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Deep Learning Technology in Brain Computer Interface Applications

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Introduction

Brain Computer Interface (BCI) systems depend on machine learning algorithms to decode the brain activity [5]. Artificial intelligence (AI) algorithms have very important role in the development of brain-computer interfaces. AI algorithms such as neural networks play powerful role in brain-computer interfaces [6]. Recent advances in the computational innovation have led to significant developments in BCI [7].

BCI translate brain activity patterns into commands which can be executed by an artificial device. Motor BCIs can be used for the augmentation of motor function by activating the neuromuscular circuit [8]. In future, BCIs may become an important communication and control technology for people with disabilities. The current range of applications also targets cognitive impairments and opportunities for human enhancement [9].

Deep Learning Technology in BCI

Big data analysis is essential to understand the complexities of brain activity with regard to BCI performance [3]. Advancements in deep learning have led many researchers to adopt deep neural networks to extract features from brain signals [10].

Deep learning can solve complex tasks using EEG data. Researchers are now doing a lot of work on deep learning-based technology in the BCI field. Important deep learning algorithms employed in EEG-based BCI applications are convolutional neural network (CNN), long short-term memory, recurrent neural network, stacked autoencoder and variational autoencoder. CNN has considerable success in several research areas making it an ideal option. Many BCI techniques produce two-dimensional visuals that can be processed by CNNs. Convolutional neural network is the most frequent deep learning algorithm used in EEG-based BCI applications [7].

BCIs based on steady-state visual evoked potentials, have the highest information transfer rate. Deep learning has provided an effective solution for solving complex classification problems and several researchers are now using deep learning to classify steady-state visual evoked potential signals [11].

Five categories of deep learning techniques used in steady-state visual evoked potential based BCI applications are convolutional neural network, recurrent neural network, deep neural network, long short-term memory and restricted Boltzmann machine [12].

BCI based on functional near-infrared spectroscopy (fNIRS) is a promising application. fNIRS measures functional changes in cerebral hemodynamics. Deep learning methods can be used in fNIRS decoding. In the study by Qin Y et al, an end-to-end hybrid neural network was proposed for feature extraction of fNIRS. The method uses a spatial-temporal convolutional layer and a spatial attention mechanism. A temporal convolutional network is used to utilize the temporal information of fNIRS. This deep learning method has high accuracy and provides an important reference for development of BCI [1].

In functional near-infrared spectroscopy brain-computer interface (fNIRS-BCI) systems, deep learning algorithms have very important role in enhancing accuracy. Deep learning neural networks automatically extract hidden features within a dataset to classify the data. Integrated contextual gate network (ICGN) algorithm applied to the dataset yielded significantly higher classification accuracy compared to long short-term memory (LSTM) and bidirectional long short-term memory (Bi-LSTM) [13]. Enhanced performance of fNIRS-BCI in terms of classification accuracy can be achieved using deep learning algorithms, including convolutional neural networks [14].

Conclusion

Brain-computer interface is a highly promising human-computer interaction method. It is an advanced multidisciplinary domain that has attracted great deal of research in recent years. Brain-computer interfaces are used in a variety of application areas. BCI research is expanding in the breadth of its applications. For improving BCI performance, collaboration is essential between clinicians, scientists and experts in data analysis. Researchers are now working on deep learning-based approaches in the BCI field. Deep learning algorithms have shown promising results in BCI research.

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