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CIS Publication Spotlight

IEEE Transactions on Neural Networks and Learning Systems

The Boundedness Conditions for Model-Free HDP(λ), by S. Al-Dabooni and D. Wunsch, *IEEE Transactions on Neural Networks and Learning Systems*, Vol. 30, No. 7, July 2019, pp. 1928–1942.

Digital Object Identifier: 10.1109/TNNLS.2018.2875870

"This paper provides the stability analysis for a model-free action-dependent heuristic dynamic programing (HDP) approach with an eligibility trace long-term prediction parameter (λ). HDP(λ) learns from more than one future reward. Eligibility traces have long been popular in Q-learning. This paper proves and demonstrates that they are worthwhile to use with HDP. In this paper, we prove its uniformly ultimately bounded (UUB) property under certain conditions. Previous works present a UUB proof for traditional HDP [HDP($\lambda = 0$)], but we extend the proof with the λ parameter. By using Lyapunov stability, we demonstrate the boundedness of the estimated error for the critic and actor neural networks as well as learning rate parameters. Three case studies demonstrate the effectiveness of HDP(λ). The trajectories of the internal reinforcement signal nonlinear system are considered as the first case. We compare the results with the performance of HDP and traditional temporal difference [TD(λ)] with different λ values. The second case study is a single-link inverted pendulum. We investigate the performance of the inverted pendulum by comparing HDP(λ) with regular HDP, with different levels of noise. The third case study is a 3D maze navigation benchmark, which is compared with state action reward state action, Q(λ), HDP, and HDP(λ). All these simulation results illustrate that HDP(λ) has a competitive performance; thus this contribution is not only UUB but also useful in comparison with traditional HDP."

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Dynamic Feature Acquisition Using Denoising Autoencoders, by M. Kachuee, S. Darabi, B. Moatamed, and M. Sarrafzadeh, *IEEE Transactions on Neural Networks and Learning Systems*, Vol. 30, No. 8, August 2019, pp. 2252–2262.

Digital Object Identifier: 10.1109/TNNLS.2018.2880403

"In real-world scenarios, different features have different acquisition costs at test time which necessitates cost-aware methods to optimize the cost and performance tradeoff. This paper introduces a novel and scalable approach for cost-aware feature acquisition at test time. The method incrementally asks for features based on the available context that are known feature values. The proposed method is based on sensitivity analysis in neural networks and density estimation using denoising autoencoders with binary representation layers. In the proposed architecture, a denoising autoencoder is used to handle unknown features (i.e., features that are yet to be acquired), and the sensitivity of predictions with respect to each unknown feature is used as a context-dependent measure of informativeness. We evaluated the proposed method on eight different real-world data sets as well as one synthesized data set and compared its performance with several other approaches in the literature. According to the results, the suggested method is capable of efficiently acquiring features at test time in a cost- and context-aware fashion."

IEEE Transactions on Fuzzy Systems

A Multiview and Multiexemplar Fuzzy Clustering Approach: Theoretical Analysis and Experimental Studies, by Y. Zhang, F.-L. Chung, and S. Wang, *IEEE Transactions on Fuzzy Systems*, Vol. 27, No. 8, August 2019, pp. 1543–1557.

Digital Object Identifier: 10.1109/TFUZZ.2018.2883022

"Multiview and multiexemplar fuzzy clustering aims at effectively integrating

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the fuzzy membership matrix of each individual view to search for a final partition of objects in which each cluster may well be represented by one and even multiple exemplars. However, how to integrate the corresponding fuzzy membership matrix of each view such that enhanced clustering performance can be theoretically guaranteed still keeps an open topic. In this study, with the proposed exemplar invariant assumption that an exemplar of a cluster in one view is always an exemplar of that cluster in each other view, the authors demonstrate that multiview & multiexemplar fuzzy clustering has a theoretical guarantee of enhanced clustering performance. Based on the above-mentioned theoretical result, the authors develop a novel multiview & multiexemplar fuzzy clustering approach (M^2FC). The key features of the proposed approach are: first, embed a quadratic penalization term into its objective function to minimize the discrepancy of exemplars across different views such that the exemplar invariant assumption can be met as much as possible; and second, optimize the proposed objective function of the proposed approach by applying the Lagrangian multiplier method and Karush-Kuhn-Tuchker conditions to assure nonnegative fuzzy memberships. Extensive experimental results show that M^2FC outperforms the existing state-of-the-art multiview approaches in most cases."

Semisupervised Fuzzy Clustering With Partition Information of Subsets, by J.-P. Mei, *IEEE Transactions on Fuzzy Systems*, Vol. 27, No. 9, September 2019, pp. 1726–1737.

Digital Object Identifier: 10.1109/TFUZZ.2018.2889010

"Pairwise constraint is a type of side information that is widely considered in existing semisupervised clustering approaches. In this paper, the authors explore a new form of supervision for clustering. They consider the partition results of a number of subsets as additional information to assist clustering. Compared to the pairwise constraint, which only involves the "must-link" or "cannot-link" relationship of two objects, the partition of a subset of objects provides information about the group structure of more objects and hence can possibly serve as a more effective form of supervision for clustering. In this paper, the authors instantiate the idea of clustering with subset partitions under the fuzzy clustering framework for document categorization. The proposed fuzzy clustering approach is formulated to learn from the partition of subsets and has the ability to handle high-dimensional document data. Specifically, the partition results of subsets are collectively transformed into pairwise relationships, based on which a penalty term is constructed and incorporated into a cosine-distance-based fuzzy c-means approach. The experimental results on benchmark data sets demonstrate the effectiveness of the proposed approach for a semisupervised document clustering."

IEEE Transactions on Evolutionary Computation

Optimal-Margin Evolutionary Classifier, by M. R. Bonyadi and D. C. Reutens, *IEEE Transactions on Evolutionary Computation*, Vol. 23, No. 5, October 2019, pp. 885–898.

Digital Object Identifier: 10.1109/TEVC.2019.2895298

"In this paper, the authors introduce a novel approach for discriminative classification using evolutionary algorithms. They first propose an algorithm to optimize the total loss value using a modified 0–1 loss function in a 1-D space for classification. They then extend this algorithm for multidimensional classification using an evolutionary algorithm. The proposed evolutionary algorithm aims to find a hyperplane that best classifies instances while minimizing the classification risk. They test particle swarm optimization, evolutionary strategy (ES), and covariance matrix adaptation ES for optimization purposes. After parameter selection, they compare the results with well-established and state-of-the-art classification algorithms, for both binary and multiclass classification, on 23 benchmark classification problems, with and without noise and outliers. They also compare these methods on a seizure detection task for 12 epileptic patients. Results show that the performance of the proposed algorithm is significantly (Wilcoxon test) better than all other methods in almost all problems tested. They also show that the proposed algorithm is significantly more robust against noise and outliers comparing to other methods. The running time of the algorithm is within a reasonable range for the solution of real-world classification problems."

IEEE Transactions on Games

ViZDoom Competitions: Playing Doom From Pixels, by M. Wydmuch, M. Kempka, and W. Jaśkowski, *IEEE Transactions on Games*, Vol. 11, No. 3, September 2019, pp. 248–259.

Digital Object Identifier: 10.1109/TG.2018.2877047

"This paper presents the first two editions of Visual Doom AI Competition, held in 2016 and 2017. The challenge was to create bots that compete in a multiplayer deathmatch in a first-person shooter game Doom. The bots had to make their decisions solely based on visual information, i.e., a raw screen buffer. To play well, the bots needed to understand their surroundings, navigate, explore, and handle the opponents at the same time. These aspects, together with the competitive multiagent aspect of the game, make the competition a unique platform for evaluating the state-of-the-art reinforcement learning algorithms. This paper discusses the rules, solutions, results, and statistics that give insight into the agents' behaviors. Best performing agents are described in more detail. The results of the competition lead to the conclusion that, although reinforcement learning can produce capable Doom bots, they still are not yet able to successfully compete against humans in this game. This paper also revisits the ViZDoom environment, which is a flexible, easy to use, and efficient three-dimensional platform for research for vision-based reinforcement

learning, based on a well-recognized first-person perspective game Doom."

IEEE Transactions on Cognitive and Developmental Systems

Deep Spiking Convolutional Neural Network Trained With Unsupervised Spike-Timing-Dependent Plasticity, by C. Lee, G. Srinivasan, P. Panda, and K. Roy, *IEEE Transactions on Cognitive and Developmental Systems*, Vol. 11, No. 3, September 2019, pp. 384–394.

Digital Object Identifier: 10.1109/TCDS.2018.2833071

"Spiking neural networks (SNNs) have emerged as a promising brain inspired neuromorphic-computing paradigm for cognitive system design due to their inherent event-driven processing capability. The fully connected (FC) shallow SNNs typically used for pattern recognition require large number of trainable parameters to achieve competitive classification accuracy. In this paper, the authors propose a deep spiking convolutional neural network (SpiCNN) composed of a hierarchy of stacked convolutional layers followed by a spatial-pooling layer and a final FC layer. The network is populated with biologically plausible leaky-integrate-and-fire (LIF) neurons interconnected by shared synaptic weight kernels. The authors train convolutional kernels layer-by-layer in an unsupervised manner using spike-timing-dependent plasticity (STDP) that enables them to self-learn characteristic features making up the input patterns. In order to further improve the feature learning efficiency, the authors propose using smaller 3×3 kernels trained using STDP-based synaptic weight updates performed over a mini-batch of input patterns. The proposed deep SpiCNN, consisting of two convolutional layers trained using the unsupervised convolutional STDP learning methodology, achieved classification accuracies of 91.1% and 97.6%, respectively, for inferring handwritten digits from the MNIST data set and a subset of natural images from the Caltech data set."

IEEE Transactions on Emerging Topics in Computational Intelligence

Data-Driven Decision-Making (D^3M): Framework, Methodology, and Directions, by J. Lu, Z. Yan, J. Han, and G. Zhang, *IEEE Transactions on Emerging Topics in Computational Intelligence*, Vol. 3, No. 4, August 2019, pp. 286–296.

Digital Object Identifier: 10.1109/TETCI.2019.2915813

"A decision problem, according to traditional principles, is approached by finding an optimal solution to an analytical programming decision model, which is known as model-driven decision-making. The fidelity of the model determines the quality and reliability of the decision-making; however, the intrinsic complexity of many real-world decision problems leads to significant model mismatch or infeasibility in deriving a model using the first principle. To overcome the challenges that are present in the big data era, both researchers and practitioners emphasize the importance of making decisions that are backed up by data related to decision tasks, a process called data-driven decision-making (D^3M). By building on data science, not only can decision models be predicted in the presence of uncertainty or unknown dynamics, but also inherent rules or knowledge can be extracted from data and directly utilized to generate decision solutions. This position paper systematically discusses the basic concepts and prevailing techniques in data-driven decision-making and clusters-related developments in technique into two main categories: programmable data-driven decision-making (P-D^3M) and nonprogrammable data-driven decision-making (NP-D^3M). This paper establishes a D^3M technical framework, main methodologies, and approaches for both categories of D^3M, as well as identifies potential methods and procedures for using data to support decision-making. It also provides examples of how D^3M is implemented in practice and identifies five further research directions in the D^3M area. We believe that this paper will directly support researchers and professionals in their understanding of the fundamentals of D^3M and of the developments in technical methods."

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