Machine Intelligence Research
www.mi-research.net

19(5), October 2022, 347-349
DOI: 10.1007/s11633-022-1376-6

Editorial for Special Issue on Brain-inspired Machine Learning

The recent years have witnessed significant progress on artificial intelligence (AI). Undoubtedly, one of the essential elements that contribute to the prosperity of current AI is brain-inspired machine learning. By introducing structural principles and operational mechanisms of the human brain into the design of computing algorithms and devices, brain-inspired machine learning has been enabling computational systems to approach the nature of human-like intelligence. Examples of the successful practice include but are not limited to the hierarchical features of deep neural networks, low energy cost of spiking neural networks, robustness in recognition, attention mechanism and sparsity for high inference efficiency, multimodal information fusion, self-supervised learning, and so forth. With the rapid developments of increased collaboration between scientists from various disciplines, such as neuroscience, psychology, computer science, engineering, and mathematics, brain-inspired machine learning opens new avenues for exploring cutting-edge methods and technologies in modern AI.

This special issue serves to call for a better understanding on opportunities and challenges emerged in devising and applying brain-inspired machine learning approaches, as well as the relations between deep and biological neural networks in terms of model structure, information encoding or decoding manner, representation/response property, and so on. Reviews on prior arts and promising future directions in this line of work are also discussed. We solicit manuscripts in the important fields of brain-inspired machine learning that explore the synergy of intelligence computing and neural information processing. In the end, seven papers are accepted to form this special issue.

The first paper, entitled "Neural Decoding of Visual Information Across Different Neural Recording Modalities and Approaches" from Yi-Jun Zhang et al., reviews recent progress on visual neural decoding. Various neural recording modalities are introduced and the advantages and disadvantages of different neural decoding methods are also compared. Additionally, the authors summarize available open resources, including public neural data and software toolkits, to provide convenience for the research community. In particular, perspectives on the open challenges and future directions are concluded in depth, offering inspiration to both neuroscience and multidisciplinary researchers looking to understand the state-of-the-art and current problems in neural decoding.

The second paper, entitled "Efficient Visual Recognition: A Survey on Recent Advances and Brain-inspired Methodologies" from Yang Wu et al., presents a review of recent advances in improving the efficiency of modern DNNs and brain-inspired SNNs for visual recognition. By investigating not only from the model but also from the data point views, the authors systematically compare and summarize related works and trends on efficient visual recognition, elaborating on major types of visual data, various recognition models, network compression algorithms, and acceleration approaches for run-time inference. Furthermore, unexplored yet promising new directions are discussed, with a particular emphasis on the data and network co-optimization.

The third paper, entitled "Towards a Paradigm for Brain-inspired Computer Vision" from Xiao-Long Zou et al., declares that the current brain-inspired computer vision has not captured the fundamental nature of biological vision, i.e., processing spatio-temporal patterns. To this end, the authors propose a new paradigm that from beginning acquires visual information in the external world in the form of spike trains, and then processes these spatio-temporal patterns using neural computation models learned from the biological system. Besides, some recent primary works towards this goal and the future directions to improve the paradigm are also presented.

The fourth paper, entitled "Clause-level Relationship-aware Math Word Problems Solver" from Chang-Yang Wu et al., focuses on the task of automatically solving math word problems. By following human understanding from lower to higher level, the proposed solver first learns the clause semantics in the lower level, and employs a multi-view method to capture the clause-level relationships. In the global level, the authors design two relationship-aware mechanisms for learning context-context and question-context dependency relationships based on the overall semantics of clauses. Additionally, a tree-based decoder to generate the mathematical expression is also developed. This work alleviates one limitation of existing methods that do not take the clause-level relationship into account.

The fifth paper, entitled "Exploring the Brain-like Properties of Deep Neural Networks: A Neural Encoding Perspective" from Qiong-Yi Zhou et al., systematically evaluates the brain-like properties of 30 kinds of com-

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puter vision models varying from CNNs and ViTs to their hybrids. Several interesting conclusions are drew that neither CNN nor transformer is the optimal model paradigm for modelling the human visual pathway; and that multi-modal and temporal networks can better explain the neural activities of large parts of the visual cortex, whereas a larger model size is not a sufficient condition for bridging the gap between human vision and artificial networks. This work provides insights into the design principles for more brain-like networks.

The sixth paper, entitled "Denoised Internal Models: A Brain-inspired Autoencoder Against Adversarial Attacks" from Kai-Yuan Liu et al., aims to address the issue that deep neural networks are very vulnerable to adversarial attacks. A two-stage approach is proposed, where the first stage uses a denoiser to reduce the noise and the dimensions of inputs, reflecting the information pre-processing in the thalamus; and the second stage yields a set of internal models covering all categories, taking inspiration from the sparse coding of memory-related traces in the primary visual cortex. Extensive experiments demonstrate the robustness of the proposed method on defensing against 42 adversarial attacks.

The last paper, entitled "EEG-based Emotion Recognition Using Multiple Kernel Learning" from Qian Cai et al., proposes an SVM classifier based on the multiple kernel learning (MKL) algorithm EasyMKL to explore the application of MKL methods in the field of EEG emotion recognition. Two data partition approaches are also designed: random division to verify the validity of the MKL method and sequential division to simulate practical applications. Experiments on recognizing neutral, negative and positive emotions show better classification performance of the MKL against the traditional single kernel SVM. Moreover, the authors discovered that higher frequency band information is more correlated with emotional state and contributes more to emotion recognition.

These papers cover a wide variety of topics including neural encoding and decoding of visual information, visual recognition, spatio-temporal information processing, math word problem solver, adversarial attacks, and emotion recognition. From the perspective of brain-inspired computing, these works endow the corresponding research field with insightful views, methodologies, and techniques, offering alternative ways to effectively improve the interpretability, robustness, generalization ability, and inference efficiency of intelligence computing approaches.

We trust our readers will enjoy learning about these excellent works.

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