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A Multi-Signal Acquisition System using IoT for Preventive Cardiology

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Abstract: Remarkable technological developments in recent years have opened up new possibilities of improving public health care system. Developments in computing, signal processing and communication technologies have resulted in new diagnostic instruments with better precision and connectivity with computing machines, communication gadgets and databases. Among the various vital biomedical signals that can be collected noninvasively, ECG, PPG, SpO2 and PCG collected simultaneously, can help in examining electrical (ECG) and mechanical (PCG) functioning of heart, efficiency of lungs (SpO2) and condition of arteries (PPG). This promises to give a composite overview of the whole cardiovascular system non-invasively. In this paper a portable multi-parameter, non-invasive biomedical signal acquisition system (which can monitor, store and communicate the above mentioned four biomedical signals) is developed for regular telemonitoring of patients especially with cardiovascular complaints. The gathered physiological data can be sent to the monitoring station and depending on the condition of the patient, further instructions can be issued from there to assist doctors in early diagnosis of crucial symptoms.
Keywords: Preventive Cardiology, Cuff-less BP, Internet of Things, ECG, PCG, sensors

I. INTRODUCTION

Cardiovascular diseases (CVDs) are emerging as the leading cause of death worldwide. In developing nations (like India), rapidly changing socioeconomic condition of the masses is resulting in changed habits and lifestyle. This makes people prone to CVDs. To address this problem, preventive cardiology appears to be the most promising approach.

For an effective preventive cardiology, prolonged collection, monitoring and maintenance of health data of the target population is important. With higher per capita income, the rural people are adopting new lifestyle, food habits and addictions thus inviting a possible endemic of the so-called life-style diseases.

A major attention now needs to get focused on these so-called modern diseases those are fast emerging in our rural society. This paper focuses on the emerging global pandemic of coronary artery diseases.

Fortunately, indications of CVDs can be obtained by several non-invasive low cost techniques, since the pumping of the heart causes several periodic predictable electromechanical changes in various observable parts of the human body which can be measured externally using appropriate sensors. The signals such as electrocardiogram (ECG) , Pulse Oximeter (SpO2) and Photoplethysmograph (PPG) are acquired and processed. These signals are compared with the predefined feature-sets with the expected behaviour in case of a healthy person.

II. METHODOLOGY

A Biomedical Signal Acquisition unit is developed that can monitor, store and communicate electrical (ECG) and mechanical (PCG) functioning of heart, efficiency of lungs (SpO2) and condition of arteries (PPG) concurrently in a non-invasive manner and extract different diagnostic information along with BP and HR. The problem is subdivided into three parts:- Data Acquisition Unit, Communication Unit and Signal Reconstruction and Feature Extraction Unit.

A. Data Acquisition Unit

This unit involves designing of electrodes and probes along with their corresponding signal conditioning and amplification units for ECG, PPG, SpO2 and PCG. The four sensors such as ECG, PPG, PCG and pulse oximeter are used to extract the biomedical signals from the patients. Data acquisition unit also digitizes analog signals with proper sampling frequency and sends them to a PC/laptop for storage with other relevant patient information.

B. Communication Unit

This unit transmits the collected data along with other relevant information to a remote location for storage, further analysis and expert's opinion.

C. Signal Reconstruction and Feature Extraction Unit

Retrieving and reconstruction of signals and extraction of clinically relevant information from these multiple signals is the goal of this module. A Data Acquisition unit for simultaneous monitoring and storing of ECG, PPG, SpO2 and PPG has been developed along with the required transducer unit and corresponding signal conditioning and amplification unit. Transducers for different signals are selected such that acceptable results are obtained from the available market components. The signals extracted are compared with the standards signals as shown in the Fig 1.

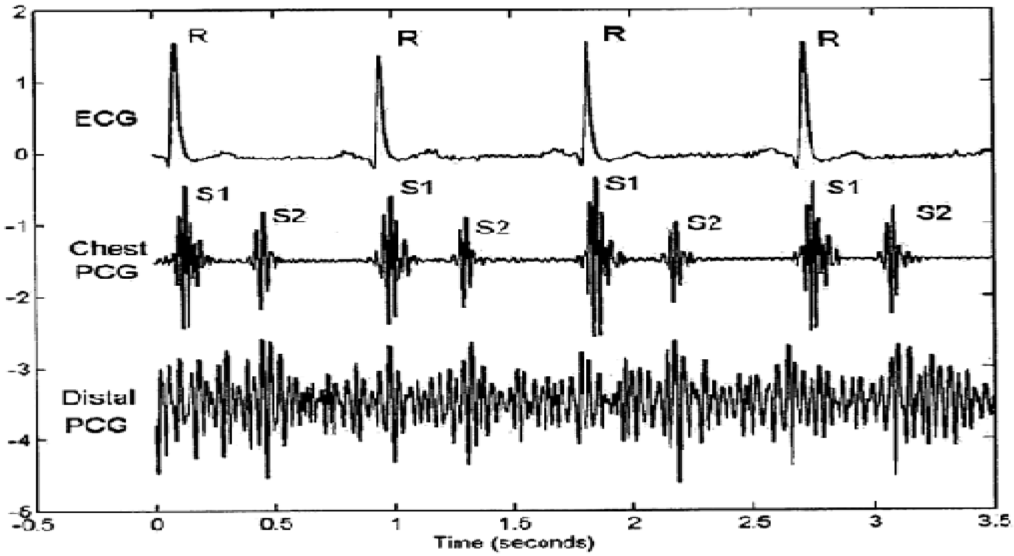

Fig. 1 Standard signals obtained from the healthy patient.

For the signal acquisition, conditioning and processing circuitry, off the shelf ICs and discrete components wired on a double layer Printed Circuit Board are used. Efforts are directed to design and assemble the SENSORS in appropriate probes so that best possible readings can be obtained from the subjects. Reflective type probe arrangement for PPG and SpO2 recordings are found to be appropriate with the available sensors. PCG recordings are obtained using a Infrared sensor which is modified to be fitted with a microphone. Non-polarizable ECG electrodes are used in the design.

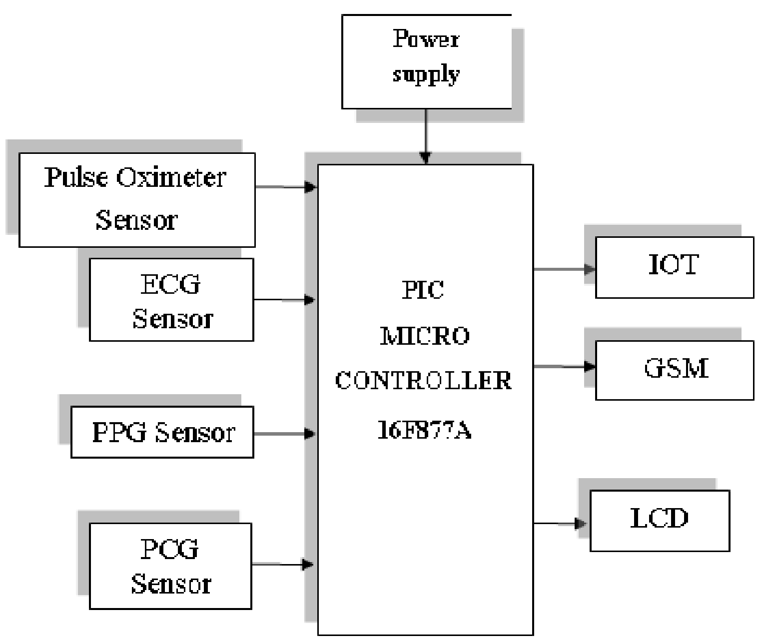

Fig. 2 Block diagram of the biomedical signal acquisition and feature extraction.

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III.EXPERIMENTAL SET-UP

Due to their high diagnostic values, BP and HR have become an active area of research. Out of the four significant physiological signals mentioned in this study, the ECG and Finger PPG are used to show BP and HR extraction using the device. During our pursuit of recording ECG and PPG signals, the developed hardware is equipped with an ECG electrodes and an optical reflective type PPG sensor is designed using LED (5mm, 562-575 nm wavelength) and a photo transistor (L14G2 NPN). ECG and PPG signal conditioning and amplification units are built using MCP6004 (Instrumentation Amplifier) which introduces stability to the circuit. The signals are digitized using 12-bit inbuilt analog to digital converter (ADC) of PIC MICRO CONTROLLER board. The advantage of using this ADC is high conversion speed; it is capable of converting up to 2 million samples per second and has a conversion time of 7 ADC clock cycles (add 1 cycle if the gain is enabled) for 12-bit results. This enables to acquire multiple signals at the same time with sampling rate as high as 1000Hz.

The ECG sensors are placed on wrists using pain-free Velcro bands, while, the PPG sensor is placed on the right hand index finger of the subject. ECG and PPG signals are simultaneously recorded for 10 seconds followed by amplification, filtering, digitization, transmission and plotting on PC/laptop screen. They are then stored for further processing. BP is extracted using both the signals while HR is extracted from ECG only.

A. Liquid Crystal display (LCD)

The LCD standard requires 3 control lines and 8 I/O lines for the data bus,8 data pins D7:D0

Bi-directional data/command pins. Alphanumeric characters are sent in ASCII format. The command register is selected when RS=0 and data register is selected when RS=1.The 8 data lines of latch are connected to PORT 1 of 8051 microcontroller. The three control lines (RS,RW and EN) are connected to PORT 3.5,3.6 and 3.7 respectively.

B. Internet of Things (IoT)

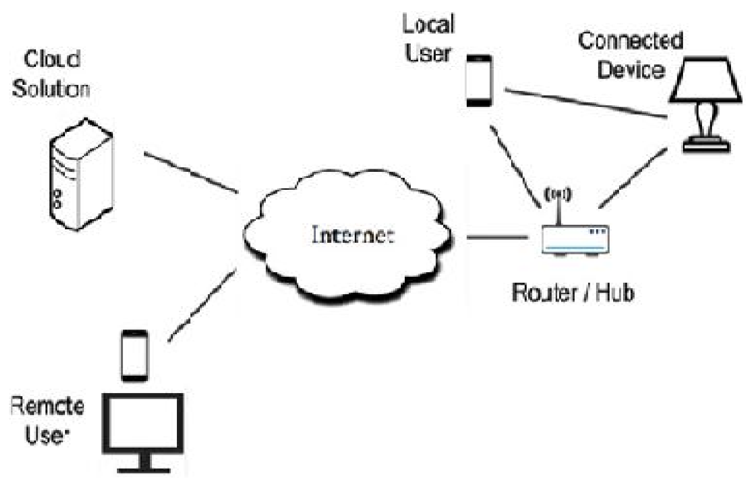

Fig. 3 General Block diagram of the IoT.

The internet of things (IoT) is the network of physical devices, vehicles, buildings and other items
embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. The use IoT is for data collection. The collected data of the patients are uploaded to a web page which can only be accessed by the doctors .Thus the privacy of the patients will be maintained. Hence for timely analysis the doctor can visit the website for maintaining a record of the patient's health

IV.RESULTS

Accuracy of BP-HR extracted by the developed device is estimated by comparing its performance with digital BP monitor from OMRON. The performance is calculated in terms of normalized mean square error (NMSE), mean absolute error (MAE) and error standard deviation. MPLAB is software used for analyzing the extracted details for the development of embedded applications on PIC and dsPIC microcontrollers. MPLAB X is the latest edition of MPLAB, and is developed on the Net Beans platform. MPLAB and MPLAB X support project management, code editing, debugging and programming of Microchip 8-bit, 16-bit and 32-bit PIC microcontrollers. The computed error for BP estimation falls under the standard allowable error mentioned by Association for the Advancement of Medical Instrumentation, that is, MAE and ESD to be less than or equal to 5 mmHg and 8 mmHg respectively.

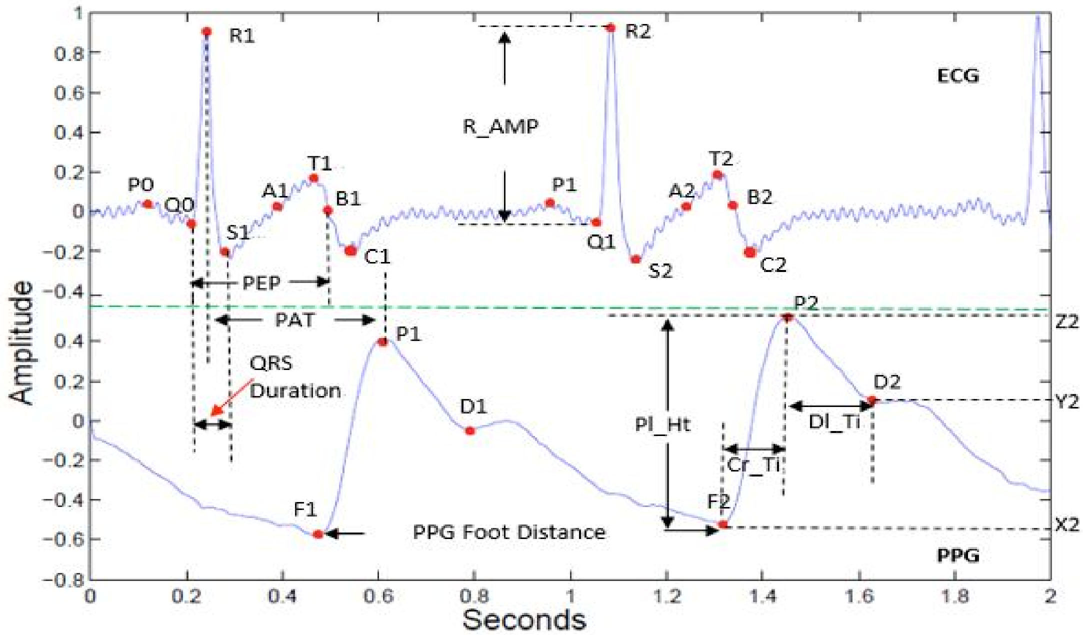

Fig. 4 Results of various biomedical signal acquisition of a patient.

V. CONCLUSION

The study proposes a portable, affordable and non-invasive biomedical signal acquisition system. The system is capable of monitoring, storing and communicating multiple physiological signals- ECG, PPG, SpO2 and PCG. Due to their high clinical importance, these signals can be used to obtain an overview of an individual's health. Cheap and easily available electronic components used in developing this device make it cost effective. The data recorded from such prolonged monitoring can be used to detect arrhythmia and heart rate variability during both, real-time as well as store-and-forward mode. In future, with some minor modifications in the mode of transmission of the acquired physiological signals, the device can be used as reliable telediagnostic and telemonitoring device.

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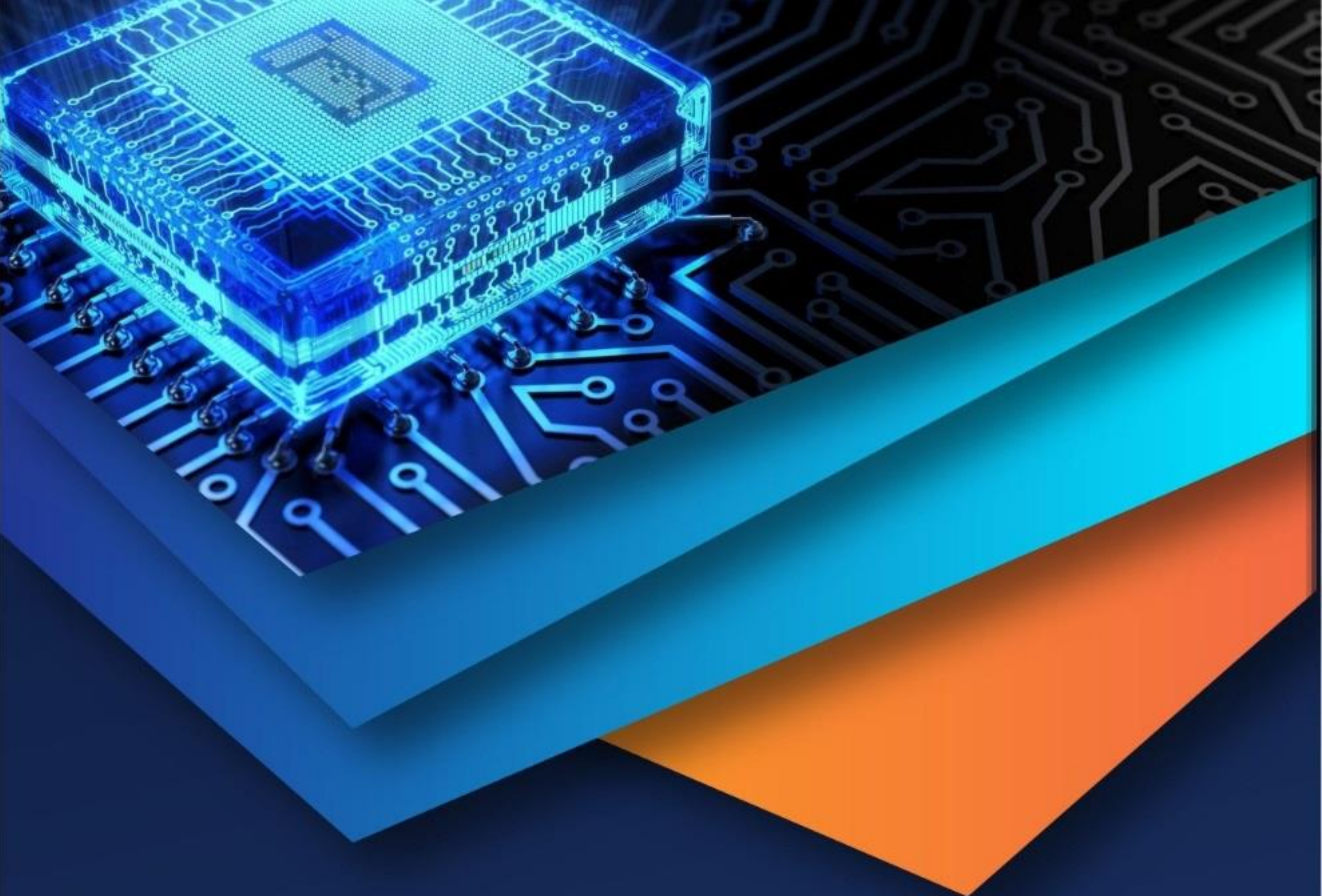

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