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Survey on Different Types of Wearable Sensors and Different QRS Peak Detection Techniques for ECG Signals

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ABSTRACT: Wearable sensors are mainly used for long-term continuous physiological monitoring, which is very important for the treatment and management of many diseases. Wearable sensors are the major part of Wireless Body Area Networks (WBANs) for providing health care services and physical activity monitoring.This paper discuss about various types of wearable sensors used for ECG signal monitoring. ECG signal is a biomedical signal that gives electrical activity of heart. Peak detection of ECG signals is therefore an important concern. QRS peak detection is one of the preliminary peak detection method for ECG signals. QRS complex is the most visually obvious part of the tracing. It corresponds to the depolarization of the right and left ventricles of the human heart. This paper also discuss about different QRS peak detection techniques used for ECG signal analysis.

KEYWORDS: ECG Signal, WBANs, Peak Detection, QRS Complex, Sensitivity.

I. INTRODUCTION

Awireless sensor network is a spatially distributed autonomous sensor to monitor physical or environmental conditions, such as temperature, sound, pressure, ECG etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring etc. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. WSN is shown in figure 1.

Cardiovascular disease is the main cause of death in the UK and it accounts for 39% of all death each year. Among patients who had heart attacks, about 30% of them died even before reaching to the hospital. Although heart attack can happen suddenly without apparent indications, cardiac rhythm disturbances can often be found before the event. They can potentially be used as the precursor to major cardiac episodes. Currently, ECG (Electrocardiogram) Holter monitoring is the most widely used technique for providing ambulatory cardiac monitoring for capturing rhythm disturbances. A wireless sensor network (WSN) (sometimes called a wireless sensor and actor network (WSAN)) are spatially distributed autonomous sensors to monitor physical conditions like EEG, EMG, blood pressure, respiratory rate, heart rate etc. The realization that the proprietary designed WSN are not ideally suited for monitoring human body and its internal environment has led to the development of a wireless body sensor network (BSN) platform. BSN architecture aims to set a standard of development of a common approach towards pervasive monitoring.

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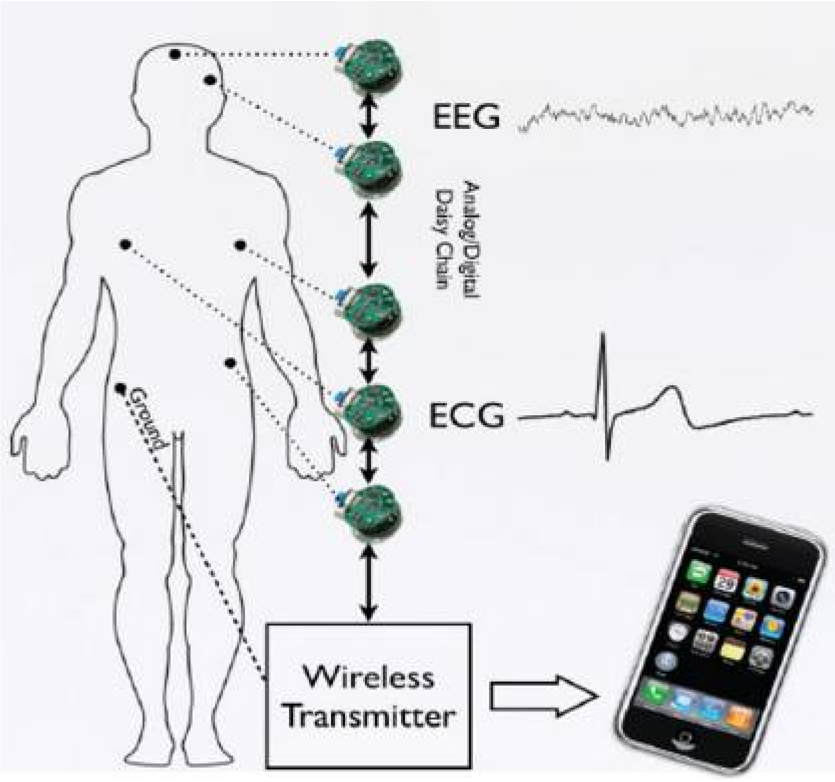

Fig. 1. Wireless Body Sensor Network

The BSN node ensures the accurate capturing of data from sensor to which it is connected, carries out low level processing of data and wirelessly transmit this information to a local processing unit (LPU). The data in this way from all the sensors are collected, processed and transmitted to a central monitoring server through a wireless LAN, Bluetooth or mobile phone. One of the major use of wireless BSN is in cardiology. Healthcare spending is increasingly becoming the major contributor of expenditure in many countries. U.S. alone spends roughly 18% of its GDP on healthcare. This can be achieved by proactive and long-term monitoring of individual's cardiovascular health using low-cost wearable electrocardiogram (ECG) sensor devices. The main features of the ECG, i.e., the P, Q, R, S, and T points, give information about the cardiac health of the person. Electrocardiography is the process of recording the electrical activity of the heart over a period of time using electrodes placed on a patient's body. These electrodes detect tiny electrical changes on the skin that arise from the heart muscle depolarizing during each heartbeat.

A wearable ECG sensor, as shown in figure.2, can be used to acquire, process, and wirelessly transmit ECG signal to a monitoring center. The main challenge involved in the development of the sensor is to make the device low profile, unobtrusive, easy to use with long battery life for continuous usage. A high level of integration with inbuilt signal acquisition and data conversion is required to minimize the size, cost, and power consumption of such a sensor. The major source of power consumption in such a system is the wireless transceiver, and hence, it is desirable to carry out preliminary ECG analysis tasks like QRS detection and RR interval estimation locally. This allows the transmission to be triggered only when it is deemed necessary based on cardiac rhythm analysis.

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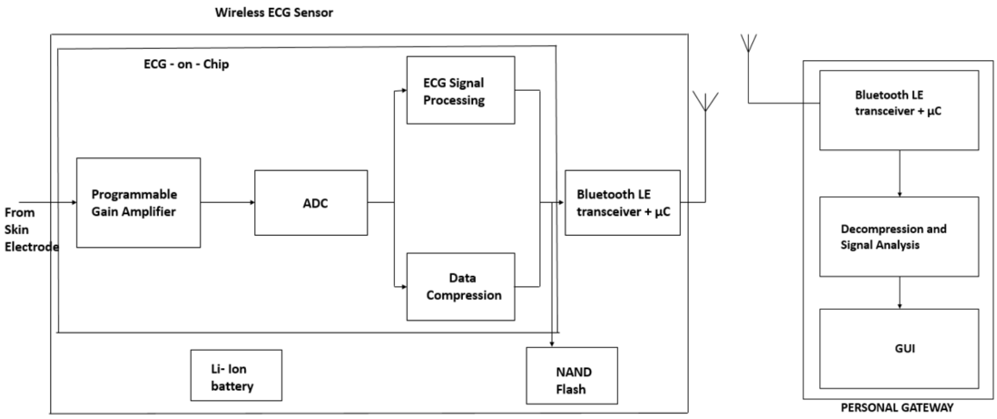

Fig. 2. Wearable ECG monitoring system

Further, the large quantity of ECG data obtained by round the clock monitoring may need to be either stored locally in a flash device or transmitted wirelessly to a monitoring gateway for further analysis. The transmission of data incurs high power consumption, and the use of a local storage increases the device cost. The cost is further affected by the need for an on-chip SRAM which is typically used to interface the ECG chip with a microcontroller to support burst transfer [1] [2].

An ECG signal representation is shown in figure.3. The ECG signal obtained from the patient are processed and compressed before transmission to a monitoring center. The main objective of data compression is to reduce the number of bits so that it reduces the cost of transmission and increases storage capacity. There are different methods for peak detection. QRS detection and RR detection are the primary ECG analysis techniques.

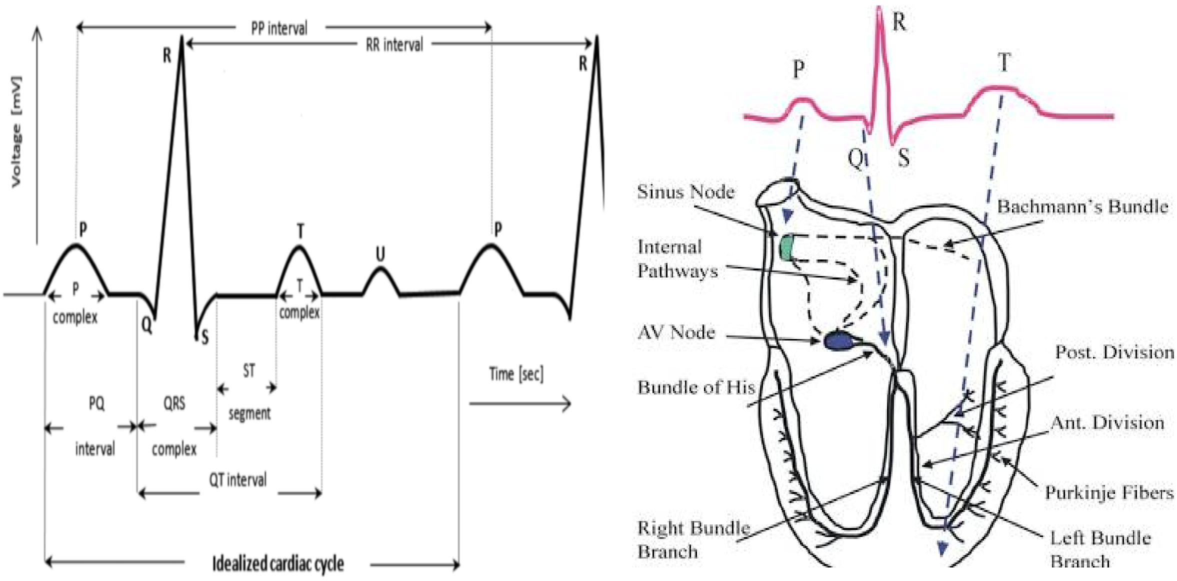

Fig.3. An ECG signal representation

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II. RELATED WORK

The proposed work [2] [11] presents a joint QRS detection and data compression scheme for ECG signals. Since QRS detection and data compression is done together, it reduces the average computational complexity and power consumption of the devices. The joint approach uses sharing of a single step adaptive linear predictor for both detection and compression. ECG data is taken from MIT/BIH Arrhythmia Database. Here a Joint QRS Detection Compression (JQDC) scheme is used. The proposed algorithm reduces the average complexity by sharing the computational load among multiple essential signal processing tasks needed for wearable sensors. The compression algorithm achieves a bit compression ratio of 2.03xx. The algorithm also achieves a Sensitivity (Se) of 100% and Positive Prediction (+P) of 100% in almost all the ECG tapes tested. In [3] [6] [9] presents different types of wearable sensors.

III. DIFFERENT TYPES OF WEARABLE SENSORS

Advancements in wearable sensors and wireless technologies create huge impact on health-care monitoring system. Now we have facilities to monitor patients from remote location on continuous basis by using wearable sensors and wireless systems. Different types of sensors available for specific applications.

2.1 Accelerometer

Accelerometer sensors or motion detection sensors are used to sense acceleration (change in body position), this acceleration might be linear or angular. Operational principle of accelerometer is based on an element named proof mass that attached to a suspension system with respect to reference point and when force applied on proof mass, deflection is produced in it. Produced deflection can be measured electrically to sense changes in body location [3], [4]. Accelerometers are most commonly used sensors to monitor physical activities of persons who recently recovered from brain disease. It specifically used in rehabilitation process of stroke and Parkinson survivors to check the level of mobility, also used in analysis of gait.

2.2 Electromagnetic Tracking System (ETS) Sensor

ETS is a body position measurement sensor based on Faraday's law of magnetic induction [5]. When a person or object that carry a sensor consists of coils perform a motion inside a controlled magnetic field, the induced voltage in sensor coils will change with respect to the change of the objects position and orientation relative to source of controlled magnetic field. This controlled magnetic field is generated by a fixed transmitter and detected by a receiver fixed on an object. By using this phenomena position and orientation of moving object can be calculated. ETS is an important sensor in gait analysis and in study of body kinematics.

2.3 Ground Reflection Force (GRF) Sensor

GRF sensor is used to realize ambulatory measurements of ground reflection force during gait analysis. It is a three dimensional vector, with actual direction depending upon the nature of interface between ground and foot. Shoe based GRF sensor is an alternative of old conventional techniques that were used in laboratory for gait analysis such as instrumented treadmill devices [6]. In [7] authors developed a shoe based GRF sensor by fixing two externally mounted sensors beneath front and rear part of a special shoe. In [6], authors proposed a new shoe based GRF sensor by using five small triaxial sensors beneath shoe. They aligned each coordinate of sensor with global coordinate systems; then collect data about each sensor position in accordance to reference positions and use this data to analyze different parameters. This GRF sensor used to measure Center of Pressure (CoP) in ambulatory measurements and also used to analyze kinetics of ankle, knee and hip joints.

2.4 EMG Sensor

In EMG electrical activities of particular muscle is monitored. During muscle contraction microvolt level electrical signals produced, that can be measured from skin surface. In other words EMG measures the action of muscles. Basically two types of EMG sensors are used, needle EMG and surface EMG. Surface EMG or sEMG is used when only basic or general information of muscle activity is required, whereas, in needle EMG, needle must be inserted inside designated muscle which required to be studied. Needle EMG sensors are used to acquire some detailed information about specific muscle [8]. EMG specifically used to study the performance of persons who suffered from skeletal problems for example used in localized muscle fatigue and gait analysis to study muscle force.

2.5 ECG Sensor

ECG is interpretation of electrical activity of heart over a period of time across chest area whose purpose is to record activities of heart during its contraction and relaxation. In conventional methods a number of electrodes were attached on body surface around chest area that measures electrical signals during heartcontraction process. Received signals from electrodes were recorded to an external device called holter. It is impossible from traditional system to perform ECG at remote location. With the advancements in technology different ideas were presented to replace wired holter with wireless holter system. Design of electrodes is also important factor in continuous monitoring that these electrodes should not damage the skin. Different electrodes were used to monitor heart activities from remote locations for continuous period, for example use of dry electrodes, electrodes made up of plastic material or rubber. However all these type of electrodes cause skin irritation problems.

In [9], authors proposed an idea to use non-contact capacitive sensing mechanism, in which capacitive electrodes can sense heart signals through clothes. They propose an idea of using two gold coated electrodes on each arm (wrist) surface and record ECG by using single channel between each arm and results show an error heart rate within range of 1%. In [10], authors developed a single chip based ECG sensor that consists of two conductive fabric electrodes to detect heart signals. This wearable ECG sensor amplifies detected signals and then transmits to server.

IV. DIFFERENT PEAK DETECTION TECHNIQUES

Wearable sensors are used to wirelessly transmit ECG signals of patients at remote locations to monitoring centres. In joint QRS detection and data compression technique, both operations are done together so that the complexity of the device gets reduced. ECG signals are collected from patients body using electrodes, it is then processed. Adaptive linear filtering is used for ECG detection and data compression. The current ECG sample is predicted from actual sample and prediction error is calculated as the difference between actual and the predicted value. The prediction error is higher for steep amplitude signals. QRS portion of ECG signal is having steep amplitude. So prediction error marks the presence of QRS complex. A simple bit packaging scheme is used for error signal coding [11]. Usually ECG datas are taken from MIT/BIH Arrhythmia Database for studies. It contains several recordings of ECG signals taken at different conditions. For the MIT-BIH Arrhythmia Database, a 48 half-hour excerpts of two-channel 24-hour are selected, ECG recordings obtained from 47 subjects (records 201 and 202 are from the same subject) studied by the BIH Arrhythmia Laboratory between 1975 and 1979. Of these, 23 (the “100 series”) were chosen at random from a collection of over 4000 Holter tapes.

The original signal is retrieved from coded signal. It is smoothened using Savitzky-Golay filter to remove impulse noise. For detecting peak, the signal is enhanced and an initial threshold value is set. It is the 25% of the maximum amplitude sample in the signal. When any signal crosses the threshold value, it checks for three continuously rising values in the signal and waits for 100ms, again checks for three continuously falling points. If it is satisfied peak is detected otherwise discards it. When 4 peaks are detected average threshold is calculated. RR interval is also calculated. For every RR interval if QRS peak is not detected then average threshold is reduced to 75%. Sensitivity and Positive Prediction is calculated. Sensitivity is the measure of QRS peaks that are correctly detected. Predictivity shows the proportion of positive results in a test. The result shows a sensitivity of 99.81% and positive prediction of 99.64%.

Another peak detection method [12] uses decision rules to discriminate the QRS complex from noise events. There is a pre-processor section which performs linear and nonlinear filtering of ECG signal. The decision rule is based on the output of the pre-processor. QRS complexes has steep amplitude, but simple peak detection algorithm falsely detects multiple peaks due to ripples in the wave. A simple local maxima peak detector is used here which can detect small-amplitude peaks. Both peaks results from same QRS complex, but one peak is classified as QRS complex and other as noise. Low pass filtering helps to reduce the ripples and multiple peaks. Instead of using a filter, in this work, a peak detection algorithm is used. It will find peaks in final output of filtering stage and these peaks define an event. The algorithm stores maximum levels and new peak is defined only after half the maximum of that height is crossed.

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MIT/BIH tapes are pre-processed and for each detected peaks a 2-dimension vector is defined. QRS detectors may be optimized with respect to false positives and negatives. Here the decision rules are optimized to minimize sum of false negative and false positive detections. Peak level estimator is used to predict next QRS peak from previous one. Here peak detection is done using mean, median and iterative prediction. Similarly RR interval is also calculated. The results shows that the detector produces 340 false negative detections and 248 false positive detections for a sensitivity of 99.69% and positive prediction of 99.77%.

V. CONCLUSION

This paper discuss about various types of wearable sensors and peak detection techniques of ECG signal. In this paper Wireless Wearable sensors has been discussed with respect to different motion detection scenarios and a brief survey of wireless wearable sensor designs. The survey includes the works and findings done by various researchers on peak detection techniques. Peak detection is done to locate QRS complex in the ECG signal. Studies shows that Sensitivity and positive prediction is very high for ECG signals.

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BIOGRAPHY

Sumi Thomas completed her Post Graduation in the Electronics and Communication Engineering, from Sree Narayana Gurukulam College of Engineering, Kolenchery, Mahatma Gandhi University, Kerala in 2015, with specialization in Communication Engineering. She received degree in Bachelor of Technology in Electronics and Communication Engineering in 2012 from KMEA Engineering College under M G University, Kerala, India. Her research interests are Biomedical Engineering, Image and Signal Processing.