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CIS Publication Spotlight

IEEE Transactions on Neural Networks and Learning Systems

Neuromemristive Circuits for Edge Computing: A Review, by O. Krestinskaya, A. P. James and L. O. Chua, *IEEE Transactions on Neural Networks and Learning Systems*, Vol. 31, No. 1, January 2020, pp. 4–23.

Digital Object Identifier: 10.1109/TNNLS.2019.2899262

"The volume, veracity, variability, and velocity of data produced from the ever increasing network of sensors connected to Internet pose challenges for power management, scalability, and sustainability of cloud computing infrastructure. Increasing the data processing capability of edge computing devices at lower power requirements can reduce several overheads for cloud computing solutions. This paper provides the review of neuromorphic CMOS-memristive architectures that can be integrated into edge computing devices. We discuss why the neuromorphic architectures are useful for edge devices and show the advantages, drawbacks, and open problems in the field of neuromemristive circuits for edge computing."

Selection and Optimization of Temporal Spike Encoding Methods for Spiking Neural Networks, by B. Petro, N. Kasabov and R. M. Kiss, *IEEE Transactions on Neural Networks and Learning Systems*, Vol. 31, No. 2, February 2020, pp. 358–370.

Digital Object Identifier: 10.1109/TNNLS.2019.2906158

"Spiking neural networks (SNNs) receive trains of spiking events as inputs. In order to design efficient SNN systems, real-valued signals must be optimally encoded into spike trains so that the task-relevant information is retained. This paper provides a systematic quantitative and qualitative analysis and guidelines for optimal temporal encoding. It proposes a methodology of a three-step encoding workflow: method selection by signal characteristics, parameter optimization by error metrics between original and reconstructed signals, and validation by comparison of the original signal and the encoded spike train. Four encoding methods are analyzed: one stimulus estimation [Ben's Spiker algorithm (BSA)] and three temporal contrast [threshold-based, step-forward (SW), and moving-window (MW)] encodings. A short theoretical analysis is provided, and the extended quantitative analysis is carried out applying four types of test signals: step-wise signal, smooth (sinusoid) signal with added noise, trended smooth signal, and event-like smooth signal. Various time-domain and frequency spectrum properties are explored, and a comparison is provided. BSA, the only method providing unipolar spikes, was shown to be ineffective for step-wise signals, but it can follow smoothly changing signals if filter coefficients are scaled appropriately. Producing bipolar (positive and negative) spike trains, SW encoding was most effective for all types of signals as it proved to be robust and easy to optimize. Signal-to-noise ratio (SNR) can be recommended as the error metric for parameter optimization. Currently, only a visual check is available for final validation."

IEEE Transactions on Fuzzy Systems

CFM-BD: A Distributed Rule Induction Algorithm for Building Compact Fuzzy Models in Big Data Classification Problems, by M. Elkano, J. Antonio Sanz, E. Barrenechea, H. Bustince, and M. Galar, *IEEE Transactions on Fuzzy Systems*, Vol. 28, No. 1, January 2020, pp. 163–177.

Digital Object Identifier 10.1109/MCI.2020.2998230
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Digital Object Identifier: 10.1109/TFUZZ.2019.2900856

"Interpretability has always been a major concern for fuzzy rule-based classifiers. The usage of human-readable models allows them to explain the reasoning behind their predictions and decisions. However, when it comes to Big Data classification problems, fuzzy rule based classifiers have not been able to maintain the good tradeoff between accuracy and interpretability that has characterized these techniques in non-Big-Data environments. The most accurate methods build models composed of a large number of rules and fuzzy sets that are too complex, while those approaches focusing on interpretability do not provide state-of-the-art discrimination capabilities. In this paper, we propose a new distributed learning algorithm named CFM-BD to construct accurate and compact fuzzy rule-based classification systems for Big Data. This method has been specifically designed from scratch for Big Data problems and does not adapt or extend any existing algorithm. The proposed learning process consists of three stages: Preprocessing based on the probability integral transform theorem; rule induction inspired by CHI-BD and Apriori algorithms; and rule selection by means of a global evolutionary optimization. We conducted a complete empirical study to test the performance of our approach in terms of accuracy, complexity, and runtime. The results obtained were compared and contrasted with four state-of-the-art fuzzy classifiers for Big Data (FBDT, FMDT, Chi-Spark-RS, and CHI-BD). According to this study, CFM-BD is able to provide competitive discrimination capabilities using significantly simpler models composed of a few rules of less than three antecedents, employing five linguistic labels for all variables."

A Novel Classification Method From the Perspective of Fuzzy Social Networks Based on Physical and Implicit Style Features of Data, by S. Gu, Y. Nojima, H. Ishibuchi, and S. Wang, *IEEE Transactions on Fuzzy Systems*, Vol. 28, No. 2, February 2020, pp. 361-375.

Digital Object Identifier: 10.1109/TFUZZ.2019.2906855

"Many practical scenarios have demanded that we should classify unlabeled data more accurately based on both physical features (e.g., color, distance, or similarity) and implicit style features of data. As most extant classification algorithms classify unlabeled data based only on their physical features, they become weak in achieving expected classification results for many scenarios. To work around this drawback in this paper, a novel classification method (FuCM) from the perspective of fuzzy social network based on both physical and implicit style features of data is proposed. Based on the proposed fuzzy social network and its dynamics about fuzzy influences of nodes, FuCM comprises two stages. In its training stage, after the fuzzy social network has been built, it learns the topological structure, reflecting physical features and implicit style features of data by carrying out fuzzy influence dynamics in the built network. In its prediction stage, both physical and implicit style features of data are effectively integrated to yield the double structure efficiency characterized by fuzzy influences of nodes. FuCM classifies unlabeled data according to the strongest connection measure based on the proposed double structure efficiency. FuCM does not assume that both data distribution and the classification by physical features or by both physical and implicit style features of data must be known in advance. Thus, it is a novel unified classification framework in this sense. In contrast to all the nine comparative methods, FuCM experimentally demonstrates its comparable classification performance on most synthetic, UCI and KEEL datasets, which can be well classified based only on physical features of data. Furthermore, it displays distinctive superiority on five case studies where satisfactory classification certainly depends on both physical and implicit style features."

IEEE Transactions on Evolutionary Computation

An Experimental Method to Estimate Running Time of Evolutionary Algorithms for Continuous Optimization, by H. Huang, J. Su, Y. Zhang, and Z. Hao, *IEEE Transactions on Evolutionary Computation*, Vol. 24, No. 2, April 2020, pp. 275-289.

Digital Object Identifier: 10.1109/TEVC.2019.2921547

"Running time analysis is a fundamental problem of critical importance in evolutionary computation. However, the analysis results have rarely been applied to advanced evolutionary algorithms (EAs) in practice, let alone their variants for continuous optimization. In this paper, an experimental method is proposed for analyzing the running time of EAs that are widely used for solving continuous optimization problems. Based on Glivenko–Cantelli theorem, the proposed method simulates the distribution of gain, which is introduced by average gain model to characterize progress during the optimization process. Data fitting techniques are subsequently adopted to obtain a desired function for further analyses. To verify the validity of the proposed method, experiments were conducted to estimate the upper bounds on expected first hitting time of various evolutionary strategies, such as evolution strategy, standard evolution strategy, covariance matrix adaptation evolution strategy, and its improved variants. The results suggest that all estimated upper bounds are correct. Backed up by the proposed method, state-of-the-art EAs for continuous optimization will have identical results about the running time as simplified schemes, which will bridge the gap between theoretical foundation and applications of evolutionary computation."

IEEE Transactions on Games

Procedural Puzzle Generation: A Survey, by B. De Kegel and M. Haahr, *IEEE Transactions on Games*, Vol. 12, No. 1, March 2020, pp. 21-40.

Digital Object Identifier: 10.1109/TG.2019.2917792

"Procedural content generation (PCG) for games has existed since the 1980s and is becoming increasingly important for creating game worlds, backstory, and characters across many genres, in particular, open-world games, such as Minecraft (2011) and No Man's Sky (2016). A particular challenge faced by such games is that the content and/or gameplay may become repetitive. Puzzles constitute an effective technique for improving gameplay by offering players interesting problems to solve, but the use of PCG for generating puzzles has been limited compared with its use for other game elements, and efforts have focused mainly on games that are strictly puzzle games, rather than creating puzzles to be incorporated into other genres. Nevertheless, a significant body of work exists, which allows puzzles of different types to be generated algorithmically, and there is scope for much more research into this area. This paper presents a detailed survey of existing work in PCG for puzzles, reviewing 32 methods within 11 categories of puzzles. For the purpose of analysis, this paper identifies a total of seven salient characteristics related to the methods, which are used to show commonalities and differences between techniques and to chart promising areas for future research."

IEEE Transactions on Cognitive and Developmental Systems

DeepFeat: A Bottom-Up and Top-Down Saliency Model Based on Deep Features of Convolutional Neural Networks, by A. Mahdi, J. Qin, and G. Crosby, *IEEE Transactions on Cognitive and Developmental Systems*, Vol. 12, No. 1, March 2020, pp. 54-63.

Digital Object Identifier: 10.1109/TCDS.2019.2894561

"A deep feature-based saliency model (DeepFeat) is developed to leverage understanding of the prediction of human fixations. Conventional saliency models often predict the human visual attention relying on few image cues. Although such models predict fixations on a variety of image complexities, their approaches are limited to the incorporated features. In this paper, the authors aim to utilize the deep features of convolutional neural networks by combining bottom-up (BU) and top-down (TD) saliency maps. The proposed framework is applied on deep features of three popular deep convolutional neural networks (DCNNs). The authors exploit four evaluation metrics to evaluate the correspondence between the proposed saliency model and the ground-truth fixations over two datasets. The results demonstrate that the deep features of pretrained DCNNs over the ImageNet dataset are strong predictors of the human fixations. The incorporation of BU and TD saliency maps outperforms the individual BU or TD implementations. Moreover, in comparison to nine saliency models, including four state-of-the-art and five conventional saliency models, their proposed DeepFeat model outperforms the conventional saliency models over all four evaluation metrics."

IEEE Transactions on Emerging Topics in Computational Intelligence

Complex-Valued Neural Networks With Nonparametric Activation Functions, by S. Scardapane, S. V. Vaerenbergh, A. Hussain, and A. Uncini, *IEEE Transactions on Emerging Topics in Computational Intelligence*, Vol. 4, No. 2, April 2020, pp. 140-150.

Digital Object Identifier: 10.1109/TETCI.2018.2872600

"Complex-valued neural networks (CVNNs) are a powerful modeling tool for domains where data can be naturally interpreted in terms of complex numbers. However, several analytical properties of the complex domain (such as holomorphicity) make the design of CVNNs a more challenging task than their real counterpart. In this paper, we consider the problem of flexible activation functions (AFs) in the complex domain, i.e., AFs endowed with sufficient degrees of freedom to adapt their shape given the training data. While this problem has received considerable attention in the real case, very limited literature exists for CVNNs, where most activation functions are generally developed in a split fashion (i.e., by considering the real and imaginary parts of the activation separately) or with simple phase-amplitude techniques. Leveraging over the recently proposed kernel activation functions, and related advances in the design of complex-valued kernels, we propose the first fully complex, nonparametric activation function for CVNNs, which is based on a kernel expansion with a fixed dictionary that can be implemented efficiently on vectorized hardware. Several experiments on common use cases, including prediction and channel equalization, validate our proposal when compared to real-valued neural networks and CVNNs with fixed activation functions."