Cursor Movement Control Development by Using ANFIS Algorithm

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Abstract: *Our non-invasive brain computer interface uses EEG signals and beta frequency bands over sensorimotor cortex to control cursor movement horizontally (i.e., one-dimension). The main goal of this study is to help people with sever motor disabilities (i.e., Spinal cord injuries) and provide them a new way of communication and control options by which they can move the cursor in one dimension. In this study, offline analysis of the data collected was used to make the user able of controlling the movement of the cursor horizontally (i.e., one dimension). The data was collected during a session in which the user selected among two targets by thinking and moving either the right hand little finger or the left hand little finger. The Adaptive-Network based fuzzy inference system algorithm was examined for the classification method with some parameters. In the offline analysis, the method used showed a significant performance in the classification accuracy level and it gave an accuracy level of more than 80%.This result suggests that using the adaptive-network based fuzzy inference system algorithm will improve online operation of the current BCI system.*

Keywords: *Brain-Computer interface, ANFIS algorithm, fuzzy logic, electroencephalogram.*

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1. Introduction

People with severe injuries (i.e., spinal cord injuries) and motor disabilities face daily challenges in living their lives as normal people. One of these difficulties facing disabled people is using the computer. Studies and researches are being conducted to help those people live a better life. The researches showed that a person can communicate by controlling certain waves from their EEG-Electroencephalogram and thus they can control the movement of a mechanical arm or control a wheel chair. Previous researches done on BCI used many different methods to search the possibility of connecting a patient's brain with a computer system successfully and so many different methods were studied and tested. The controlling of any system or object by using a BCI system is done by the extraction and the conversion of EEG Brain signals and controlling the use of specific brain waves in order to control a computer system or a mechanical arm for example. Some of these researches used linear methods, non-linear methods in order to classify the brain signals extracted and others used genetic algorithm or classical classification algorithms to classify the signals coming out of the brain. In this research, the (adaptive-network based fuzzy inference system) algorithm was used in order to classify the signals where it showed a better performance.

The main goal of this study is to help those people and provide them a new way of communication and control options by which they can move the cursor of the computer in one dimension (1D horizontally). Offline analysis was used in this study on the data collected where some features were extracted from the data and used in the classification.

The better the classification is, the better the application of any BCI system will be. ANFIS showed significant results in the accuracy of the classification which helps improve different BCI applications in order to help the people and provide them with efficient solutions.

2. Methodology

The Data set was provided by Fraunhofer-FIRST, Intelligent Data Analysis Group (Klaus-Robert Müller), and Freie Universität Berlin, Department of Neurology, Neurophysics Group (Gabriel Curio) [3].

This dataset was recorded from a normal subject during a no-feedback session. The subject sat in a normal chair, relaxed arms resting on the table, fingers in the standard typing position at the computer keyboard. The task was to press with the index and little fingers the corresponding keys in a self-chosen order and timing 'self-paced key typing'. The experiment consisted of 3 sessions of 6 minutes each. All sessions were conducted on the same day with some minutes break in between. Typing was done at an average speed of 1 key per second [3].

Eight simple features or parameters were extracted from the data set provided. Only two channels (C3, C4) were used in the feature extraction in which the trials were divided into trial signals coming out from C3 when thinking of moving the right hand finger to press a key, and when thinking of moving the left hand finger to press a key. In addition, trial signals coming out of C4 when thinking of moving the right hand finger and trial signals coming out of C4 when thinking of moving the left hand finger to press any key. The number of trial signals that are relevant to the right hand finger movement were 157 epoch (trial), and those trials that are relevant to the left hand finger movement were 159 epoch (trial).

All the parameters extracted from channels C3 and C4 that are relevant to the right hand finger movement were transposed and then sorted column wise and the same operations were done on the parameters that are relevant to the left hand finger movement. Moreover, all the parameters extracted that are related to the left hand finger movement were stored and sorted after the last trial signal that is related to the movement of the right hand finger (row wise). By this, the training data set that consists of 8 parameters (columns) and 316 trials (row) were made and every parameter consists of two columns; one for the trials from C3 and the other for the trials from C4.

Before feeding the training data set to the classification algorithm, the parameters were minimized to 6 parameters excluding 2 parameters. The two parameters were excluded in the feature selection phase by the Genetic Algorithm (GA) that decided that they are inefficient for the classification phase.

3. Classification Scheme

A modular classification algorithm based on the ANFIS has been used for this application; ANFIS applies two techniques in updating parameters. For premise parameters that define membership functions, ANFIS employs gradient descent to fine-tune them. For consequent parameters that define the coefficients of each output equations, ANFIS uses the least-squares method to identify them. This approach is called hybrid learning method since it combines gradient descent and the least-squares method [5, 1].

In a fuzzy inference system, there are three types of input space partitioning: grid, tree, and scattering partitioning. The "curse of dimensionality" refers to such situation where the number of fuzzy rules increases exponentially with the number of input variables [5, 8]. Therefore, six features were used in the diagnostic system. These features have to be very accurate, so the Genetic Algorithm combined with K-Nearest Neighbor (KNN) classifier was used to determine our best 6 features out of the eight features that were extracted previously. Feature Selection Methodology in many supervised learning tasks, a very large number of features represent the input data, but only few of them are relevant for predicting the class. To avoid the presence of large number of weakly relevant and redundant features; this is usually attributed to the fact that irrelevant features decrease the signal-to-noise ratio [5]. In this paper we used the feature selection GA combined with KNN classifier [6] that mainly deals with the optimization problem and based on the crossover and mutation functions and reproduction process where the KNN controls the fitness function to find the best features in the given population.

The genetic pool of a given population potentially contains the solution, or a better solution, to a given adaptive problem. This solution is not "active" because the genetic combination on which it relies is split between several subjects. And only the association of different genomes can lead to the solution [5, 4].

4. ANFIS Structure

In this paper, for the classification method the ANFIS algorithm was used in order to classify the trial signals into signals coming out when the subject thinks of moving right hand finger (right), and trial signals coming out when the subject thinks of moving the left hand finger (left).

ANFIS's network organizes two parts like fuzzy systems. The first part is the antecedent part and the second part is the conclusion part, which are connected to each other by rules in network form. If ANFIS in network structure is shown, that is demonstrated in five layers. It can be described as a multi-layered neural network as shown in Figure 1. Where, the first layer executes a fuzzification process, the second layer executes the fuzzy AND of the antecedent part of the fuzzy rules, the third layer normalizes the Membership Functions (MFs), the fourth layer executes the consequent part of the fuzzy rules, and finally the last layer computes the output of fuzzy system by summing up the outputs of layer fourth. Here for ANFIS structure, as shown in Figure 1, two inputs and two labels for each input are considered. The feed forward equations of ANFIS are as follows [5]:

$$w_i = \mu_{A_i}(x) \times \mu_{B_i}(y), \quad i = 1,2 \qquad (1)$$

$$\overline{w_i} = \frac{w_i}{w_1 + w_2}, \quad i = 1,2 \qquad (2)$$

$$f = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2} = \overline{w_1} f_1 + \overline{w_2} f_2 \qquad (3)$$

where $f_1 = p_1, \quad f_2 = p_i$

In order to model complex nonlinear systems, the ANFIS model carries out input space partitioning that splits the input space into many local regions from which simple local models (linear functions or even adjustable coefficients) are employed. The ANFIS uses fuzzy MFs for splitting each input dimension; the input space is covered by MFs with overlapping that means several local regions can be activated simultaneously by a single input. As simple local models are adopted in ANFIS model, the ANFIS approximation ability will depend on the resolution of the input space partitioning, which is determined by the number of MFs in ANFIS and the number of layers. Usually MFs are used as bell-shaped with maximum equal to 1 and minimum equal to 0 such as [5]:

$$\mu_{A_i}(x) = \frac{1}{1 + \left[\left(\frac{x - c_i}{a_i}\right)^2\right]^{b_i}} \quad (4)$$

$$\mu_{A_i}(x) = exp\left\{-\left[\left(\frac{x - c_i}{a_i}\right)^2\right]^{b_i}\right\} \quad (5)$$

where $\{a_i, b_i, c_i\}$ are the parameters of MFs which are affected in shape of MFs.

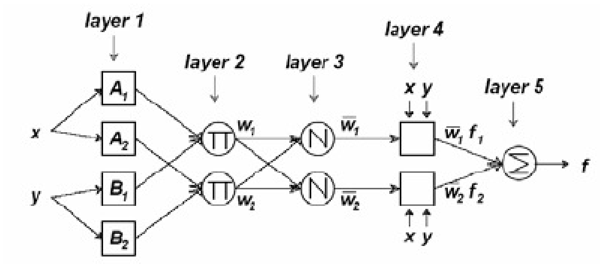

Figure 1. The equivalent ANFIS (type-3 ANFIS).

5. Experimental Results

After applying the methodology and running the classification algorithm for 3 iterations, it reached the minimum RMSE value after the second epoch. The classification algorithm task was to classify and distinguish between the signals that are coming out when thinking to move the right hand finger to the right, and the signals that are coming out when thinking to move the left hand finger to the left. That means one class (right signals and left signals).

The data obtained contains 416 trial of 500 ms length each. The training data set was formed from 90% of the total data; that means it was formed from 316 trials. The testing data set was formed from the rest 10% of the total data; that means 100 trials. After that, three versions of the training data set were made, where each version was randomly disordered in order to cross-validate the results.

The classification accuracy result for the first version of the data set was 84% and for the second data set was 83.46% and for the third data set the accuracy was 80.90%.

From these results, it can be seen that the ANFIS classification algorithm that was used performed efficiently and the performance was at a high level where it accurately predicted the testing signals and classified them either to be coming out of the brain when thinking to move the right hand finger to the right or when thinking to move the left hand finger to the left. That means, the ANFIS classification system is an excellent system for predicting and classifying.

6. Conclusion

ANFIS algorithm showed significant results of the accuracy of the classification (above 80%). This means that using ANFIS to classify the data extracted from the brain of the patient is efficient and can improve the quality of any BCI application. Thus, improving the life of disabled people. However, using ANFIS algorithm requires top-notch PCs. This research dealt with offline analysis of the BCI where the analysis required some time to run and give results. In addition, ANFIS can be applied to any BCI application such as cursor control, word typing, and even controlling a wheel chair.

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