Noise Elimination and Arrhythmia Detection Using Adaptive Filtering in ECG Analysis

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ABSTRACT: For noise cancellation and arrhythmia detection, several adaptive filter designs are presented. The adaptive filter reduces the mean-squared error between a primary input, which is the noisy ECG, and a reference input, which is either noise that is correlated in some way with the noise in the primary input or a signal that is solely correlated with the ECG in the primary input. Baseline drift, 60 Hz power line interference, muscle noise, and motion artifact are all examples of noise that can be eliminated using different filter architectures. For acquiring the impulse response of the typical QRS complex, an adaptive recurrent filter structure is proposed. For acquiring the impulse response of the normal QRS complex, an adaptive recurrent filter structure has been developed. The ECG signal to be studied is the filter's primary input, while an impulse train coinciding with the QRS complexes serves as the filter's reference input. P-waves, premature ventricular complexes, conduction block, a trial fibrillation, and paced rhythm are all detected with this method.

KEYWORDS: Adaptive filters, Biomedical signal processing, Digital filters, Electrocardiography, Noise cancellation.

1. INTRODUCTION

Recording of ambulatory electrocardiogram (ECG) A is now commonly used to detect asymptomatic arrhythmias and to track the impact of cardiac medications and surgical treatments. Microprocessor-based event recorders that perform online signal processing and data reduction have recently been created. The detection of arrhythmias. The microprocessor's computational capacity allows us to use digital filters for noise suppression and arrhythmia detection. The first goal of this work is to show how adaptive filters can be used for noise cancelling. We provide specific filter structures to suppress noise from a variety of sources. The second goal is to demonstrate how a heart arrhythmia can be detected using an adaptive recurrent filter construction. Our goal is to create a QRS complex impulse response and identify signals whose impulse response deviates from normal as arrhythmias. Van Alste and Schilder present a finite impulse response (FIR) notch filter that removes baseline wander and power line interference quite well. The adaptive filter for removing baseline wander is a type of notch filtering with a zero frequency notch (or dc)[1]. Only one weight is required, and the reference input is a one-valued constant. At dc, this filter is "zero," resulting in a notch with a bandwidth of (p/n) * fs, where fs is the sampling rate. To reduce baseline drift, frequencies in the range of 0-0.5 Hz should be deleted. The convergence parameter p should be less than 0.003 if the sampling rate is 500 samples per second. To achieve the desired low-frequency response, the parameter p can be dynamically modified. Because the low-frequency components of the ECG are muted, this filter will cause some ST-segment distortion. Because p is set to a low value, this filter converges slowly and so cannot track rapid transients caused by motion artifacts[2]. EMG noise has a wide bandwidth that sometimes overlaps with ECG noise. As a result, simple low-pass filtering is insufficient. We intend to use more than one ECG lead. The EMG noise from several leads may be uncorrelated because electrodes are frequently placed at separate locations. By picking two orthonormal ECG leads, we ensure that the filter's inputs are uncorrelated. Three limb leads—I, 11, and 111--as well as three augmented leads—a Vr, aV1, and a Vf—are used in the typical ECG lead system. The aVr-aV1 vector is orthonormal to a Vf, according to the cardiac vector analysis. Noise is supposed to be uncorrelated in orthonormal leads. The process of reducing noise from a signal is known as noise reduction. Audio and picture noise reduction techniques are available. The signal may be distorted to some extent by noise reduction methods. Both analogue and digital signal processing equipment have characteristics that make them prone to noise. Random or white noise with an even frequency distribution, as well as frequency-dependent noise created by a device's mechanism or signal processing methods, are all examples of noise. Hiss is a common sort of noise in electronic recording systems caused by random electron motion caused by thermal agitation at all temperatures above absolute zero. The voltage of the agitated electrons is rapidly added and subtracted by these agitated electrons. Figure 1 discloses the circuit model for ECG[1].

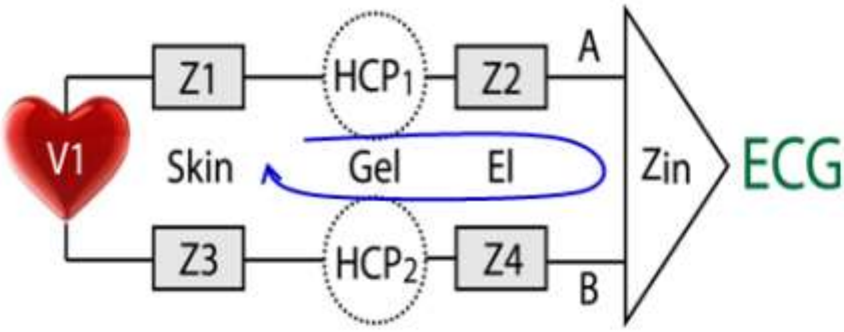

Figure 1: Electrical circuit model for ECG CH

Where Zi is the impedance of each layer of the skin–electrode interface and HCPi is the half-cell potential between the electrode and electrolyte. The half-cell potential value varies depending on the electrode material. Ideally, if Z1 + Z2 and Z3+ Z4 are the same, the half-cell potential values (HCP1, HCP2) are cancelled out.

2. LITERATURE REVIEW:

Shweta Jain et al. in their case study suggested that The electrocardiogram (ECG) is one of the most significant physiological signals in the human body, containing vital clinical data about the heart. QRS detection is used to monitor the ECG signal. An improved QRS detection algorithm based on the adaptive filtering principle has been devised in this study. Through fidelity parameters including sensitivity and positive predictivity, the efficiency of several LMS variations employed in adaptive filtering based QRS detection algorithm has been determined. For comparison, the entire LMS algorithm family has been implemented. Variable leaky LMS, variable leaky LMS, basic LMS, and normalised LMS are re-implemented, whereas variable leaky LMS, variable leaky LMS, and variable leaky LMS are re-implemented.[3].

Nicola Martini et al. in their case study suggested that Electrocardiogram (ECG) monitoring using portable equipment is complicated by motion artefacts, which can overlap the distinctive ECG waveforms. An adaptive filtering technique was used in this work to the removal of artefacts is being researched. The method used makes use of motion-related data. An accelerometer linked to the ECG electrode provides data. The results of the experiments show that adaptive filtering is a viable option. Reduces the number of motion artefacts while removing a huge number of them Detection mistakes are reduced, making our method an effective pre-processing methodology[4].

Pablo Laguna et al. in their case study suggested that the reduction of baseline wander is a common difficulty in ECG signal processing. We describe a cascade adaptive filter for removing baseline wander from the ECG while retaining the ECG's overlapping deterministic low frequency components, such as the ST segment components. There are two steps to this cascade adaptive filter. The first step is a zero-frequency adaptive notch filter. The second step is an adaptive impulse correlated filter, which calculates the ECG signal that is correlated with the occurrence of the QRS. The LMS method is employed in both stages, with differing gain constants of 1 and 2. We look at the frequency response of the filter as a function of the 1 and 2 parameters, and choose the ones that are most appropriate[5]

3. DISCUSSION:

1.1. Motion Artifact Cancellation:

The most problematic type of artefact is usually motion artifact this \spolated. There is certainly some signal distortion as a result of this. Because its spectrum completely overlaps that of the ECG, and its morphology often resembles that of the P, Play 9 but the noise-free QRS comPlexes at the Output be in such as heart rate measure, the resulting ECG is not suitable for diagnostic quality dis- noise to be removed from ambulatory ECG is because its spectrum completely overlaps that of the ECG, and its morphology often resembles that of the T waves and QRS. The majority of linear filtering algorithms and arrhythmia detection methods fail to address this issue. The adaptive recurrent filter is effective for cancelling noise from repeating morphological signals. This filter's principal input is the structure of a bination filter The ECG signal collected from a jogging subject is the principal input. 60 Hz, baseline drift, EMG noise, and motion aqifact are all examples of noise. The first stage of the filter separates baseline wander yl from 60 Hz noise y2. A recurrent filter is used in the second stage to reduce EMG noise and motion artefact. A two-stage filter is required: if the baseline and 60 Hz noise are not removed first, spurious QRS detections may occur, causing the impulse sequence to the recurrent filter to be wrong. The required noise-free signal is output by the second stage, y3 Half-cell potential (HCP), a major factor in the production of motion artifacts, is described by the simplified model of the Gouy-Chapman-Stern model of the double layer. In this model, the potential can be calculated by the change rate of the metal electrode's area while it is in the electrolyte . Therefore, measurements related to a real changes are needed in order to accurately predict artifacts induced by motion[6].

1.2. Applications:

Arrhythmia analysis can benefit from adaptive filtering. Two factors make this application easier The ECG signal normally has a well-defined P-QRS-T complex, and 2) the signal complexes are recurring with each heartbeat. In normal circumstances, the morphology of the heartbeat remains consistent from beat to beat (though slight deviations may occur). Any major morphological change indicates the presence of an arrhythmia. The P-QRS-T complex is nicely synced under typical conditions. The adaptive filter takes out uncorrelated components in the sequence if the usual sequence is disturbed, as it is in many arrhythmias. Let's start with the ARF's ability to acquire the QRS-T complex's impulse response. Shows the waveform of a normal ECG, as well as coincident impulses collected following QRS detection and the transversal filter's gradual adaption. As a result, the QRS-T complex is effectively cancelled, leaving the P-wave sequence as the filter error. The ARF should respond to tiny beat-to-beat fluctuations in the QRS shape if the convergence parameter p is large enough. After that, algorithms can use P-waves to detect atrial arrhythmias. . Ectopic Beats Detection Ectopic beats frequently have a different shape than normally conducted QRS complexes[7]. An ECG signal with irregularly conducted ectopic beats that have varied shapes. The ARF adjusts to the impulse response of typically conducted QRS complexes first, resulting in a low filter error. A severe misadjustment occurs as a result of a later ectopic beat. The ectopic beat is clearly defined by the filter mistake, or residue. The ARF swiftly re-acquires the normal complexes' impulse response, resulting in low adaptation error for succeeding beats. The customized measurement device has two-channel (2CH) instrumental amplifiers, a CPU, a wireless data communication module, and a battery. The two channels are the ECG channel and the HCP channel. The sensing device and 2CH electrode are shown in Fig 4. The continuous 2CH signal was recorded by a computer through wireless communication. To evaluate the correlation coefficients between data from ECG CH and HCP CH, the sensing device was placed on the subject's arm. Then the defined four motions (push, pull, stretch, and shake) were applied around the skin to induce motion artifacts. Combined with these simple motions were local changes in the skin and electrode interface that induce motion noise during such daily activities as walking and running[8].

3.3. Advantage:

The surface ECG has a pacemaker spike artefact when a patient has a pacemaker inserted. Because the pacemaker spike is only a few milliseconds wide, it can easily be detected. Conduction block has been discovered. The pacemaker spike activates the ARF, which then adapts the filter weights to obtain the paced rhythm's impulse response. The pacemaker may occasionally fail to initiate a paced rhythm (either to lead failure or a change in the heart's pacing threshold). The timed and non paced signal complexes have different geometries in this scenario. The ARF detects a substantial adaptation mistake when it is triggered by a non paced beat. This method can be used to track the performance of pacemakers. The signal-to-noise ratios (SNRs) before and after applying the adaptive filter were compared to evaluate the performance of the adaptive filtering methods. We employed two criteria to optimize filter coefficients: the SNR and the artifact-reduction %. (ARP). The number of patients with chronic diseases is constantly increasing. Cardiovascular disease in particular, including hypertension and heart disease, is prevalent in as much as 19.6% of the population, one report showed . Medical expenses are rising as the population ages and more people develop chronic cardiovascular diseases such as high blood pressure and heart disease. Patient-specific disease management and exercise are helpful in reducing the expense and improving the quality of healthcare. Recently, connected healthcare systems using wireless biological monitoring devices, gateway servers, and data servers have been applied to various healthcare services, such as family healthcare and elderly patient care . To monitor signs of cardiovascular disease, the convergence of mobile devices (smart phones and tablet PCs) and wearable sensors to measure physiological signals have been pursued more actively[9].

3.4 .Working:

The surface ECG has a pacemaker spike artefact when a patient has a pacemaker inserted. Because the pacemaker spike is only a few milliseconds wide, it can easily be detected. Conduction block has been discovered. The pacemaker spike activates the ARF, which then adapts the filter weights to obtain the paced rhythm's impulse response. The pacemaker may occasionally fail to initiate a paced rhythm (either to lead failure or a change in the heart's pacing threshold). The timed and no paced signal complexes have different geometries in this scenario. The ARF detects a substantial adaptation mistake when it is triggered by a no paced beat. This method can be used to track the performance of pacemakers. It was anticipated that motion artefacts were super-positioned in the ECG from the heart to evaluate adaptive-filtering performance. The motion artefact is used for simulation purposes. was added to the ECG data collected at rest from the chest, Using the same apparatus We used the least mean squares method.(LMS) adaptive filter with 0.01 filter coefficients was utilized. ECGs contaminated by noise or artifacts disrupt the normal functioning of the automatic analysis algorithm. Noise and artifacts are caused by several factors, such as power-line interference, skin-electrode motion artifacts, and electromyography noise .Artifacts in ECGs can mimic the frequency bands and morphologies of interesting features. Analyses of these artifact-impaired, low-quality signals can therefore generate false positives or false negatives. Before attempting signal processing, it is important to acquire an ECG with a high signal-to-noise ratio by optimally positioning sensors and preparing skin surfaces for their attachment. Beyond this, however, adding adaptive filtering using a reference signal has been proposed, to estimate and remove the inevitable occurrence of motion artifacts. The reference signal measures motion artifacts by means of various sensors (a strain gauge, optical sensor, and accelerometer). Indirectly measured reference signals show a low correlation with motion artifacts because they yield inaccurate estimates of the electrical characteristics of the skin/electrode interface. This low correlation results from the accumulated errorsin field changes, errors created by estimation and approximation. The simplified model of the Gouy-Chapman-Stern model of the double layer describes half-cell potential (HCP), a crucial element in the creation of motion artefacts. The potential in this model can be estimated using the change rate of the metal electrode's area in the electrolyte .As a result, measurements of areal changes are required in order to effectively forecast motion-induced artefacts[10].

4. CONCLUSION:

In this study, we obtained correlation coefficients from signals measured on the arm using the proposed sensing device and evaluated the effect of artifact reduction through numerical simulation. When the correlation coefficient is high, ARP rises (Fig 9). We successfully used the ARP metric suggested by Liu [5] to evaluate the performance of our adaptive filtering method. The major causes of motion artifacts are changes in the impedance and the half-cell potential originating from changes in the skin–electrode interface. The influence of the impedance change is very small because the impedances from Z1–Z4 are so small (less than 1%), as compared with the input impedance (10 Mohm). When the impedance of all elements fluctuates between 50% and 150%, the noise level via the desired signal is only 0.73%. The typical half-cell potential values are much larger than the desired measurement signals (HCP: 0.1–0.5 V vs. ECG: 1–2 mV). The noise from HCP variations overlap each other, rendering the desired signals without attenuation. Then, the imbalance of HCP (HCP1–HCP2) has larger amplitude than the ECG signal. In this paper, we have proposed a modified bipolar electrode for eliminating motion artifacts when taking ECG measurements during daily activities and exercise. We found that changing the interface of the two channels was the same as having a high correlation coefficient.

In this paper, we have proposed a modified bipolar electrode for eliminating motion artifacts when taking ECG measurements during daily activities and exercise. We found that changing the interface of the two channels was the same as having a high correlation coefficient; The suggested electrode's limitations for 1CH ECG recording necessitate the addition of a second channel to check motion artefacts. A homogeneous load distribution can ensure a high degree of correlation because two channels are geographically separated. However, because direct measurement of motion artefacts follows the same path as ECG monitoring, a higher correlation might be expected when additional sensors are used. The capture of high-quality ECG data will increase diagnostic accuracy and can help improve the performance of heart-rate monitors for both novice and experienced athletes.

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