A Ubiquitous Telehealth System for the Elderly

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Abstract. Chronic diseases are becoming the world's leading causes of death and disability, and are predicted to account for almost three quarters of all deaths by 2020. A working prototype was built to capture vital signs for the elderly staying at home and deliver prompt care remotely by using wearable ECG wireless sensors. This prototype has been tested to capture data on a 24/7 basis for a number of patients at the KFUPM Medical Center. The developed system includes a suit of signal processing algorithms for the detection of severe cases of arrhythmias in elderly patients. After identifying patients with potential arrhythmia variability, an alarm system sends emergency requests to caregivers for immediate response. Our results were benchmarked against the standard MIT physiobank. The performance of the system was also tested on simulated data with very satisfactory results, and very positive feedback from users and medical practitioners.

Keywords: Telehealth · Ubiquitous · Electrocardiogram · Arrhythmia

1 Introduction

During the last few years we have witnessed an increasing interest in wearable/mobile health monitoring devices, both in research and industry. These devices are particularly important to the world's increasingly aging population, whose health has to be assessed regularly or monitored continuously. Chronic diseases are becoming the world's leading causes of death and disability, and are predicted to account for almost three quarters of all deaths by 2020 [1].

Traditionally, part of the difficulty in achieving equitable access to healthcare has been the required presence of the patient at the Medical Center. Recent advances in information and communication technologies, in addition to wearable computing technologies, have created unprecedented opportunities for overcoming this. This is possible by increasing the number of ways that healthcare can be delivered. Telehealth, the area where medicine, information, and telecommunications technology meet, is probably the part of this revolution with the greatest impact on healthcare delivery. A telehealth system can be defined as the delivery of medical information over a distance by using telecommunication means. Home telehealth, on the other hand involves the use of telehealth techniques in a non-institutional setting such as home, or in an assisted-living facility. In store-and-forward telehealth, vital signs and clinical data are captured and stored, then sent to caregivers for further analysis. Physiological monitoring leads to richer data and therefore to improved decision making [2, 3].

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Recently, there has been a growing awareness of the need for new ways to improve the well-being of older people at home as well as the availability of increasingly affordable technology and computational power. Nevertheless, consumer and clinician adoption and acceptance have been slow. For example, social alarms or personal emergency response systems (PERS) enable a person to call for help in the event of an accident (e.g. fall) or other problem. Services like using a wireless pendant or wearable bracelet connect the older person to a call center, which then notifies ambulance services and family members in the event of an emergency [4]. The usual clinical or hospital monitoring of physiological events such as electrocardiogram or blood pressure provides only a brief window on physiology of a patient. It usually fails to capture rare events during sleep times, while it performs well during daily life activities. Therefore, there is a vast need for acquiring and adopting wearable telehealth solutions for the long run.

The implications of wearable health monitoring technologies are paramount, since they could: (1) enable the detection of early signs of health problems; (2) notify healthcare providers in critical situations; (3) find correlations between lifestyle and health; (4) bring healthcare to remote locations and developing countries, and help doctors and researchers with accessing multi-sourced real-time physiological data [5]. With the advent of advanced telecommunication technology, long-term home care of the elderly or what we call telehealth is becoming a rapidly growing area of healthcare industry. Lately, many researchers have begun investing their time into the research of wireless telehealth systems. Proponents of wireless systems claim that the increased mobility and the lower cost of the systems are highly beneficial to telehealth. Mobility and lower cost healthcare solutions are benefits of new telecommunications technologies. [6]. Telehealth has the potential of improving the quality of delivered health services and reducing total healthcare costs by avoiding unnecessary hospitalisations and ensuring the fast delivery of healthcare. In addition to cost-effective telehealth, remote health monitoring can significantly contribute to the enhancement of disease prevention, early diagnosis, disease management, treatment and home rehabilitation [7, 8]. This paper presents a novel approach to affordable mobile telehealth infrastructure for the purpose of arrhythmia early detection in KFUPM for patients to satisfy the vast need for the telehealth solution in Saudi Arabia . The paper is organized as follows. Section 2 describes the proposed system architecture. Section 3 presents the ECG Graphical user interface used by the elderly. Section 4 presents the Wavelet transform approach or algorithm for arrhythmia analysis.

2 Proposed System Architecture

In the following section, system architecture for telehealth is developed. We propose an architectural telehealth solution for the elderly living at home. The elderly might be handicapped in various ways, as senses and capabilities to remember are not always good. Also relatives, who might be spread all over the world, would like to make sure that loved ones are all right and perhaps keep an eye on them 24/7. The elderly may not able to see a physician anytime they need, because they may be unable to make their way to the clinic or hospital. Therefore, a solution must be developed to allow the elderly to talk to their physicians in a user-friendly manner. The physicians must have a remote-view of the vital signs that they look at, like electrocardiogram (ECG), oxygen saturation, blood pressure, heart rate, etc. In case of emergency, a reliable emergency system must call a physician and ambulance for help. We have integrated a portable ECG sensor with a Bluetooth interface, called Alive ECG, into the proposed Telehealth system. A number of sample ECG data were captured from 30 volunteers between the ages of 20 and 23, in addition to a couple of elderly patients suffering from arrhythmia using the alive ECG sensor and sent through Bluetooth to a PC for further analysis. The ECG data captured is compared on the spot with normal ECG stored in a local database server to detect any abnormalities. The R-R interval in a typical ECG sample is the time taken to conduct electrical discharge spread through different parts of the heart. Any deviation of the R-R interval from its normal range can indicate the onset of arrhythmia and hence requires immediate intervention by specialists. Figure 1 shows an overview of the general layout of the proposed Telehealth monitoring system for the elderly using an IP digital camera and the web, in addition to a GSM modem for sending emergency messages or calls to the physician as well as to the ambulance. The database is used to store the information related to the health status of the elderly to be analyzed by a physician or caregiver. The layout shown in Fig. 1 has been built and tested in the lab for the purpose of using it as a ubiquitous Telehealth solution for home use. It also includes a smart card access control interface for securing access to critical medical information. Changes in an individual's daily routine often signal onset of illness and potentially cognitive decline.

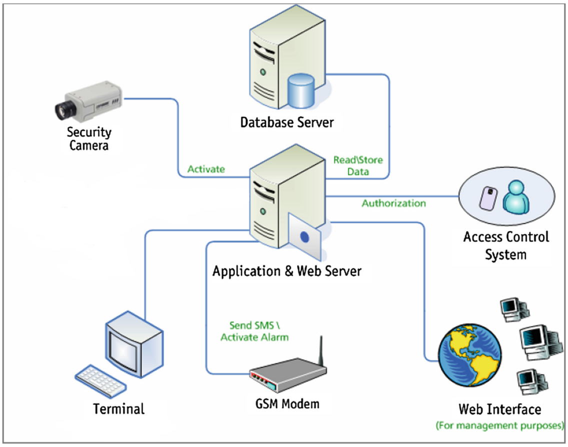

Fig. 1. An overall layout of the elderly monitoring system

The focus in this paper is on a Telehealth monitoring system for the elderly at home, which can also be used to monitor the elderly at the hospital. To make this possible, the biosensors capturing the vital signs are programmed to communicate with a centralized station using Ad hoc network or even wireless infrastructure LAN. The medical wearable sensors capture the vital signs of the elderly and send these vital signs upon request to the physician. The proposed Telehealth system has been successfully tested for sending high and low blood pressure alarms remotely via SMS. The system was tested in the lab for sending blood pressure and pulse rate values to a central database server. Records of the elderly's vital signs measurements, including the ECG (Electrocardiogram) measurements are stored on the local home server for future use. A scenario of how the system is used is that a patient suffering from arrhythmia wears the Bluetooth enabled portable ECG, shown in Fig. 2 and runs his daily life activities for a week or so. If the patient feels unwell, he presses a button and his ECG data is sent immediately to his doctor for examining. While at the clinic, the doctor meets the patient for closer testing. See Fig. 3.

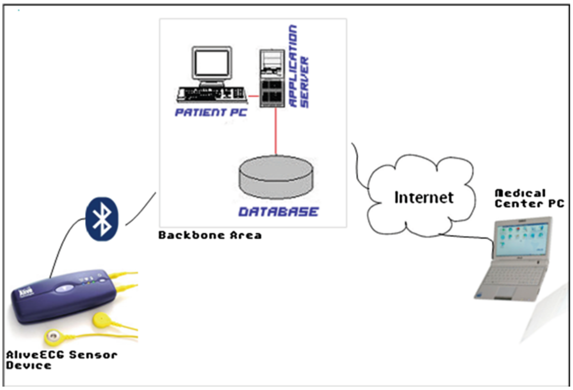

Fig. 2. The layout of a mobile cardiac Telehealth system

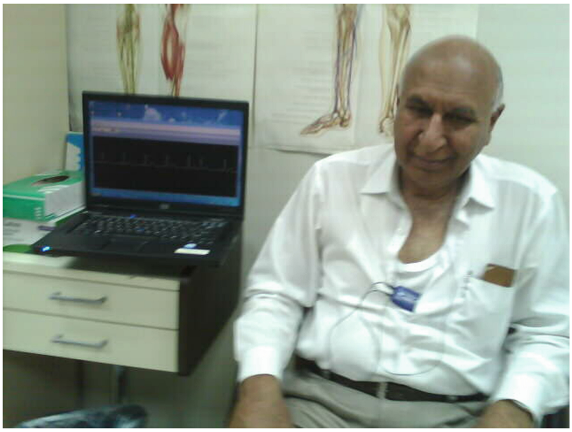

Fig. 3. A snapshot of using the Alive ECG system in KFUPM clinic

3 ECG GUI

The application consists of two main GUI interfaces. One is called ECG SYSTEM and the other is called PATIENT.

The ECG system has the following functions:

- Fetch the data.
- Compare the collected data with the data saved in the server.
- Store the collected data into the SQL server.
- E-mail emergency notifications.

The ECG system captures data generated from MATLAB after specifying the patient ID and presents it on the screen. After that, the program compares the data fetched against some default values to find out the abnormalities. If an abnormality is detected, the application sends a message via OUTLOOK to the medical center specifying the patient ID. See Fig. 4.

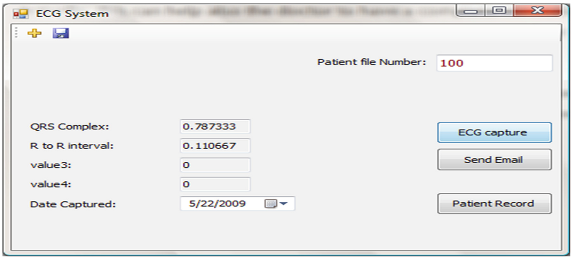

Fig. 4. ECG GUI home alarm system

4 Wavelet Transform Approach

Another effective approach learned from literature was using the wavelet transform approach as follows. Using the LABVIEW ASPT (Advanced Signal processing Toolkit), WA detrend VI, the low frequency trend of the signal can be removed. We used daubechies6 (db06) wavelet which is similar to the real ECG signal for removing the trend.

Prior to the capturing an actual ECG signal, National Instruments software LABVIEW was used for the simulation and analysis of the ECG signal. For this purpose, Simulate ECG LABVIEW palette was used as shown below. Using the simulate ECG signal, a lot of parameters could be controlled like the beats per minutes (bpm), P-QRS delay, QRS-T delay, amplitude of ECG, number of samples etc. Also, three different scenarios could be selected from Atrial Tachycardia, Hyperkalemia and normal ECG signal. To this simulated ECG, white Gaussian noise was added programmatically with a controlled signal to noise ratio as seen from the block diagram of the below vi. Finally results were stored in a LABVIEW measurement file for further analysis. See Fig. 5.

See Fig. 6 for using Wavelet algorithm to filter the noisy ECG with LABVIEW.

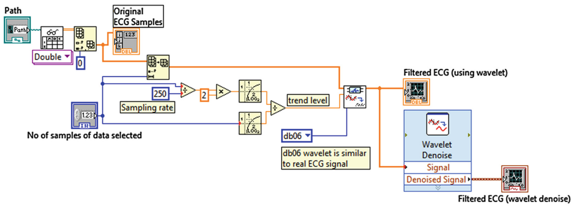

Fig. 5. Simulating the ECG signal with controlled white Gaussian Noise using LABVIEW

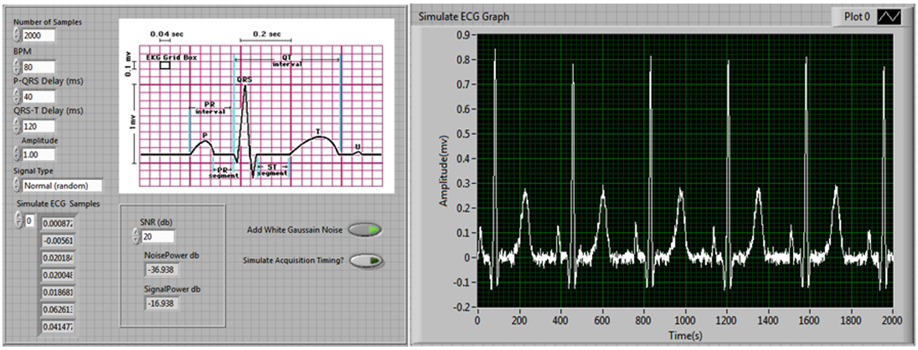

Fig. 6. ECG waveform filtered using the wavelet approach.

5 Discussion

The system will also open new opportunities for further research in the area of biomedical signal and image processing. Rapid development of Telehealth technology will also motivate health centers and hospitals to adopt the infrastructure and necessary skills to provide better & efficient medical treatment for patients to boost the quality of life.

The use of Telehealth will provide higher-quality service and increased efficiency to the practice of medicine. Emergency and critical response professionals can be given immediate access to a wealth of vital information, particularly for the elderly and disabled. It also becomes possible to observe and deliver care to patients while living in their homes, instead of spending months or even years in the hospital. With the development of new products from Telehealth, there is a growing need to develop standards for the field. Standards will improve reliability and allow the interoperability of the various different services being created. The proposed design represents a good approach to research in Telehealth for the elderly, keeping in mind that many things have been generalized to a certain extent and the analysis of the vital sign data captured from the medical sensors is still an on- going research. Certain crucial issues still have to be resolved regarding the user-friendliness of the Telehealth system and how the elderly will interact with all of this complex technology. In addition to that, some measures have to be taken to ensure the privacy of the web enabled solution which physicians use to view the health status of the elderly since the web is vulnerable to hackers. The proposed design has been kept under closed application for a relatively small environment to cut down design cost and simplify the testing methodology. Research is also ongoing to support the automatic self-diagnosis feature of the Telehealth system regarding reliable detection of cardiac diseases symptoms.

6 Conclusion

LABVIEW along with Vernier sensors were used to successfully capture an ECG signal from individuals out of the 30 student's participants, after which ECG signal was filtered using wavelet transform approach. Finally, Heart rate (R-R) and QRS complex of the ECG signal was successfully analyzed from the filtered signal. Further analysis of detecting the p-wave and t-wave is underway which will help us detecting arrhythmia later.

A graphical user interface (GUI) based Telehealth system has been developed using LABVIEW instrumentation software. The purpose of the developed system is real time analysis of the vital signs captured from the elderly suffering from arrhythmia. The MATLAB & LABVIEW simulation results were used to validate the real data captured from volunteers using ECG sensors. The successful implementation and utilization of the wireless ECG system in the KFUPM Medical Center has paved the way for establishing a ubiquitous mobile Telehealth which proved to be a cost effective solution for patients suffering from severe arrhythmia. The deployed system provides big hope for patients with chronic diseases and it could therefore help avoid catastrophic results in the future by providing immediat medical care in the field. The real-time analysis and feature extraction algorithms implemented in LABVIEW, in conjunction with the ALIVE wireless ECG will enable physicians to use the system by delivering better emergency care.

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