Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Diyala
College of Science

Enhancement of Brain Computer Interface System Based on A classified Blind Sources Separation

A Research
Submitted to the Department of Computer Science\ College of Sciences\ University of Diyala in a Partial Fulfillment of the Requirements for the Degree of Master in Computer Science

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2020 A.D **1441A.H**

بِسمِ ٱللَّهِ ٱلرَّحمنِ ٱلرَّحِيمِ

﴿قُلْ هُوَ الَّذِي أَنشَأَكُمْ وَجَعَلَ لَكُمُ السَّمْعَ
وَالْأَبْصَارَ وَالْأَفْئِدَةَ قَلِيلاً مَا تَشْكُرُونَ ٢٣
قُلْ هُوَ الَّذِي ذَرَأَكُمْ فِي الْأَرْضِ
وَإِلَيْهِ تُحْشَرُونَ ٢٤﴾

صَدقَ ٱللَّهُ العَظيم

سورة الملك

آيات (٢٣-٢٤)

Dedication

To...

My dear parents

My dear brothers and sisters

All our distinguished teachers those who paved the way for our science and knowledge

Zainab kadham Abees

Acknowledgment

First of all, praise is to GOD, the lord of the whole creation, on all the blessing was the help in achieving this research to its end.

I wish to express my thanks to my supervisors, ***Assist. Prof Dr. Taha Mohammad Hassan*** *and* ***Assist. Prof Dr.Ahmed Kareem Abdullah*** *for supervising this research and for the generosity, patience and continuous guidance throughout the work. It has been my good fortune to have the advice and guidance from them. My thanks to the academic and administrative staff at the Department of the computer sciences.*

I would like to express my gratitude to my father, my mother, my sisters and my brothers who were unlimited support and patience.

Finally, there are no words enough to thank my friends for being supportive and believing in me all the time and encouragement during the period of my study. Praise be to God Who helped me and gave me the ability and power to perform and complete my thesis.

Zainab Kadham Abees

Supervisor's Certification

*We certify that this thesis entitled "**Enhancement of Brain Computer Interface System Based on A classified Blind Sources Separation**" was prepared under my supervision at Department of Computer Science\ College of Sciences\ University of Diyala in a partial fulfillment of the requirements for the degree of **Master of Science in Computer Science.***

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Linguistic Certification

I certify that this thesis entitled **"*Enhancement of Brain Computer Interface System Based on A classified Blind Sources Separation* "** *was prepared by* ***Zainab Kadham Abees*** *And was reviewed linguistically. Its language was amended to meet the style of English language.*

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We certify that we have read the thesis entitled ***"Enhancement of Brain Computer Interface System Based on A classified Blind Sources Separation"*** *and as examination committee, examined the student* ***"Zainab Kadham Abees"*** *in the thesis content and that in our opinion, it is adequate as fulfill the requirement for the Degree of Master in Computer Science at the Computer Science Department, University of Diyala.*

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Abstract

In the past ten years, there was a considerable advancement in researches that concern with brain-computer interfaces (BCI) system for providing new quality to interactions between humans and machines. BCI as a communication system that is developed for allowing individuals experiencing complete paralysis sending commands or messages with no need to send them via normal output pathways of brain. The presented study has the aim of being a reference in the field of BCI by presenting the fundamental knowledge concerning the waves of the brain and their measuring, and also emphasize on chosen algorithms which are capable of separating and classifying task-related Electro-encephalography signal (EEG).The task is the motions of the index finger of right or left. The separation process based on hybridization between the classical method represented by the filtering process and modern method represented by Stone's blind source separation technique (SBSS) .The proposed method is able to separate artifacts as Electrocardiography(ECG),electromyography (EMG), electrooculography (EOG) and power line (LN) into individual components. This separating would effectively speed up classification patterns of EEG. Task-related signals of the EEG were taken resulting from separation algorithms and classified using two classifiers (Naïve Bayes and Hoeffding Tree) and compare proposed system with other systems used other blind source separation algorithms such as Fast Independent Component Analysis (FICA), Joint Approximation Diagonalization of Eigenmatrices (JADE). The proposed algorithm is tested and trained with the use of real recorded signals of EEG measured according to the International system which has been termed as the ten-twenty and has been obtained from computerized systems of EEG. The results obtained indicate

that ;the proposed system has high average precision rate compared to other existing methods. Where it (82%) average precision rate using stone with Naïve Bayes, and average precision rate using stone with Hoeffding Tree is (82%).

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List of Abbreviations

Abbreviations	Meaning
AC	alternating current
BCI	Brain Computer Interface
BPF	Band-pass filtering
BSS	blind source separation
CA	Classification accuracy
CLT	central limit theorem
CVFDT	Concept-Adapting Very Fast Decision Tree
DC	direct current
DOC	disorders of consciousness
ECG	Electrocardiography
ECoG	Electrocorticography
EEG	Electroencephalogram
EMG	electromyography
EOG	electrooculography
F, T, C, P, O	frontal, temporal, central, parietal and occipital
FICA	Fast Independent Component Analysis
FIR	finite impulse response
fMRI	Functional Magnetic Resonance Imaging
FN	False negative
FP	False positive
HOS	higher-order statistics
HT	Hoeffding Tree
ICA	independent component analysis
JADE	Joint Approximation Diagonalization of Eigenmatrices
LN	power line
MEG	Magnetoencephalography
MRI	Magnetic resonance imaging
NB	NaiveBayes
NIRS	Near Infrared Spectroscopy
NN	Neural Network
PCA	Principal component analysis
PET	positron emission tomography
SBSS	stone blind source separation
SNR	Signal-to-noise ratio
SOS	second-order statistics
TCP/IP	Transmission Control Protocol and the Internet Protocol
TN	True negative
TNR	True negative rate
TP	True positive
TPR	True positive rate

Symbols Table

Symbol	Meaning
δ	Delta rhythm
θ	Theta rhythm
α	Alpha rhythm
β	Beta rhythm
γ	Gamma rhythm
μV	microvolt
mV	millivolt
Sˆ	estimated sources

List Algorithms

Chapter One

Introduction

Chapter One
Introduction

1.1 Over View

Brain Computer Interface (BCI) is defined as a software and hardware system of communication. BCI enables the individuals to have some sort of interaction with their environments, with no participation of the muscles and peripheral nerves, novel non-muscular channel is used via the BCI for relaying the intentions of individuals to external devices like neural prostheses, speech synthesizers, computers, and assistive appliance. Persons with extreme motor disability are the major target of such system, since the system is assumed to decrease the costs of their care and enhance their life quality. BCI is considered as an AI system which have the ability of recognizing a specific sequence of patterns in the signals of the brain following 5 successive phases: signal acquisition, pre-processing or signal improvement, feature extraction, classification, and control interface [1].

The disabled patients are majorly assisted via using this system. The system of BCI require analyzing, assessment, observing and measurement regarding the electrical activity of the brain. These necessities will be obtained via electrodes which are implanted in the brain or electrodes that have been set on the scalp. One type of the signals of the brain is EEG signals. The classification regarding EGG is achieved according to the frequency which 5 major types: (Delta rhythm δ that is between the frequency range 0.5-4 Hz, Theta rhythm θ that is between (4-7) Hz, Alpha rhythm α that is between (8Hz-13Hz), Beta rhythm β that is between (13Hz -30Hz), Gamma rhythm γ that is over 25 Hz) [2] [3] [4].

The EEG signals are captured via Brain Computer Interface along with certain activity of the individual, after that it utilizes various algorithms of signal processing for the purpose of translating the records to control commands for various machine and computer applications. It is a fact that the intentions of the individual can be effectively represented via signals which have been recorded from the brain activity [5] . EEG signal is one of the most widely used signals in the bioinformatics area because of its rich information about human activity. The Electroencephalogram (EEG) has been an important clinical tool to assess human brain activity [6].

There is some sort of mixing between the signals of the brain with other signals which are obtained from finite set of activities related to the brain which overlap in space and time. Furthermore, the signals are not typically stationary, also they could be distorted via artefacts like electrooculography (EOG) and electromyography (EMG). The dimension of the feature vector should be low, for reducing the complexity of feature extraction, yet with no significant loss of information. The classification stage signals taking into account the feature vector. Thus, choosing optimum discriminating features very important for achieving efficient pattern recognition, for the purpose of deciphering the intentions of the users. Lastly, the phase of control interface operate by translating classified signals to important commands for the connected devices, like computer or wheel chair [7].

In the year 1999, BCI had been introduced in the first international conference which had been dedicated to BCI studies held in Rensselaerville Institute near Albany, New York, it has been identified in the following way: ("A BCI is a communication system that does not depend on the brains normal output pathways of peripheral nerves and muscles"[8].

1.2 Related Works

Several researchers have shown their interest in BCI since the importance of the system lies in many applications, such as medical applications especially to assist people with disabilities as their assistance Dealing with computers or helping people with Syndrome In-Locked communicate with the External world , and advertising applications, educational applications and security applications; The following are some of the published works that are related our:

- ***Salim 2007***[8]: that researcher Used the algorithms to separate and classify the EEG signals related to the movement of the left index finger or the right finger index finger.For the separation process they used the independent component analysis algorithm .This separation increases the speed of classification of electrical brain electrical signals, and the signal is classified by using the adaptive pattern class consisting of combing Kohonen map Self-Organizing (SOM) with Quantitative Learning (LVQ),The recognition rate was 75% and 53% .
- ***Mousa, El-Khoribi, and Shoman 2015*** [2]: The researchers developed a novel EEG signal analysis method. They used a high pass; filter to remove artifacts and also DWT algorithms for the feature Extract like Mean Absolute Value, Root Mean Square and Simple Square Integral. Clustering the feature vectors by using KNearest Neighbor algorithm and then use the neural network algorithm to find the correct label for the EEG signal class after clustering. The results of this proposed method outperform better than the methods mentioned in the literature. a FKNN classifiern gave a poor accuracy comparing to the results when we used a proposed method that gives us 81.8% accuracy than FKNN that gives us 61.1% accuracy.

- ***Pan, Li, and Wang 2016.*** [9] ***:***They suggested EEG-based BCI system that was used to identify emotions to detect two emotional states of happiness and sadness. The selection of frequency bands played a vital role in the differentiation of emotion-related brain patterns. They discovered a new way of identifying appropriate frequency bands for the subject rather than using fixed frequency bands to identify emotions. Where a common spatial pattern and vector support were used to classify two affective states. They began two experiments involving six topics to verify method as well as the BCI system. The average accuracy of the Internet achieved 74.17% for two categories. The results of the data analysis indicated that the suggested method based on the specific frequency bands of the subject gave higher results than the method based on fixed frequency bands.
- ***Anh et al. 2016***[10]***:*** The researchers had recorded the EEG signals from 4 individuals as they were going through various mental states. Their study was introduced ANN-based method to classify EEG signals into various mental states that were considered to be corresponding to various control commands for the implementation of Brain Computer Interface. The inputs for ANN are the spectral features which are dimensionally decreased through PCA. The experimental results have outperformed the other classifiers (K-NN, Naïve Bayesian, SVMs, and LDA) in the data set of EEG with highest classification results on dual and triple mental state problems of 95.36% and 76.84%, respectively.
- ***Bhaduri et al. 2016*** [11]***:*** The researches had used feature extraction approach and classifier. Pre-processing regarding EEG signals are implemented and the related features will be extracted. After that, the extracted features will be utilized for classifying right and left imagery movements via Naïve-Bayes and K-NN. The optimum accuracy for

classification was recorded via K-NN for the power spectral density feature set necessitating a time of 0.0531 seconds.

- ***Abiyev et al. 2016*** [12]***:*** this study talk about BCI for Control of Wheelchair Using Fuzzy Neural Networks .They used a Fast Fourier Transform(FFT) to extract important features from the EEG signal. Then the extracted features are input signals of the FNN based classifier, they found that using FFN is very effective in the classification of EEG signals. accuracy of FNN classification model is 100%.
- ***Kucukyildiz et al. 2017***[13]***:*** Researchers had suggested designing and implementing multi-sensor-based BCI. The created system consisted of EMG and EEG sensors, Kinect camera, wheel chair, computer, and motor controller card of high-power. Initially, ANNs, SVMs, and random forest methods are utilized to classify the EMG data. There are 3 cognitive tasks: relaxing, math problem solving, text reading which are specified for the system's EEG based control. The subjects have been required to carry out certain cognitive tasks for the purpose of controlling the wheel chair. The average specificities of ANN, SVM, RF and the proposed classifiers were 0.767, 0.899, 0.828 and 0.904, respectively. Besides having the highest sensitivity, the proposed scheme also had the highest specificity
- ***Azhar et al., 2017***[14]***:***Non-invasive EEG data from a healthy subject of right-hand movement were processed by using two feature extraction algorithms on the basis of independent component analysis (ICA) using coefficient of determination. Results by using the proposed ICA algorithm showed compatibility with the results obtained based on Independent Component Analysis (ICA) method written in MATLAB platform. by "EEGLAB".

- ***Kim, Kwak, and Lee 2018***[15]***:*** researchers utilized conventional electrodes which were attached around the ear in a distance of 1.5 cm from the ear. The researchers had classified 2-class MI tasks through the use of ear-around EEG. Furthermore, They had suggested common spatial pattern (CSP)-based frequency-band optimization algorithm and put it to comparison with 3 present approaches. The optimum results of classificants for 2 data sets were 71.8 percent and 68.07 percent, respectively.
- ***Wu et al. 2018*** [16]***:*** The researchers performed preprocessing of EEG signals in the computer brain interfaces (BCI) which have been simply contaminated via noise and artifacts by using mysterious groups which collected 143 session related to the important motor vigilance data from seventeen subjects in 5 months, prior being presented to the algorithm of machine learning for regression or classification. Using spatial filters for increasing the SNR of the EEG, the researchers suggested candidates for CSP regarding the EEG-based regression problems in BCI, that is extending from CSP filter to classification. The results have indicated that the quality of EEG signals could be increased via the suggested spatial filters. When utilized in LASSO and assessed k gradient(KNN) for estimating the speed of the user's response. the spatial filters can reduce the root mean square estimation error by 10.02 − 19.77%, and at the same time increase the correlation to the true response speed by 19.39 − 86.47%.
- ***Taran et al. 2018***[17]**:** The researchers proposed analytic intrinsic mode functions (AIMFs) to classify the EEG signals that are related to various MI tasks. The following features: raw moment related to the first derivative of the instantaneous frequency, area, spectral moment that is related to the power spectral density, and PSD's peak

value are estimated from AIMFs. For reducing the classifier's biased nature, the features will be normalized. The normalized features have be utilized as inputs for the least squares support vector machine (LS-SVM). The system presented by this study has better performance than state-of-the-art approaches. The radial basis kernel function for IMF1 provides better MI task classification accuracy 97.56%, sensitivity 96.45%, specificity 98.96%, positive predicted value 99.2%, negative predictive value 95.2%, and minimum error rate detection 4.28%.

- ***Gonzalez et al. 2018***[18]***:*** They presented a system which has 3 major phases: organizing the EEG signals, feature extraction, and executing the classification algorithms. There are 4 motor actions represented via the utilized EEG signals: Right Hand, Left Hand, Foot, and Tongue movements, in the context of Motor Imagery Paradigm. The phase of feature extraction has been implemented through utilizing the CSP algorithm as well as a statistical approach which is referred to as Root Mean Square (RMS). The utilized classification algorithms are: K-NNs, SVMs, Multi-layer Perceptron (MLP), and Dendrite Morphological Neural Networks (DMNN). The algorithm has been utilized in the recognition between 4 classes of MI tasks. Subject 1 - 93.9 percent and Subject 2 - 68.7 percent.
- ***Buvaneash and John 2018***[19]: The study discuss the recorded EEG signals from the scalp of the subjects via noninvasive electrodes. Time-Frequency (TF) analysis approaches have been utilized for the purpose of extracting the features from EEG signals. ANN machine learning algorithm has been utilized as a classifier for learning EEG signals features for efficient classification of the output. They study presented performance analysis regarding the system's precision for