Multi-Channel Electroencephalogram (EEG) Signal Acquisition and its Effective Channel selection with De-noising Using AWICA for Biometric System

B.Sabarigiri [#1], D.Suganyadevi [#2]

[#] Department of Computer Science,
Sree Saraswathi Thyagaraja College,
Pollachi, Tamilnadu, INDIA.
[1] sabarigiri.may03@gmail.com
[2] sugan.devi1@gmail.com

Abstract— the embedding of low cost electroencephalogram (EEG) sensors in wireless headsets gives improved authentication based on their brain wave signals has become a practical opportunity. In this paper signal acquisition along with effective multi-channel selection from a specific area of the brain and denoising using AWICA methods are proposed for EEG based personal identification. At this point, to develop identification system the steps are as follows. (i) the high-quality device with the least numbers of channels are essential for the EEG signal acquisition and Selecting the equipment and verdict the best portions on the scalp is the primary step. (ii) Scrutiny of the acquired EEG signals and de-noising from EMG, ECG, EOG Signals and power line artifacts using AWICA (iii) Obtain the features from the Enhanced EEG signals by Wavelet Transform (WT) and LS-SVM Classification in the MATLAB Environment. Based on the outcome, there is possibility for implementation of an EEG based Practical biometric system.

Keyword- AWICA Method, LS-SVM Classification, Electroencephalogram (EEG), MATLAB, Wavelet Transform (WT),

I. INTRODUCTION

Biometrics such as Fingerprints, Retina, Voice, Iris and Face are energetically used for Identifying Individuals. At the present time, Electroencephalogram (EEG) biometrics using brain signals have befall fascinating as Personal recognition tools. On behalf of that, to take out EEG signals from human Scalp are indispensable. There are techniques like electroencephalography (EEG), magneto encephalography (MEG), function magnetic resonance imaging (fMRI), and positron emission tomography (PET) have been utilized. Each technique has its own Pros and Cons. To scrutinize brain wave signals, Electroencephalography (EEG) Measurement is non-invasive and inexpensive, highly accurate recording method and it has an enviable property for exceptional time resolution and low cost of instrumentation.

The recorded brain waves that can be Processed (De-Noising, Feature Extraction, Classification and Matching) and used in access control systems (Unlock Doors, Get access to bank accounts, Biometric Passports, Access Computer Data and Entry restrictions) when security is needed. Whereas, using EEG for Biometrics has many advantages, (1) An Effective liveness Detection method [1], (2) EEG has an effective external force detection method to enhance the anti-spoofing capability of the existing biometric system to meet higher security requirement applications [2]. (3) EEG is hard to mimic, (4) EEG can be used as an excellent complementary modality to the existed biometric systems which are not easy to be forged. (5) No one can gain access to the brain waves, because it is safely protected inside the skull. (6) Our brain activities are changeable. So this is first changeable biometrics system [3]. The practice to mine the human brain information provides a new research prototype as EEG-Based Biometry. Idea about the “Pass-Thoughts” using as a biometry in the realistic applications is having various troubles. To launch the EEG based biometric system the price of the equipment, Time taken for the Signal mining from human skull, tolerability of the end user become a very big nuisance. However, So many researches and bulky amount of investments are rising progressively developing EEG Based systems for various applications. At this time, to investigate the feasible traditions to EEG Based Biometric in the real time deployment is highly essential.

This paper is organized as follows. Related work and the various devices are compared with each other and the method of EEG Signal Acquisition is proposed. Channel Selection and its discussions are reviewed in Section 2 and 3 correspondingly; Section 3 gives the artifacts removal technique using AWICA. Section 4, the feature Extraction and classification methods are described. Finally, in the section 5 and 6 provides analysis and discussions, conclusions respectively.

II. Related Work

EEG has biometric potential as they were able to discriminate between 40 subjects with 8 channels using auto regressive models with a correct classification rate of 82% [4], One channel of EEG from 75 subjects in one session provides 91% person identification [5], 61 channels 20 subjects 95% classification performance achieved [6], 4, 2, 1 combination of channels with different recording procedures, 5 separate session in 2 weeks described and 70% to 97% classification rates were produced [7]. 21 electrode locations and cost effective EEG recording system proposed in [8], From the 16 electrodes 4, 3, 2 combinations of electrodes were divided. 1820 four channel combinations, 520 three channel combinations and 120 two channel combinations were analysed Fp1, P3 and C4 are truly relevant locations efficiently used for personal identification [9] some other studies based on EEG authentication tool proposed in [10], [11].

III.EEG Signal Acquisition

While bearing in mind real time exploitation of EEG based biometrics, Low price devices for signal acquisition, uncomplicated mechanisms, and less time utilization are required. At this point the following devices were compared with diverse parameters.

TABLE I
Low Cost EEG Sensors and Its Comparison [12], [13], [14]

Name of the Device	Neuro Sky Mindset	EEG Emotive Epoc Neuro headset	Enobio
No. of Channels	1+1 References	14+2 References	8 (or) 20 Channels
Cost	$200	$1500	€3995(8 Channels) €12495(20 Channels)
Type of Signal Extraction	Brain Wave Only	EEG, Gyro, Facial Expression	EEG,EOG,EMG,ECG Signals
PC Connection	Available	Available	Available
Real time Data Exchange	Yes, But There is no Use in Project	Yes	Yes
Update Per Second	Only Once	Four Times per Second	16bit Per Second
Stability	Very Low	High	Very High
Affordability	Good	Good	Good
Time Taken for Setup the device	15 Seconds	2-10 Mins	2-10 Mins
Sampling Rate	Up to 512SPS	128SPS	500SPS
Usage in stages	Attention, Meditation	Expressive, Short Term Excitement, Meditation, Frustration Boredom, Cognitive	Meditation, Excitement, Expressive
Programming Source	Less Availability	Available	Available
Artifact Resilience	No	Yes	Yes

Neuro Sky Mindset has fixed position of Fp1 with only one Reference Channel. To design the Personal identification System a few number of channels required. So, Neurosky Mindset is not suitable to the EEG recording for biometrics. Real time revealing of blinks, left/right winks, Horizontal glances left/right, eyebrow raise, furrow, smile, smirk left/right, clench teeth, laugh and several Expressive, cognitive states can be recorded by far in EEG Emotive Epoc Neuro headset. In this projected system visual stimuli of self-images are used, it affects in the visual cortex area of the brain. Emotiv Epoc standard electrode position covers the visual cortex area using O1, O2, F7 and F8 locations. Moreover Emotiv has few limitation like setup time of the device, 16 sensors around head could construct player uncomfortable so that it's very tough to manage the brain waves perfectly. Conversely, Compare to Enobio it's less cost and covers 14+2 Electrode positions. From the analysis Emotiv Epoc EEG Headset performs better in programming, Comfortability level of an EEG headset is high enough, Wireless with Bluetooth, Fast data refresh rate, Real time data exchange and Data acquisition in the well-organized manner.

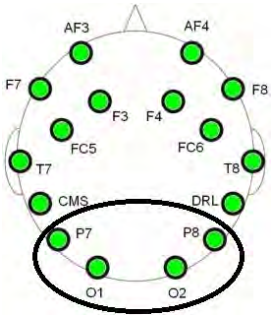

Fig 1: 14-Visual Cortex Electrode Position of EEG Epoc Neuroheadset

The EEG Measurements is obtained based on the Emotiv EPOC Research EEG neuroheadset in Fig 4: a 14 channel bio potential sensors with gold-plated connectors offer optimal positioning for accurate spatial resolution (plus CMS/DRL references, P3/P4 Reference Locations). 14 EEG channel names based on the International 10-20 locations are in Fig 1: AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4.

Fig 2: EEG Epoc Headset

The sampling rate of the emotive EEG headset is 128 Hz on the output (To ensure the precise output values, the Emotiv headset has the internal sampling rate of 2048Hz frequency) with 1.95 µv least significant bit (LSB) voltage resolution, Therefore it is possible to detect VEPs (Which can be beneficial to deduce latencies of electrical impulse exchange representing uniqueness of neural-wiring of subjects brains), since average amplitude for VEP waves falls between 5 to 10 microvolt's.

Fig 3: Subject Wearing Headset

Fig 4: Displaying self-Image using webcam and EEG Signals Acquisition through EEG Epoc Headset

The proposed method has also been tested by 32 healthy subjects (Students and Working employees) (20 males and 12 females) has been collected in order to evaluate the performance of our system. An informed consent along with a health related questions were raised and questionnaire was signed and filled by all subjects before the data collection. The subjects are asked to sit in a comfortable chair, to relax and be quiet. The background is set as white board and foreground is blue window screen. There are two laptops with good configuration were fixed in front of the subject showed in Fig 4. The first Laptop used for displaying Subject's own face using Webcam with high resolution camera. EEG Epoc headset is used to extract the Brain wave signals, and its High performance wireless automatically transfers the Signals to USB Dongle in the Second laptop. No custom drivers specially required for USB Dongle in this Extraction Process. To establish a good connection between the scalp and EEG electrodes, the saline liquid solution was put on every electrode before

each experiment. However it was necessary to redo the experimental procedures, after checking if the EEG data is valid or not for the further analysis.

IV. CHANNEL SELECTION

There are 256 electrode locations are accessible on the scalp. While allowing for all the 256 Locations for signal acquisition, the amount of features formed by the system is extremely huge. Preparing the device and Recoding 256 locations is further tedious process. According to the practical application, less number of channels should be used. Because, it reduce the time of recognition in the EEG based Biometry. EEG signals are predominantly strong while a person is bare to visual stimuli, and the visual cortex area of the brain on the reverse side of the head is the best place to measure brain-waves. Depends on the EEG Epoc Neuro Headset device, particularly focus given on the number channels used is 1, 2, 4 and 14.

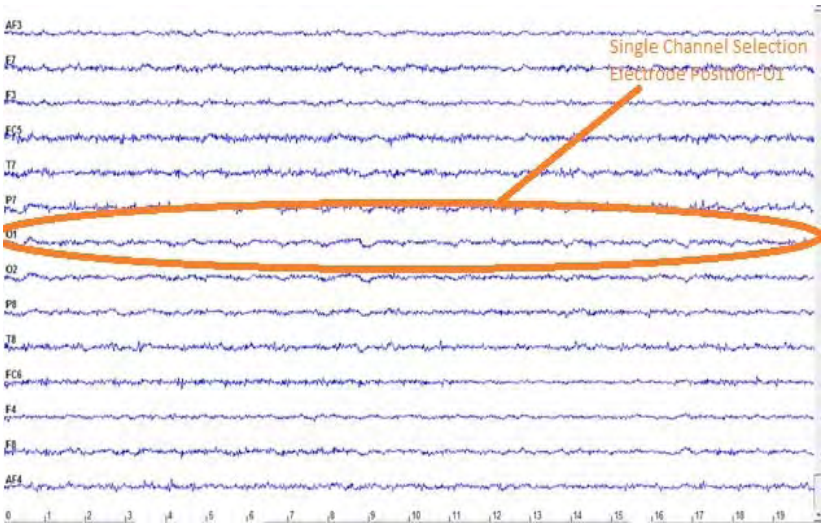

Fig 5: Single Channel Selection Plotted with Biosignalplot

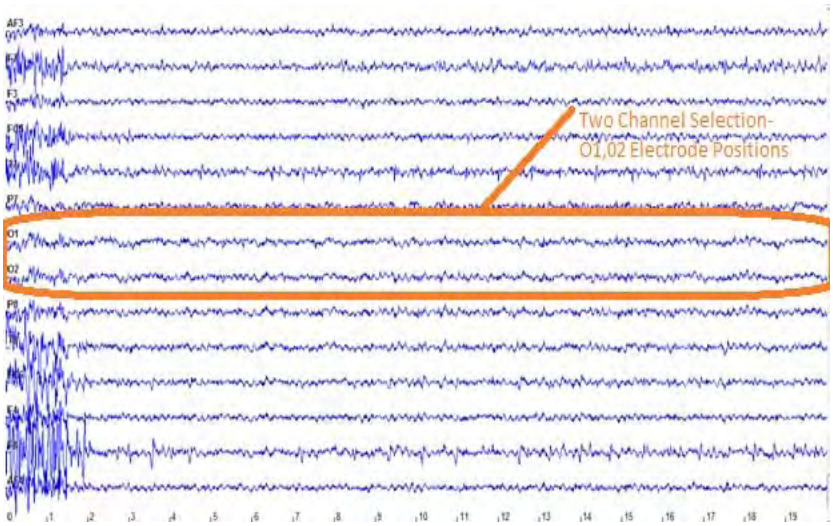

Fig 6: Two Channel Selection-O1, O2 Electrodes

Here, the system arranged to utilize the subjects and their own face as Visual stimuli. The Extracted EEG signals clustered according to where the surface electrodes placed on the Scalp. Mostly in our system has taken the Occipital and Parietal Channel Positions for Authentication. Normalized value of Signals used for Authentication. The channel selection is in table 1.

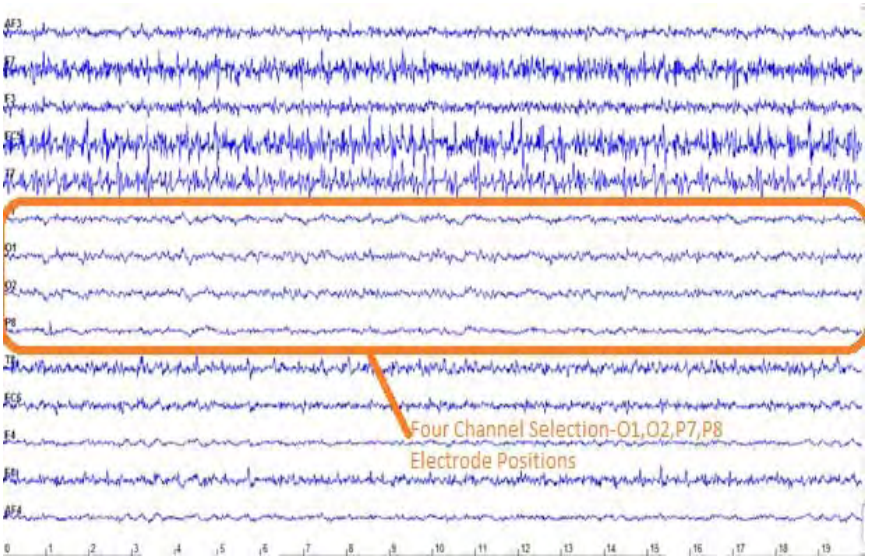

Fig 7: Four Channel Selection

V. Removal of Artifacts using AWICA

A. Artifacts Avoidance

Managing artifacts is to avoid their occasion by issuing suitable directives to users. Instructing individuals to steer clear of generating artifacts during data collection has the benefit that it desires less computational demand among the artifacts handling methods, since it is assumed that no relic is present in the signal. But it has a number of drawbacks.

First there is no leeway to stop our heart during the EEG signal extraction. Even in the case of EOG and EMG activities, it is not easy to organize eye and other progress activities during the data recording in our body. Second the amount of ocular and force activity during the online operation does not exist, and power line interference is also manifest. Third collecting possible amount of data mining will be less due to artifacts presents in the EEG signal, particularly in cases where a consumer has a neurological disability.

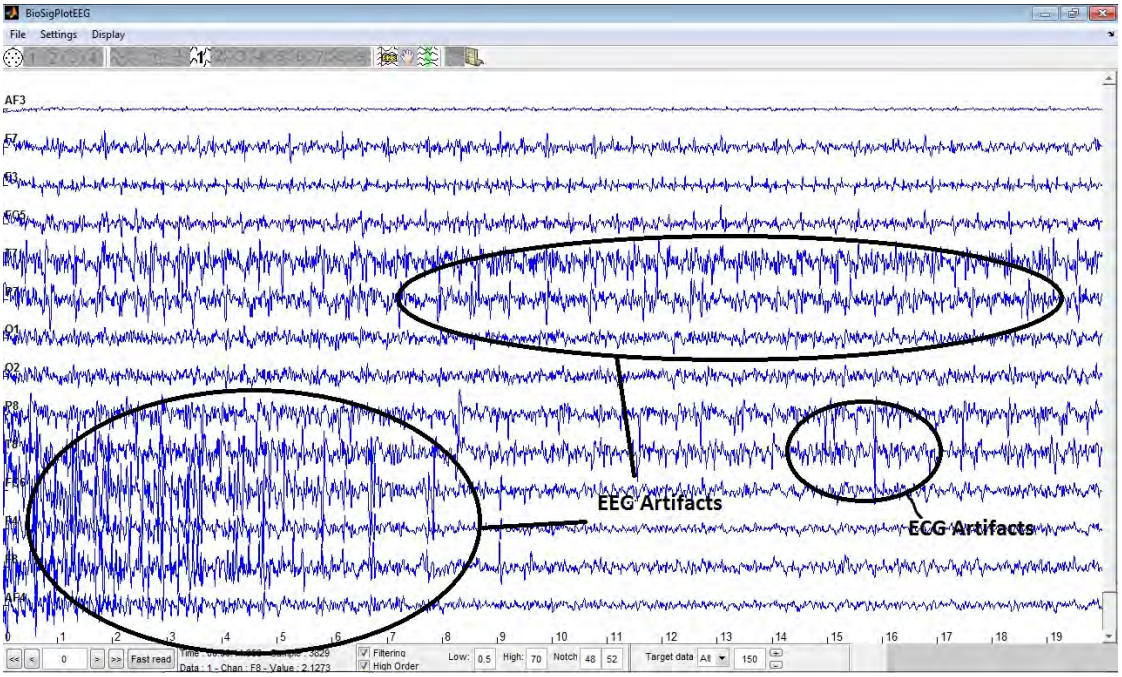

Fig 8: EEG Signal Contaminated with Artifacts and ECG Artifacts in EEG.

There are countless techniques were discussed by several Bio signal Researchers. The most of the proposed methods had a limited success rate. Some methods took more time to carry out the required computation work and others were very multifarious for practical applications. It is not easy to control eye and other progress activities during the data recording. Second the amount of ocular and influence activity during the online

operation does not exist. Third collecting adequate amount of data lacking artifacts may be difficult, particularly in cases where a consumer has a neurological disability. Each recording is a single two minutes EEG event. There are totally 32 Subjects X 5 Samples=160 Sessions in the data set. The EMG, a high frequency component, is due to the random contraction of muscles, while the sudden transients are due to impulsive movement of the body. This well known problem that appears in the recorded EEG as intrusion causes cruel problems in EEG illumination and assessment. To remove the EOG, EMG from the EEG, we required to order the artifacts and brain waves without changing important in turn of EEG activity. The occasion of electrical artifacts generated by eye movements, open and closing of eyes, blink infectivity produce a signal known as Electro-oculogram (EOG).

B. Cancelation of Artifacts

The proposed algorithm [15] combines the valuable ICA knack of sorting out artifacts from brain waves, mutually among the online interference (50Hz) termination achieved by adaptive filtering. Wavelet based de-noising used to extract the low frequency component in order to eliminate the High frequency component the EMG signal. The main steps of hybrid Pre-processing AWICA approach are the following.

Step 1: The extracted EEG data can be processed by adaptive filtering, which removes the power line interference, broken wire contacts and electrode impedance (50Hz and above).

Step2: To apply Wavelet Transform algorithm to 14 channels of the multichannel recordings separately. Finally, set of signals with different frequencies were obtained.

Step3: The base line was removed using wavelet decomposition and the signal was de-noised by wavelets.

Step 4: To identify and select the highly correlated artifact components and produce the new data set.

Step 5: To transfer the constructed data set to Independent Component Analysis (ICA) Block.

Step 6: To make the signal to be uncorrelated and apply the whitening in order reduces the dimensionality and to light the computational charge.

Step 7: To estimate the independent components and remove ones related to the artifacts.

Step 8: According to the sources ICA would split and cleaned the signals. The correlated EOG, ECG and EMG signals should be classified which will be eliminated using FASTICA.

Step 9: Finally, to perform the wavelet reconstruction by (7) using the non-selected details and cleaned details after ICA step; finally, we obtain the multichannel recordings in which the artifacts are removed.

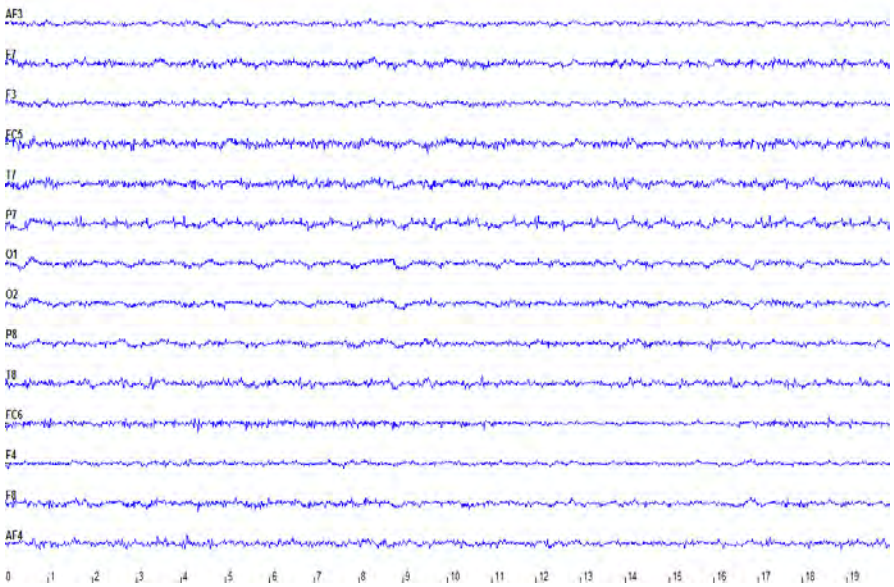

Fig 9: Default 14-Channel after Artifacts Removal using AWICA Method

VI. FEATURE EXTRACTION AND CLASSIFICATION

A. *Feature Extraction*

After Removal of artifacts signals are converted into vectors of extracted distinctive features that can be used for Human Identification System using EEG. An influential method was projected in late 1980's to perform time-scale analysis of signals: The Wavelet Transform, It is a mathematical microscope is used to analyse different scales of neural rhythms is shown to be a powerful tool for investigating small-scale oscillations of the brain signals. The wavelet decomposition of the EEG records, transients features are precisely capture and

localized in both time and frequency context. Last of all, The Wavelet Transform is an efficient feature extraction from non-stationary signals such as EEGs.

B. *Data Reduction*

It is reducing the amount of data generated after wavelet transform by without losing the Original in sequence of the signal features. All the data Reduction methods will lose some amount of useful data features on data reduction process. So now we required a new method to reduce the feature set but not leaving any features extracted from the EEG Signals. So, here we applied weighted mean to reduce the value but which is not leaving any feature vectors.

C.EEG Signal Classification

The Classification Performance is depends on Features which is supplied to the classifier. So, Improving the Feature Extraction and Feature Reduction Method will give the accurate classification Results for EEG Signals. The System will give only two results Authenticated/ Not Authenticated. So, The Least Square Support Vector Machine (LS-SVM) had been used.

VII. ANALYSIS AND DISCUSSIONS

First, Emotiv EPOC neuroheadset EEG signal is a non-invasive system and does not need any surgical involvement. But, it might take relatively long time to set up the Emotiv EPOC headset, which potentially makes the EEG authentication service impractical. Adjusting sensors on the correct locations by avoiding hair is making some troubles. So, Building the adjustable extraction device will solve this issue. In this proposed system requires only sensors, which are placed on a subject's scalp over the parental and occipital lobes, thus eliminating other sensors might moderately resolve the problem. Second, Emotiv EPOC device have 6 surface electrode placements in the parental and occipital lobes portions. Name of the locations are P3, P4, P7, P8, O1 and O2. In this P3 and P4 are reference locations, Therefore in our authentication system we tested with the following combinations (i) O1 (ii) O1 and O2 (iii) P7, P8, O1 and O2 (iv) all the fourteen channels. From the four combinations P7, P8, O1 and O2 channels producing enhanced results. Fig.7 shows that four channel selection without artifacts removal which provides excellent signal quality to the suitable self-image stimuli. Since, the investigational results, visual analysis of the brain wave signals producing unique patterns, hence practical implementation of an EEG-based biometric system is achievable.

TABLE 2: EEG SIGNALS LOCATIONS USED FOR AUTHENTICATION

Electrode Positions	No. of. Channels	Channel Positions on Scalp
O1	1	Occipital Lobe
O1,O2	2	Occipital Lobe
P7,P8,O1,O2	4	Parietal and Occipital Lobe
AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4	14	Default Channel With All 14 Positions

TABLE 3: NO. OF CHANNELS AND TAR, TRR AND ACCURACY OF PROPOSED SYSTEM

No. of. Channels	1	2	4	14
Accuracy (%)	95%	93%	97%	96%
True Acceptance Rate(TAR)	100%	100%	100%	100%
True Rejection Rate(TRR)	8.33%	5.13%	4.49%	3.84%
Time Taken for the Process (In Seconds)	5.09	6.49	7.62	16.98

VIII. CONCLUSION

The paper is consists of three main modules. (1) Low Cost EEG sensor selection and using that sensor to find the best locations to extort EEG signals using Visual stimuli and 2) Enhance the signal quality using AWICA and remove the artifacts. The realistic method for identifying accurately significant EEG Signals from fixed 14+2 Locations is proposed. The high-quality signals can be extracted from the visual parietal-occipital cortex of the brain. (3) The Wavelet Based feature extraction and LS-SVM classification Module for identifying individuals. Therefore, the channel selection is created and is set to acquire the data from the following four

EEG sensor locations: P7, P8, O1, and O2, based on the international 10-20 system. The AWICA was applied in order to remove the artifacts like ECG, EMG, EOG and Power Line Artifacts. The projected wavelet feature extraction and LS-SVM classification will necessitate improving further.

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