# Implementation of Complete Ensemble Empirical Mode Decomposition to Analyze EOG Signals for Eye Blink Detection

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## Abstract

This paper reports on application of Complete Ensemble Empirical ModeThis paper reports on application of Complete Ensemble Empirical Mode Decomposition (CEEMD) technique to pre-process Electro-Oculogram (EOG) signals before eye blink detection technique is implemented. EOG is a non-stationary signal which is affected by different kinds of interferences. During the time of recording EOG signal gets contaminated by Electromyography (EMG) signal. In this paper CEEMD is used to decompose the EOG signal into several intrinsic mode functions (IMFs). After thresholding each IMF the signal is reconstructed using all of the IMFs. The resulting denoised signal is then used to detect eye blink

***Index terms***— EOG, complete ensemble empirical mode decomposition, eyelid movement

# 1 I. Introduction

Author: Electrical and Electronic Engineering from Khulna University of Engineering & Technology, Bangladesh department of EEE in the Khulna University of Engineering & Technology as a lecturer. e-mail: galib.kuet.eee@gmail.com EMD [6] decomposes a signal into a number of IMFs. An IMF has two properties : (i) number of extrema and number of zero crossing are equal or differ by one; and (ii) at any point the average value of upper and lower envelop is zero. EEMD algorithm adds different realizations of white noise to the original data x **??**n]. Thus an ensemble of data sets is generated. To cancel out white noise ensemble average of different trials is calculated. EEMD algorithms can be described as [4] The CEEMD algorithm can be described as [5]:

1. Add white noise to the original signal x[n] 2. Obtain the first decomposed component applying EMD.

he EOG signal is an electrical measurement of the potential difference between the front of the eye (cornea) and the back of the eye (retina). This potential varies from 0.4 to 1.0 mV **??**Malmivuo & Plonsey, 1995). EOG signal can be measured in horizontal channel and vertical channel. The eye movements in horizontal directions are recorded by horizontal channel and vertical channel records the eye movements in vertical direction. In addition to eye movements vertical channel also records eyelid movements i.e. eye blinks. An EOG signal is shown in Figure 1 which includes eyeball rotation, movements and eyelid movements. The muscles of the eye, eye blinks, electrode placement and head movements produce EMG signals [1]. To eliminate unwanted signals from EOG signal Empirical Mode Decomposition (EMD) has been used [2]. EMD algorithm is sensitive to noise. This can cause mode mixing. Mode mixing is defined as an IMF that includes oscillations of dramatically disparate scales or a component of similar scale residing in different IMFs [3]. To eliminate the mode mixing problem an extension to EMD algorithm was proposed [4] which is called Ensemble EMD (EEMD).It performs EMD over an ensemble of Gaussian white noise assisted data. But the reconstructed signal contains residual noise and different realizations produce different modes. To overcome these limitations variation of EEMD has T been proposed [5] which is called Complete-EEMD (CEEMD). CEEMD algorithm provides an exact reconstruction of the original EOG signal which can be used to detect eye blinks precisely.

3. Repeat the decomposition and add white noise of different realizations. 4. Average over the ensemble to obtain the IMF1:IMF 1 = 1 L ? E 1 [x[n] + ?w i [n]] L ??=1

L= number of realizations, ?= ratio coefficient, E i computes ith IMF. 5. Compute the residue, r 1 [n]=x[n]-IMF 1 . 6. Compute the second IMF component IMF 2 :IMF 2 = ?? ?? ? E 1 [[x[n] + ?E 1 [w i [n]]] ?? ??=1

7. Repeat the above steps to obtain the (m+1)th IMF component IMF m+1 :IMF m+1 = ?? ?? ? E 1 [x[n] + ?E m [w i [n]]] ?? ??=1

III. Eog Signal Denoising

Generally EOG signals are affected by the noises of power-line interference and EMG interference during data acquisition. In this paper CEEMD has been used to eliminate the interferences from EOG signals collected from Physionet database. The EOG signal is considered to be corrupted by additive white noise during the process of signal acquisition. CEEMD decomposes the EOG signal into 11 IMFs shown in Figure **??** 2. It can be seen that see that most of the noise information are distributed to the 1st intrinsic mode functions [7]. Suppressing the insignificant components we can reconstruct the signal as follows:X T =? I n ?? ??=1

where I is the set of N IMFs. The noisy EOG signal and the corresponding denoised signal is shown in Figure **??** 3

# 2 IV. blink detection

The algorithm [8] used here to detect the blinks includes the following steps: 1. Locating some 'events' in the EOG velocity data that have EOG velocity increase above the threshold of eyelid downward velocity and followed by a period below the threshold of eyelid upward velocity. 2. Identification of the events which have duration longer than 0.5 seconds and amplitude of closing and opening phase greater than a threshold value. These events will be considered as valid blinks. 3. Merging the contiguous events together causing double blinks which will be checked again. This algorithm has been applied on the denoised signal obtained by CEEMD. The results have been shown in Table **??** 1. **??** 3(a). This noisy signal is decomposed into 11 Intrinsic Mode Functions using CEEMD after which discarding insignificant components a denoised signal has been obtained which is shown in Figure **??** 3(b). MIT-BIH data sets are used for the investigation of the denoising performance of CEEMD and also the detection performance. The obtained results are shown in Table **??** 1. We calculate sensitivity and specificity has been calculated as [2]:Sensitivity= ???? ????+???? ×100

False Positive (FP) corresponds to detection of a blink where there is no blink, False Negative (FN) corresponds to failure to detect a blink and True Positive (TP) corresponds to properly detected valid blinks. We can see from the table that the performance of detection is better in case of specificity compared to sensitivity. The signal to noise ratio has been calculated as [2]:SNRo= ? [?? ???? (??)] 2 ?? ? [?? ???? (??)???(??)] 2

# 3 ??

where x de (i) is the denoised EOG signal and x(i) is the original EOG signal. signal to ratio calculated for different datasets. The results reveal that the blink detection technique used here has more specificity compared to sensitivity as it detects some extra blinks (False Positive). This blink detection procedure may also ignore the long blink that has very slow eyelid movement velocity. There is scope to design more reliable blink detection technique to detect blinks.

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Figure 1: Figure 1 :

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| Data set | SNRo | Blink Detection | | |
|---|---|---|---|---|
| | | Blinks | FP | FN |
| sc4002e0 | 35.00 | 04 | 00 | 00 |
| sc4012e0 | 32.02 | 03 | 01 | 00 |
| sc4102e0 | 30.08 | 03 | 01 | 00 |
| | Sensitivity=83% | | | |
| | Specificity=100% | | | |

V. Results and Discussion

EOG signals have been collected from Physionet databases [9]. EOG signals are taken from Physionet database [11].The original EOG signal is shown in Figure. 1 and the noisy EOG signal is shown in Figure

Figure 2: Table 1 :

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