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ECG Wireless Telemetry

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Abstract*— Biotelemetry is defined as transmitting biological or physiological data to a remote location that has the capability to interpret the data and affect decision-making. Biomedical telemetry is a special field of biomedical instrumentation that often enables transmission of biological information from an inaccessible location to a remote monitoring site. Telemetry is the science of gathering information from a distant location and then transmitting the data to a convenient location to be examined and recorded. Telemetry is a process by which transmission of objects or environments characteristics via different transmission channels is conducted. Air, space for satellite application, coaxial cable or fiber optic cables are used as transmission channels. Wireless telemetry systems are used when the measurement point is far from the monitoring place or there is a risk for work safety. Wireless telemetry systems are preferred at biotelemetry application because of the fact that biological signals can be observed in natural living surrounding.

***Index Terms*— ECG, ECG Signal Processing, Wireless Telemetry.**

I. INTRODUCTION

ECG consists of graphical recording of electrical activity of the heart over time. It is most recognized biological signal, and with non- invasive method; it is commonly used for diagnosis of some diseases by inferring the signal. Cardiovascular diseases and abnormalities alter the ECG wave shape; each portion of the ECG waveform carries information that is relevant to the clinician in arriving at a proper diagnosis. The electrocardiograph signal taken from a patient is generally get corrupted by external noises, hence necessitating the need of a proper noise free ECG signal. A signal acquisition system, consist of several stages, including: signal acquisition though hardware and software instrumentation, noise or other characteristics filtering and processing for the extraction of information. Electrocardiography signals recorded on a long timescale (i.e., several days) for the purpose of identifying intermittently occurring disturbances in the heart rhythm. Simple ECG waveform as shown in Fig.1. It is a combination of P, T, U wave, and a QRS complex. The complete waveform is called an electrocardiogram with labels P, Q, R, S, and T indicating its distinctive features.

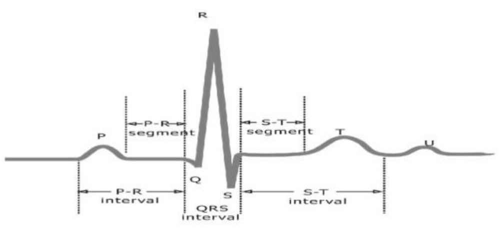

Fig.1. ECG waveform

II. AIMS AND OBJECTIVES

(1). Improving the signal quality without disturbing the tiny features of the ECG signal i.e., improving the signal to noise ratio. This allows the cardiologist to observe the ECG with high resolution and better diagnosis.

(2). Reducing the computational complexity of the adaptive filter. Complexity reduction of the noise cancelation system, particularly, in applications such as wireless biotelemetry system is very important. This is because of the fact that with increase in the ECG data transmission rate, the channel impulse response length increases and thus the order of the filter increase. The resulting increase in complexity makes the real time operation of the biotelemetry system difficult, especially in view of simultaneous shortening of the symbol period, which means that lesser and lesser time will be available to carry out the computations while the volume of computations goes on increasing.

(3). Block Processing of input data, which facilitates the system with fast computation and good filtering capability. These characteristics plays a vital role in biotelemetry, where extraction of noise free ECG signal for efficient diagnosis, fast computations and high data transfer rate are needed to avoid overlapping of pulses and to resolve ambiguities. ECG (electrocardiogram) is a test that measures the electrical activity of the heart. The heart is a muscular organ that beats in rhythm to pump the blood through the body. The signals that make the heart's muscle fibers contract come from the senatorial node, which is the natural pacemaker of the heart. In an ECG test, the electrical impulses made while the heart is beating are recorded and usually shown on a piece of paper. This is known as an electrocardiogram, and records any problems with the heart's rhythm, and the conduction of the heart beat through the heart which may be affected by underlying heart disease. Electrocardiograph (ECG) is one of the most widely used biomedical sensing procedures to date. The heartbeat is the definitive indicator for a wide range of physiological conditions. Although ECG instruments were quite bulky, miniaturization in recent years has opened up brand new applications by enabling wearable versions to collect data in scenarios that were not possible before.

III. ECG SIGNAL PROCESSING

Signal processing is performed in the vast majority of systems for ECG analysis and interpretation. It is used to extract some characteristic parameters. Now a day biomedical signal processing have been towards quantitative or the objective analysis of physiological systems and phenomena via signal analysis. The field of biomedical signal analysis or processing has advanced to the stage of practical application of signal processing and pattern analysis techniques for efficient and improved non invasive diagnosis, online monitoring of critical ill patients, and rehabilitation

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and sensory aids for the handicapped. The basic ECG has the frequency range from 0.5Hz to 100Hz. artifacts removal plays the vital role in the processing of the ECG signal. It becomes difficult for the specialist to diagnose the diseases if the artifacts are present in the ECG signal.

IV. ECG WIRELESS TELEMETRY

The extraction of high-resolution ECG signals from recordings contaminated with background noise is an important issue to investigate. The goal for ECG signal enhancement is to separate the valid signal components from the undesired artifacts, so as to present an ECG that facilitates easy and accurate interpretation. Complexity reduction of the noise cancelation system, particularly, in applications such as wireless biotelemetry system has remained a topic of intense research. This is because of the fact that with increase in the ECG data transmission rate, the channel impulse response length increases and thus the order of the filter increase. The resulting increase in complexity makes the real time operation of the biotelemetry system difficult, especially in view of simultaneous shortening of the symbol period, which means that lesser and lesser time will be available to carry out the computations while the volume of computations goes on increasing. Thus far, to the best of the author's knowledge, no effort has been made to reduce the computational complexity of the adaptive algorithm without affecting the signal quality. In order to achieve this, we considered two classes of algorithms, first one is with reduced computational complexity, achieves high signal to noise ratio and the second class is with fast computation, high signal to noise ratio ie., good filtering capability. Various adaptive filter structures are proposed and implemented for the removal of different kinds of noises from the ECG signal. The proposed implementation is suitable for applications requiring large signal to noise ratios with less computational complexity particularly for biotelemetry application. The proposed scheme mostly employs simple addition and shift operations and achieves considerable speed up over the other LMS based realizations. Simulation studies shows that the proposed realization gives better performance compared to exiting realizations in terms of signal to noise ratio and complexity. Finally we apply these algorithms on real ECG signals and compare with the conventional adaptive filtering techniques in terms of signal to noise ratio, computational complexity and time taken to perform the operation.

V. ARTIFACTS PRESENT IN ECG

The electrocardiogram (ECG) is a graphical representation of hearts functionality and is a important tool used for diagnosis of cardiac abnormalities. The extraction of high resolution ECG signals from recordings contaminated with background noise is an important issue to investigate. The goal for ECG signal enhancement is to separate the valid signal components from the undesired artifacts, so as to present an ECG that facilitates easy and accurate interpretation. When the doctors are examining the patient on-line and want to review the ECG of the patient in real-time, there is a good chance that the ECG signal has been contaminated by noise. The predominant artifacts present in the ECG include:

(1). Baseline Wander(BW): During ECG acquisition there is a good chance that the ECG signal has been contaminated by baseline wander, mainly caused by patient breathing, movement, bad electrodes and improper electrode site preparation. The low frequency ST segments of ECG signals are strongly affected by the wandering that leads to false diagnosis.

(2). Power-line Interference (PLI): One of the periodic artifacts commonly encountered in the ECG signal is power-line Interference at 60Hz (or 50Hz). It degrades the signal quality, frequency resolution and masks tiny features that may be important for clinical monitoring and diagnosis.

(3). Muscle Artifacts (MA): The ECG signal recorded in ambulatory conditions is affected by the influence of extra-cardiac bioelectrical phenomena. These can hardly be avoided due to the variable recording conditions or due to the simultaneous activity of adjacent muscles. Muscle noise causes severe problems as the spectral content of the noise considerably overlaps with that of PQRST complex.

(4). Motion Artifacts(EM): Electrode movement causes deformations of the skin around the electrode site, which in turn cause changes in the electrical characteristics of the skin around the electrode. Motion artifacts produces large amplitude signals in ECG and can resemble P, QRS and T waveforms of the ECG. These artifacts strongly affects the ST segment, degrades the signal quality, frequency resolution, produces large amplitude signals in ECG that can resemble PQRST waveforms and masks tiny features that may be important for clinical monitoring and diagnosis. Due to these artifacts, the patient's movement can result in the poor performance of the ECG instrument. These biomedical signals vary in time and are non linear, so the Least Mean Square (LMS) adaptive filter is mainly used. To allow doctors to view the best signal that can be obtained, we need to develop an adaptive filter to remove the noise in order to better obtain and interpret the ECG data.

VI. SIMULATION RESULTS

Removing Baseline Wandering Baseline wandering usually comes from respiration at frequencies wandering between 0.15 and 0.3 Hz, and you can suppress it by a high pass digital filter. You also can use the wavelet transform to remove baseline wandering by eliminating the trend of the ECG signal.

1. **Digital Filter Approach**

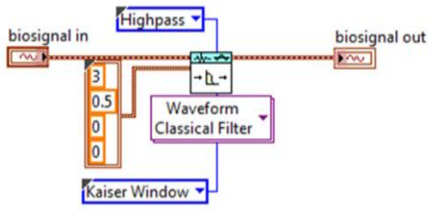

Fig **2. Designing and Using a High Pass Filter to Remove Baseline Wandering**

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Biomedical Toolkit provides a Bio-signal filtering under Bio-signal Measurements-bio-signal Preprocessing palette. You can use this VI to design a Kaiser Window FIR high pass filter to remove the baseline wandering. Figure 2 shows an example of removing baseline wandering by using Bio-signal Filtering.

2. Wavelet Transform Approach

In addition to digital filters, the wavelet transform is also an effective way to remove signals within specific sub-bands. The ASPT provides which can remove the low frequency trend of a signal. Figure shows an example of removing baseline wandering.

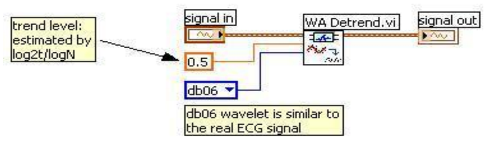

Fig 3. Remove Baseline Wandering

This example uses to the real ECG signal. In this example, the ECG signal has a sampling duration of 60 seconds, and 12000 sampling points in total; therefore the trend level is 0.5 according to the following equation:

$$trend\ level = \left\lceil \frac{\log_2 2t}{\log_2 N} \right\rceil$$

Where t is the sampling duration and N is the number of sampling points. The original ECG signal and the resulting ECG signals processed by the digital filter-based and wavelet transform-based approaches. You can see that the resulting ECG signals contain little baseline wandering information but retain the main characteristics of the original ECG signal. You also can see that the wavelet transform-based approach is better because this approach introduces no latency and less distortion than the digital filter-based approach.

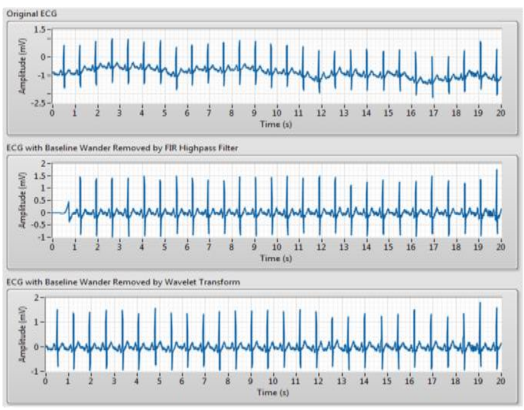

Fig 4 Comparing the Digital Filter-Based and Wavelet Transform-Based Approaches

Removing Wideband Noise

After you remove baseline wandering, the resulting ECG signal is more stationary and explicit than the original signal. However, some other types of noise might still affect feature extraction of the ECG signal. The noise may be complex stochastic processes within a wideband, so you cannot remove them by using traditional digital filters. This based higher-level Express first decomposes the ECG signal into several sub bands by applying the wavelet transform, and then modifies each wavelet coefficient by applying a threshold or shrinkage function, and finally reconstructs the signal. The following figure shows an example of applying the wavelet transform (UWT) to the ECG signal.

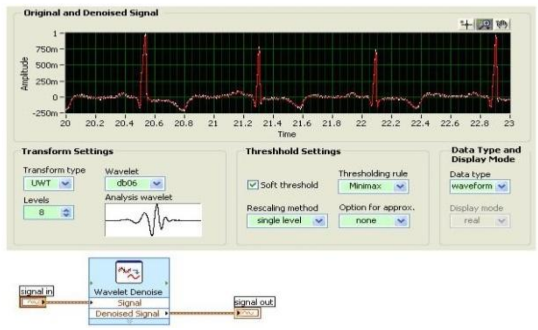

Fig 5 Removing Wideband Noises from an ECG Signal by Applying the UWT

The UWT has a better balance between smoothness and accuracy than the Discrete Wavelet Transform (DWT). By comparing the ECG signal with the non-denoised ECG signal, as shown in Fig 6, you can find that the wideband noises are strongly suppressed while almost all the details of the ECG signal are kept invariant.

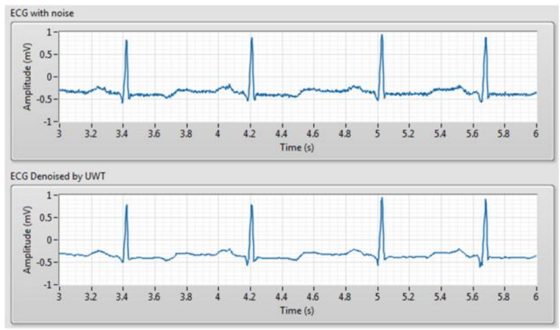

Fig 6 ECG Signals Before and After UWT

A. Performing Feature Extraction on ECG Signals

For the purpose of diagnosis, you often need to extract various features from the preprocessed ECG data, including QRS intervals, QRS amplitudes, PR intervals, QT intervals, etc. These features provide information about the heart rate, the conduction velocity, the condition of tissues within the heart as well as various abnormalities. It supplies evidence for the diagnoses of cardiac diseases. For this reason, it has drawn considerable attention in the ECG signal processing field. This section mainly discusses how to perform ECG feature extraction. The ECG Feature Extractor firstly detects all beats (R waves) in the signal, and then extracts other features for every beat. Thus the accuracy of detecting R waves is very important. Signal enhancement usually contains two steps: filtering and rectification. R waves of human ECG usually have a frequency between 10-25Hz. Thus R waves can be more obvious and easily for detection after filtering using a band pass filter. Rectification sometimes can further enhance the R waves to make them easier to detect. Absolute and square are two common used rectification methods. Figure7 shows the processing result of an ECG signal with some negative R waves and very large T waves. It can be seen that, after enhancement, all beats can be easily detected.

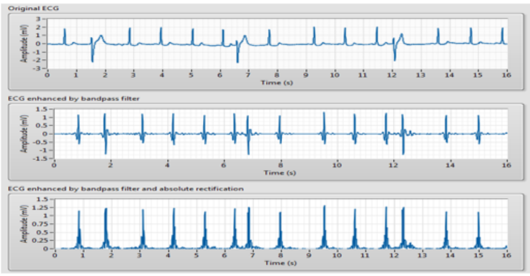

Fig 7. Original ECG, ECG after MRA and ECG after peak/valley detection

After extracting the features, you can perform heart rate variability (HRV) analysis on the R-R interval signal to demonstrate the state of the heart and nerve system. In HRV Analyzer of Biomedical Toolkit, you can directly synchronize the RR intervals from ECG Feature Extractor.

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