A Labview Based Ubiquitous Telehealth System for the Elderly

M.W. Raad(✉) and Tarek Sheltami

King Fahd University of Petroleum and Minerals KFUPM,
Box # 1874, Dhahran 31261, Saudi Arabia
raad@kfupm.edu.sa

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 Graphical User Interface (GUI) based telemedical system has been developed using LabView instrumentation software for real time analysis of vital signs captured for elderly patients suffering from Arrhythmia. The developed system includes a suit of signal processing algorithms for the detection of severe cases of Arrhythmias in elderly patients. In particular, we used time frequency distributions and wavelets to estimate a number of features from ECG traces which are then used in classification. The performance of the system was tested on simulated data and the real data from MIT, and our own collected data with very satisfactory results. A questionnaire was conducted with physicians and health practitioners to study the feasibility of implementing a Tele-health system at the KFUPM Medical Center.

Keywords: Telehealth · Ubiquitous · Electrocardiogram · Arrhythmia

1 Introduction

The world's population is aging. In Japan, for example, a quarter of the population will soon be older than 65 years. As we age, the incidence and prevalence of chronic illness continue to rise. Chronic diseases are becoming the world's leading causes of death and disability, and will account for almost three-fourth of all deaths by 2020. Demographic trends indicate rapidly aging population throughout the world, particularly in Europe. In many societies the proportion of elderly population larger than 60 by 2050 is expected to double from 11 %–22 %. [1]. This is one reason why expenditure on healthcare is skewed: in most healthcare delivery systems, 5 % of patients are responsible for 50 % of costs. These patients are at the heart of crisis in healthcare costs that is beginning to occupy the policy discussions of most governments in the industrialized world. Telehealth clearly has a role in the case of emergencies in remote environments such as the Antarctic and in ships or aeroplanes, where it may be difficult, if not impossible, to get medical care to the patient in time. On the other side, home telehealth as a definition is intended to indicate the use of telehealth techniques in a non-institutional setting at home, or in an assisted-living facility. Physiological monitoring leads to richer data and therefore to improved decision making. Giving patients access to their own physiological data leads to improved self-care. In some

B. Mandler et al. (Eds.) IoT 360° 2015, Part I, LNICST 169, pp. 508–516, 2016.
DOI: 10.1007/978-3-319-47063-4_55

cases, patients are so enthusiastic that they purchase the equipment with their own money. The use of home telehealth thus allows patients to be monitored at home, nurses to visit in person less often and better management of chronic disease [2, 3].

ECGs are a well-established and widely accepted method for monitoring the electrical activity of the heart. Numerous ECG monitoring devices have been developed and marketed for the sports industry. Athletes needs have been targeted so that they can be monitored under conditions that are physically stressful. Ambulatory elder patients have significantly different needs.

One of the first prototypes for monitoring arrhythmia is the arrhythmia monitoring system (AMS), which is a wireless telemetry system developed at NASA. Next generation cardiac monitoring systems makes available continuous monitoring to patients whenever necessary. It consists of wearable wireless biomedical sensors (for measuring 3 lead ECG, spo2, heartbeat, and blood pressure) which constantly communicate to the monitor, a unit about the size of a mobile phone or PDA. The monitor is battery powered and equipped with signal processing/conditioning module, memory, and different wireless interfaces and radios [4].

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]. Furthermore, a number of researchers have investigated the feasibility and success factors of implementing telehealth and its cost effectiveness in delivering healthcare including the financial relevance and patient satisfaction [9].

This paper is based on our previous published research for an integrated portable wireless ECG sensor used in home telehealth for monitoring the vital signs of Elderly, particularly the ECG for the purpose of arrhythmia early detection in KFUPM [10]. See Fig. 1. The current research focuses on simulation of ECG signals captured from elderly patients using Labview as well as using Wavelet transform approach for filtering data for patients to satisfy the vast need for the telehealth solution in Saudi Arabia. The paper is organized as follows. Section 2 describes the simulation of ECG using Labview. Section 3 presents the feasibility study of implementing Telehealth in KFUPM.

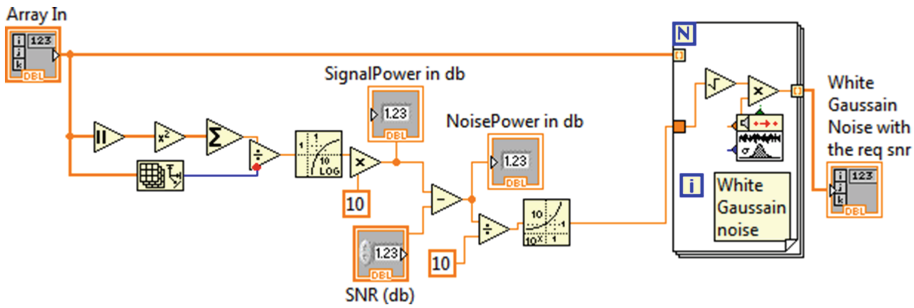

Fig. 1. White Gaussian Noise block diagram (Labview) with required SNR

2 Simulating the ECG Signal Using Labview

Prior to the capturing an actual ECG signal, National Instruments software Labview is used for the simulation and analysis of the ECG signal. For this purpose, Simulation ECG Labview palette is 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. See Fig. 1.

2.1 Data Collection

ECG data is collected from the university community comprising of youth, middle-aged and elderly faculty and staff. These data are recorded as txt files with 2000 Hz sampling rate in the first phase and then using 250 Hz for rest of the data. In all, about sixty five ECG signals (fifty-five samples from students and ten samples from elderly faculty and staff) comprise our ECG signal databank. Few ECG data has also been taken from the university clinic in our databank for analysis.

2.2 Filtering the Signal

The next challenge faced during its implementation was the filtering of the signal for extracting the characteristics of signals. As seen from the above sample, the recorded ECG is often contaminated by noise. So we need to preprocess the signal to remove this inherent noise. Contamination of ECG signal can come from the following sources:

- Power-line interference
- Baseline wandering
- Contact noise
- Patient-electrode motion
- Electromyographic noise

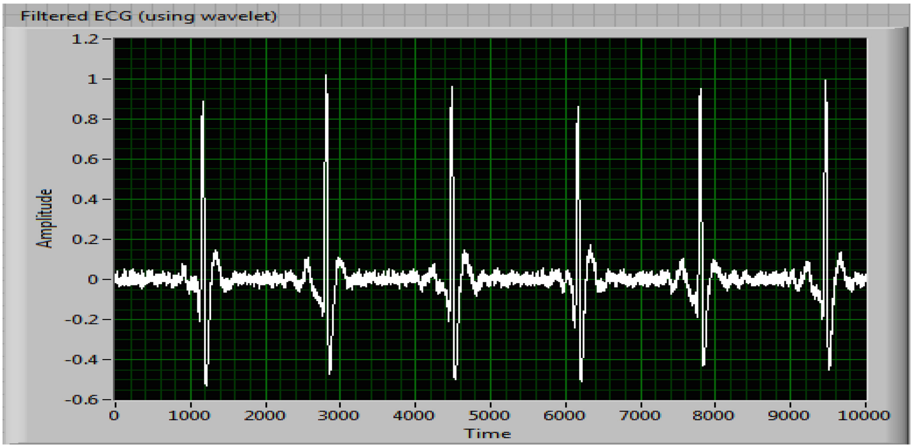

Fig. 2. ECG waveform filtered using the wavelet approach

The first two being the most common type of contaminations that can strongly affect the ECG signal.

In our case we try to minimize the baseline wandering of the ECG signal. Following are the two methods used to remove the baseline wandering. Baseline wandering usually comes from respiration at frequencies wandering between 0.15 and 0.3 Hz and we can use high pass digital filter or we can use the wavelet transform by eliminating the trend of the ECG signal.

Wavelet Transform Approach.

Another effective approach learned from literature is 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 use daubechies6 (db06) wavelet which is similar the real ECG signal for removing the trend using the following formula for establishing the trend level. Figure 2 shows the implementation of wavelet transform approach and its result. When we compare the output, we see that the trend or the baseline wandering has been removed and has retained most of the characteristics of the original signal. This approach is much better when compared to the digital filter approach.

Then the next step is to remove other type of noise so that the features extraction of the ECG signal is possible. To remove these wideband noises, wavelet denoise express VI is used as follows.

This express VI first decomposes the EC signal into several subbands by applying the wavelet transform, and then modifies each wavelet coefficient by applying a threshold or shrinkage function, and finally reconstructs the denoised signal. Figure 3 shows an example of applying the undecimated wavelet transform (UWT) to the ECG signal.

The UWT has a better balance between smoothness and accuracy than the discrete wavelet transform (DWT). By comparing the denoised ECG signal with the non-denoised ECG signal, we find that the wideband noises are strongly suppressed while almost all the details of the ECG signal are kept invariant.

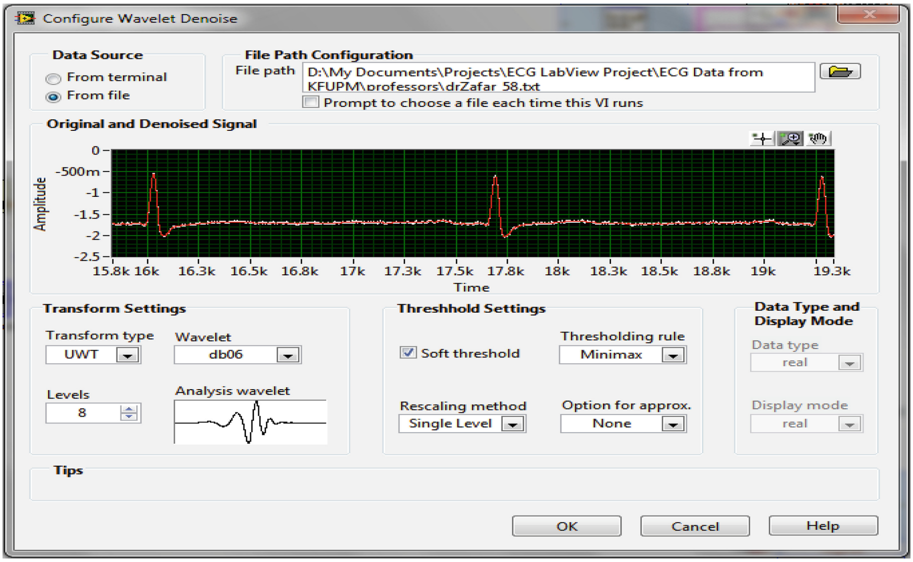

Fig. 3. ECG waveform denoised using undecimated wavelet transform (UWT)

3 ECG Peak Detection

The procedure is that we first identify the peaks and valleys within the ECG signal and then identify these peaks and valleys as R, P, T, Q and S points within our plot. Then other feature extraction is done. For the QRS duration the difference in the values of the S point and Q point gives us the no of samples and dividing them by the no of samples gives is the duration. For the P and T duration, few samples are collected around the P and Q duration and a second order polyfit analysis is done to extract the duration of the P and T waves. For obtaining the heart rate in bpm, the R-R duration is extracted and divided by the sampling rate to give us the value. See Figs. 4 and 5.

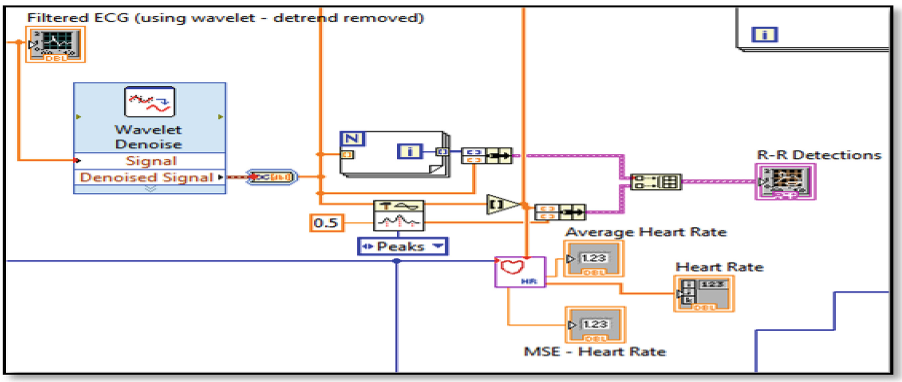

Fig. 4. ECG R-R peak detection Labview block diagram

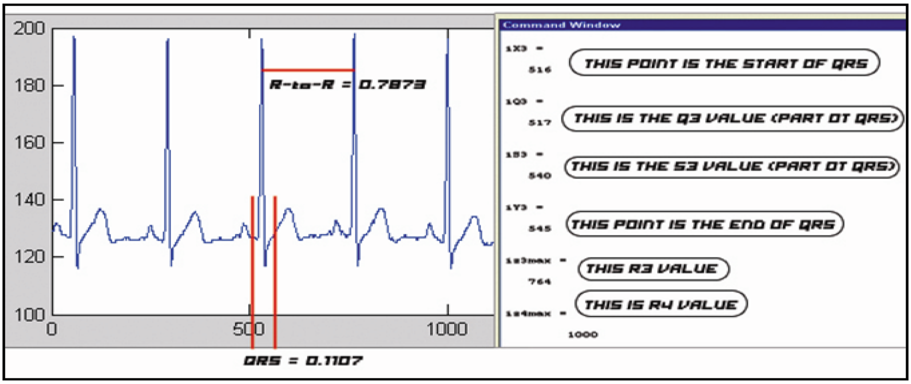

Fig. 5. A sample shows both QRS and R-to-R intervals with their values

4 Feasibility of Implementing Telehealth at the KFUPM Medical Centre

Conducting a careful planning and readiness study is critical before developing and implementing a telehealth system. A questionnaire survey on a likert scale of ‘1’ to ‘5’, where ‘1’ represents least important and ‘5’ represents most important, was used to collect the data and descriptive analysis was performed. The questionnaire raises many vital issues that were identified. The purpose of the study is to investigate the feasibility of implementing telehealth in the KFUPM medical centre and the readiness of the physicians to use telehealth. The questionnaire was developed in collaboration with a cardiologist working at the KFUPM medical centre. The questionnaire was distributed to 17 physicians working at the KFUPM medical centre. To examine respondent’s specific view on the evaluation of telehealth feasibility, a detailed item list is presented to them on various issues of implementing telehealth at the medical centre. Regarding the feasibility of implementing telehealth in clinical practice, the results show that the transmission of foetal cardiotograph information to consultant is the most important mean (4.83), followed by radiology transmission to a remote specialist e.g. head injury prior to transfer mean (4.67), pathology e.g. a remote specialist looking at a slide on a computer screen mean (4.5), remote consultation and routine remote consultation between GPs and specialists on a routine basis mean (4.5). See Table 1. There are a few components that contribute to efficient implementation of telehealth that were investigated in the research. The list of items is presented in Table 2, together with the analysis of importance level. Regarding the impact of travelling and distance problems on telehealth, the majority of physicians agreed that telehealth is critical for disabled patients and patients in remote areas of the country with a mean of (4.67) and 4.33) respectively. Regarding the readiness of the medical centre physicians to implement telehealth the majority agreed that telehealth would increase the number of patients in his/her practice with a mean (4.67). The study also showed that most of them were ready to adopt new technology with a mean of (4.83). Regarding the role of telehealth in follow-up care it took the highest score mean (5.5), followed by applying telehealth

Table 1. The role of telehealth in clinical practice

Type of medical care	Mean	STDEV
Antenatal e.g. transmission of fetal cardiotocograph information (obtained by midwives doing home visits) to consultant obstetricians at the nearest obstetric unit	4.83	0.41
Radiology e.g. image transmission to a remote specialist e.g. head injury prior to transfer	4.67	0.82
Pathology e.g. a remote specialist looking at a slide on a computer screen	4.50	0.84
Remote consultation between GPs and specialists on a routine basis	4.50	0.55

Table 2. Feasibility aspects in Telehealth

Statement	Mean	STDEV
The need to attend lectures/courses in Telehealth if they were offered	5.00	0.00
Readiness to adopt promising new technologies	4.83	0.41
The readiness to use telehealth for the following applications:		
a- Initial office visits	3.33	1.63
b- Follow-up care	4.50	0.84
Patients are likely to receive better quality care when they see the specialist in person	4.67	0.82
Plan to use telehealth in practice	4.67	0.52
Telehealth might be effective for the following types of care:		
a- Chronic condition management	4.67	0.52
b- Home health care	4.67	0.52
c- Preventive services	4.33	0.82
d- Emergency care	3.33	1.63
e- Acute non-emergency care	3.33	1.63
An adequate physical exam cannot be conducted without the patient being present physically	4.17	0.98
Telehealth combined with easy public access to health information and advice will make for a healthier population in the future	4.50	0.84
Use of Telehealth will blur the distinction between primary and secondary healthcare by improving the links between patients, nurses, GPs and consultants	4.00	0.89
Use of Telehealth could encourage more team working in healthcare	4.50	0.84
Use of Telehealth could make the distribution of healthcare more even with more emphasis on prevention	4.50	0.84

for initial office visits a mean of (3.33). Regarding the effect of telehealth on various types of healthcare, the study showed that the chronic condition management of patients and the home health care were among the most critical factors in determining the need for telehealth with a mean of (4.67), followed by preventive services a mean of (4.33), post surgical follow-up mean of (3.83), emergency care and acute none-mergency care both with mean of (3.33). Many of the physicians believed that telehealth combined with easy public access to health information and advice will make for a healthier population in the future in addition to encouraging more team working in healthcare with a mean of (4.5). Nevertheless, some of the physicians believed that an adequate physical exam cannot be conducted without the patient being present physically with a mean of (4.17). The study also showed that some physicians believe that more research has to be made on the effectiveness of telehealth before they can refer patients for teleconsultation with a mean of (3.50).

5 Conclusion

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 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 clinic, 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 a big hope for patients with chronic diseases and could therefore avoid catastrophic results in the future by providing immediate medical care in the field. The system will also open new opportunities for further research in the area of biomedical signal and image processing. 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. As a result of the feasibility study conducted in KFUPM medical center, many of the physicians believed that telehealth combined with easy public access to health information and advice will make for a healthier population in the future in addition to encouraging more team working in healthcare with a mean of (4.5).

Acknowledgements. The authors would like to acknowledge the support of King Fahd University of Petroleum & Minerals for this research.

References

1. Bujnowska-Fedak, M.M., Grata Borkowska, U.: Use of telemedicine based care for the aging and elderly: promises and pitfalls. Smart Homecare Technol. Telehealth **3**, 91–105 (2015)
2. Wootton, R., Dimmick, S.L., Kvedar, J.C.: Home Telemedicine: Connecting Care Within the Community. Royal Society of Medicine Press Ltd., London (2006)
3. Wootton, R., Craig, J., Patterson, V.: Introduction to Telemedicine. Royal Society of Medicine Press, London (2006)

4. Kumar, S., Kambhatla, K., Hu, F., Lifson, M., Xiao, Y.: Ubiquitous computing for remote cardiac patient monitoring: a survey. Int. J. Telemed. Appl. **2008**, 1–19
5. Oliver, N., Mangas, F.F.: HealthGear: a real-time Wearable System for monitoring and analyzing physiological signals. Technical report MSR-TR-182 (2005)
6. Xiao, Y., Chen, H.: Mobile Telemedicine: A Computing and Networking Perspective. CRC Press, Boca Raton (2008)
7. http://www.suunto.com
8. http://www.bodymedia.com
9. Trobec, R., Stanic, U.: Telehealth: a myth or reality? In: MIPRO, 2011 Proceedings of 34th International Convention, Opatija, Croatia, pp. 295–300
10. Raad, M.W., et al.: A ubiquitous telehealth system for the elderly. In: 1st International Conference on IOT Technologies for Healthcare, 28–29 October 2014, Rome, Italy