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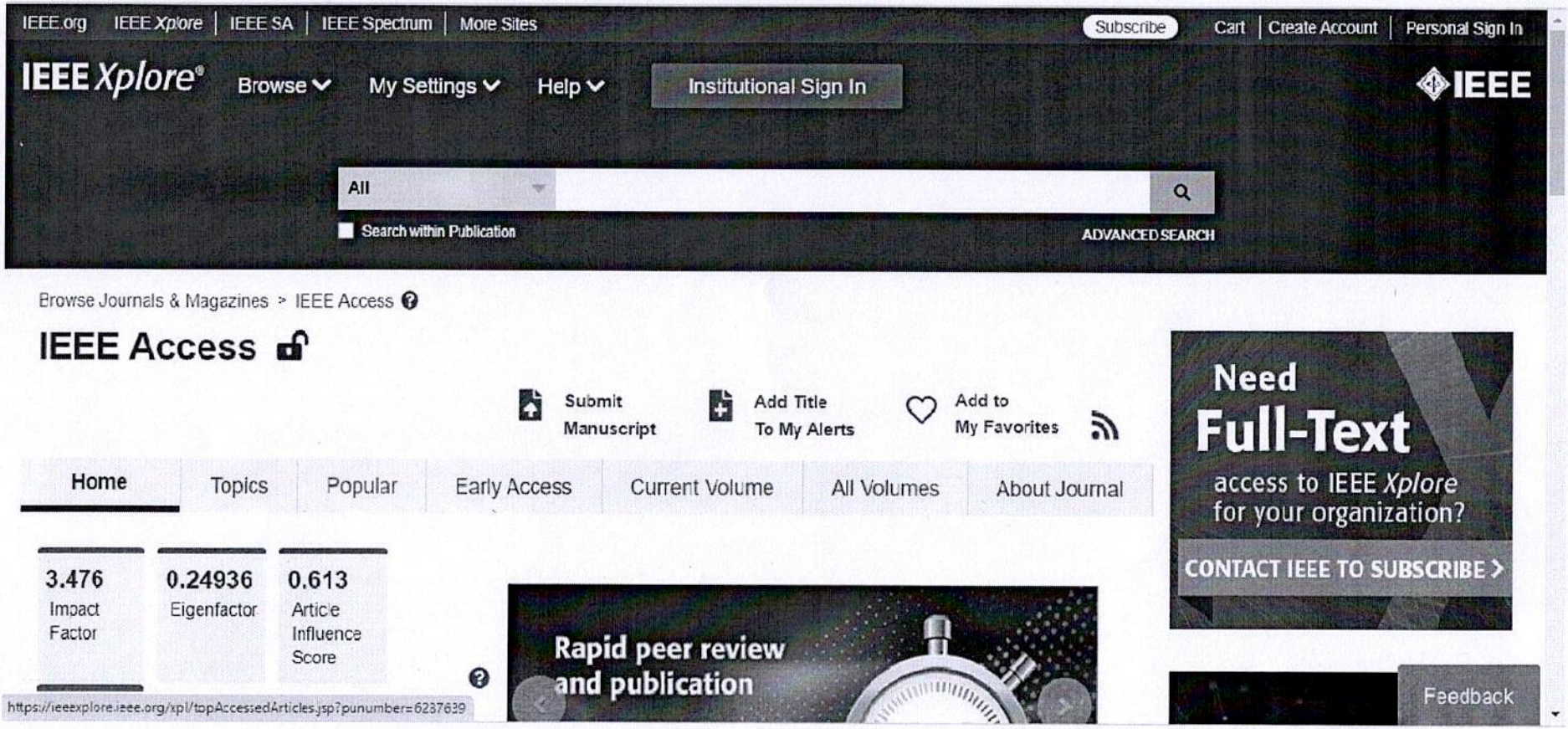
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Ramesh Babu Vallabhaneni ; Pankaj Sharma ; Vinit Kumar ; Vyom Kulshreshtha ; Koya Jeevan R... All Authors

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Deep Learning Algorithms in EEG Signal Decoding Application: A Review

RAMESH BABU VALLABHANENI[1], PANKAJ SHARMA[2], VINIT KUMAR[3], (Senior Member, IEEE), VYOM KULSHRESHTHA[2], KOYA JEEVAN REDDY[4], S. SELVA KUMAR[5], V. SANDEEP KUMAR[6], (Fellow, IEEE), AND SURENDRA KUMAR BITRA[7], (Student Member, IEEE)

[1]Department of ECE, NRI Institute of Technology, Agiripalli, Vijayawada, Krishna, Andhra Pradesh 521212, India
[2]Department of Computer Science and Engineering, Eshan College of Engineering, Farah, Mathura 281122, India
[3]Department of Computer Science and Engineering, Galgotias College of Engineering and Technology, Greater Noida 201310, India
[4]Department of ECE, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana 501301, India
[5]Department of Computer Science and Engineering, BMS College of Engineering, Bengaluru 560019, India
[6]Department of ECE, School of Engineering, SR University, Warangal, Telangana 506371, India
[7]Department of ECE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh 522502, India

Corresponding author: Ramesh Babu Vallabhaneni (rameshvece@gmail.com)

ABSTRACT In recent years, deep learning algorithms have been developed rapidly, and they are becoming a powerful tool in biomedical engineering. Especially, there has been an increasing focus on the use of deep learning algorithms for decoding physiological or pathological status of the brain from electroencephalographic (EEG). This paper overviews current application of deep learning algorithms in various EEG decoding tasks, and introduces commonly used algorithms, typical application scenarios, important progresses and existing problems. Firstly, the basic principles of deep learning algorithms used in EEG decoding is briefly described, including convolutional neural network, deep belief network, auto-encoder and recurrent neural network. In this paper, existing applications of deep learning on EEG is discussed, including brain-computer interfaces, cognitive neuroscience and diagnosis of brain disorders. Finally, this paper outlines some key problems that will be addressed in future applications of deep learning for EEG decoding, such as parameter selection, computational complexity, and the capability of generalization.

INDEX TERMS Brain-computer interface, decoding, deep learning, electroencephalographic, neural networks.

I. INTRODUCTION

Electroencephalogram (EEG) is a spontaneous and rhythmic electrical activity of the brain [1], [2]. Due to the simplicity, ease of operation and high time resolution of signals, EEG technology has played a great role in clinical and basic scientific research. For example, EEG is used as an indicator for the detection and monitoring of diseases such as epilepsy [3], [4] and sleep disorders [5], [6] in clinical practice. EEG is a brain imaging method that uses electrodes attached to surface of scalp to identify and record electrical activity signals of neuronal clusters in the cerebral cortex through precise electronic measurement technology, which can obtain brain idea and cognition. Neural electrophysiological information related to thinking and decision-making is one of the widely used brain function research methods. Compared with other brain imaging functions, such as intra cortical neural recording, functional near-infrared spectroscopy and magnetic resonance imaging, the EEG is used in the research and development of rehabilitation equipment, such as the development of brain-computer interface (BCI) and neuro feedback technologies to achieve the recovery of patients' motor cognition and other functions [7]. In the above clinical application and scientific research of EEG, the machine learning algorithms are often used to decode EEG signals to accurately identify physiological or pathological conditions. However, shortcomings of less spatial resolution and signal-to-noise ratio (SNR) of EEG signals [8], the accuracy of machine learning decoding has greater limitations, causing many difficulties in practical applications. In, recent years rapid evolution in learning, researchers has gradually applied new and efficient machine learning algorithms to EEG decoding, and initially demonstrated its advantages over traditional machine learning. The following first introduces the

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