Merging brain computing interface (BCI) & neural networks for better authentication & recognition

Q Ramzan¹, ², V I Syryamkin¹
¹National Research Tomsk State University, Tomsk, Russia
²toggleTechs (a creativity platform), Islamabad, Pakistan
E-mail: qaseemramzan0@gmail.com

Abstract. Brain Computing Interface (BCI) has been proved helpful for the different streams of technology, considering the sensitivity of data in the current era it is required to build new security protocols and authentication models. Just like other fields of technology Brain Computing Interface could also be useful for making the data security better by using BCI as an authentication method without any hard physical inputs. The focus of the issue shifts to ‘recognition’ of EEG signals pattern and making the authentication model self-learning to increase its efficiency. This leads us to involve Artificial Neural Networks in the authentication system to make it efficient and intelligent.

1. What is a Brain Computer Interface?

What is Brain Computer Interface (BCI)? A brain computer interface (BCI), sometimes called a mind-machine interface (MMI), direct neural interface (DNI), or brain–machine interface (BMI), is a direct communication pathway between an enhanced or wired brain and an external device. BCIs are often directed at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions [1, 2].

1.1 Working of BCI

The purpose of a BCI is to detect and quantify features of brain signals that indicate the user's intentions and to translate these features in real time into device commands that accomplish the user's intent. To achieve this, a BCI system consists of 4 sequential components.

1. Signal Acquisition,
2. Feature Extraction,
3. Feature Translation
4. Device Output.

These 4 components are controlled by an operating protocol that defines the onset and timing of operation, the details of signal processing, the nature of the device commands, and the oversight of performance. An effective operating protocol allows a BCI system to be flexible and to serve the specific needs of each user.

Electrical signals from brain activity are detected by recording electrodes located on the scalp, on the cortical surface, or within the brain. The brain signals are amplified and digitized. Pertinent signal characteristics are extracted and then translated into commands that control an output device, such as a spelling program, a motorized wheelchair, or a prosthetic limb. Feedback from the device enables the user to modify the brain signals in order to maintain effective device performance. BCI = brain-computer interface; ECoG = electrocorticography; EEG = electroencephalography [1,3].
2. What are ANNs (Artificial Neural Networks)?

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the biological nervous systems, such as the human brain’s information processing mechanism. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. NNs, like people, learn by example. A NN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of NNs as well [4].

2.1 Neuron Model

When a neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon (Figure 1). Learning occurs by changing the effectiveness of the synapses so that the influence of one neuron on another changes [4].

![Figure 1. Basic Neuron Model.](image1)

We conduct these neural networks by first trying to deduce the essential features of neurons and their interconnections. We then typically program a computer to simulate these features [4].

2.2 Artificial Neuron

An artificial neuron is a device with many inputs and one output (Figure 2). The neuron has two modes of operation; the training mode and the using mode [4].

![Figure 2. Artificial Neuron Model.](image2)

2.2.1 The Training Mode

In the training mode, the neuron can be trained to fire (or not), for particular input patterns [5].
2.2.2 The Using Mode
In the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output. If the input pattern does not belong in the taught list of input patterns, the firing rule is used to determine whether to fire or not [5].

3. Recognition in Neural Networks
An important application of neural networks is pattern recognition. Pattern recognition can be implemented by using a feed-forward neural network that has been trained accordingly (Figure 3). During training, the network is trained to associate outputs with input patterns. When the network is used, it identifies the input pattern and tries to output the associated output pattern [6].

Suppose a network is trained to recognize the patterns T and H. The associated patterns are all black and all white respectively as shown above [6].

Since the input pattern looks more like a ‘T’, when the network classifies it, it sees the input closely resembling ‘T’ and outputs the pattern that represents a ‘T’ (Figure 4).

4. Complex Neurons
A more sophisticated Neuron is known as the McCulloch and Pitts model (MCP). The difference is that in the MCP model, the inputs are weighted and the effect that each input has at decision making, is dependent on the weight of the particular input. The weight of the input is a number which is multiplied with the input to give the weighted input (Figure 5) [6].
5. Combining Brain Computing Interface (BCI) with Neural Networks

Presently every device is under a threat of security breach and taking into account the sensitivity of personal data and how human lives are half digital makes this issue an important one for humans. It is required to secure our devices with a more secure and innovative protocols instead of the mainstream methods. All the past authentication methods being used by us are breach-able and have a history of either hack attacks or simple security breach due to the weak type of authentication models. All of the authentication models we have so far need an input from the user. This input method is the main loophole which makes it not good enough to protect our devices [1, 8].

If the authentication models will need a physical input from users, then it is highly likely that the user is at risk because the input can be acquired either by trick or by force.

An authentication model based on EEG signals was proposed to overcome this problem and it could be a method of thoughts without any hard physical input. BCI is capable of reading the Brain Signals and then the proposed model in previous paper was developed to authenticate a user based on brain signals and matching the pattern with the one stored in a database [1].

5.1 Authentication for BCI with Neural Networks

As we have developed a consensus above that Neural Networks can perform recognition in a very impressive way which is not possible otherwise. So a better thought is to use Neural Networks on the EEG Based Authentication Model and make the Neural Network learn the patterns of user’s authentication routine. Here the Neural Network will not only match the pattern to authenticate the users but it will learn gradually the changes in EEG Signals pattern and become more intelligent in a way to recognize the user [6].

The ultimate task will be to train the Neural Network to the point where it will not need to match the EEG Signals with the first every stored pattern but it will be able to recognize the user based on the later learnings which were learnt in result of trainings [6].

5.2 Proposed BCI Authentication Model Combined with Neural Networks

The model shown in Fig. allows the BCI system to send the gathered pattern from input to neural network system which uses different learning techniques to recognize the pattern of signals as well as use this as a learning to improve the previously stored recognition pattern for signals [1].

**Headset**
EEG headset of any company can be used with the authentication module.

**Processing**
In processing step all the information gathered from the EEG Headset will be processed for further feature extraction.

**Feature Extraction**
Feature extraction is the process of analyzing the digital signals to distinguish pertinent signal characteristics (i.e., signal features related to the person's intent) from extraneous content and representing them in a compact form suitable for translation into output commands. These features should have strong correlations with the user's intent (Figure 6).

**Figure 6.** Proposed BCI Authentication Model Combined with Neural Networks.

**Neural Networks Input**
In this step the meaningful data after feature extraction will be provided to Neural Networks as an input.

**Data Analysis**
Data Analysis is a step of Neural Networks processing, here the data is analyzed for further processing.

**Backprop Algorithm**
Backpropagation is a method used in artificial neural networks to calculate a gradient that is needed in the calculation of the weights to be used in the network. It is commonly used to train deep neural networks, a term referring to neural networks with more than one hidden layer.

**Associative Learning**
An associative neural network (ASNN) is a combination of an ensemble of the feed-forward neural networks and the K-nearest neighbor technique. The introduced network uses correlation between ensemble responses as a measure of distance among the analyzed cases for the nearest neighbor technique and provides an improved prediction by the bias correction of the neural network ensemble both for function approximation and classification. Actually, the proposed method corrects a bias of a global model for a considered data case by analyzing the biases of its nearest neighbors determined in the space of calculated models.

**Final Authentication Module**
This is a final step of authentication; the final authentication module could either be on server or on the local machine.
6. Conclusion
This approach specifies the importance of using EEG Based Authentication Model and uncovers the important aspects in creating a recognition system to correctly authenticate a user based on unique patterns found in EEG signals using the above specified algorithm structure. This proposed system uncovers a new way to combine BCI with Neural Networks for the purpose of correctly learning the authentication patterns.

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