IJEW 国际工程期刊 International Journal of Engineering Works انجینئرنگ کاموں کا بین الاقوامی جرنل

International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 6, Issue 05, PP. 182-186, May 2019
https://www.ijew.io/
https://doi.org/10.34259/ijew.19.605182186

Denoisation of ECG Signal using JADE ICA and FAST ICA Comparison

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Received: 30 April, Revised: 06 May, Accepted: 15 May

***Abstract*—**Electrocardiograph signal is effective tool in diagnosis of cardiac related diseases and plays an important role in biomedical research. To diagnose the cardiac disease, the signal must be recorded properly. The addition of artifacts like Persistent noises, Burst noises and their types play an important in making it difficult to interpret and analyses the electrocardiograph signal. A Blind source separation (BSS) related technique named Independent Component Analysis (ICA) is the right solution for it. In this paper, different ICA Algorithms like JADE, FAST are used to de-noise the ECG signal from the artifacts and a comparison between both is shown which is done on the basis Performance Index (PI) using a dsp ICALAB toolbox in MATLAB**.**

***Keywords*—**Blind Source Separation, Electrocardiography signals, Independent Component Analysis, Performance Index, Signal to Interference ratio

I. INTRODUCTION

An ECG signal is a vital mechanism for analyzing the problem of cardiac. It is storage of imbalances of different electrical potential generated by heart beats with reference to time. ECG is an important and vital tool from the point of view of functionality and circulatory system. Premature diagnosis of cardiac irregularities can help saving one's life and a proper treatment will lead to a quality life. As ECG is primary source of any disorder that initiates from heart and a lot of work is already done on it but still it is famous issue for various researcher. By in large the ECG signal with its heart rate depicts the healthiness situation inside the heart [1].

II. CHARACTERISTICS OF ECG SIGNALS

The characteristics of ECG Signal can best be explained by the peaks in the graph.The graphical form of electrical action of the cardiac is known as Electrocardiography signal shown in Figure 1. Mainly two things in this figure need to be noticed. One is about the electrical movements observed though the muscles of heart and second is the period of the tramp the electrical waveform across the heart.

The nominal limit (0.05 – 100) Hz where the frequency of the electrocardiograph signal lies. The signal is further categorized on the basis of their discontinuity level like peaks sometimes called valleys named as P, Q, R, S, T. Occasionally, with very rare case the U peak also appears. A person health is only detected or the indicator to check one's health is to check whether the P wave, T wave and QRS complex interval is there or not? These indicators are the essence of the electrocardiograph waveform as the T wave and QRS complex interval show the activities involves in the ventricular portion and P wave which shows atrial activities

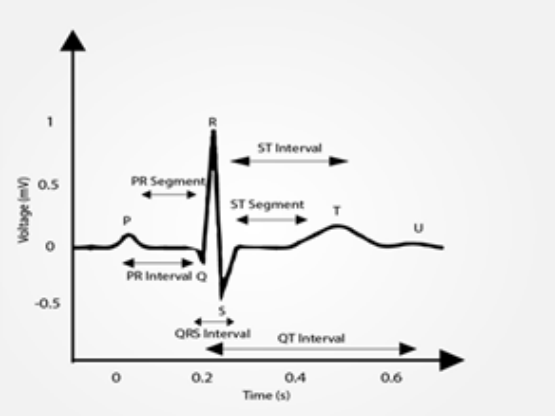


Figure 1 Characteristics of ECG Signal [9]

Basically the deep analysis of ECG signal shows that the waveform is divided into three parts, one is middle part the QRS complex interval (which is surely the identity of this signal) and the part before and after the QRS complex part is somewhat inverted replica with first having magnitude lesser than the last one [3].

TABLE I. DIFFERENT PARTS OF THE ECG SIGNAL WITH THEIR VOLTAGES [10]

INTERVAL	DURATION (sec)
P-R	0.12-0.20
Q-T	0.35-0.44
S-T	0.05-0.15
P wave	0.11
QRS	0.09

Out of these QRS complex interval is of great importance in any machine which is used for the analysis of the electro cardiograph signal. If the QRS complex is identified in the

oscilloscope which is basic of the most of the cardiac checkups. The below table explains the duration of each particular interval in the ECG signal [11]

III. NOISE AFFECTED THE ECG SIGNALS

There are two mainly two types of noise that affect the ECG signal. One is Persistent noise and another is Burst noises [7].

A. Persistant Noises

These noises come up with the electrocardiograph signal with variation of range of frequencies. Their limit of intensity is dissimilar but the time-based distribution is same. Due to having a variety of frequency ranges their types are categorize on the basis of frequency range.

- Power Line Interference Noise
  This type of noise comes from the interference of wires that carries the biomedical signals, normally in this case for medical equipment. The signal faced interference with 50 Hz or 60 Hz frequency, mostly in the case in which the electromagnetic creates the disturbance to the line which has to analyze in monitoring room and comes from examination box [8]

- Baseline Wander (BW)
  This type of noise is due the impedance involved in the contact of the electrode terminal and human skin and also main cause involves the breathing and maneuvering initiated by patient[10]. These noises lie in the range less than unity Hz but considering electrocardiograph signal it may varies to long range. It is one of the leading noise in the reception of electrocardiograph signal with different monitoring system [12]

- Electromyography Noise
  Though electromyography is used for recording the movement of skeletal muscles and it is a bio signal but it also acts as noise to other bio signal like ECG signals. These muscles when contracts and relaxes in the tertiary of cardiac, their movement or activity is being recorded by the terminals and acts as a noise in the way of desired ECG signals. The muscles contraction and relaxation provide necessary level of the noise which is added to our desired signal but also the reading equipment terminals quality also play important role in it. The electromyography noise is random in nature and studies have proved that its distribution is Gaussian in nature which greatly dependent upon environmental condition

B. Burst Noises

This type of noise is due to production of noise through the leads of the equipment for measuring ECG signal. They are white gaussian in nature and have arbitrary range of frequency.

- Contact Noise or Electrode popup
  The main reason of this type of noise is disconnection of the contacts between the probe of the electrode and the human skin. The loss of connection amongst the parties will lead to affect the reading system which results in greater noise in ECG signal. The major factors of electrode or contact noise are the location of electrode with reference to heart and the medium of propagation between them and they play their part in the artifacts because of capacitive coupling nature of the ECG signal. The level of conductivity between the human skin and the electrode have also their importance as low level of conductivity will lead to low values of signal to noise ratio meaning greater amount of noise involved in the signal.

- Patient Electrode motion artifact
  These types of burst noise are produced by the motions of electrode causing changes to baseline. Normally, the main causing of this type of burst noise are movement by patient like respiration, shuddering etc [13]

- Instrumentational Noise
  This type of burst noises is due to the electrical hardware which is utilized in ECG estimations moreover contributes noise. The main causes of this type of noise includes probes of electrodes, A-D converters, cables, signal amplifiers or signal processor. One thing should be noted here that it is almost impossible to eradicate this type of burst noise but it can be minimized by utilizing the machines of better quality with cautiously developing the circuits

IV. INDEPENDENT COMPONENT ANALYSIS

Independent Component Analysis is a technique that can be used for removing artifacts from the noisy ECG signal. In this thesis we will compare the different algorithms of ICA for removal of noise from ECG signal [4].

A. JADE ICA

An ICA algorithm named Joint Approximation Diagonalization of Eigen matrices which works on retrieval of source signals using good advantage of moments of order fourth from the original source signal.[14]

Its working is based on calculating the P matrix, which leads to finding the signal $z = P x$ [10]. Furthermore, the calculation of cumulates which are related to whitened mixtures are processed. By using the joint diagonalization, λiVi is used find out the R rotation matrix. For rotation matrix R conditions like keeping the diagonal behavior of cumulants as much, orthogonal optimization is achieved which is the basic working of JADE algorithms [15]. The JADE algorithms operates mostly on difficulties of low dimensions and there is no legal requirement of adjusting the variable. These all factors

makes the JADE ICA fast to calculate the un mixing matrix [9].

B. FAST ICA

Another famous and well organized algorithms for Independent Component Analysis is FAST ICA. This fixed point iteration algorithms deals statistical independence as a factor of non gaussianity with capitalizing on non gaussainity [7].

This algorithm basically works on iteration for finding the more of variable which are non gaussainity in nature and that can be obtained from estimation of Newton iteration [2]. As this algorithm is associated to series of fixed point algorithms and with w weight vector is explained as follow.[12]

1. Let $w^+ = E\{xg(w^T x)\} - E\{g'(w^T x)\}w$
2. Let $w = {}^{w^+}/_{\|w^+\|}$
3. If not converged go back to one

Some of the key features of FAST algorithm is explained below which differ it from rest of the algorithms.

1. The algorithm has linear convergence, while have on issue of gradient it has cubical. This convergence makes the algorithm a fast algorithm which is further proved from testing on the real data.

2. Under the supposition of ICA generalized model (in quadratic no step size is needed). In contrast to algorithm constructed on gradient algorithms. Which shows dissimilarities as compared to other ICA algorithm which show it convenience for implementation.

3. The algorithm uses non linearity to search out any independent component related only to non gaussian distribution which is the unique quality of this algorithm which is not present in others, While the others works on the principle of digs out first the probability density function and then search the independent components [18]

4. One of the factor which enhance the process, is by choosing appropriate value of non-linearity. Precisely algorithms having low variance and robustness are mostly preferable and actually ideal characteristics are showed up by the two linearities.

V. RESULT AND DISCUSSION

ECG is an apparatus or tool in sensing the nature of the disorder related to cardiac. Also, the behavior of electrocardiograph signal (bio signals), being a non-stationary signal show lot of variety in domain of time. So, because of this reason the identification of heart disorder is a bit tricky to find but there is some irregular interval which would rather help the cause [6].

Furthermore, for an ECG signal to be analyzed efficiently things like signal variation, signal shape and heart rate should be taken into account and deeply studied. Independent Component Analysis is a technique that can be used for removing artifacts from the noisy ECG signal. In this thesis we will compare the different algorithms of ICA for denoisation of ECG signal [5].

It includes the results of the overall theory discussed before about the simulated signals, how the noise being added and how then finally the denoised signal is retrieved using ICA Algorithms.[11] The whole process is about the taking the data from the MIT-BIH Arrhythmia Database (PhysioNet) and then some noise is being added to the signal using MATLAB. Then the process is forwarded to ICALAB. A signal processing toolbox used in MATLAB for denoisation of different things using different ICA Algorithms. Where the original ECG signal retrieved which makes our whole process complete.[13]

Figure 2 show the original signal ECG signal which is taken from MIT-BIH source

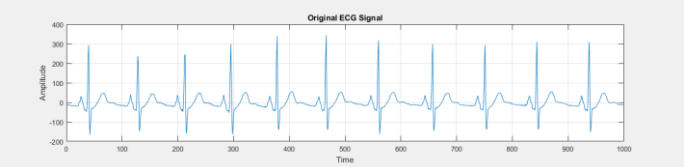


Figure 2 Original ECG Signal [9]

Figure 3 shows the noised version of Figure 2. The noise is been added in the original signal. 10dB in the first figure, 15db in the second figure and 20dB in the third figure.

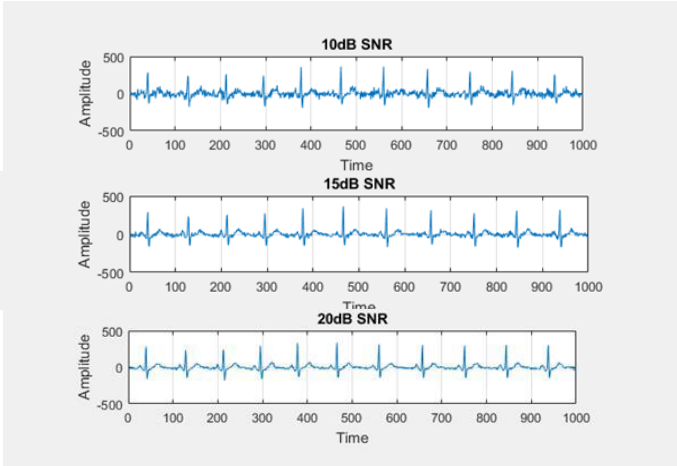
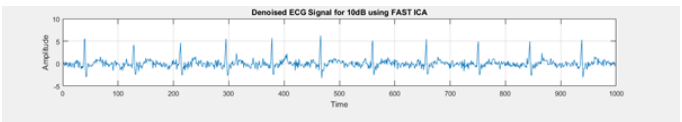


Figure 3 ECG noised signal with 10dB,15dB and 20dB [9]

The noised signal is then processed using two of the algorithms of ICA i.e. FAST and JADE and the de noised is shown using ICALAB tool box. The Figure 4 shows the denoised version of Figure 3 using FAST ICA. Figure 5 shows the denoised version of Figure 3 using JADE ICA.



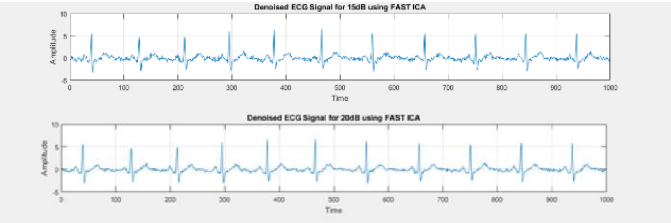


Figure 4 ECG de noised signal using FAST ICA [9]

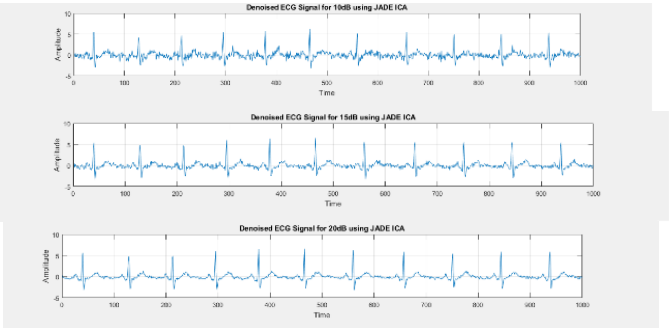


Figure 5 ECG de noised signal using JADE ICA [9]

Finally, the whole comparison is described in a tabular form to make a comparison of both the algorithms applied in this thesis. After applying the whole process with 10dB, 15dB and 20dB on the both the algorithms i.e. FASTICA and JADEICA. FAST ICA algorithm is found to be the better one in terms of their performance index that is being observed on the ICALAB toolbox used in MATLAB [15]

TABLE II. TABLE 1 PERFORMANCE INDEX WITH DIFFERENT NOISES OF FAST ICA [9]

S.No	Algorithms	Noise (dB)	Performance Index
1	FAST ICA	10	0.357305
2		15	0.391784
3		20	0.430206

TABLE III. TABLE 3 PERFORMANCE INDEX WITH DIFFERENT NOISES OF JADE ICA [9]

S.No	Algorithms	Noise (dB)	Performance Index
1	JADE ICA	10	0.294056
2		15	0.319209
3		20	0.33043

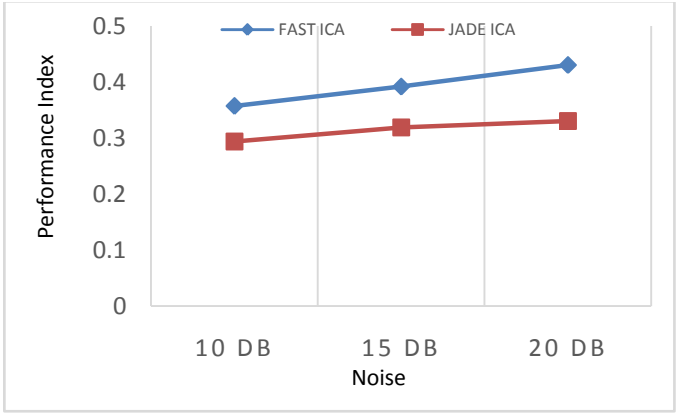


Figure 6 Graphical comparison of FAST and JADE Algorithms [9]

The Figure 6 shows the graphical comparison between the two algorithms of ICA and it is clearly shown in the figure that FAST ICA shows better performance in the circumstances

CONCUSLION

In this research paper, a comparative ¬analysis of two ICA algorithm namely JADE and FAST were analyzed on the basis of their performance index. The Signal to interference ratio is the main source of performance index in this research.

Different types of artifacts have contaminated the ECG signal like Types of Burst noises and Persistent noises. This result explore that Fast ICA is better than Jade ICA under the circumstance discussed in this research paper.

FUTURE WORK

FAST ICA as compared to JADE ICA shows better performance in the thesis, but one thing is observed that It memory used by FAST ICA is higher than JADE ICA. Although it is outweighed by its performance [16]

On the Other hand, JADE shows low performance in this scenario but balance by its low memory usage. According to the above two point, future work can be done on either JADE ICA to increase its performance as its memory utilization is better or to research on FAST ICA to make it use on low memory as its performance is better in this case [17]

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