AN EFFICIENT IOT BASED PLATFORM FOR REMOTE REAL TIME CARDIAC ACTIVITY MONITORING

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ABSTRACT: In this article, a novel and an efficient methodology is presented for real-time monitoring of ECG signals. The method involves fast Fourier transform (FFT) based discrete wavelet transform (DWT) for extracting the features from the heartbeats which involves less computational complexity in terms of additions and multiplications operations for higher order filter lengths. These features extracted are recognized using particle swarm optimization (PSO) tuned twin support vector machines (TSVM) classifier. The TSVM classifier is four times faster than the standard SVM while the PSO technique is employed to gradually tune the classifier parameters to achieve more accuracy. The proposed methodology is implemented on IoT based microcontroller platform and validated on the benchmark Physionet data to classify 16 categories of ECG signals. Once an abnormality is detected, the platform generates a pop-up message as a warning and sends the information to a remote platform allowing hospitals to take preventive measures. The platform reported a higher overall accuracy of 95.68% than the existing studies. Further, such implementation can be utilized as a warning system in both homecare as well as tele-monitoring applications to continuously monitor the cardiac condition of a subject anywhere to the state-of-art heart disease diagnosis.

Keywords *– Electrocardiogram (ECG), feature extraction, machine learning, microcontroller platform, wifi-module.*

1. INTRODUCTION

Smart healthcare has emerged as a growing sector due to increased health awareness among consumers and rapid technological advancements [1]–[4]. As a result, various advanced devices or gadgets are developed, those will serve an estimate of 808.9 million users by the end of 2020 to improve the healthcare technology [1]. These devices are widely used to serve different purposes including but not limited to continuously monitor the biomedical signals like electrocardiography (ECG). These devices facilitate automatic efficient diagnosis of cardiac diseases by processing longer duration ECG recordings which is done by an experienced cardiologist and hence, they reduce the time required for analysis. These devices are developed considering the following key points like i) saving large quantity of biomedical data ii) developing devices having features offering low-energy consumption, higher computation capable, i.e., working at higher speed, battery operated, and long life iii) tele-medicine servicesusing up-to-date smartphones based technology [3], [4]. Due to enhanced health care and increased patient compliance, usage of such devices have reported significant growth in the market [3], [4]. These devices/systems typically monitor the subject's condition which include blood pressure, essential indications and ECG [6].

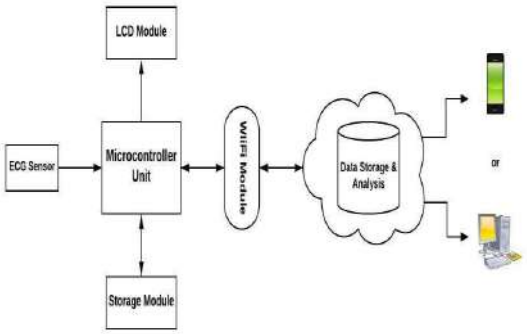

Fig.1: Example figure

As such, many new devices aiming to diagnose the cardiac diseases have evolved in market. Among those include (a) ECG monitoring system that provides cardiac activity of the subject, i.e., no storage of ECG data (b) event monitors that captures and record cardiac activity for lesser amount of time; (c) device that stores the condition of heart for longer period of time, i.e., the loop recorder, (d) telemetry solutions for ECG [3], [4], [6]–[8]. Inspite of these available solutions, the loss of life of patients are reported in many cases where the patient is unable to reach hospitals on time. The analysis of longer duration ECG records is time consuming, the cardiologists must depend on self-monitoring and symptom observed in subjects for their diagnosis. Therefore, it becomes necessary for the existing devices cardiac monitoring devices to deliver more features and must be smart rather than just storing the ECG.

2. LITERATURE REVIEW

Internet of Things for smart healthcare: Technologies, challenges, and opportunities

Internet of Things (IoT) technology has attracted much attention in recent years for its potential to alleviate the strain on healthcare systems caused by an aging population and a rise in chronic illness. Standardization is a key issue limiting progress in this area, and thus this paper proposes a standard model for application in future IoT healthcare systems. This survey paper then presents the state-of-the-art research relating to each area of the model, evaluating their strengths, weaknesses, and overall suitability for a wearable IoT healthcare system. Challenges that healthcare IoT faces including security, privacy, wearability, and low-power operation are presented, and recommendations are made for future research directions.

Consumer health care: Current trends in consumer health monitoring

The term health care has a very wide scope that ranges from lifestyle and wellness to care for acute conditions. With the availability of digital accessories for monitoring basic biological functions, the potential for obtaining detailed data on the lifestyle, habits, and behavior of an individual exists. Such data can enable the diagnosis of the causes for a condition with higher accuracy. Recently, a large number of devices have become available on the market that can monitor various aspects of lifestyle and biological functions. Such data provide feedback to an individual for compliance with healthy guidelines as well as contributing information to the health-care provider for use in the diagnosis of an ailment. In this article, we identify the various aspects of care that can benefit from consumer-grade health-monitoring devices and present the overall landscape in the context of self-care. We qualify the term consumer health care, assigning the context to it and identifying the services available in that context.

Developing residential wireless sensor networks for ECG healthcare monitoring

Wireless technology development has increased rapidly due to it's convenience and cost effectiveness compared to wired applications, particularly considering the advantages offered by Wireless Sensor Network (WSN) based applications. Such applications exist in several domains including healthcare, medical, industrial and home automation. In the present study, a home-based wireless ECG monitoring system using Zigbee technology is

considered. Such systems can be useful for monitoring people in their own home as well as for periodic monitoring by physicians for appropriate healthcare, allowing people to live in their home for longer. Health monitoring systems can continuously monitor many physiological signals and offer further analysis and interpretation. The characteristics and drawbacks of these systems may affect the wearer's mobility during monitoring the vital signs. Real-time monitoring systems record, measure, and monitor the heart electrical activity while maintaining the consumer's comfort. Zigbee devices can offer low-power, small size, and a low-cost suitable solution for monitoring the ECG signal in the home, but such systems are often designed in isolation, with no consideration of existing home control networks and smart home solutions. The present study offers a state of the art review and then introduces the main concepts and contents of the wireless ECG monitoring systems. In addition, models of the ECG signal and the power consumption formulas are highlighted. Challenges and future perspectives are also reported. The paper concludes that such mass-market health monitoring systems will only be prevalent when implemented together with home environmental monitoring and control systems.

A personalized point-of-care platform for realtime ECG monitoring

With the advancement in personalized healthcare technology, the usage of wearable devices for continuous monitoring and analysis of long-term biomedical signals, such as electrocardiography (ECG) has shown explosive growth. However, the existing ECG monitoring devices exhibit limited performance, such as they only store the ECG data, have low accuracy and their inability to perform event-by-event diagnosis at the place of data acquired. Therefore, the personalized healthcare demands an efficient method and point-of-care platform capable of providing real-time feedback to consumers as well as subjects. In this paper, a novel ECG signal analysis method using discrete cosine stockwell transform for feature extraction and artificial bee colony optimized least-square twin support vector machines as classifier is developed and prototyped using commercially available 32-bit microcontroller test platform. The prototype is evaluated under two schemes, i.e., the class and personalized schemes and validated on the benchmark MIT-BIH arrhythmia data. A higher overall accuracy of 96.14% and 86.5% respectively is reported by the prototype in the aforesaid two evaluation schemes than the existing works. The platform can be utilized as an early warning system in detecting abnormal ECG in home care environment to the state-of-art diagnosis.

An efficient method for computer-aided diagnosis of cardiac arrhythmias

In this chapter, an efficient features representation and machine learning methods are combined and developed to process the ECG signals. Initially, the raw heartbeats are pre-processed for eliminating various kinds of noises inherited within them. Consequently, the QRS-wave is located by applying Pan-Tompkins (PT) technique within the signals. Following the QRS-wave localization, a rectangular window of fixed size is selected for segmenting the heartbeats. Then, the empirical mode decomposition (EMD) algorithm is utilized for extracting the time domain information from heartbeats as features. Few coefficients are selected for an efficient representation of heartbeats using principal component analysis (PCA) which further reduces the complexity during processing using classifier. These output coefficients represent the characteristics of individual heartbeats and supports in distinguishing between them based on their morphology. Further, the R-peak to R-peak information between heartbeats are captured and concatenated with the output time-frequency coefficients. As a result, this final feature vector represents each heartbeat that are applied to support vector machine (SVM) model for recognizing these feature representations into corresponding classes of heartbeats. The classifier performance is also enhanced as its parameters are employed by employing the particle swarm optimization (PSO) algorithm under patient specific scheme. The proposed methodology is validated over Physionet database and the output of classifier model are compared to the labels of corresponding heartbeats of the database to formulate the results. The experiments conducted reported a higher overall accuracy of 95.86% over existing state-of-art methods.

3. METHODOLOGY

Currently, three possible ECG solutions [12]–[17], [19], [20] reported. Among them include: 1) the solutions are used to store ECG signals only which is analyzed in off-line mode by a cardiologist. The devices such as Holters and Loop recorders typically stores the data only, i.e., no analysis is done, 2) the solutions performing real-time

analysis from a remote place using servers such as mobi-health using personal development assistant (PDAs) or mobiles. These devices only send the data to the hospitals for processing allowing remote real-time monitoring, and 3) the solutions providing real-time evaluation within the device using updated smartphones to provide some intermediate level of diagnosis at the place of subject (point-of-care service). However, all these solutions manifest some limitations in analyzing ECG signals such as event-by-event evaluation is not conducted at the subject's place, patient is unknown about his cardiac status and has to be home bound . And the most important being the time required by the patient to get diagnosed from a nearest hospital upon an emergency. Several works have reported remote monitoring of ECG with the integration of wireless technology with the mobile devices/PDAs. The wireless technologies Include Bluetooth, wifi, RFID (Radio Frequency Identification) and ZigBee modules for enhancing the healthcare of a patient. The use of wireless technologies enables the development of a remote monitoring device targeting mass market. In, a Personal DigitalAssistant (PDA) integrated with newly designed wireless sensor structure is reported to transmit ECG signal for monitoring with high flexibility. In, a monitoring system consisting of ECG sensors, data acquisition system (DAQ), processing module, and a transceiver is presented which transfers the ECG signal using through Bluetooth to the server for analysis. In , a wearable and wireless ECG system is designed using Bluetooth to detect 3-lead ECG signals using different algorithms where wavelet algorithm is reported as the most efficient. In , a wireless monitoring system consisting of a WiFi module and Bluetooth is developed which transfers the physiological signals through Bluetooth to a server. In , a monitoring system is designed using a video camera, an ECG transceiver where the data transferred is analyzed by physicians. In , the active RFID devices is employed through a mesh type multihop network extending the network area coverage, alongwith ZigBee modules between the hubs and the RFID readers for remote healthcare monitoring. In, a home healthcare monitoring wearable system using ZigBee is presented to monitor ECG and fall of subjects. In, an e-health monitoring system is presented to make the decision related to person's health.

This study advances a step further considering the third type of solution. The basic idea of this study is to prototype a cardiac activity monitoring platform capable of allowing realtime diagnosis at the place of patient and integrated with the IoT technology. To perform automatic analysis and remote monitoring of ECG of a particular subject, an efficient signal processing and pattern recognition techniques are combined together [4] and implemented on a suitable hardware platform. A discrete wavelet transform (DWT) method using fast Fourier transform (FFT) is employed for extracting vital characteristics from the pre-processed ECG signals. The use of FFT in standard DWT diminishes the computational burden significantly offering the implementation to be fast. These features extracted representing the heartbeats are applied as input to twin support vector machine (TSVM) algorithm forrecognition into the sixteen categories. Here, the TSVM classifier performance parameters are optimized by implementing the particle swarm optimization (PSO) scheme. The proposed methodology is validated on the benchmark Physionet data and implemented on a microcontroller platform. The platform is evaluated under category oriented scheme to provide a generalized solution. The input signals are generated in real-time and processed to identify sixteen classes of cardiac abnormalities. The categories of heartbeats identified by transmitter platform are transferred to a receiver platform using Wi-Fi unit interfaced with both the platforms. The proposed methodology is faster and efficient than the conventional methods. The implementation can be considered as an extension of a hospital setup where a patient's ECG can be monitored remotely and thus, reduces the time required in delivering treatment to a subject remotely, thus enhancing the cardiac healthcare.

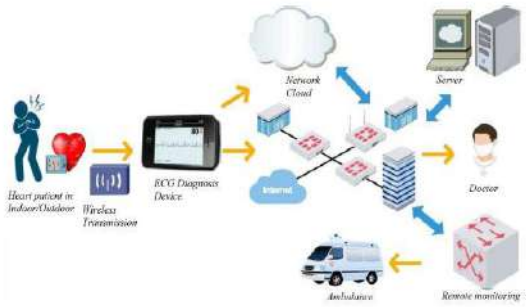

Fig.2: System architecture

However, all these solutions manifest some limitations in analyzing ECG signals such as event-by-event evaluation is not conducted at the subject's place, patient is unknown about his cardiac status and has to be home bound [7]. And the most important being the time required by the patient to get diagnosed from a nearest hospital upon an emergency. Several works have reported remote monitoring of ECG with the integration of wireless technology with the mobile devices/PDAs [7]. The wireless technologies Include Bluetooth, wifi, RFID (Radio Frequency Identification) and ZigBee modules for enhancing the healthcare of a patient The use of wireless technologies enables the development of a remote monitoring device targeting mass market. In, a Personal DigitalAssistant (PDA) integrated with newly designed wireless sensor structure is reported to transmit ECG signal for monitoring with high flexibility. In, a monitoring system consisting of ECG sensors, data acquisition system (DAQ), processing module, and a transceiver is presented which transfers the ECG signal using through Bluetooth to the server for analysis. In a wearable and wireless ECG system is designed using Bluetooth to detect 3-lead ECG signals using different algorithms where wavelet algorithm is reported as the most efficient. In [26], a wireless monitoring system consisting of a WiFi module and Bluetooth is developed which transfers the physiological signals through Bluetooth to a server

4. IMPLEMENTATION

The major modules of the project are

1. Patient
2. ECG Device
3. Server
4. Doctor

5. EXPERIMENTAL RESULTS

Fig.3: Home screen

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Fig.4: Patient registration

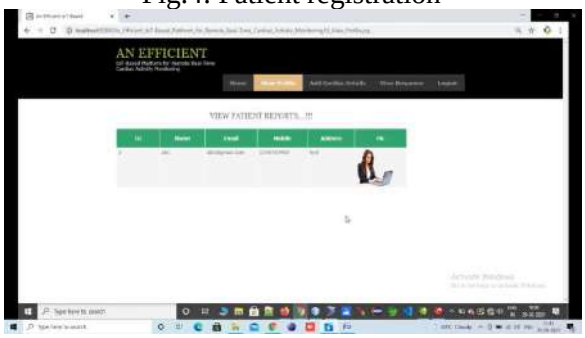

Fig.5: View profile

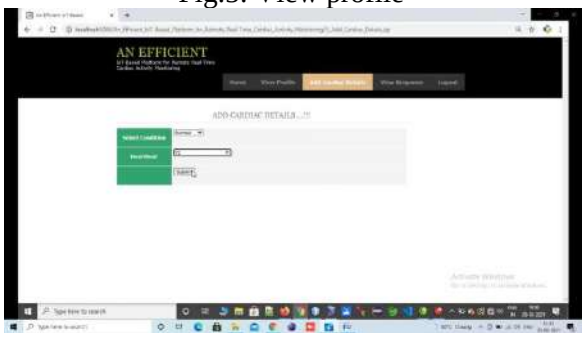

Fig.6: Add cardiac details

Fig.7: ECG device login

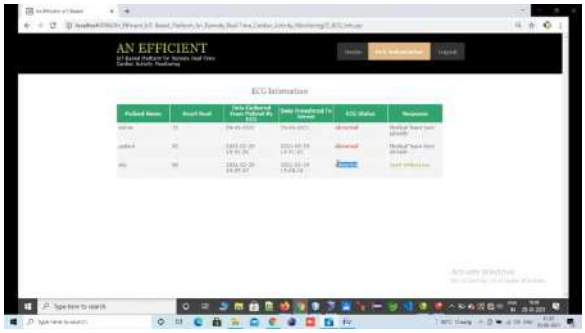

Fig.8: ECG information

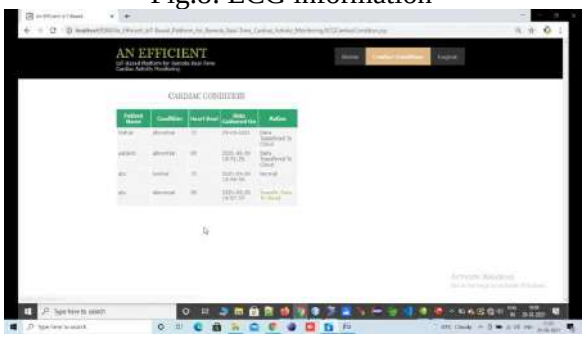

Fig.9: Cardiac condition

6. CONCLUSION

This chapter presents an Internet-of-Things (IoT) based embedded platform to monitor and analyze the electrocardiography (ECG) of cardiac outpatients for improving the healthcare, i.e., smart healthcare. An improved version of discrete Wavelet transform (DWT) is implemented using FFT that extracts the important time-frequency features from corresponding ECG signals of patients. These features are classified using particle swarm optimization (PSO) based twin support vector machine (TSVM) classification scheme. The PSO technique determine the optimal classifier parameters to achieve the best classification accuracy. The proposed method has significant advantage of computational complexity over conventional DWT and SVM methods. The scheme is prototyped on a microcontroller platform to facilitate real-time processing and validated on the physionet data. The platform is interfaced with the Wi-Fi module to send the classified outputs to receiver platform. The platform reported an accuracy of 95.58% which can be considered as efficient in arrhythmia detection.

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