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Robot control system using SMR signals

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Abstract

One of the important issues in designing a brain-computer interface system is to select the type of mental activity to be imagined. In some of these systems, mental activity varies with user intent and action that must be controlled by the brain-computer system, and in a number of other signals, the received signals contain the same activity-related mental activity that should be performed by the brain-computer system. Take up The purpose of this paper is to identify and distinguish between multiple movements of the hand, including lifting and lowering the whole hand, from the electromagnetic signal (EEG) signal and the control of a robot by these signals. Since the purpose of using motor signals is selected from the various channels, channels 3c and 4c are selected as the preferred channel. This set of signals in total was about six healthy people. In this paper, support vector machines (SVM), multilayer perceptron (MLP) and probabilistic neural network (PNN) were designed to extract data properties.

Keywords: Brain-computer interface system, Feature extraction, Support vector machine, Multilayer Perceptron, Probabilistic neural network

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1. Introduction

The brain is the center of the nervous system of the body. The brain, spinal cord, and peripheral nerves are made of microscopic neurons called neurons. There are about 10,000 million neurons in the cortex, about 100,000 million neurons throughout the brain, and several million neurons in the peripheral spinal cord and nerves. There are many neurological diseases in which neurons of the motor nerves are damaged and the patient is not able to send orders from the motor neuron. The disease (ALS) is a type of neuromuscular disease that progresses rapidly and reduces the ability to control the body's muscles from the patient, while the senses, emotions, and ability to process and recognize the environment remain healthy [1]. Such people are not able to communicate with the outside world, so researchers have been working to fix this problem by using the brain signal recording and processing to establish a way to connect the human brain with the outside world, which leads to the design Brain-Computer Interfaces (BCIs). One of the goals of this technology is to help people with severe motor disorders, disorders that prevent them from performing many routine tasks that all require muscle contraction.

2. Background

In December 1990 Decety and Inqvar (also Jeannerod and Frark in 1999) considered motion imagery as simulated kinetic signals, and to demonstrate their activity, myocardial activity was derived from EEG signals of the sensory-motor cortex (without any type of physical movement of the body) was used [2].

However, many people struggled to use imaginative imagery because they did not know how to imagine a perceptible feeling of imagination and a tendency to imagine instead of moving their arms or legs. Therefore, one of the challenging issues was based on EEG-based BCI studies, and the question arises as to how and in what way one can create unique education for the proper conduct of motion imagery [2].

Over the past decade, various feedback techniques have been proposed for the teaching of motor imagery, most of which based on visual stimuli (Blankertz et al., 2007; Leeb et al., 2006; Pineda et al., 2003), and feedback Hearing (Hinterberger et al., 2004; Nijboer et al., 2008) [3] and [4]. One of the obvious reasons for explaining the misconceptions is that the participants tend to imagine motion pictures (VMIs) that produce a kind of brain activity pattern that is completely different from real imagery (Neuper et al., 2005).

Processing on such signals was carried out in two ways, in-line and non-synchronous. When processing such signals, there was a question: "Which range of registered signals contains the desired information? "This question was solved by expressing and considering a condition for performing brain activity within a specific time frame. For example, the Graz standard BCI system represents an in-line system that, when using the system and recording a signal, a mental activity must be known in advance, and when a specific sign occurs, [5] and [6]. In the next research area, it was determined that the sensory-motor regions of the cerebral cortex are distinct from the two-handed one and, by examining the sensory-motor rhythms; it is easy to disassociate the two-handed motion [7].

3. Base system

In general, a set of signals based on the concept of hand gestures has been used which includes the imagination of two types of movement. For this experiment, a brain-computer interface was used to receive brain signals from people. This brain-computer interface is called OpenBCI. With the help of this device, people receive brain signals and they enter the computer via Bluetooth. The device has sixteen channels, which means sixteen electrodes can be placed on different parts of the brain. In this study, nine electrodes of silver and a cap were used to capture electrical waves of the movement of brain neurons. It also has a ten-20 cream that has adhesion and keeps the electrodes in place until the end of the test. This gel has been used to better pass electric current and reduce scalp resistance. A UNO board has been used to read the serial port and send commands to drivers for game engines. After the signals were entered into the computer via Bluetooth, we saw it in real time in the Java Processing software. This software is Open Source and implements EEGlab's analysis in real time and communicates with robot hardware through a serial port. With the help of Arduino, you can issue commands to game drivers. The base of Arduino programming is C ++ language. EEGLAB is a toolbox and graphical interface in MATLAB, which is used to process EEG signals. The data from the brain will be entered into the Toolbox and the analysis of the signals will be done. With this toolbox, we will have the ability to filter, remove artifacts, put FFT, wavelet, put our experiment events, observe the behavior of the signals of each channel individually, and so on [13].The test procedure is as shown in Fig. 1.

4. Present Scenario

The model of the present scenario has been carried out as follows (Fig. 1):

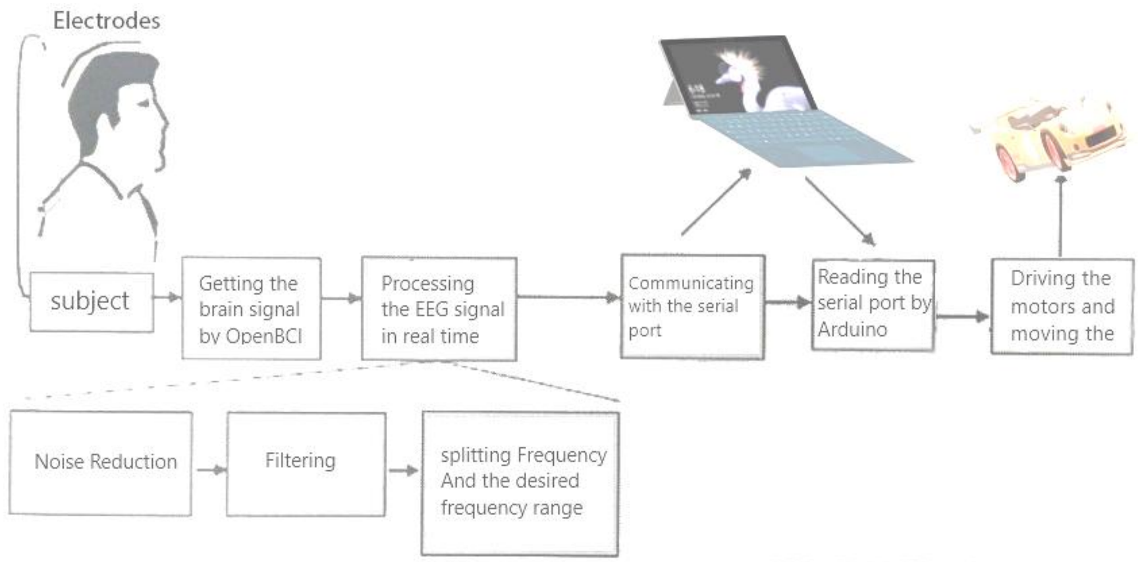

Fig. 1. The test procedure

Our signal collection is based on the recorded signals from six healthy people (two women and four men with an average age of 25 years). To record such signals, the person was asked to imagine the motion of his right hand in the direction for three runs, each containing ten tests. The user used the same pattern for the down direction. EEG brain signals using 9 electrodes C3, C4, Cz, F3, F4, Fz, P3, Pz, P4 and reference electrode A1 Also, the Earth G electrode, in the frequency range of 2-60 Hz Filtered and sampled at 256 Hz with the OpenBCI device. In order to obtain the brain signals, the educational model of Fig. 2 has been used. First, a black screen is displayed for two seconds on the front of the screen, during which time the person can do any kind of activity and prepare himself for the test. Then a small white circle appears in the center of the black screen for four seconds, during which time no person can imagine (relaxation). In the following, according to the type of hand motion (raising or lowering), one of the symbols (↓ or ↑) is displayed at the center of the screen for four seconds and the person must imagine the motion of his right hand, which is related to the sign. Figure 2 shows how to do this experiment and its timing.

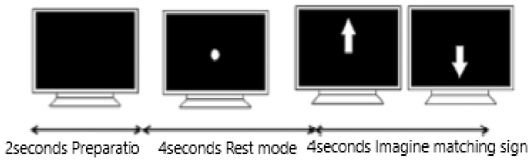

Fig. 2. educational model of getting signals

A) Extracting motion imagery pattern

The moving a member of the body, or even constructing a muscle, makes changes in the activity of the cortex. In fact, movement or imagination creates changes in sensory-motor rhythms. Sensory-motor rhythms are oscillations in the brain that are recorded in the sensory-motor and motor region. The variations are usually performed at different frequencies, ie, in the delta, theta, alpha, beta, and gamma bands, and the activity of the alpha band in the sensory area - Movement is also called Miu activity. Reducing oscillations in a particular frequency band is called non-matching with an event [1](ERD). Also, the increase of volatility at a certain frequency is called the Coincidence of an Event (ERS). ERD / ERS patterns can be created by imagining voluntary movement. Mio and beta frequencies in the EEG signal are important with the idea of motion. [11].The activities created by the notion of a greater right-hand movement are present at the location of the c3 electrode. The movement of the left-hand motions causes activity in the c4 region. Imagining the movement of the hand on the opposite side will trigger stimulated activity. Feeling the motion of a leg causes activity in CZ. The distinction between the right and left legs is not possible due to the proximity of the corneal region from the EEG signal. Also, ERD / ERS patterns of single fingers are also not distinguishable from the EEG signal. To create distinct patterns, the associated cortical region should be large enough. The areas of the hand, foot, and tongue are large enough [11]. Therefore, brain-computer interface systems can be controlled by imagining the movement of the left, right hand, foot and tongue [12][13][14][10].The occurrence time of ERD and ERS and their occurrence in brain signals is very important in determining the movement of the individual. When moving consciously, ERD and ERS are observed at several stages and in certain regions of the brain. Before moving and about 2 seconds before it starts, the ERD is observed in the beta wave received from the region of the brain's imaginary motion in the hemisphere opposite the member of the target for movement. When performing the ERD movement in beta waves, it is seen from the side of the brain on the side of the moving member. After moving the energy recovery process, the signal is started and slowly executed for a few seconds at a rate in beta, which is seen as ERS signals in the opposite moving brain hemispherical brain waves.

In this experiment, a two-step algorithm is proposed to differentiate brain signals from each other. First, we divide the existing data into two equal categories, half of them for training, and the other half for testing. Using CSP filtering data, the CSP is designed and the available data from The CSP [14][15] filters are passed, and then the output variance logarithm is given as the attribute to the classifier. In this test, the algorithm is designed three times, each time using one of the three categorizing methods, the SVM [16], the MLP [17], and the PNN [18].

Of the 8 electrodes, three of which are on Parietal (Pz, p3 and p4 points in the system 10-20), and three on the Frontal (F4, F3, and Fz points in the system 10-20), and three on the Central (C3, C4, and C2 points in the 10-20 system) are used.

After these steps, turn the event on. In such a way, we need to specify the seconds we consider to be an event. Here are the important seconds for us 2, which is the rest state and the seconds 6 that start the command. In the figure.3, signals for 9 channels and the timing of the events are specified. The No comment command is for when the rest mode is shown and the comment command is the time when the motion command is issued. After detecting events, three baseline filtrations were used to remove Line Trend, the Filter Natch was rejected to remove the city's electrical fluctuations (which is 50 Hz), as well as ocular artifacts (due to the blink of an individual).Next, we need to identify the epochs. In fact, the epoch is a set of input neurons in the neural network that is selected to enter the neural network or the network input layer. After doing this, we can see the map and signal of each channel and remove the noisy channels. We will give the references below. In this project, our references are ears. And then to run the ERP, we need to launch the ICA. ICA method is a statistical method that is used to separate signals into a variety of independent sources. After launch ICA, we can see all the components or the same components. In this we can see the signals based on their potential in terms of time. In Fig. 4, the signals for the 9 channels received are shown in terms of the potential-time.

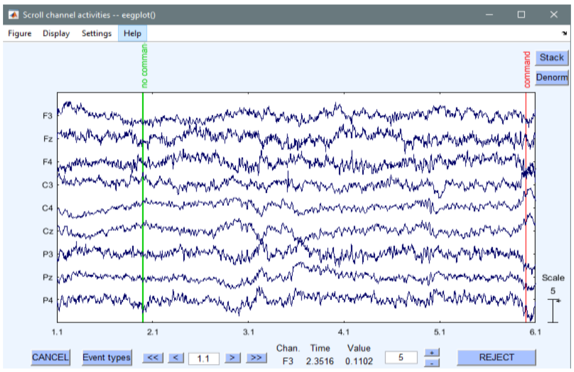

Fig. 3. 9 Channels Signals and Events Timeout

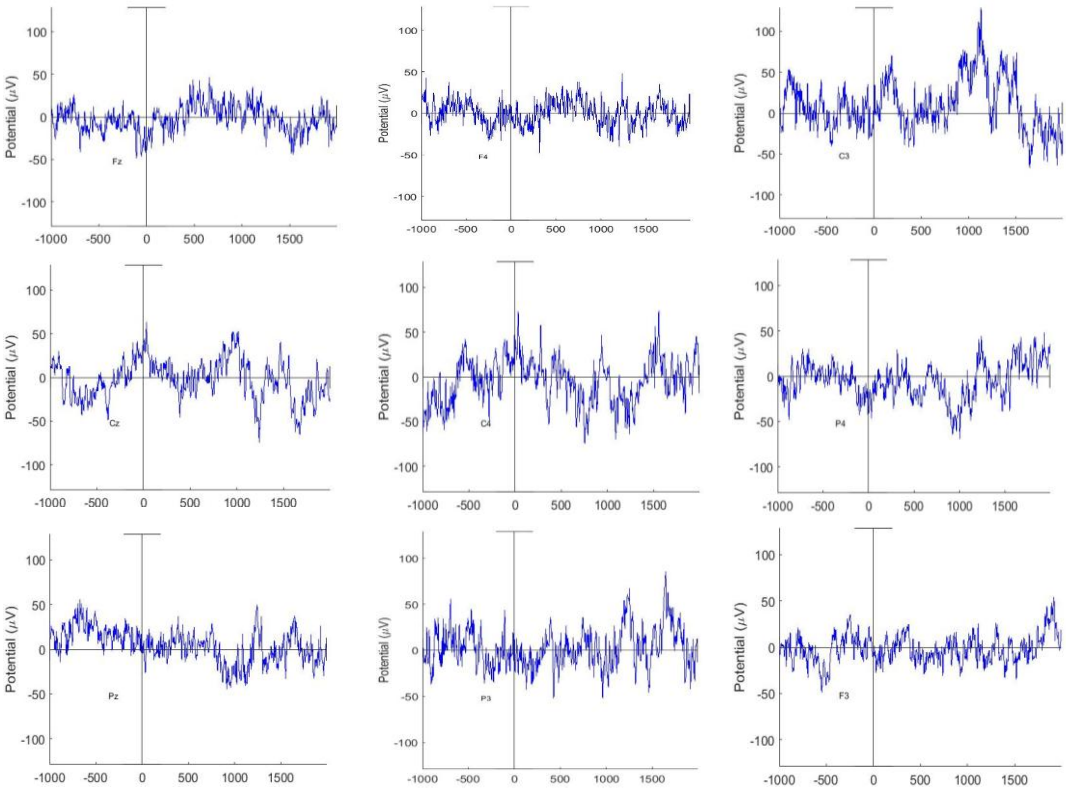

Fig. 4. Signals for 9 channels received in terms of potential-time

And for further analysis, we need maps with components in the 2-D model. In these maps, we can see the places where the potential has increased or decreased. And by using them, we can determine what action has been taken. For example, here in figure.5 the maps are obtained from seconds zero to 10 seconds at the end of the imagery motion instruction. This shape is related to the concept of raising the right hand, and as you can see, the potential on the left side of the brain increases when you imagine lifting the right hand. As we have already said, the impression of moving the right hand on the left side of the brain and the impression that the left-hand moves to the right of the brain occurs.

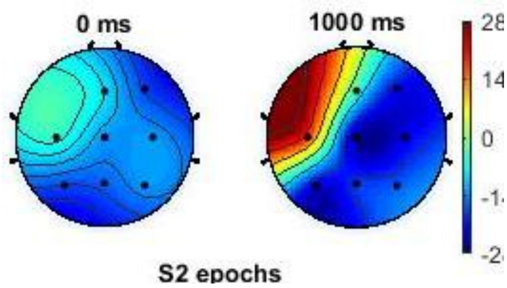

Fig. 5. 2-D Maps in seconds zero and ten

Each session consists of thirty tests. As a result, these 30 intermediate tests should be obtained and, finally, a time-frequency spectrum will be obtained for each received channel. An example of a time-frequency analysis of brain signals with a short-term Fourier transform, with an intermediate method in 30 tests in the ERSP method, is presented in Fig. 6. In these shapes, the line of chains at the zero moments represents the appearance of the start command of the imaginary movement. The negative moments before the line of chains, the resting state and the positive moments after the line of time are the time when the tested person has imagined moving his hands up. As shown in Figs.3, When it is supposed to move in the upward direction, an increase in power in the frequency band (13-8 Hz) is seen in most of the participants' brain signals relative to the imagination of the hand down. We also find that although in all 9 channels, ERD has occurred in the alpha and beta frequency range, this is better in the right and back channels (Pz, P3, and C3). Also, when imagining the movement in the upward direction, increase power in the frequency band (13-8 Hz) is seen by the majority of participants in the brain signals of lowering the hand.

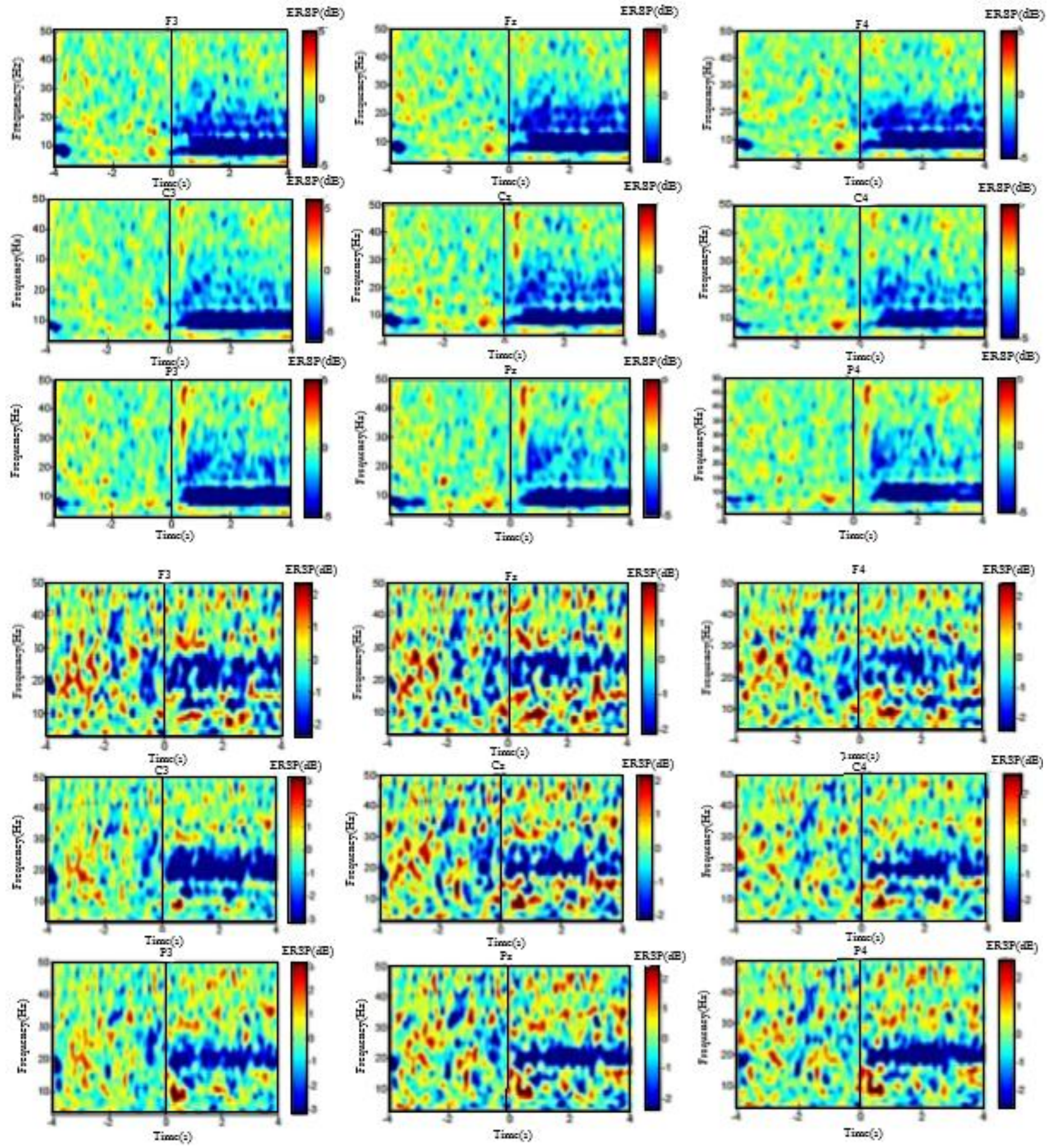

Fig. 6. Time-Frequency Analysis of Brain Signals in the Third Session in 30 Tests with Fourier and in the method ERSP. A) Imagine the movement of raising the hand. B) Imagine the hand down movement.

B) Communication with the Robot

Here, we use a robot machine, so that with the impression of raising the hand, the robot moves to the right, and with the impression of lowering the hand, the robot moves to the left. When the signal is conceived, it enters the computer via Bluetooth, and it is viewed in Java by the Processing software and implements EEGlab's analysis in real time, and through a serial port with robot hardware, we communicate. We used a car chassis to build a car robot, a Uno board, a Bluetooth module, two 9V batteries, two DC motors, and an L293D driver. The circuit is closed as shown in Figure 7.

5. Comparison of results for different methods of extracting features

Table 1 shows the results of the classification of brain signals related to the idea of hand-lifting, hand-down. All data are randomly assigned 10 times for training and the remainder for testing. The results show that the PNN classifier works well with an average of 78.15%. Compared to [19], which detected the direction of the real movement of the hand using brain signals with an average accuracy of 71/50%, the CSP filter and the PNN classifier mentioned in this study are better. Also, in table.2, the performance of three persons is represented by three categorizing methods.

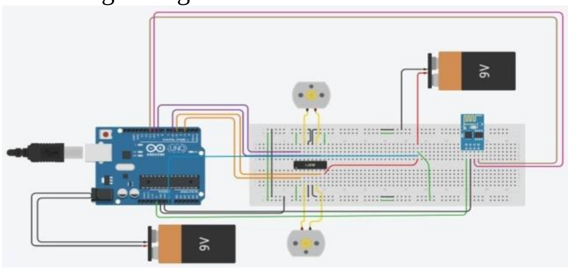

Fig. 7. Robot Communications Map

Table.1.
Degree of accuracy of the classification (%) of the related brain signals (imagination of the movement of raising and lowering the hand)

Method	Person	Session1	Session2	Session3	Average of each person	Standard deviation	Average of six persons	Standard deviation of six persons
SVM	1	81/00	84/12	87/27	86/00	3/68	74/81	5/90
	2	82/500	76/10	71/00	76/53	4/18		
	3	69/35	55/34	95/67	75/37	4/78		
	4	70/77	72/18	80/30	74/16	5/36		
	5	54/72	72/93	80/34	70/30	6/45		
	6	60/90	69/93	68/80	66/54	5/15		
PNN	1	82/23	97/77	90/00	90/00	4/67	78/15	5/65
	2	83/50	83/10	80/35	82/31	5/45		
	3	75/00	65/00	99/50	75/50	4/76		
	4	75/40	76/88	73/45	٧٥/٢٤	5/83		
	5	65/00	80/00	83/32	74/77	4/86		
	6	62/92	70/80	79/56	71/09	5/45		
MLP	1	80/00	97/77	90/00	88/98	7/15	76/81	7/98
	2	87/80	90/76	92/45	60/33	6/89		
	3	62/32	56/65	99/50	72/15	11/50		
	4	73/45	75/68	89/99	79/70	5/89		
	5	80/00	84/12	88/37	86/00	11/43		
	6	68/85	75/17	77/19	73/73	7/18		

Table.2.
Three-person performance charts using 3 feature extraction methods

	person (A)	***person (B)***	***person (C)***	***person (D)***	***person (E)***	***person (F)***	***average***
SVM	86	76.53	75.37	74.16	70.3	66.54	74.81
PNN	90	82.31	75.5	75.24	74.77	71.09	78.15
MLP	88.98	60.33	72.15	79.7	86	73.73	76.81

6. Conclusion

To categorize a diagnostic algorithm, it was proposed and implemented. The algorithm consists of three steps, which are as follows: In the first step, the resting signal is detected from the signal of the motion image. In the second stage, the signal related to the general movement of the hand (hand lift, hand down) is separated. Finally, in the third stage, the signal of the imagination signal is related to the overall motion of the hand with the robot, causing the movement and control of the robot Get The recorded signals are sampled at 256 Hz, then transmitted through a pass filter of 60-2 Hz. First, in each step of the algorithm, the classification of the two data categories was performed using a type of feature extraction technique. Then, 6 subjects were taken in 3 sessions and the CSP method was used to extract the attribute. It's well-known that in all parts of the PNN classifier it works better. In addition, the result obtained in this study was 5% better than that of article [19], which detected real hand motion in two groups with an average accuracy of 71.5%.

This series of research can be considered to be somewhat more advanced and more elegant, for example, in previous research work on motion-based signals, a reference [20] to distinguish between the perception of right hand movement, left hand movement, The foot and tongue were designed and implemented by a combination of SVM and CSP with a precision of 79.7% and 64.68%, and these four groups were divided into four arm dentures (hand forward, hand back to the first position, open And closing the wrists) while in the research project Tay, the manual movement imagery that is separated is combined with motor commands that can be applied to the prosthesis of the prosthesis (for example, the notion of hand-lifting can be regarded as equivalent to the command of an enlarged neuroprotection) . By describing this, BCI superiority with our proposed algorithm can be compared to reference [20], the convenience and coordination of imagination with commands given by the person with disabilities to the neuroprotection. In the reference [21], the imagination of left-hand movement of the left hand was separated by the combination of SVM and LDA with a precision of 12.25% and 70.34%, while in our project; the images of different movements were separated by one. Which itself reduces the cost of constructing BCIs designed with our proposed algorithm. It should be recalled that changes in sensory-rhythms resulting from one-handed imagery in the opposite's semicircle are clearly visible. With this, it can be seen that the BCI designed with the proposed algorithm in reference [21] requires a lot of signals and thus the use of many electrodes. While the BCI designed with the proposed algorithm is only capable of using half of these electrodes, it has its own signals and has similar commands with an equivalent number of BCIs in reference [21].

7. Proposals

According to the work done in the current project and the experience gained during the course of the project, suggestions are made to improve the system efficiency and overcome the shortcomings of work in the future:

- Use intelligent neural networks to increase the accuracy of categorization.
- Since the reception of a signal with wet electrodes is very time-consuming, it is associated with a lot of difficulties. Therefore, the use of dry electrodes is recommended to simplify the signalling operation.
- It is recommended to increase the number of users in order to increase the reliability of the results, if possible, and provide time and laboratory conditions.
- The use of people with motor disorders as a user can be better served by this system.
- Using a method for choosing optimal bipolar or multipolar channels for each individual according to the type of mental activity
- Using other extraction methods such as FFT, ICA, PCA, EMD and ... to design a new algorithm
- Designing a specific algorithm for each person for higher performance
- Join imagery such as open or open wrist and elbow
- Use commands to control a wheelchair or quadcopter
- Use EMOTIV instead of OpenBCI for higher ease of installation

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Abbreviations

ALS Amytropic Lateral Sclerosis
BCI Brain-Computer Interface
VMI Visual-motor Imagery
SMR Sensorimotor Rhythms
ERD Event-related Desynchronization
ERS Event-related Synchronization
ICA Independent Component Analysis
SVM support vector machines
MLP multilayer perceptron
PNN probabilistic neural network
EEG Electroencephalography
CSP Common spatial pattern