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Special Issue Editorial: Cognitively-Inspired Computing for Knowledge Discovery

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Knowledge discovery is an emerging topic in many domains addressing a variety of methodologies for extracting useful knowledge from data. In an era of explosive data growth, together with wide-spreading powerful distributive and parallel computing, we are faced with an urgent demand for research and development of more efficient, effective and smart methodologies. On the other hand, it is also crucially challenging to extract, summarize, and even generate knowledge due to the large-scale, noisy, heterogeneous nature of big data. To this end, significant efforts have been reported in the literature on social networks, computer vision, data science, machine learning, data mining, statistical analysis, and fast computing. A number of successful models have recently emerged and led to great impact in the field. Interestingly, despite the diverse research topics and applications, these works recognize that cognitively-inspired mechanisms should be investigated in order to make the algorithms more intelligent, powerful, and effective in extracting insightful knowledge, from huge amounts of heterogeneous Big data.

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This timely special issue aims to inspire and promote both theoretical and practical studies into cognitively-inspired knowledge discovery, including pattern recognition, signal processing, data mining, computer vision, and machine learning. Consequently, the issue tries to deepen our understanding of the biological, mathematical, logical, and practical aspects of knowledge discovery, with the hope that we can better explain and develop existing and new knowledge discovery methodologies. We summarize the Special Issue papers as follows, organized in six main topics:

1. *Knowledge tracing.* Deep knowledge tracing (DKT) presents an important methodology that aims to automatically trace students' knowledge states by mining their exercise performance data. Previous DKT models usually suffer from psychological interpretation as well as manual feature selection. To alleviate these issues, Yang et al. design an automatic system to embed heterogeneous features implicitly and effectively into the DKT model. In particular, by exploiting heterogeneous features, they apply tree-based classifiers which are able to predict whether the student can correctly answer the exercise. They also design a practical way to see if a student could be different from others in the exercise. Experimental results show that the proposed algorithm is much more effective and could possibly be used in real applications.
2. *Cognitively-inspired neural networks.* Neural networks, especially deep neural networks, have achieved great success in a range of fields including pattern recognition, computer vision, and natural language processing. It has been widely recognized that biologically inspired thoughts or ideas should be more emphasised so as to further advance the development of neural networks. In particular, current neural networks strongly rely on a large amount of data for good performance and lack effective mechanisms to differentiate input samples from outliers. Inspired by the human brain, Zhang et al. design a memory network (MN) trying to alleviate

the strong dependance of the current neural network on data. Specifically, the novel network is designed to record the activations from previous samples (i.e., holds a memory of previous training). Experimental results on benchmark datasets show that the new MN can remarkably improve the classification performance when training data are limited. On the other hand, to solve the second limitation of existing neural networks, Wang et al. propose two neural network models based on the Lagrange programming neural network (LPNN), with application to the robust source localization problem of time-of-arrival (TOA) models. Interestingly, an ℓ_1 -norm objective function is engaged to reduce the negative influence caused by outliers. With its insightful discussion and solid experimental verification, the proposed approach shows very encouraging results. In addition to the above two theoretical explorations, Doborjeh et al. apply Spiking Neural Networks to spatio-temporal EEG Data in attentional bias pattern recognition, demonstrating an interesting application of how a cognitively-inspired neural network can efficiently solve a real problem.

3. *Cognitively-inspired, scalable semi-supervised learning.* In the process of human learning, training samples can be considered for feeding into our brains successively. Therefore, many human learning tasks exhibit online and semi-supervision characteristics, that is, the observations arrive in sequence and the corresponding labels are presented very sporadically. Motivated by this phenomenon, Ding et al. design a novel manifold regularized model to solve semi-supervised learning in an incremental or online way. Specifically, they propose two algorithms to simulate the human learning behaviors. Empirical evaluations validate that the proposed online learning algorithm is both scalable and effective.
4. *Semantic knowledge understanding.* In machine learning and pattern recognition, semantic meaning is more highly valued than low-level knowledge for extracting semantic knowledge from given texts, images, or videos. In this special issue, two papers discuss semantic knowledge understanding. First, Ning et al. investigate the semantic image segmentation problem. Inspired by multi-scale cognitive mechanisms, they attempt to integrate multiple-scale contextual information upon Convolutional Neural Networks (CNN). With a novel hierarchical dilation block, the depth of CNN can be reduced significantly. Experimental results demonstrate that the new framework can achieve fast and accurate semantic image segmentation. Second, Zhang et al. discuss a semantic framework for biomedical question answering. In particular, they propose a two-stage Semantic Sequential Dependence Model framework (SSDM2) based on a cognitively-inspired model, Sequential Dependence Model (SSDM) to answer biomedical questions with relevant snippets in academic papers. The whole system achieves better performance against the state-of-the-art algorithm in biomedical question answering.
5. *Knowledge-inspired document and image analysis.* When reading documents or watching images or videos, humans can exploit certain habits or mechanisms to extract and integrate knowledge. Wang et al. investigate a human reading, knowledge-inspired text line extraction approach. They build a directed graph upon the candidate characters from left to right, inspired by human reading habits. The directed graph can automatically construct a relationship to eliminate the disorder of character components. Plugging the information with the directed graph, the text extraction performance is shown to be greatly improved. On the other hand, Yan et al. study a cognitive fusion of thermal and visible imagery for pedestrian detection and tracking. Inspired by human visual perception, they combine various cognitive models for effective pedestrian detection. This model is shown to be the best when compared with several state-of-the-art techniques.
6. *Cognitively-inspired applications.* In this final Special Issue topic, Luo et al. discuss a semi-blind model to estimate building temperatures. Inspired by human perception of the real world, the proposed model does not rely on data-driven models that require a large amount of data for training. Instead, the proposed semi-blind model is able to accurately estimate the temperature based only on the first several days' data. Specifically, the authors propose a highly integrated parameter identification method in conjunction with self-adaptive algorithms and the grey prediction technique for parameters estimation. Experimental results indicate that the proposed cognitively-inspired semi-blind method attains greater improvement over previous methods.

Concluding the editorial, we extend our sincere thanks to authors, reviewers, and the management team of Cognitive Computation journal, all of whom enabled the publication of this special issue. All papers have been through a rigorous review process of two to four rounds, in order to generate a high quality special issue.

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