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COGNITIVE APPROACH TOWARDS DETECTING HUMAN EMOTIONS ALONG WITH ROBOT CONTROL USING BRAIN COMPUTER INTERFACE

Naren K[1], Ritesh Kumar[2], MD Amir[3], Manjunatha Siddappa[3], Ravikumar K M[4]

[1,2,3]Student, Department of Electronics and Communication, SJCIT, Chikkaballapur, Karnataka, India
[4]Assisstant Professor, Department of Electronics and Communication, SJCIT, Chikkaballapur, Karnataka, India
[4]Principal, SJCIT, Chikkaballapur, Karnataka, India

Abstract – *Brain computer Interfaces (BCIs) are systems that can bypass conventional channels of communication to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into signal commands in real time. However, it is essential to establish methods to recognize the brain state accurately in order to implement BCI, and a number of challenges still remain. Emotions are intrinsic to the way humans are interacting with each other. A human being can understand the emotions of another human being to a certain extent and behave in the best manner to improve the communication in a certain situation however a machine cannot. Using EEG-based emotion detection, the computer can literally observe the user's mental state. The applied domains for these studies are varied, and include such fields as communication, education, entertainment, and medicine.*

As a result of various forms of illnesses or accidents such as spinal cord injury (SCI) or a form of motor neurons disease or ALS, many people suffer from a severe motor function loss and are forced to accept a reduction in the value of life, depending on the care of others. BCI can provide logistic support to those suffering from said disease.

The intention of project paper is to develop a novel BCI system that accurately detects and isolates emotions into valence and arousal states and to develop a novel BCI based robot which can be used as a wheelchair to assist the disabled people in their daily life to do some work independent of others

***Key Words*: EEG, BCI, SVM, KNN, DEAP Dataset**

1. INTRODUCTION

The human brain is formed by the billions of neurons which are interconnected among themselves; the interaction between these neurons are represented as thoughts and emotional states. For every interaction between neurons a minuscule electrical discharge is created; alone these charges are impossible to measure from outside the skull. However, when the activity is created by hundreds of thousands simultaneous discharges, it is aggregated into waves which can be measured.

As a result of different patterns of neural interaction, it can be classified into different brain states. These patterns lead to waves characterized by different frequencies and amplitudes called EEG waves. EEG waves are mainly of 5 types which are as follows: Delta waves (0.5 to 3 Hz), Theta waves (4 to 7 Hz), Alpha waves (8 to 12 Hz), Beta waves (12 to 30 Hz) and Gamma waves (above 30 Hz). These are

Brain Computer interfaces (BCI) use the different variations in these EEG waves to communicate with external assistive devices. The BCI system should also be able to classify different EEG signals of brain activity as accurately as possible and the BCI user should learn to produce distinct brain signals to perform the different task. The robot mentioned in this paper can be used as a stepping stone to create wheelchair and other assistive devices.

Several measures have been devised for classifying the human emotion. Such classification is generally divided into two perspectives namely Dimensional and Discrete perspectives. Discrete perspectives analyses emotion in a way that every specific emotion (e.g. fear, sad, happy, etc.) maps to its own unique parameter of environment, physiology and behavior. In Dimensional perspective, human emotions are organized in few fundamental dimensions. The most commonly assumed dimension is arousal and valence proposed by Russell in his bipolar model of emotion classification. In this dimension, valence represent from negative to positive whereas arousal represent from not excited to aroused or dull to intense.

2. OBJECTIVE AND PROBLEM STATEMENT

The main goal of BCI is to enhance the communications between the people and computers. Since the greater part of computers are not able to understand the person's emotion, most of the time they can't react to the person's needs naturally and accurately. So, here we worked on detecting emotions (Valence and Arousal) efficiently by working on the pre-processed data obtained from DEAP database to detect the state of mind of a person.

Independent mobility is core to being able to perform activities of daily living by oneself. Millions of people around the world suffer from mobility impairments and hundreds of thousands of them rely upon powered wheelchairs to get on with their activities of daily living However, many patients are not prescribed powered wheelchairs at all, either because they are physically unable to control the chair using a conventional interface, or because they are deemed incapable of driving safely. For some of these people, non-invasive BCIs offer a promising solution to this interaction problem. In this project along with detecting emotions, we have also developed a cost effective BCI robot which can be used as a wheelchair that will help the physically challenged to lead an independent life with the help of their brain signals.

3. METHODOLOGY

This project consists of two phases one for detecting human emotions and next for controlling the robot. Not only can BCI be employed to mentally control devices/robots, but it can also be implemented for understanding our mental states. Emotion recognition algorithms potentially bridge the gap between human and machine interactions.

3.1 BCI based Robot Control

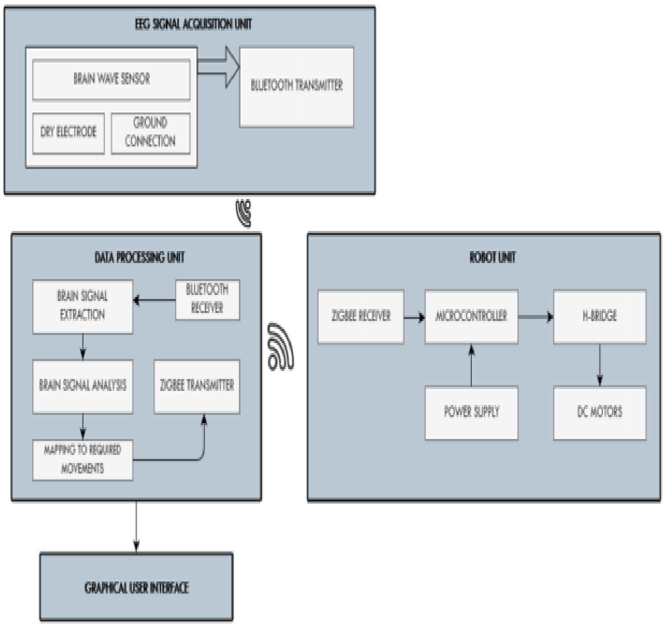

Fig-1: Block Diagram of BCI based Robot Control

The proposed system for robot control contains three main subsystems, the EEG signal acquisition device, the data processing unit and the robot. The EEG signal acquisition device used here is a Neurosky MindWave sensor. It is non-invasive single dry electrode that consists of a headset, an ear-clip, and a sensor arm. The headset's reference and ground electrodes are on the ear clip and the EEG electrode is on the sensor arm, resting on the forehead above the eye (FP1 position). It safely measures and outputs the EEG power spectrums (alpha waves, beta waves, etc), NeuroSky eSense meters (attention and meditation) and eye blinks via Bluetooth to the signal processing unit. For the purpose of our project we use NeuroSky eSense meters and eye blinks only.

The data processing unit here is a computer/laptop. The data is then received by the computer from the MindWave sensor via Bluetooth. The received data is in the form of attention, meditation and eye blink values all which range from 0-100 depending on the strength. The Attention Meter algorithm indicates the intensity of mental "focus" or "attention, the Meditation Meter algorithm indicates the level of mental "calmness" or "relaxation" and for the eye blinks a higher number on the 0-100 scale indicates a "stronger" blink, while a smaller number indicates a "lighter" or "weaker" blink. These processed values are then sent over to the robot via a ZigBee transmitter. The graphical user interface is designed using the computer as well.

The robot consists chiefly of a microcontroller (AT89S52), H-bridge, and DC Motors. The microcontroller is programmed in such a way that for certain values of eSense meters, the robot will move in a required direction, here we made it such that for high Attention values it will move forward, moves backward for high Meditation values and using Eye blinks to stop the robot.

3.2 Emotion Detection

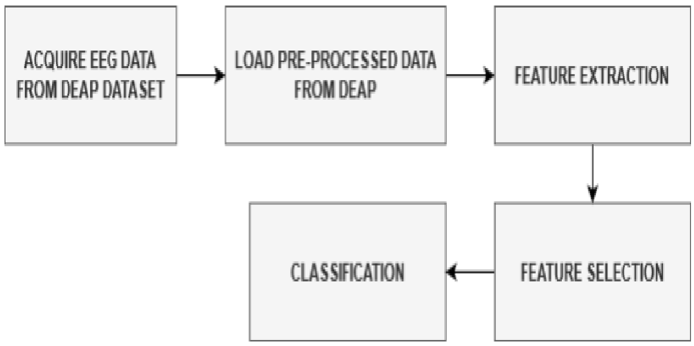

Fig-2: Block Diagram for Emotion Detection

The proposed methodology for emotion detection is outlined as follows:

3.2.1. Data Collection and Pre-Processing

Here we have used the Dataset for Emotion Analysis using EEG, Physiological and Video Signals (DEAP). The DEAP dataset observed the physiological responses of 32 subjects as they watched one-minute extracts of 40 music videos. Following each video, the subject would rate the video on a scale of 1-9 based on their feelings of arousal, valence, dominance, and liking. During the experiment, the EEG signal was obtained from 32 different channels placed according to the international 10-20 system

The preprocessed EEG data from DEAP was used This enabled us in applying classification algorithms without worrying about the preprocessing phase. Some of the preprocessing done include downsampling the data from 512 Hz to 128 Hz, removing EOG artefacts and filtering the frequency from 4 to 45 Hz using a bandpass filter

3.2.2. Feature Extraction

The Toolbox for Emotion Analysis using Physiological signals (TEAP) was used to load the data and extract statistical features from it. The statistical features include mean, median, standard deviation, skewness and kurtosis In addition, the signals' Power Spectral Density (PSD) for each frequency band, the energy, entropy, and fractal dimensions were obtained for these signals. A total 13 features were extracted from EEG signals.

3.2.3. Feature Selection

Afterwards, a subset of the features that correlate to the labels for valence and arousal were selected using a combination of Sequential Forward Selection (SFS) and Sequential Backward Selection (SBS). The criterion for SFS and SBS was the ratio of error in the classification with a selected subset of features using Quadratic Discriminant Analysis (QDA). SFS algorithm starts with the feature that results in the smallest criterion value, and it stops when the criterion value increases. In contrast to SFS, SBS starts with calculating the criterion for all the features then it keeps dropping one feature at a time until the criterion value increases. Both algorithms were applied on the features, and the combinations of features that produced the lowest criterion values were selected.

3.2.4. Classification

The selected features were then used to train KNN and SVM classifiers. Two classifiers for each type were trained: one for arousal detection (high or low) and one for valence detection (high or low). All the classifiers were trained using K-fold cross-validation with a K value of 10. The KNN classifiers were trained with varying values of K, and the K value that had the best performance was 1000 for both arousal and valence. The SVM classifiers were tested with linear and radial basis function (RBF) kernels. The average accuracy for each classifier and the training time were then recorded and compared.

4. HARDWARE AND SOFTWARE REQUIREMENTS

4.1 Hardware components

4.1.1 MindWave sensor:

The Mind wave sensor is a device for monitoring electrical signals generated due to neural activity in the brain. The device is worn on the head and consists of a headband, an ear-clip, and a sensor arm containing the EEG electrode where it rests on the forehead above the eye.

4.1.2. Signal processing unit:

For the robot control, a computer is used as a signal processing unit. It should have the following minimum specifications: -

- Windows 7 SP1, Windows 8.1 or Windows 10 (version 1507 or higher)
- 1.8 GHz or faster processor. Dual-core or better recommended
- 2 GB of RAM; 4 GB of RAM recommended

4.1.3. Zigbee:

ZigBee is an IEEE 802.15.4 based specification for a suite of high-level communication protocols. One of the main reasons for using ZigBee is its extremely low power consumption. Despite that, it has a long reach.

4.1.4. Micro-Controller

AT89S52is an 8-bit microcontroller and belongs to Atmel's 8051 family. ATMEL 89S52 has 4KB of Flash erasable and programmable read only memory (PEROM) and 128 bytes of RAM. It is erasable and programmable to a maximum of 1000 times. In the 40 pin AT89S51, four ports are designated as P1, P2, P3 and P0. All these ports are 8-bit bi-directional ports, which can be used as both input and output ports.

4.1.5 H Bridge and DC Motors

Two DC motors and a H-bridge are then used to form the robot prototype where control signals from the H-bridge circuit are sent to the motors. A H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction i.e. essentially changing the polarity of the DC motors so that is can run in both directions allowing it to move either front or back

4.2 Software Components

4.2.1 Keil Ide v5

It is an IDE developed by MicroVision which combines project management, runtime environment, source code editing, and program debugging in a single powerful environment. Micro vision is easy to use and accelerates the embedded software development. Micro vision supports multiple screens and allows us to create individual window layouts anywhere on the visual surface.

4.2.2 Willar Program Loader

It is software that is used to burn .hex file from the laptop or a computer to the particular microcontroller. It works on windows XP, Vista and Windows 7. It has got an on board 40 pin ZIF socket for the target IC.

4.2.3 Microsoft Visual Studio 2017

For designing the GUI for robot control we used Visual Studio 2017. It is an integrated development environment (IDE) developed by Microsoft which is mainly used to develop computer programs for Windows OS among other uses.

4.2.4 Matlab R2019b

Matlab is a powerful tool which integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: having built-in editing and debugging tools, and supporting object-oriented programming. Along with MATLAB, two toolboxes were used: EEGLAB and TEAP

EEGLAB is a MATLAB toolbox mainly for processing continuous and event related EEG, MEG and other electrophysiological data. TEAPhysio the Toolbox for Emotion Analysis using Physiological signals, is another MATLAB toolbox used in EEG experiments.

5. RESULTS AND DISCUSSION

The variations of the meditative and attentive levels of the subject at different intervals has been shown in the form of graphical data interface. The design made is interfaced with the code in such a way that, the states of mind is mapped with the micro-controller codes. According to the state of mind maintained, we can control the movement of the robot in forward or backward direction.

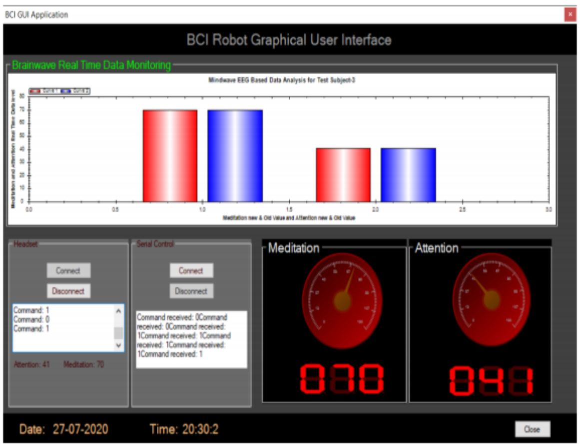

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Fig-5: Brainwave Graphical Data Interface

The Robot Prototype is given below: -

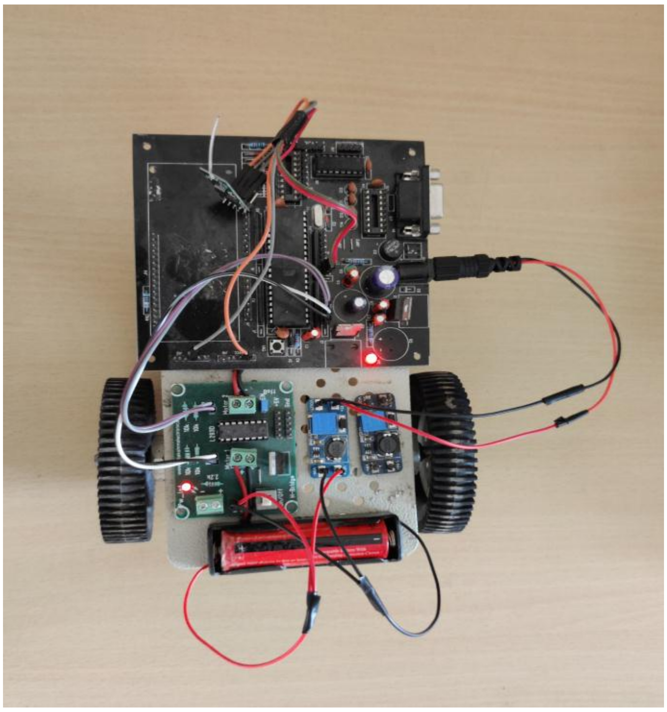

Fig-6: Robot Prototype

The results obtained from during emotion detection have been summarized in figure 7, 8 and 9, each of the classifier's functions at a prediction accuracy between 50-60%. Since all 3 of the classifiers are heavily dependent on the extracted features, they all performed comparably. Regarding Figures 7 and 8, the optimal classifier would appear in the top left corner of the scatter plot. A classifier present in this position would convey a high accuracy with a short training time.

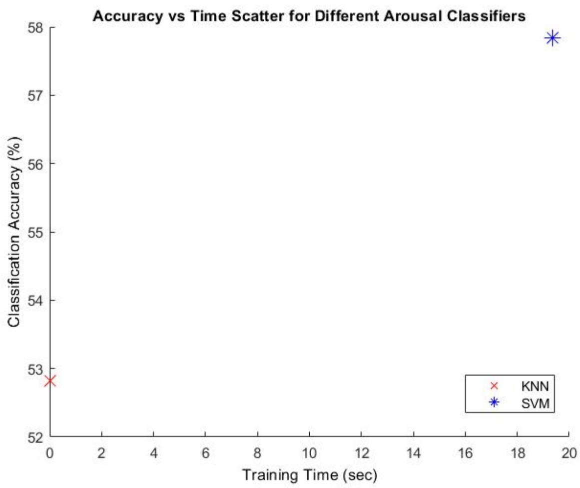

Fig-7: Accuracy vs Time for Arousal Classifiers

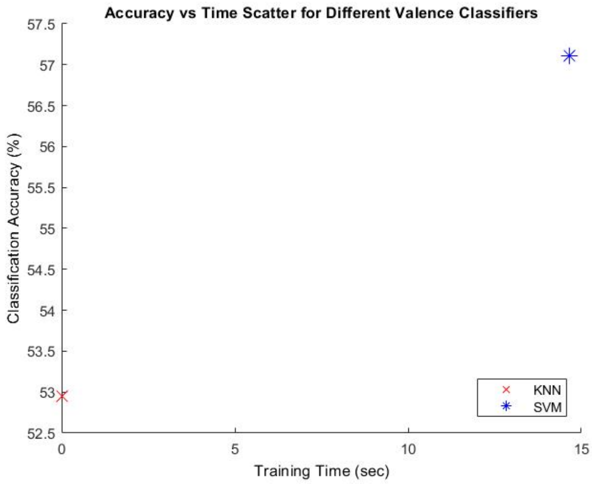

Fig-8: Accuracy vs Time for Valence Classifiers

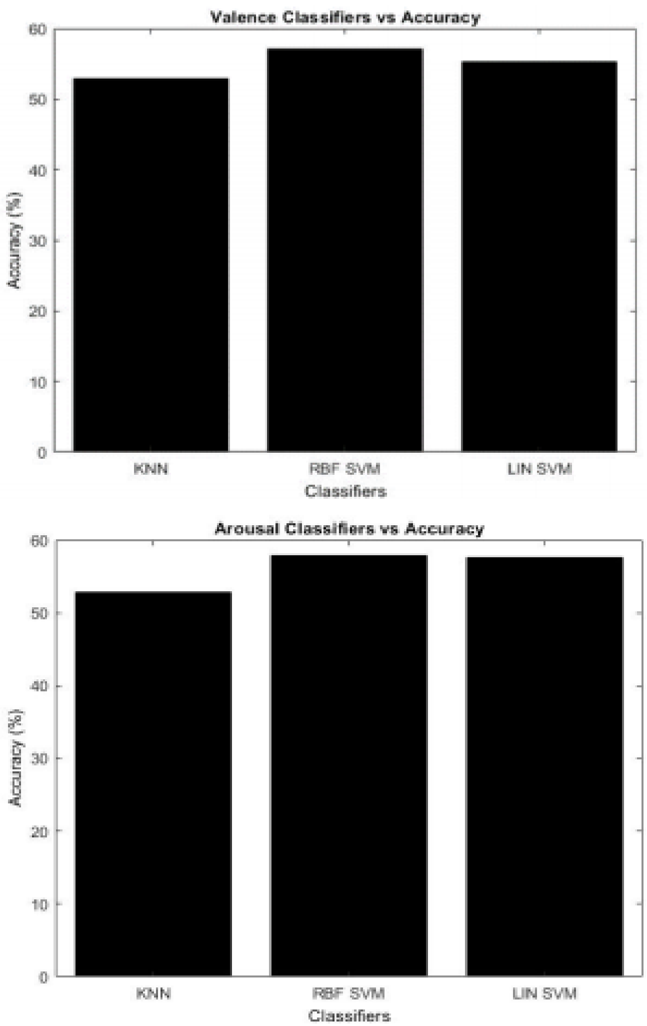

Fig-9: Accuracy of various classifiers for valence and arousal detection

6. APPLICATIONS AND ADVANTAGES

6.1 Applications

- Provide disabled people with communication, environment control and movement restoration.
- Provide enhanced control of devices such as wheel chairs, vehicles or assistance robots for people with disabilities.
- Provide additional channel for control in computer games.
- Monitor attention in long distance drivers or aircraft pilots, send out alert and warning for aircraft pilots.
- Develop passive devices for monitoring function such as monitoring long-term drug effects, evaluation phycological state
- Develop intelligent relaxation devices.
- Create a feedback loop to enhance the benefits of certain therapeutic methods
- Monitor stages of sleep

6.2 Advantages

- Cost effective and portable.
- Non-invasive BCI is easy to wear and has no issues of scar tissue formation.
- Mapping of brain signals to corresponding motor movements
- Less power consumption
- Relatively fast in training in classifiers
- Good accuracy in emotion detection

7. CONCLUSIONS

Brain-Computer Interface (BCI) is a method of communication based on voluntary neural activity generated by the brain and independent of its normal output pathways of peripheral nerves and muscles. The neural activity used in BCI is recorded using noninvasive techniques by a MindWave sensor and we managed to move the robot in two directions, forward and reverse while using Eye Blinks to stop the robot.

For emotion detection we managed to train and compare multiple classifiers on the EEG signals from the DEAP dataset. However, many challenges were identified with this classification problem. The most significant challenge with this problem is in the feature extraction phase. The features extracted for this problem displayed no signs of interclass separability for valence or arousal detection. These features were chosen based on the previous work done on the DEAP dataset. All the classifiers demonstrated here rely on the extracted features, and in order to obtain better classification results, a breakthrough in feature extraction will need to be achieved.

Another challenge that was identified is the shortcomings of the TEAP toolbox. It was observed that TEAP is specifically tailored for the DEAP dataset and most of the functions from TEAP were hardcoded for it. This did not affect the classification here but the lack of a toolbox that can generalize to different datasets can hinder the advancements in emotion classification based on physiological signals.

8. FUTURE SCOPE

The work presented in this can be extended in several directions. Here several research directions are presented which might be followed for further applications. To perform an evaluation of the BCIs aiming at fostering its development. Present its actual state and future perspectives. Identify and analyze the main social, technological, economic, environmental and emerging political and ethical questions associated to BCIs. Offer opinions and suggestions to researchers and other stakeholders in order to promote the development of the technology. BCIs can change the way human beings are perceived and accepted, as well as change how the world is seen. Its implications in social, ethical, technological and even anthropological and religious aspects can be severe. Contribute to the development of BCIs through a comprehensive analysis of the present challenges and obstacles to the advancement of the technology. Offer a broader view of the relevance of BCIs, as well as of the difficulties and impacts associated with its development. Offer future perspectives of the development and the evolution of BCIs looking to prevent and/or minimize negative impacts perceived. The results of this project should be able to provide insights to pave the way for the future.

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