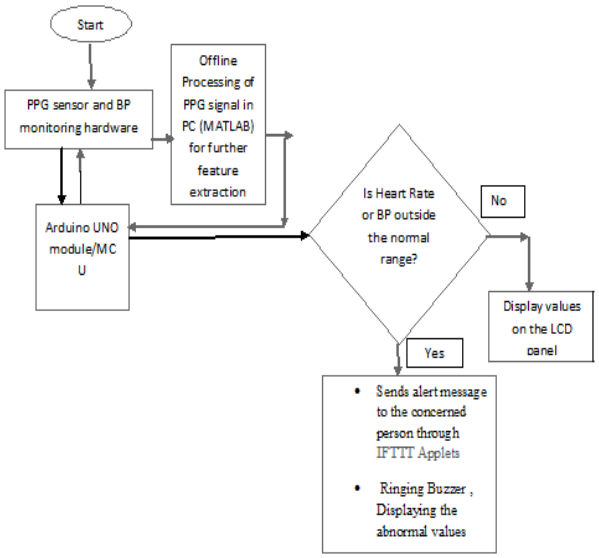

Fig. 3

VI.METHODOLOGY

i) In this research work firstly PPG signal from a Spo2 sensor (pulse oximeter) will be acquired by suitable data acquisition system. The PPG signal being weak in nature, proper signal conditioning is necessary before it is being analysed. Before extracting features from a PPG signal its pre-processing include separation of different artifacts from the original signal (Fig.3.). Common sources of artifacts in a PPG signal like motion artifacts, powerline artifacts can be separated by suitable filtering schemes. Often the PPG signals obtained have low amplitude due to poor connectivity of the sensor with the measurement site.

Detection of heart rate from the pulse intervals of such low amplitude PPG signal becomes quite difficult. Hence such PPG signals are first amplified before it is being analysed. Thus from the PPG signal obtained from blood oxygen saturation, heart rate, blood pressure and different cardiovascular anomalies can be analysed.

ii) Oxygen saturation can be defined as the ratio of the oxygenated haemoglobin to the haemoglobin in the blood.

$$\text{Oxygen saturation} = \frac{C(HbO_2)}{C(HbO_2) + C(Hb)} \times 100\ (\%)$$

C (Hb) = Concentration of deoxygenated hemoglobin

$C(HbO_2)$ = Concentration of oxygenated hemoglobin

iii) From the systolic amplitude of PPG waveform systolic stroke volume can be calculated [5]. Continuous measurement of peak to peak interval gives an indication of the HRV [6-10]. Augmentation index [6], Arterial stiffness index [7] all of which contribute to arterial pressure can be calculated from the PPG waveform itself.

iv) First derivative of the PPG signal could be performed for better peak detection and hence peak-to-peak time interval (Fig.4.). Comparison of the HRV obtained from the original PPG and its first and second derivative can be recorded for future use. Second derivative of the PPG signal closely correlates with ECG signal include four systolic and one diastolic peak (Fig.5.). From the height of each of the wave arterial stiffness can be calculated.

v) Each of the parameters calculated (For our case HR-78 BPM obtained etc.) will be compared with clinical standard. After comparison the methods which would be found more accurate would be finalized for transmission at remote end wirelessly for immediate diagnosis in case of emergency.

vi) Apart from measuring these parameters, Blood Pressure will be measured and both the Heart Rate and BP will be displayed in a LCD display mounted on the watch-like proposed instrument.

vii) Now if there is any abnormal HR (above 100 BPM (beats per minute) - Tachycardia, below 60 BPM bradycardia) or BP level (Fig.7), through aurdino/NODE MCU, an emergency signal will be sent by the sensor and the emergency situation will be indicated by a buzzer/light.

viii) Moreover through GPS module along with other components like NODE MCU (ESP8266) and ITTT(If This Then That) website, an auto message can be sent to the registered mobile number of his or her family member stating the emergency situation and his/her current location.

viii) Moreover using the USB port and memory chip provision of our proposed device, in abnormal/emergency condition sensor data can be saved in external memory chip/internal storage which can be used for further processing in PC as discussed in step i).

VII. CIRCUIT DIAGRAM

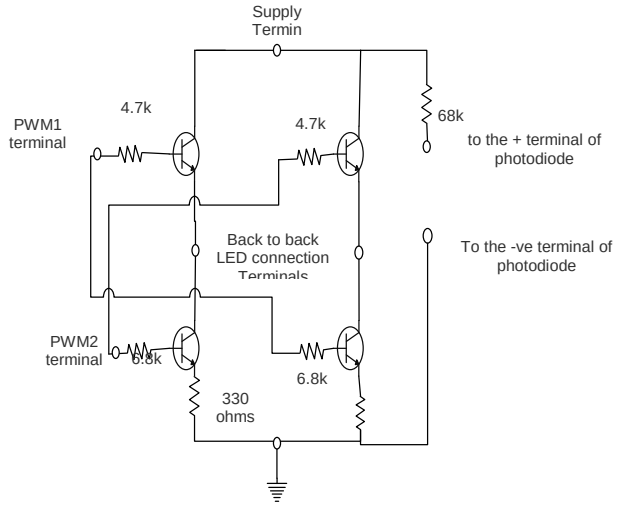

Fig.4. Basic circuit Diagram

VIII. NOVELTY

- ✓ Different physiological indices like Augmentation index, Stiffness index, Aging index etc. can be calculated both from the first and second derivative of the PPG signal and each parameter can be validated by comparing with standard signal obtained from software like BIOPAC or other similar software. Hence accuracy of the obtained data will be confirmed.
- ✓ Calculation of blood flow rate from the PPG signal could also be performed and from the plot of blood flow rate and original PPG signal individual physiological parameters would be measured and compared. Blood flow rate being measured would give us an indication of cardiac risk.
- ✓ Heart Rate and BP can be displayed in a LCD display mounted on the watch-like proposed instrument.
- ✓ His/her family member will be intimated in case of any emergency through an auto-message.

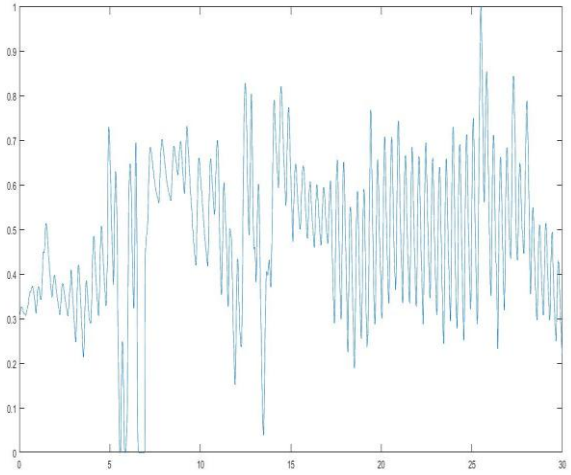

Fig.5. PPG signal obtained after filtering and processing.

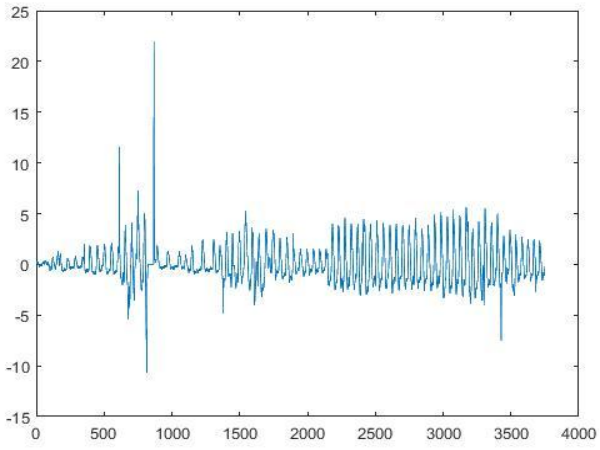

Fig.6. First derivative of the PPG signal obtained after filtering and processing.

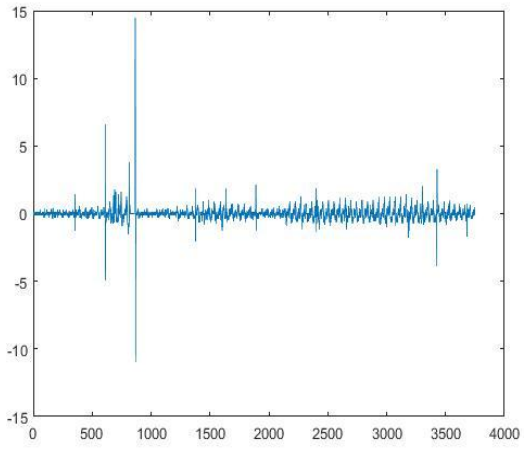

Fig.7. Second derivative of the PPG signal obtained after filtering and processing.

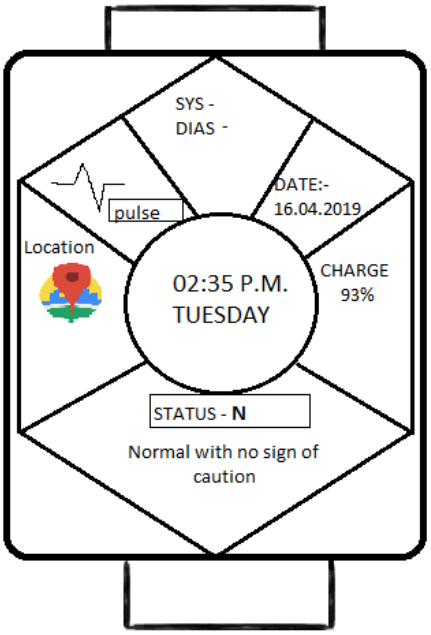

Fig.8. Proposed PPG based watch-like Device for HR and BP measurement.

BP Category	Systolic Pressure mmHg	Diastolic Pressure mm Hg
Normal	< 120	< 80
Prehypertension	120-139	80-89
Hypertension stage1	140-159	90-99
Hypertension stage2	>160	>=100
Hypertensive Crisis	>180	>110

Fig..7. Blood Pressure table.

IX.CONCLUSION

In this paper a new device has been proposed which can continuously monitor, measure and display heart rate (HR) and blood pressure (BP) at the same time. A band or watch-like system can be placed in the wrist which will contain multi-LCD displays to display the HR, BP, date & time, present location, and health status. As soon as there is any abnormality in HR or BP level, sensor will send an alarm signal and the emergency situation will be indicated by a buzzer/light .Moreover using GPS,ITTT, an auto message will be sent to his or her family member stating the emergency situation and his/her current location.

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