EXTRACTION OF NOISE LIMITED ECG USING ICA TECHNIQUE FOR IMPROVING CARDIAC MONITORING SYSTEM

[1]Palanivel Rajan.S, [2]Sri Nivethini.C, [2]Manimala.K,
[1] Assistant Professor, [2] PG Student,

Department of Electronics and Communication Engineering,

Kamaraj College of Engineering and Technology, Virudhunagar, Tamilnadu.

Abstract

Cardiovascular disease usually refers to conditions that occupy narrowed or blocked blood vessels that can direct to a heart attack, chest pain. An electrocardiogram is a recording of waveforms that reveals the electrical commotion of the heart. Generally ECG recordings are often corrupted by artifacts. The prevailing artifacts present in ECG recordings are high frequency noise affected by electromyogram induced noise that may be down to respiration or the motion of the patients or the instrument. Though, the presence of noise in an ECG trace complicates the classification analysis. In the proposed system the work examines the principal noise sources and identifies their features. The separation of ECG and EMG should be done by using Independent Component Analysis (ICA) later the ICA calculations can be done by using Fast ICA algorithm. This algorithm which finds one at a time all non-gaussian independent components without any loss of original information. Further the separated ECG is used for the diagnostics decision support and patient monitoring system.

Keywords: *Blind Source separation (BSS),Fast ICA, Independent Component Analysis(ICA),Principal Component Analysis(PCA).*

1. Introduction

Largest-ever study of deaths shows heart ailments have replaced communicable diseases. Heart Attacks and **Cardiovascular Disease (CVD)** can affect People of Any Age. The heart attack, or myocardial infarction, is caused due to a blockage in the flow of blood to the heart. The main cause of heart attacks is believed to be fatty deposits on the walls of arteries. Fat deposits leads to the narrowing of the arteries and they get ruptured, leading to clotting of bloodstream.

According to **WHO** (World Health Organisation) estimates, 16.7 million people around the globe die of cardiovascular diseases each year[1].By 2010 CVD is estimated to be the leading cause of death in developing countries. According to a projection by the World Health Organization (WHO) and the **Indian Council of Medical Research (ICMR)**, One fifth of the deaths in India are from coronary heart disease[2]. In developing countries, half of all deaths of women over 50 are due to heart disease[3]. Among the types of heart disease, coronary heart disease is the most common type, with about 75% of heart disease-related deaths stemming from this type[4].

1.1 Heart attack statistics for older

The majority of health issues related to cardiovascular disease involve older people. About 33 percent of cardiovascular disease deaths occur in people over the age of 75. Cholesterol, a leading cause of cardiovascular disease, affects older men and women. For the U.S., 50.0% of men and 67.8% of women ages 55-64 have over 200 ml/dL total cholesterol levels. And, the problem affects the next age bracket as well. 37.3% of men and 59.8% of women ages 65-74 have over 200 ml/dL total cholesterol levels [4].

1.2 Demographic Risk Factors

• *Age*
– About 82% of people who die from CHD are 65 or older [5].
• *Gender*
– Men are more likely than women to have CHD [5].
• *Heredity/Genetic factors*
– Risk of CHD increases 2-3 times if a close relative has the disease.[5]

ISSN: 2278-0181
Vol. 2 Issue 2, February- 2013

• *Socio-economic Status*
– Those of low socioeconomic status are at a higher risk for developing .CHD than those of high socioeconomic status.[5]

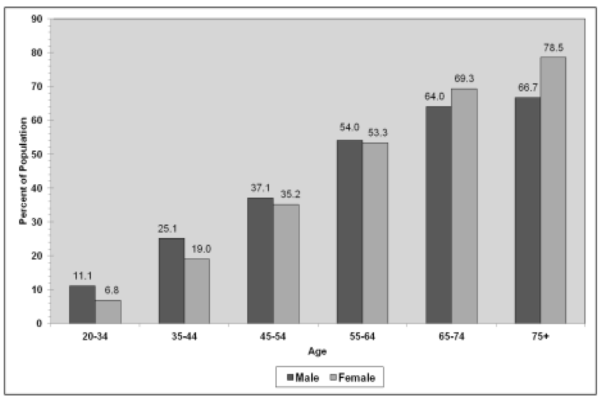

Figure 1: General Statistics For Heart Attacks As Per The Age Of A Person

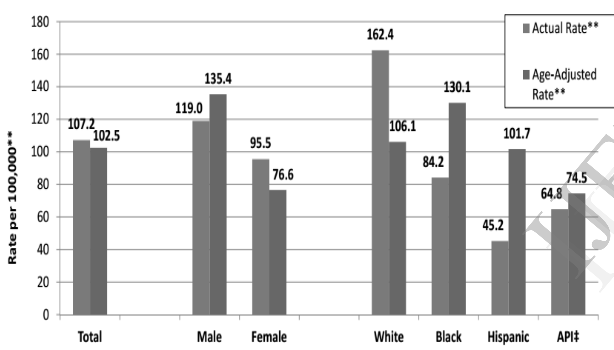

Figure 2 **:** CHD Deaths Actual and Age-Adjusted Rates [6].

The testing approach to confirm the diagnosis and plan suitable treatment desires to be individualized for every patient diagnosed with heart disease [7]. Several other medical conditions and lifestyle choices can also put people at a higher risk for heart disease, including:

- Diabetes
- Overweight and obesity
- Poor diet
- Physical inactivity
- Excessive alcohol use

The main problem of digitalized signal is interference with other noisy signals like power supply network and breathing muscle artifacts (EMG).These noisy elements have to be removed before the signal is used for next data processing like heart rate frequency detection.

The main sources of noise in ECG are,

- Baseline wander (low frequency noise)
- Power line interference (50Hz or 60Hz noise from power lines)
- Muscle noise (i.e. EMG noise.)
- Other interference (i.e., radio frequency noise from other equipment).

In this work the main noise is the EMG noise which generates other than the heart muscle which create the physician difficult to rectify the clear ECG signal.

1.3 Electromyogram

Electromyogram (EMG) is a technique for recording the opening signal of muscles. Electromyogram perceives the electrical potential produced by muscle cells when these cells contract and relax. While monitoring the ECG signals the EMG artifacts generated by muscles other than the heart muscle can interfere with ECG signal which cause the observer difficult to monitor the clear ECG signal. However, in principle, EMG represents a distributed source and cannot be immediately assumed to originate from a single or a small number of discrete sources comparative to the number of ECG leads. EMG is the most common noise in dynamic ECG, and it has great influence on detection of R-wave.

1.4 Interference Of ECG And EMG Signal

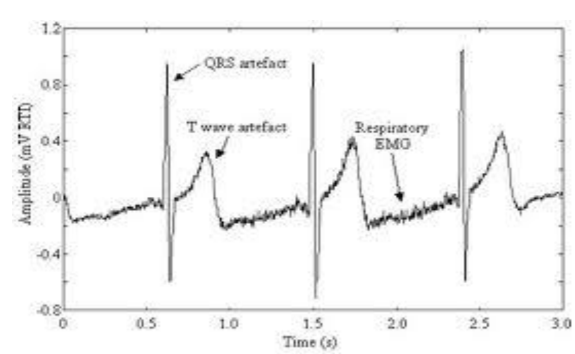

Figure 3: Interference of EMG over ECG Signal

EMG noise is origin from the contraction of other muscles besides the heart. When added muscles in the vicinity of the electrodes contract, they create depolarization and repolarization waves that can also be selected up by the ECG.

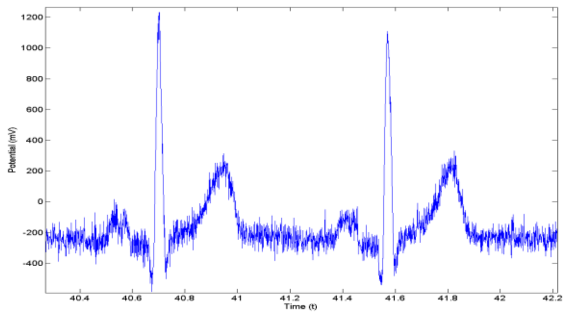

Figure 4: Two second segment of an ECG trace. The *x*-axis is time in seconds, and the *y*-axis is the electrical potential in millivolts. Exact positions of P and T complexes are obscured be presence of EMG noise**.**

The degree of the crosstalk depends on the quantity of muscular contraction (subject movement), and the worth of the probes. It is well-known that the amplitude of the EMG signal is stochastic (random) in character and can be rationally modelled by a Gaussian distribution function.

The special effects of typical EMG noise can be pragmatic in the ECG signal shown in Fig. 3, and is particularly challenging in the areas of the P and T complexes.

2. Materials and Methods

A) Previous work

Conversely for many applications specially in biomedical signal processing ,extraction of EMG signals from ECG can be made using various Transform methods like wavelet Transform, Morlet transform, Non stationary harmonic Modeling and using common types of linear and nonlinear filters Lean Mean Square (LMS) ,Widrow adaptive structure combinations of Neural-ICA. The principal noises that perturb such signals are the power line interferences and EMG artifact of the muscles. Notch filters, and high-pass filters have been used to cancel artifacts from EMG signals.

B) Existing Approaches

Though using such methods, that are not predicted the correctness of ECG signal due to the presence of low distortions and also these extraction methods are not resulted in more accuracy of the ECG signal for the field of applications.

These methods do suffer from losing frequency portions of the EMGs. Due to a moderately slow convergence rate, the LMS algorithm is fewer capable of improving signal-to-noise ratio in rapidly varying environments. Using the Wavelet which requires more investigations of ECG signals in order to improve the accuracy level of ECG. Discontinuity is explicit in the case of both Morlet and Wavelet techniques.

Consequently, to overcome these drawbacks, in the proposed work it mainly focused on removing all such drawbacks in an efficient way by using the PCA and ICA techniques mainly the Fast ICA algorithm However, in the proposed method, EMG is recorded separately but simultaneously with ECG signal giving higher accuracy.

3. Proposed Methodology

Limiting the effect of the discussed noise sources is the best way to ensure accurate signal processing, however this is not always possible, so Independent Component Analysis (ICA) techniques need to be utilized. The characterization of the noise sources should provides a basis for feature extraction and signal pre-processing. As of analysis in many reviews the different techniques can be used to separating the ECG signals from EMG signals. In the proposed work, Principal Component Analysis (PCA) can be used to differentiate the characteristics and attributes of EMG signal. This work is focusing for the most part on conditioning ECG signal and to remove the turbulence caused by EMG signal. It employs higher order statistics & Blind Source Separation. Then Independent Component Analysis (ICA) can be used to separate ECG from EMG signal. Further ICA calculations can be performed by using Fast ICA algorithm in an efficient manner.

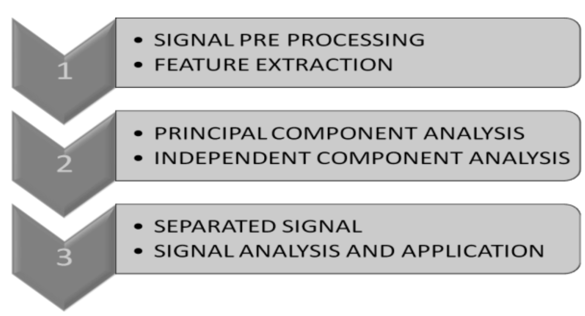

Figure 5: Block diagram for the Proposed Methodology

3.1 Signal Pre Processing

The aim of pre-processing steps is to recover the general quality of the ECG for more precise analysis and measurement. Noises may agitate the ECG to such an amount that measurements from the original signals are undependable. some pre-processing techniques that create the problem of ICA evaluation simpler and enhanced conditioned .Apart from reducing the dimension, the experimental signals are centered and decorrelated. ICA normally includes pre-processing the ECG signals by mean removal and dimension reduction.

3.2 Feature Extraction

Within this process the signals are processed and analysed, it characterise each signals with their properties. And it differentiates the signals ECG & EMG based on their attributes the signal is conditioned and trained. Next is the PCA based on the dimensionality of data it will process and extracted the principal components.

4. Principal Component Analysis (PCA)

Principal Component Analysis is one of the simplest and better known data analysis techniques. The main purpose of PCA analytic techniques are:

- to detect structure in the relationships between variables that is to classify variables.
- Maximize the variance of the "new" variables (factor).
- Minimizing the variance around the new variable.
- to reduce the number of variables

One of the applications in which both PCA and ICA have been successfully applied in noise reduction by excluding noise carrying components from the reconstruction. PCA has been successfully applied in **Noise** and **Dimensionality Reduction**.

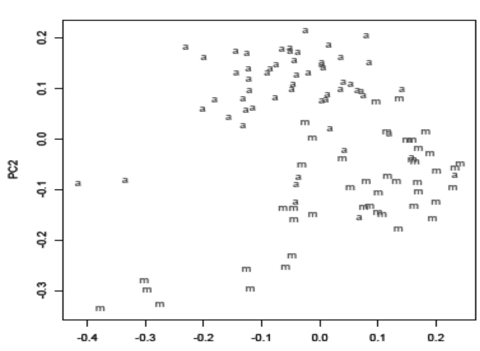

Figure 6: Projection of the separated signals two principal components. Labels: \a" for ECG signal, \m" for EMG signal

In PCA the ECG signal processing obtained its starting point early the samples of a segment situated in some appropriate part of the heartbeat. The location inside the beat differs from single application to one more and may involve the complete heartbeat or a meticulous activity such as the P wave, the QRS complex, or the T wave. Before the samples of a segment can be removed, however, a fiducial point be required to be determined so that the exact segment location within the beat can be clear. Finally the output obtained from the PCA is given as input to the ICA.

5. Independent Component Analysis (ICA)

It is a statistical and computational technique for enlightening hidden factors that cause sets of random variables, measurements, or signals. ICA is based on higher order statistics and decorrelates the input signals in addition to creating the result signals independent from each other. It is a computational procedure for sorting out a multivariate signal to additive sub-components supposing the mutually statistical independence of the non-Gaussian source signals. This is indicated by the mixing model,

$$\mathbf{Y} = \mathbf{AS} \qquad (1)$$

Over a limited period of time the voltage signal samples calculated are in the rows of the measurement matrix **Y**, and **A** is the mixing matrix the source signals are in the rows of **S**.

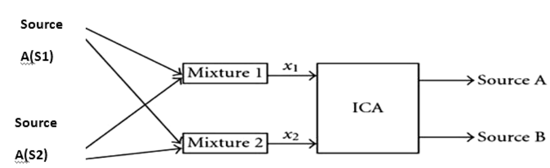

Figure 7: Independent Component Analysis

ICA is apparently related to principal component analysis and factor analysis. While ICA operates purely based on the input signals and a few assumptions, ICA which belongs to the class of methods called blind source separation (BSS) methods. ICA requires the ful fillment of two assumptions:

1) The measured signals are linear combinations of independent source signals,

2) The independent source signals are non-gaussian. Writing (1) out with signal samples, we get,

$$\begin{bmatrix} y(1,1) & \cdots & y(1,N) \\ \vdots & \ddots & \vdots \\ y(L,1) & \cdots & y(L,N) \end{bmatrix} = \begin{bmatrix} a(1,1) & \cdots & a(1,L) \\ \vdots & \ddots & \vdots \\ a(L,1) & \cdots & a(L,L) \end{bmatrix} \begin{bmatrix} x(1,1) & \cdots & x(1,N) \\ \vdots & \ddots & \vdots \\ x(L,1) & \cdots & x(L,N) \end{bmatrix} \qquad (2)$$

After successful ICA, the rows of the matrix **X** contain the ICs. In general, the aim of applying ICA is that each IC carried a signal generated by a single physiological or physical source, such as a signal generated by the heart or its individual structure, possible additive noise, or other artifact, such as EMG artifact.

From (1) and (2), common application of ICA measurement reconstruction with only the ICs carrying preferred information. First, calculating ICA on **Y**, yields mutually **A** and **X**. Thereafter, the ICs in **X** can be analyzed to resolve which ICs carry noise or artifacts and which carry offerings from the actual ECG.

To reconstruct the ECG without the noise and artifacts, the corresponding rows of **X** are put to zero in (2), and **Y** is calculated according to (2) devoid of altering **A**. This totally removes the contributions of the zeroed ICs. This is the basis of several ECG applications of ICA. The above described ICA model is the easy model since it ignores all noise components and any time remain in the recordings.

5.1 ICA By Maximization of Non-Gaussianity.

Non-Gaussianity is actually most important in ICA estimation. In classic statistical theory, random variables are assumed to have Gaussian distributions. So we start by motivating the maximization of Non-Gaussianity by the central limit theorem. It has important consequences in independent component analysis and blind source separation. Even for a small number of sources the distribution of the mixture is usually close to Gaussian.

5.2 Minimization Of Mutual Information

Mutual information is a natural assess of dependency involving random variables exclusively it is a measure of the information that a component of a set of random variables has on the other random variable in the set. Another approach for ICA estimation stimulated by information theory, is minimization of mutual information.

6.The Fast ICA Algorithm

In the foregoing sections, different measures of non-gaussianity, purposely objective functions for ICA estimation. In observe, there is an algorithm for maximizing the contrast function, In this section, a very well-organized method of maximization suited for this task. It is here assumed that the data is pre-processed by centering and whitening as discussed.

Fast ICA algorithm acts as one of the majority popular algorithm of independent component analysis algorithm, it can initiate from observation signal and approximate source signals with minute known information, and get the rough calculation of original signal independent each other. The process which includes preprocessing, centering and whiteninig**.**

Preprocess the Data

Before the Fast ICA algorithm can be useful, the input vector data X should be centered and whitened.

Centering the Data

The input data X is centered by computing the **mean** of every component of X and subtracting that mean. This has the cause of making each component have zero mean. Thus:

$$X \leftarrow X - E\{X\} \quad (3)$$

Whitening The Data

Whitening the data that involves linearly transforming the data so that the fresh components are uncorrelated and have variance one. If $\tilde{X}$ is the whitened data, then the covariance matrix of the whitened data is the identity matrix:

$$E\{XX^T\}=I \quad (4)$$

By using Fast ICA algorithm with also graphical user interface we generate and extract the separate signals(ECG &EMG).Mainly ECG signals are focussed and to used for daignosis.

7. Simulated Results

7.1 Mixed Signals

Transmission of ECG results in the corruption of signal due to introduction of noise. Various factors responsible for introduction of noise include poor channel conditions, Baseline wander (caused by respiration), 50 or 60 Hz power line interference etc. Analyzing such a noisy signal is bound to give erroneous results. Thus the signal is first made free of noise. The above figure is the corrupted ECG signal by EMG and other noises.

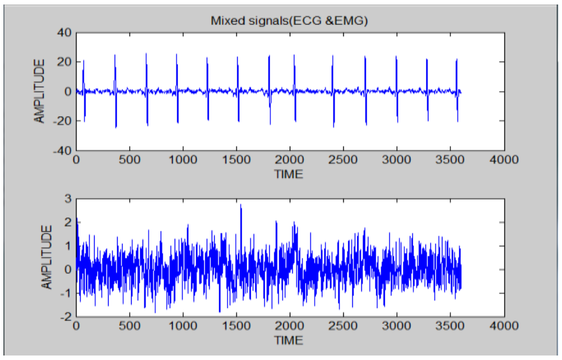

Figure 8: Mixed Signals

7.2 Separated ECG Signal

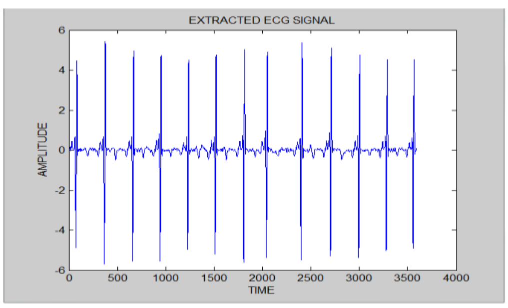

Figure 9: Separated ECG Signal

This is the extracted ECG signal after removal of noise by Independent Component Analysis. For receiving the accurate ECG signals from the other noises this ICA technique is used based on, non-gaussianity, uncorrelatedness, statistscal independence. while the result for the ICA the objective is that the resulting independent component signals are the original source signals (ECG) .Finally the extracted ECG signals are the original source signals without loss of information.

7.3 Clear EMG After Extraction By ICA

This figure which clear gives detailed information about the EMG signal without any interferences. It is generated by the electrical activity of the muscle around the chest portion which due to the patient movement and other internal functions inside the body. Muscle Signals are Analog in nature. Vice versa the EMG signal can also be used for further assessment as an alternative of ECG. In conclusion the EMG signal was alienated from the ECG signals based on statistical independence several matrix methods and analysis methods with out any loss of information.

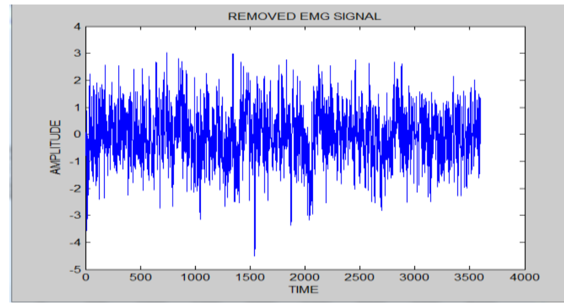

Figure 10: Separated EMG Signal

8. Conclusion and Future Scope

The noise source (EMG) discussed in this paper are the ones which are of greatest concern to accurate real time analysis of ECG data. EMG noise resulted from crosstalk introduced by muscle contractions (other than the heart) during ECG measurement. A more thorough statistical analysis should be performed to better characterize the effect of EMG noise on the ECG signal.

In the proposed methodology we have separated the ECG signal from the EMG artifacts was done by using Independent Component Analysis (ICA). Finally the clear ECG signal is extracted as the original signal without having any loss of information. The future work indicates, ICA has found to be in several applications such as signal processing systems which are aimed at aiding in diagnostics and cardiac monitoring system.

ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to my Project Guide, **Mr.S.PALANIVEL RAJAN M.E., M.B.A., P.G.D.I.C.L.,** Assistant Professor, Department of Electronics and Communication Engineering, Kamaraj College of Engineering and Technology, for his precious and worthless guidance, tremendous supervision as well as providing necessary information regarding this project and also for his support in completing the project.

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AUTHOR'S PROFILE

C.Sri Nivethini received her B.E. (CSE) degree at Kamaraj college of Engineering and Technology. Now she is pursuing her M.E (Computer and Communication**)** at Kamaraj college of Engineering and Technology. Her areas of interests are Wireless communication, Operating Systems, wireless networks and Database Management,Bio-Signal Processing, and Network Security.

S. Palanivel Rajan pursuing his Ph.D in the faculty of Information and Communication Engineering from Anna University Chennai. He has obtained his M.E degree in Communication Systems from Thiagarajar College of Engineering, Madurai, Tamilnadu and B.E degree in Electronics and Communication Engineering from Raja College of Engineering and Technology, Madurai, Tamilnadu. He is presently working as Assistant Professor in the Dept. of Electronics and Communication Engineering at Kamaraj College of Engineering and Technology, Virudhunagar, Tamilnadu. His interest includes Bio-Signal Processing, Telemedicine, Telemetry, Wireless Networks and Wireless Communication. He has contributed 64 technical papers in various reputed journals and conferences. He is a life member of ISTE, IE (I), IACSIT, ITE, IAAA, IAMI, TSI, INHS, COE, BMESI, IAENG and IETE**.**

K.Manimala received her B.E. (CSE) degree from JJ college of Engineering in 2011. Now she is pursuing her M.E (Computer and Communication**)** at Kamaraj college of Engineering and Technology. She got District First in the subjects of Tamil, Science and Social Studies in her 10th standard and for that, she awarded a Gold Medal. She got Department first in her U.G. Her areas of interests are Wireless Networks, Operating systems and Database Management.