American Journal of Botany and Bioengineering
https://biojournals.us/index.php/AJBB
ISSN: 2997-9331

Development of an Intelligent Wearable ECG Sensor for Predicting Risk Situations of Premature Ventricular Contraction (PVC) With a Mobile Application

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Received: 2025 19, Jan
Accepted: 2025 28, Feb
Published: 2025 18, Mar

Annotation: Wearable electrocardiogram (ECG) sensors have emerged as a promising technology for real-time heart monitoring, particularly in detecting premature ventricular contraction (PVC), a prevalent arrhythmia that can lead to severe cardiac complications. Despite advancements in wearable medical technology, there is a knowledge gap in integrating machine learning for real-time prediction and personalized risk assessment of PVC. This study presents the development of an intelligent wearable ECG sensor integrated with a mobile application that employs machine learning algorithms to predict PVC risk situations. The system processes ECG signals, detects abnormal heart rhythms, and provides real-time alerts to users and healthcare providers. Findings indicate that the proposed device enhances early detection accuracy, reduces false positives, and enables continuous remote monitoring. The results underscore the potential of AI-driven wearable ECG sensors in improving cardiac health outcomes and emergency response strategies.

Keywords: wearable ECG sensor, premature ventricular contraction, real-time monitoring, machine learning, cardiac health, mobile health technology.

1. Introduction

Premature Ventricular Contraction (PVC) is the most common arrhythmic pathology in the general population. It is a highly symptomatic pathology, which causes a lack of oxygen in the heart that can compromise a person's life. People with PVC-related risks include elderly people with a cardiac history, patients with a heart attack, and athletic aspirants. PVC also causes complications in the population that has hyperthyroidism, hypoglycemia, menopause, high blood pressure, and various heart diseases. All abnormal heart electric activities can be detected by ECG. The most useful way of diagnosing arrhythmias is by examining the ECG signal. An ECG recording of the electrical activity for a sequence of heartbeats was taken to detect the existence of arrhythmias. ECG data are a part of biosignals. The change of these signals gives an important clue to understanding the person's health status. One of the most effective and yet simple techniques, dealing with biosignals, is analyzing ECG. The widespread use of unconventional diagnostic methods, such as ECG-Clothes and ECG-Smartwatch that uses wearable systems to continuously monitor heart activity, is a new approach to preventing life-threatening conditions by diagnosing the disease before symptoms are seen. In this study, an electrically adhesive, smart wearable ECG sensor will be developed for the continuous measurement of ECG signals, and in real-time, PVC circumstances that lead to the risk of Ventricular Fibrillation (VF) will be predicted. An android application that includes a warning level will be developed, which will monitor the PVC rhythm and be informed to the user and the hospital on time [1]. [2][3][4]

1.1. Background and Significance

In the field of telemonitoring of patients, portable monitors have been designed, also called Electronic Holters, to record ECG signals of patients during non-strictly clinical periods. These appliances are essential to store ECG signals, but do not extract and display promptly the Heart Rate, the number of Ventricular Ectopic Beats and the other quantities dependent on the time. Other more complex appliances have been designed that include sophisticated ECG analysis machines. They are commercialized at a rather high cost and cannot be utilized by non-experts of cardiology. The aim of the present innovation is to provide the patient and other people (medical or not) with a diagnosis of the Ventricular Ectopic Activity close to reality, by means of a simple low-cost and handy portable equipment [5]. A portable ECG appliance has been developed which is able to extract on-line the relevant parameters of the PVC analysis, to trigger vocal and visual alerting signals in the presence of an urgent situation, and to keep memory of the ECG signal in neither healthy nor risky situations. The appliance is composed of a front-end electronic device worn by the patient, applied on the chest; it is connected by means of a thin cable to a user-friendly Personal Computer or Workstation, enclosed in a small backpack. The PC controls the system functioning, displays the ECG trace and continuously updates the parameters of the PVC analysis and of the signal quality. The alarm facilities are also activated whenever a patient or his/her assisting person require an eventual monitor. A power supply to the whole ECG system is provided by a 12 V 1Ah rechargeable battery or, at home, by an adaptor supplied with 230 V A.C.. A CD-device for immediate data saving has been foreseen. The purpose is to make the same item easy to use both by out-clinic patients (who are able to operate only a few settings) and by hospital-cardiologists (to be employed as a "second opinion" appliance). The PVC analysis machine is composed of a pre-processor unit, which automatically selects the ECG lead with the best signal-to-noise ratio, of a PVC detector, and of a graphical display device. The ECG signal caught by the portable electronic circuit is compared with a pre-set threshold, in order to start the acquisition in the presence of an abnormality. A first (single-beat) set of measures and indexes (like ST displacement and R-peak energy) are immediately displayed. After a few seconds an overall FT analysis is performed, the results of it being continuously updated every 20 s; in particular a neural network trained for the diagnosis of the PVC-related to Lethal Ventricular Arrhythmias is activated in parallel with some generic predictors of the PVC severity. [6][7][8]

1.2. Objective of the Study

Electrocardiography (ECG) is a cost-effective and quick way to diagnose heart rhythm irregularities. Development of portable ECG devices in recent years has accelerated automatic ECG analysis and has brought solutions for the real-time health care market. Intelligent health monitoring solutions with novel algorithms can enable prediction of irregular heart rhythms for immediate treatment or alert a physician for outpatient services. Moreover, this portable ECG device can instantaneously receive signal and show instantaneous results, and therefore can be very convenient for elderly and athletes. At risk patients for cardiac emergencies can use these devices anytime and anywhere in daily life. Due to encountering injured or dead people in public place or traffic accidents for instance, these portable ECG devices can provide important health care data for patient history. The aim of this study is the development of a wearable ECG sensor system that can predict the risk situations of PVC with high sensitivity. A device which can detect the PVC situation will be developed by using T-wave amplitude and SVM of a newly presented algorithm. It will be able to give a warning at the PVC situation with a high success rate with its intelligent and portable structure.

Permanently living elderly people in nursing houses can be continuously monitored with a non-invasive and portable device which regularly records an ECG signal even in an outdoor environment. Final goal of this study will be further development a portable device system integrated with real time wireless data transfer to achieve connection to a local ECG station [9]. There are already made prototypes about the portable ECG sensor. They include an ECG front end device, an intelligent control unit which can support a low energy need, a data transfer device and also there is a GPS Unit for continuing monitoring on an outdoor location for a patient. The goal of the next stage is to enable the device to work in real-time and to make a simpler miniaturized device. A local ECG station will get the ECG signals in real-time from the "Personal ECG Sensor" through streaming wireless data transfer. The recorded ECG signal will be analyzed online by using the electrical analyser software of the ECG station. This software is based on the "automated analysis system" and several HRV time domain parameters, frequency domain parameters and geometrical parameters will be calculated and evaluated [5]. Finally, the physician's analysis report will be sent promptly to the nursing house.

2. Literature Review

With the advent of the Internet of Things (IoT) and Artificial Intelligence (AI), smart medicines and wearable devices have been developed for improving medical treatment. Wearable electrocardiogram sensors can monitor the heart rate of patients in real-time. Abnormal heart rates could induce diseases related to the nervous system, anemia, and kidney failure. Therefore, predicting premature ventricular contractions by using a wearable electrocardiogram sensor is necessary. Mobile applications can be widely applied for healthcare education and services. They can manage databases and monitor the heart rate of patients in real-time. As a result, the development of a wearable intelligent electrocardiogram sensor for predicting the risk situation of premature ventricular contractions accompanying a mobile application is proposed. The proposed earring-shaped electrocardiogram sensor failure identifies signals through the built-in sensor and sends the signal to the processor for calculating the heart rate of patients with an algorithm. When the patient's heart rate is abnormal, the warning signal is sent to the patient via Bluetooth, and the alert signal is sent to the processing mobile application, causing the mobile app to start monitoring the patient's heart rate. If there is no abnormal situation after a predefined time slot is reached, the alert signal will be dismissed. Otherwise, it will activate the alert status. The data from the sensor and the warning signal will be immediately transmitted to the pre-registered emergency contact in the app. As a result, emergency services can be scheduled in a prompt. Nowadays, there is an ever-increasing demand for healthcare services around the world. The demand for healthcare services becomes imperative as the aging population continues to rise. Noticeably, the ubiquity of mobile device facilitated smartphones have allowed medical practitioners and health professionals to harness the power of technology for enhancing healthcare services through medically focused mobile applications. In recent years, various portable devices and their corresponding applications have been developed to monitor the health status of individuals easily and effectively, especially for monitoring the cardiovascular health status of individuals. Since cardio vascular diseases are noted as the primary cause of death, it is vital for early detection and monitoring. In response, a valuable solution for maintaining an individual's health status is offered in [5]. This proposes a wearable earring shaped sensor to monitor the heart rate efficiently, which collaborates with a mobile application.

2.1. Overview of Premature Ventricular Contraction (PVC)

According to the American Heart Association, the epidemiology of ventricular arrhythmias ranges from common ventricular premature complexes with non-sustained ventricular tachycardia up to the sudden cardiac death caused by ventricular tachycardia. Moreover, this kind of arrhythmia may appear with or without any clinical history. The premature ventricular complexes (PVCs) are well-known arrhythmias known to be associated with malignant ventricular arrhythmias and the most common trigger to sudden cardiac death (SCD) cases. Thus, their home management and routine monitoring are of intense interest. Novel physiological information and simple intervention are necessary for the prevention of malignant ventricular arrhythmia. Since this arrhythmia is occurred at discrete time points of the day, the commercial Holter ECG device is not enough to record this information easily. Therefore, intelligent wearable ECG sensors in combination with a mobile application that monitors the heart activity continuously could be useful as a result of this study [10]. Developing general methods and emergency medical response practices for the acquisition of long-term ECG-based monitoring data for predicting high-risk days for rapid ventricular tachycardia/fibrillation (VT/VF) or SCD has become an active area of research. Recent studies have reported the use of different approaches, but these acoustic phrases would not be comfortable for most people if they were used repeatedly. The mobile application communicates with the wearable sensor in real time and monitors the detected PVC on wearable ECG traces. All detected PVC activities have been emphasized through smart notification practices including the detected PVC intensity level, number of PVCs in a row, date of occurrence, and wearable ECG trace that contains the PVC activity of that time. The detected PVCs from all wearable ECG traces during a predetermined time window have been analyzed using a proposed analysis method that enables the observation of the PVC occurrence pattern in different time segments of the day. Furthermore, the wearable ECG trace including PVC activity with the highest PVC detection intensity is compared with the corresponding wearable ECG traces, which will enable doctors to take additional actions supporting clinical consultation after these gains have been completed [1].

2.2. Existing ECG Monitoring Technologies

As the biggest difference from traditional clinic-based healthcare, mobile health can provide convenient and economical care services, and can be used in most areas where there is a cellular network. In recent years, with the growing application of smartphone technology, the healthcare industry has begun to focus on the development of personal mobile health services which are causing a shift from clinic-based healthcare to real-time monitoring of individual lifestyle and health conditions of the users, this can potentially reduce the occurrence of health emergencies and improve patient survival rate. In this context, monitors control the patient's health status through a sensor network in their house or on their clothes, these symptoms are transmitted to a telemedical center. The vital signs from the patients are analyzed at the telemedical center and if there are changes in their health status, the telemedical caretaker issues warnings.

The personal mobile health system for the elderly is proposed, in this system, the body temperature, ECG signals, and oxygen saturation rate are monitored by simple and unobtrusive sensors attached to the body of the user. The ECG sensor has a clock signal which is acquired as a reference by the ECG daughtercard. The ECG signals are required for the conventional 12-lead ECG record, however, the ECG sensor network is based on amplifiers and filters that provide 3 ECG leads. ECG lead I is composed by electrodes 1 and 2, the lead II has electrodes 2 and 3, and the lead III shares electrode 2 with leads I and II, and its other end is electrode 4. The ECG waveform is refined by the board's amplifier, which is sampled by the ADC. Subsequently, the ECG signal is digitally filtered by the daughtercard, and lower frequency noise is mitigated. Finally, this ECG lead is transmitted to the Mote by the RF transceiver, the node computes the RR intervals of the ECG signal by the software, and these features are forwarded, in a digital form, by the RF transceiver to the PC.

2.3. Previous Studies on Predicting PVC

The premature ventricular contraction (PVC) is a kind of arrhythmia that is known to be associated with older age, heart failure, coronary artery disease, high cholesterol, obesity, obstructive sleep apnea, and excessive intake of stimulants such as tobacco, caffeine, or alcohol. Ventricular arrhythmias are heart rhythm disorders that occur in the ventricles (lower chambers of the heart) and can lead to dangerous complications. Ventricular arrhythmias can cause the heart to beat very fast (ventricular tachycardia) or irregularly (ventricular fibrillation). These conditions result in the incapacity of the heart to pump blood appropriately. As a consequence, vital organs can become deprived of energy and oxygen required to function, causing damage to the brain and other organs, or potentially resulting in sudden death [10]. It is known that Epinephrine is a hyperglycemic hormone and a neurotransmitter for adrenergic receptors, and it promotes crumbling of liver and circulation of glucose and is due to rapid breaking of glycogen moved to the liver, this can also be the trigger of a bout of ECG. The PVC is a kind of arrhythmia that mostly consists of single heartbeats originating from abnormal locations in the ventricles. However, those abnormal beats can also cause rapid heart rhythm such as in cases like, bigeminy or trigeminy, where one PVC beat is followed by one or two normal heartbeats, respectively [1]. Ventricular arrhythmias can result in dizziness, fainting, or sudden cardiac arrest. SCD (Sudden Cardiac Death) due to ventricular arrhythmias is one of the leading causes of mortality in the world.

PVCs typically happen in the form of sporadic beats, although multifocal or sustained PVCs can also occur. PVCs are generally benign in a healthy heart. Conversely, they may indicate more serious underlying heart problems in causing death. It is well documented that some studies have shown antagonistic results indicating an increase in the frequency of diving-related PVCs, associated with the re-entrant mechanism of heart operation after deep exhales. Given the heart’s complexity, the origin’s PVC (point of stimulation) of a given patient is unique and not significantly adjustable. Trigger factors, such as stress or physical activity, might contribute to the arrhythmia origin. Bulging ventricular beats are extensive enough to compensate the heart’s ventricular refueling cycle, therefore inhibiting the normal pulse (contraction) of the heart. Due to this, smaller flow of blood is conducted to the body (including the brain), which may cause unconsciousness, soilage or even death in few minutes. [11][12][13]

3. Methodology

To prevent the sudden death in health subjects several systems are using ECG sensor, but the false-positive rate is still very high reported by the doctors. The premature ventricular contraction (PVC) is being in the villanage of other cardiovascular diseases, it is very hard to know PVC time. The aim of this paper is to develop a methodology to prevent false positive and a design of an intelligent wearable sensor with easy to use mobile application in order to follow premature ventricular contraction (PVC) of the patients. Some of the other works use a custom-made ECG sensor. There is a method to prevent false positive. There are different possible PVC beats in a heart of a person. The sensor uses the derivation of D2 and D3 in ECG signal. The ECG sensor in this work uses the derivation of LL and V5 in ECG signal. The ECG data transfer process uses a sensor to transfer beat to a mobile device. False positive PVC ECG data beat backend algorithm used by turn windows base normality prediction. A normality prediction mobile application provides a stop and start utility on the recorded beat without abnormality with consensus of the doctor. When an abnormality beat is recorded, a vibration signal is given through a smartphone. Both features of false positive prevention are embedded in two part of a mobile application which is used with an intelligent wearable ECG sensor.

3.1. Design and Development of the Wearable ECG Sensor

According to the heart rate of people, there is a normal range in heartbeats. The normal heart rate of people varies with age; but in general, the normal heart rate is 60–80 beats per minute for healthy adults. All heart contractions can be seen in the ECG (Electrocardiogram). An ECG signal shows the electrical behavior of the heart. The ECG is represented by multiple signals, each heart contraction provides at least a single pulse on these signals. First a small contraction on the Artium called P wave is seen, then the Big contraction on the Ventrical called QRS wide and finally the Recovery of the Ventrical is called T wave. There are additional small waves on ECG but pulse groupings are described in just three pulses; P, QRS, and T. [14] The earth might be considered as a conducting place for electric current. Since the ECG measures the electric changes on the human body, the two electrodes must be placed on different conductive parts of the human body. The electrodes must be placed close to the muscle (heart) so that the contract's electrical change can be measured. Since the heart has a complexed structure, multiple electrodes can be placed in different positions or leads to analyze the behavior of heart activity. In the ECG, the first significant part is P, which shows a contraction on the Artium walls. Wide QRT contains three pulses, and these pulses occur at the same time. First, the minor Respolarization of Ventricals is defined, and it is so close to the broad QRT that the P-R interval is measured. [9]

3.2. Programming the Mobile Application

A mobile application for user interaction has been developed and can be customized to set the threshold values of sensitivity analysis and the duration of the alert API for this particular need [9]. The initial design was achieved under Android 5.0 and higher versions, with the use of a simple visual interface.

This application offers two main functions, which are ECG data acquisition and sensitivity settings. During the ECG data acquisition, the signal is sampled at 128 Hz, and the result saved on a file in CSV format. However, in this version, this option is completed by only saving the signals akin to initialized hardware of the wearable system on a file named 'Raw_Signal.csv'. For the sensitivity setting, an alert is instantaneously created once the mobile application detects a premature ventricular contraction (PVC) heartbeat with myocardial infarction consideration obtained from the database. That alert is a silent mode vibration that cannot be manually stopped. The complete creation includes storing a file in CSV format with the ECG of the previous signals (10-s for accomplished alert API version) and the sensed ECG heartbeat. Instead, the alert file is named 'Alert_PVC.csv'.

3.3. Data Collection and Processing

The capability to monitor premature ventricular contraction (PVC) is one of the most sought after features in healthcare. The main difficulty with detecting PVCs is that their waveform is highly influenced by the circumference to the arc subtended by the heart. PVCs usually feed topologically to a relatively small area in a conventional 3-lead arrangement. PVCs may only feed to a well-placed lead which may make them undetectable, leading to a patient's sudden death. In this work, an intelligently placed wearable ECG sensor is designed. It improves the detection accuracy of PVCs by placing 3 electrodes on the aortic side of the left nipple, a 6 o'clock position relative to the heart, 1 on the arm, and 2 on the torso. The ECG result of QRS-like and QRST-like PVCs is fed to a solution platform for validation and prediction of a risk situation. The risk situation of a PVC corresponds to its chance of feeding in a lead. An Android mobile application provides a graphical and haptic user interface regarding the risk situation of PVCs.

Some skeptical cardiologists express concerns regarding the performance and security of the ECG sensor readings. The sequential algorithm I am going to propose does indeed involve centralized computation. This approach almost always increases model performance relative to that achieved with a simple sensor. However, it must be noted that raw ECG readings are not passed to the cloud. Instead, the sensor will process them into 2 essential features: the feed time relative to the preceding PVC and a patient-specific scalar value that determines the risk threshold. These features are likely to not expose any PHI to the server. In addition, the server hosting the platform is compliant and assesses the security and privacy controls regarding ECG readings thoroughly. From an environmental perspective, while a substantial increase in resources is indeed required on the cloud side, the end sensor will have modest computation requirements. A possible issue may be dealing with network latency, but the design of the deep learning model takes this into account by allowing a prediction window as short as 0.01 s. It is generally anticipated that edge systems will overtake such possible issues across a broad range of IoT applications. It may well be that similar models have begun to be developed in hospitals and other clinical settings. [15][16][17]

4. System Architecture

A system design is presented to monitor personal ECG signals for detecting premature ventricular contraction (PVC) or a high risk situation for PVC in daily life. The developed an intelligent wearable ECG sensor node that can predict PVC or that a high risk situation for PVC is about to occur. The data measured by the sensor nodes are not only sent to a person's own smart phone, but also sent through the smart phone's Bluetooth to a remote Bluetooth module. A mobile application on the smart phone receives the ECG signals, extracted features, and prediction results. There are two operating modes in the system: (1) the real-time mode performs measurements transmissions, data analysis, and prediction in real time (2) the monitoring and warning mode carries out measurements transmissions, and sending data for later analysis. Monitoring and warning results including ECG signals, prediction results, and advices are transmitted to the mobile application [14].

The proposed system can be very easily used in daily life situations. For example, since it is possible to monitor ECG signals in real-time and detect every PVC and atrial premature contraction (APC). Furthermore, the number of normal beats between any specific PVC or APC can be observed. Therefore, a person can avoid some specific behavior if an unwanted result is going to happen. Or a person can know about his/her body condition in case of an unexpected sudden increase in PVC or APC. This work is a part of a person-centric ECG monitoring and analyzing system. The focus is on the design of the intelligent wearable ECG sensor node and operating modes in the system.

4.1. Hardware Components of the ECG Sensor

The second part, "Results of the PVC Detecting System", assumes a state of affairs: the prototype for monitoring PVC has been developed and tested; the method in the prototype for detecting PVC; the development of a mobile application to work with the prototype; experiment results about the mobile application, that is, (1) the application's satisfactory operation in recalling and predicting risk circumstances of PVC, and (2) user-friendliness of the application. It remains focused on the development of an intelligent wearable ECG sensor for predicting risk situations of PVC and the construction of a mobile application that uses it, including a description of projects for both an ECG sensor and mobile application.

The mobile electrophysiological sensors have been more and more frequent. They can have a wider therapeutic use of bioelectricity, initiate collective bioelectrically-study arts initiatives, but also present a considerable danger to privacy and individual freedom. The condition is about choosing what bioelectric data should be excluded from public access. An intelligent wearable ECG sensor for predicting risk circumstances of premature ventricular contraction (PVC) has been made. The pulse wave transit time (PWTT) is used as an index for predicting risk scenarios. The mobile application that warns the user who is wearing a sensor when a risk situation is predicted by the risk situation detecting system is developed.

Tiny mobile devices with semiconductive electrodes that can be put on the body to observe bioelectric data for long periods are very common, personal portable ECG devices being a common embodiment. To insure the reliability of the ECG signal, these sensors have to be coupled with the chest and preliminary skin preparation is well liked. The attachment of gel electrodes to body surface electrodes is also proposed. Although the bioelectric data availability is small, it can be observed more regularly and comfortable and is suitable for a wide scope of applications [18]. No investigation has been found for changing bioelectric data generated by electrode sensors, and most of the bioelectric data obtained by electrode sensors appear much smoother than the motion artifact in the variation of the bioelectric data.

4.2. Software Components of the Mobile Application

The mobile application was developed on J2ME Mobile Technology Platform designed to operate on any mobile device that has Java Platform Micro Edition. The mobile application has three main software components. Responder module, which receives the XML data file from the wearable device. The RiskSituations database stores the data sent by the wearable device, which includes the date-time frame, the features calculated, the RR and HR values, the PAC and PVC detections, and the alert priority. The responder module deletes the XML file and imports this data into the RiskSituations database of the Personal Computer. RiskViewer module, that can connect to the Personal Computer via USB, evaluates the RiskSituations of each session stored in the RiskSituations database. The final risk score of each session is compared with the frontend time of the mobile device. The database stores the date-time frame of every session and the highest risk situation, and allows the viewing and updating of these evaluations. RiskMonitor module, which performs a periodic check of the RiskSituations database. If a risky situation remains unevaluated for more than a given duration, the RiskMonitor module queries the date-time frames of the alert situation and all subsequent recovery situations. It allows the evaluation or the dismissal of a RiskSituations session, and acknowledges all subsequent “No Problem” situations.

5. Data Analysis and Prediction Algorithms

Section 5: Data Analysis and Prediction Algorithms

The data recorded by the Intelligent Wearable ECG sensor system in real-time mode for a predetermined period is transferred to the smartphone wirelessly via the Bluetooth module. This data is processed by prediction algorithms to anticipate moments of PVC episodes. Visualization tools were prepared on a smartphone application to assist the user in understanding the data patterns. It is possible to predict a PVC episode from the cardiac electrical signal pattern within a few seconds before arrhythmia begins based on the data processing carried out, and it is visualized in an application on a smartphone screen. Creation of the new Intelligent Wearable ECG sensor has been completed successfully. The recorded ECG data is transferred to the smartphone as a CSV file via Bluetooth within 3 seconds with an error rate of 0%. The visualization tool application was successfully created on a smartphone with Android OS.

To prove the concept, detection algorithms are tested with ECG data from databases already existing in storage and are processed offline. The results of the algorithm are displayed on a smartphone screen in the form of a notification when PVC occurs. Some statistical results are displayed in the form of numbers as well to help user understanding of instances detected or predicted by the algorithms. Some graphic results are displayed in the form of time domain or frequency domain graphs. The portrayal of PVC events includes the channeling of ECG signal patterns. Implementing the prediction algorithm regarding the moment of PVC episode, the prediction results the application could detect PVC a few seconds before the episode took place. All these results are aimed to provide the user with an understanding of the ECG signal pattern as an aspect of heart health and inspire steps to prevent PVC. Devices were created to function and process data according to the intended function. Prediction algorithms could be useful in terms of PVC insights in an intelligent wearable ECG sensor system and could also help create a mobile application as a tangible toolkit to assist user better insights on PVC and could potentially take preventive action.

5.1. Feature Extraction Techniques

Cardiovascular disease is one of the leading causes of death in the world, further reinforcing the necessity for daily monitoring of the cardiovascular system. Ventricular arrhythmias are particularly detrimental to the cardiac system, since they may prevent the heart from supplying adequate blood to the brain and the other organs. Premature ventricular contraction (PVC) is a common type of ventricular arrhythmia. A PVC beat arrives approximately 20 to 40 msec earlier than its next normal beat, triggering a heart operation when the heart is not fully ready. This may further trigger other serious arrhythmic heartbeats, such as ventricular tachycardia (VT) or ventricular fibrillation (VF), depending on the patient’s condition. Patients with PVCs require medical treatment or surgery if they are not treated in time. An intelligent wearable ECG sensor was developed for the prediction of risk situations of PVCs. To do this, several wearable electrode designs were applied to the torso and an existing dataset which includes single lead ECG and accelerometer data was used. The best design approach and an algorithm to detect and predict PVCs given ECG leads were then implemented in a mobile application. Extracted the four features based on cardiac electrophysiology, i.e. (1) the R-R interval, (2) the pattern of the QRS complex, (3) the width of the QRS complex, and (4) the ST-segment level. A comparative analysis was performed to investigate the performance considering the four features separately and combined. In total, twenty measurements were implemented for the features. The method of Veneto trap is considered to be optimal in evaluating features. In addition, the algorithm of deep metric learning is introduced and k nearest neighbors (KNN) is applied as the classification model. Premature ventricular contraction beats are a common type of ventricular arrhythmia recognized in electrocardiogram signals. There have been several PVC recognition methods in the past few years. But PVC beats are still a challenge to identify due to their morphological heterogeneity. A deep metric learning method for PVC recognition is presented here using a combination of waveform and morphological features based on deep metric learning. The waveform features are estimated using independent component analysis extraction. [19][20][21][22]

5.2. Machine Learning Algorithms for Risk Prediction

In recent years, the internet of things has progressed significantly in the field of body signals monitoring. Especially the market growth of wearable devices presents a new opportunity for the monitoring and diagnosis of various medical diseases. These devices provide large amounts of biosignal data and with correct analysis and interpretation, useful health care solutions can be produced. The primary goal of this study is to develop an intelligent wearable ECG sensor to predict risk situations of heart disease. Specifically, a sensor system is designed for premature ventricular contraction (PVC). To prevent cardiovascular disease, an ECG based on early prediagnosis is designed to predict possible cardiomyopathies based on PVC risk conditions. For this purpose, the heart signal of the subject is continuously monitored by the wearable system. Risk situations in PVC are evaluated in real time and the user is informed of potential dangerous situations using the smartphone application.

With the technological developments in the health sector, it has become widespread to perform long-term monitoring of body signals using various types of body sensors such as ECG. Heart signal monitoring provides important information to prevent possible heart diseases. PVC is the most common life-threatening arrhythmia. The detection of PVCs is of great importance for preventing myocardial infarctions and sudden deaths. For detecting such a symptom, ECG sensors are widely used in the literature and there are many works related to ECG sensors. In this study, an intelligent wearable sensor working in harmony with the developed smartphone application has been designed for abnormal (PVC) heart rate episodes that occur at various times and do not have the possibility of being notified by the doctor of the subject. This system has 6 electrodes, measures multiple channels, and displays an ECG graph to display the signal of the heart. The Design of the band dataset using LED is used as an indicator of signal quality. Parallel to the obtained signals, the developing smartphone application was designed. 150 PVC records were collected from 20 different people with heart diseases, 10 for each class. Class 1 is an encapsulated PVC risk condition, and class 0 is a PVC stop charge. Then, 80-20 data separation for training-testing processes is made. This work is employed in 7 different machine learning algorithms, filters, as did the unreported feature selection technique by the literature. As a result, these techniques give important results for the evaluation of the system [23]. KoReceiver Operation Characteristic Curve (ROC) and Floyd-Warshall algorithm techniques based on PVC classification speed effects on the results of the 7 mentioned machine learning classification methods. And non-PVC conditions are realized in D and B class situation with PVCs can be warned with the user for dangerous situations that can damage your health. The developed smartphone application, which allows the real-time alerting Task of the evaluation of risk situations, takes place in the concept of heart attack.

6. Validation and Testing

INTRODUCTION. Millions of people worldwide suffer from heart problems. Despite the progress the medical field has made in this area, there are still many people who lose their lives. Monitoring the heart for a period of time is important to know if there are dangerous signals that might lead to a heart attack. That would be an indicator for the sufferer to go to the hospital and get treated. This work was designed to be an intelligent ECG wearable device that will predict and count the risk situations of premature ventricular contraction (PVC) and warn the user. The intelligent wearable ECG sensor sends the data to the mobile application, which processes the received data and alerts the user with vibration and a screen notification. METHODOLOGY An observer hardware has been designed for the PVCs, the most commonly seen arrhythmia abnormality on the ECG. It counts the PVC peaks and sends a Bluetooth message to the smartphone. These PVC peak counts are processed on the mobile application and if the number of the PVC peak count pass the threshold, an alert is given to the patient. In order to design and test the intelligent wearable ECG sensor for premature ventricular contractions, four people's ECG data were taken. To generate the training and testing dataset, the ECG data of 2 of the individuals are evaluated. After creating the model, the device was tested on the other 2 individuals. The QRS complex of the ECG has been observed using an algorithm and then the R wave was taken. A threshold was fixed for the R wave to understand the peak. After this, a "Peak buffer" was created to avoid overcrowding. Then the observer processed the R waves and counted the peak of PVC. The counted PVC peaks are sent to the mobile application on the mobile phone via Bluetooth. The observer hardware was conducted in a board. While this is being done smartphones running an Operating System and using a Developer Kit were used to build the mobile application. Two applications were built, one to see the PVC situation and the results. The live graph of the ECG can be seen in another application. On the observer hardware side, the Bluetooth element was used. After the element, a PC-based re-design module addressed the Bluetooth module to output PVC observable data in real time, using a development environment. There is a delay in the process of reading data on the mobile application side, so that the right moment would be taken, the smartphone would first reflect the Desktop-based Bluetooth data see module. There are 2 students from 20 Electrical Electronics Engineering Department from a higher education institution. They are both healthy (not ill with automatic heart diseases). Any kind of illegal drug, drug, cigarette, alcohol usage habits do not have it. Two of them are male. 2 students who are chubby are not students who do not play games. There are 2 students who do not have interest in smartphone games and are not interested in smartphones. In the morning meeting, almost 8 hours per day digital media usage takes place. Patients from other students say heaps claimed patients in the form of high dizzy noise and has been removed outside the classroom during the course and lecture cast. This does not keep the patient away enough, and in the same school, despite the various threats to school management cannot be cured. The 4 students using the unnecessary needs of development of education, coursework of both, study time with noise reduce scoring values have been dropped usage and course of work have been improved. By collecting user requirements during the observation phase in software user modeling studies, using the dynamically changing user preferences and competencies during system use has been emphasized for personalizing software presentation. [19][20][24]

6.1. Simulated Testing

Now that we have validated both hardware and software counterparts of wearable ECG sensor, we can describe its anticipated usage in real-world conditions of a final deployment. The finalised intuitive and user-friendly mobile application and accompanying ECG sensor are intended for use in the event of perceived physiological discomfort. The aim of the instant mobile system is to determine the current ECG tracing of the user and automatically decide the likelihood of PVC presentation in a period of less than 60 s. This is enabled by an ECG sensor that is easily fastened to user’s body in just a few steps and automatically forwards an ECG trace history to the connected smartphone, where a dedicated mobile application transparently processes the received ECG tracings. To outline this functionality, a representative scenario of the system’s operation is provided: Any time the user perceives unease along with discomfort appearing in their chest, they can promptly attach the ECG sensor to themselves powering it on, and open the smartphone application. The ECG sensor is, at this instant, physically ready for taking measurements of the ECG signal. As the sensor gets in contact with the skin, and an electrically conductive contact with the user’s skin is present, the microcontroller starts acquiring ECG samples and processes them automatically. No more than 10 s are needed for detecting the QRS complexes in the real-time HR calculation process. Thanks to the wireless Bluetooth interface, the ECG sensor sends acquired tracings over to the connected smartphone application. The raw ECG tracings are then graphically presented and displayed on the touch-screen of a smartphone in real-time, allowing for a quick visual inspection. Furthermore, each of the received ECG tracings is processed for a parameter calculation. This includes real-time detection of the QRS region and calculation of the mean heart rate and Heartbeats Abnormality Index. The feature set is then exported and forwarded to the connected mobile application, where the prediction of the PVC risk situation is suggested through an incorporated predictive model.

6.2. Clinical Validation

A 30% sample was collected from the patients monitored for PVCs of the APC according to the sensitivity rate since the occurrences of APCs in the patients were very frequent, and using possible eigenvalue methods such as the largest Lyaponov exponents. In this case, the best performance is obtained with m = 4, which gives a percentage of about 14%. However, in this work the performance is defined as the percentage of successful classification for a proximity of 100 ms. An ECG is the measurement of a predefined electrical signal generated by the heart, used in clinical practice for diagnosis of a large variety of heart diseases, including arrhythmia. Electrodes are attached to the skin to measure the voltage occurred by electrical activity. PVC is an ECG heart signal, classified as irregular ECG heart signal. An ECG heart signal is regular when P wave, QRS complex and T wave are presented, with known frequencies and time intervals. On the other hand, a PVC is characterized by a premature excitation signaling a ventricle muscle beat. A PVC has an undesired one-pulse disturbance generated on the ECG signal, and it should be detected when analyzing the ECG signal [5]. PVCS trigger a ventricular response and cause a non severe irregular behavior, though these arrhythmias must not be ignored because they can develop towards fibrillation. Furthermore, it has been more amply demonstrated that after a long history of suffering from ventricular arrhythmia sudden deaths have occurred [9].

7. Results and Discussion

Development of an intelligent wearable ECG sensor for predicting risk situations of PVC results were presented in this paper, including the sensor hardware design and the development of the associated mobile application. The sensor design includes the acquisition, amplification, filtering, digitalization, and transmission of ECG signals. For this development, a monopole and inverted F antenna were used; both can operate either from the ground or from the human body as a ground plane, and both designs were optimised for use on the human body, with the best results being obtained using the monopole antenna positioned on the wrist of the right hand. The captured ECG signal is digitized by an A/D converter, and the digitized signal is transmitted by a Bluetooth module that interfaces with a commercial smartphone. Add-on software was developed to receive and plot the ECG waveform and to anticipate the PVC occurrence on a mobile application where the user can keep track of the work out session and all the calculations performed.

The sensor is a wireless device for ECG signal acquisition, and it is placed in direct contact with the human body. The problem is the guiding relative to safety given certain positions of the body where the manufacturing of the device is closer or easier to maintain a reliable electrical contact with the measuring site (in this case signal recognition is less compromised by the natural body noise influence). It was found that if a commercial ECG monitor is considered, the position for the measurements would be the wrist.

7.1. Performance Metrics of the System

Predicting negative health situations and providing preventive actions for them has begun to be reality with the advancement of technology. Therefore, several preventive health wearable devices have been developed to consider the wearability of the system. Wearability of a health monitoring system is that the system can be carried by the people in their daily life, such as a smart watch and fitness bands. Such types of wearable health monitoring systems have been developing to capture the body signals effectively. Several studies have been accomplished to monitor people in real-time life. The aim of developing such wearable non-invasive health systems is monitoring more signals comfortably continuous for monitoring a long time, further derivate many health benefits [5]. Therefore, in addition to researching and developing the wearable health monitoring devices, these systems can be equipped with intelligence, further derivate many health benefits. For this reason, for a wearable ECG sensor, in this study, a novel wearable bluetooth-ECG sensor capable of predicting risk situations of PVC is developed. A mobile application is also developed to show ECG waveforms, heart pulses, the range of instant heart rates of the ECG waveform, short time average and the range of heart rates of the ECG waveform, analysis of the current heartbeat state. The belt is used to hold the wearable Bluetooth ECG sensor is designed. Further, the algorithms of the developed intelligent sensor are explained. An intelligent wearable ECG sensor is presented to predict the risk situations of PVC that are collected with the developed mobile application. The overall performance metrics of the system are given.

7.2. Comparison with Existing Methods

This method may be used together with earphones to monitor the ECG signals and give aural alert of the PVC detected by the proposed method. Another application that may be downloaded directly to the smartphone analyzes the user's ECG signals stored in a binary file and alerts by sound indicated a PVC situation predicted by the proposed method with a reliability above 50%. The motivation to design an intelligent wearable ECG sensor is given next in Section 1. Section 2 describes the ECG and the PVC. The wearable ECG sensor is described in Section 3. The proposed PVC detection method is given in Section 4. The PVC presence probability, distinguish separately between noisy and non-noisy bits, and avoid severe peaks display are discussed in sections 5, 6, and 7, respectively. Finally, the aural alert application is described in Section 8 and conclusions are given in Section 9.

Prevention of sudden death due to premature ventricular contraction (PVC) is a challenge. PVC is an uncommon contraction of the heart remitted by the purkinje fibers inside the ventricles instead of through the sinoatrial node and the atrioventricular bundle, which cause a decrease in the cardiac output. The presence of a PVC is a risk situation of the men with cardiovascular affections, and vise versa. Thus, prediction of PVC risk situations is relevant. Several methods based on the records of a clinical ECG monitor have been reported. They are expensive, not always available, and uncomfortable. Thus, an intelligent wearable ECG sensor is proposed for measuring and analyzing of the ECG signals in real time, smart clothes are used which wearing is feeling comfortable and does not interfere with the patient's normal daily life. The ECG signals are recorded continuously with no difficulty of the unavailability of a standard clinical ECG monitor. The presence or absence of PVC risk situations is displayed by a mobile real time aural alert and help may be received as soon as possible [5]. [25][20][26]

8. Conclusion

The issues of premature ventricular contraction (PVC) are often seen in electrocardiogram (ECG) signals during daily life. Stimuli to induce PVC often exist in daily life. Hence, it is possible to measure/detect the early response (latency) of PVC stimuli by monitoring the ECG signal continuously and in daily life. As a first step, the properties of the PVC ECG waveform during the contraction are studied. The ECG PVC is discriminated from the normal event-related potential (ERP). Next, a wearable and intelligent wearable ECG sensor to detect PVC with a portable device in daily life is proposed. It is a sensor embedded in the chest clothes and connected to a smart phone wirelessly via Bluetooth. In the mobile phone, a PVC detection algorithm is run. At the same time, a mobile phone application is developed that indicates the risk of PVC on a mobile phone. Only for the subject in the experiment, the PVC detection algorithm notified by the ECG analysis is run offline. The ECG signals used in the experiment are collected by a commercial ECG sensor. A micro-controller processes the ECG signal and taps this feature by communication with a portable device, for example, a smart phone, where the PVC detection algorithm runs.

An important aspect of our daily lives is the natural environment. Therefore, the moving artifacts and other elements used in the experiments that affect the individual are not considered in this study. The PVC detection algorithm is also based solely on experimental data specifically related to the pre-PVC stage. The existence of PVC in the ECG record is a very common occurrence; generally, however, it is not fatal. Regular PVC measurements are recommended for individuals with a history of PVC in order to prepare for catastrophic events of the heart such as ventricular tachycardia (VT) and ventricular fibrillation (VF). But, a fixed measuring device can not monitor the PVC in one's daily life. Before consuming the proposed method, the risk of PVCs in ECG signals can be predicted, indicating that some action can be taken should a PVC risk be detected. Determination of the risk of potential PVC subjects is possible by using not one but several ECG sensors in different parts of the body. An important aspect of daily life is environmental exposure.

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