Publication Spotlight

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CIS Publication Spotlight

IEEE Transactions on Neural Networks and Learning Systems

Improving the Accuracy of Spiking Neural Networks for Radar Gesture Recognition Through Preprocessing, by A. Safa, F. Corradi, L. Keuninckx, I. Ocket, A. Bourdoux, F. Catthoor, and G. G. E. Gielen, *IEEE Transactions on Neural Networks and Learning Systems,* Vol. 34, No. 6, Jun. 2023, pp. 2869–2881.

Digital Object Identifier: 10.1109/TNNLS.2021.3109958

"Event-based neural networks are currently being explored as efficient solutions for performing AI tasks at the extreme edge. To fully exploit their potential, event-based neural networks coupled to adequate preprocessing must be investigated. Within this context, we demonstrate a 4-b-weight spiking neural network (SNN) for radar gesture recognition, achieving a state-of-the-art 93% accuracy within only four processing time steps while using only one convolutional layer and two fully

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connected layers. This solution consumes very little energy and area if implemented in event-based hardware, which makes it suited for embedded extreme-edge applications. In addition, we demonstrate the importance of signal preprocessing for achieving this high recognition accuracy in SNNs compared to deep neural networks (DNNs) with the same network topology and training strategy. We show that efficient preprocessing prior to the neural network is drastically more important for SNNs compared to DNNs. We also demonstrate, for the first time, that the preprocessing parameters can affect SNNs and DNNs in antagonistic ways, prohibiting the generalization of conclusions drawn from DNN design to SNNs. We demonstrate our findings by comparing the gesture recognition accuracy achieved with our SNN to a DNN with the same architecture and similar training. Unlike previously proposed neural networks for radar processing, this work enables ultralow-power radar-based gesture recognition for extreme-edge devices."

IEEE Transactions on Fuzzy Systems

More Than Accuracy: A Composite Learning Framework for Interval Type-2 Fuzzy Logic Systems, by A. Beke and T. Kumbasar, *IEEE Transactions on Fuzzy Systems*, Vol. 31, No. 3, Mar. 2023, pp. 734–744.

Digital Object Identifier: 10.1109/TFUZZ.2022.3188920

"In this article, we propose a novel composite learning framework for interval type-2 (IT2) fuzzy logic systems (FLSs) to train regression models with a high accuracy performance and capable of representing uncertainty. In this context, we identify three challenges, first, the uncertainty handling capability, second, the construction of the composite loss, and third, a learning algorithm that overcomes the training complexity while

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taking into account the definitions of IT2-FLSs. This article presents a systematic solution to these problems by exploiting the type-reduced set of IT2-FLS via fusing quantile regression and deep learning (DL) with IT2-FLS. The uncertainty processing capability of IT2-FLS depends on employed center-of-sets calculation methods, while its representation capability is defined via the structure of its antecedent and consequent membership functions. Thus, we present various parametric IT2-FLSs and define the learnable parameters of all IT2-FLSs alongside their constraints to be satisfied during training. To construct the loss function, we define a multiobjective loss and then convert it into a constrained composite loss composed of the log-cosh loss for accuracy purposes and a tilted loss for uncertainty representation, which explicitly uses the type-reduced set. We also present a DL approach to train IT2-FLS via unconstrained optimizers. In this context, we present parameterization tricks for converting the constraint optimization problem of IT2-FLSs into an unconstrained one without violating the definitions of fuzzy sets. Finally, we provide comprehensive comparative results for hyperparameter sensitivity analysis and an inter/intramodel comparison on various benchmark datasets."

Fuzzy Clustering With Knowledge Extraction and Granulation, by X. Hu, Y. Tang, W. Pedrycz, K. Di, J. Jiang, and Y. Jiang, *IEEE Transactions on Fuzzy Systems*, Vol. 31, No. 4, Apr. 2023, pp. 1098–1112.

Digital Object Identifier: 10.1109/TFUZZ.2022.3195033

"Knowledge-based clustering algorithms can improve traditional clustering models by introducing domain knowledge to identify the underlying data structure. While there have been several approaches to clustering with the guidance of knowledge tidbits, most of them mainly focus on numeric knowledge without considering the uncertain nature of information. To capture the uncertainty of information, pure numeric knowledge tidbits are expanded to knowledge granules in this article. Then, two questions arise: how to obtain granular knowledge and how to use those knowledge granules in clustering. To the end, a novel knowledge extraction and granulation (KEG) method and a granular knowledge-based fuzzy clustering model are proposed in this study. First, inspired by the concept of natural neighbors, an automatic KEG is developed. In KEG, high-density points are filtered from the dataset and then merged with their natural neighbors to form several dense areas, i.e., granular knowledge. Furthermore, the granular knowledge expressed by interval or triangular numbers is leveraged into the clustering algorithm, which is the framework of fuzzy clustering with granular knowledge. To concretize this model into clustering algorithms, the classical fuzzy C-Means clustering algorithm has been selected to incorporate the granular knowledge produced by KEG. Then, the corresponding fuzzy C-Means clustering with interval knowledge granules (IKG-FCM) and triangular knowledge granules (TKG-FCM) are proposed. Experiments on synthetic and real-world datasets demonstrate that IKG-FCM and TKG-FCM always achieve better clustering performance with less time cost, especially on imbalanced data, compared with state-of-the-art algorithms."

IEEE Transactions on Evolutionary Computation

Explainable Artificial Intelligence by Genetic Programming: A Survey, by Y. Mei, Q. Chen, A. Lensen, B. Xue, and M. Zhang, *IEEE Transactions on Evolutionary Computation*, Vol. 27, No. 3, Jun. 2023, pp. 621– 641.

Digital Object Identifier: 10.1109/TEVC.2022.3225509

"Explainable artificial intelligence (XAI) has received great interest in the recent decade, due to its importance in critical application domains, such as self-driving cars, law, and healthcare. Genetic programming (GP) is a powerful evolutionary algorithm for machine learning. Compared with other standard machine learning models such as neural networks, the models evolved by GP tend to be more interpretable due to their model structure with symbolic components. However, interpretability has not been explicitly considered in GP until recently, following the surge in the popularity of XAI. This article provides a comprehensive review of the studies on GP that can potentially improve the model interpretability, both explicitly and implicitly, as a byproduct. We group the existing studies related to explainable artificial intelligence by GP into two categories. The first category considers the intrinsic interpretability, aiming to directly evolve more interpretable (and effective) models by GP. The second category focuses on post-hoc interpretability, which uses GP to explain other black-box machine learning models, or explain the models evolved by GP by simpler models such as linear models. This comprehensive survey demonstrates the strong potential of GP for improving the interpretability of machine learning models and balancing the complex tradeoff between model accuracy and interpretability."

IEEE Transactions on Games

Procedural Generation of Narrative Worlds, by J. T. Balint and R. Bidarra, *IEEE Transactions on Games*, Vol. 15, No. 2, Jun. 2023, pp. 262–272.

Digital Object Identifier: 10.1109/TG.2022.3216582

"A narrative world typically consists of several interrelated locations that, all together, fully support enacting a given story. For this, each location in a narrative world features all the objects as required there by the narrative, as well as a variety of other objects that plausibly describe or decorate the location. Procedural generation of narrative worlds poses many challenges, including that, first, it cannot lean only on domain knowledge (e.g., patterns of objects commonly found in typical locations), and, second, it involves a temporal dimension, which introduces dynamic fluctuations of objects between locations. In this article, we present a novel approach for the procedural generation of narrative worlds, following two stages: first, a narrative world mold is generated (only once) for a given story; second, the narrative world mold is used to create one (or more) possible narrative worlds for that story. For each story, its narrative world mold integrates spatio-temporal descriptions of its locations with

the object semantics and the domain knowledge previously acquired on typical locations. We describe how a narrative world mold can be generated, as well as how it can be fed to existing procedural generation methods, to create a variety of narrative worlds that fit that narrative. We evaluate our own implementation of this approach, performing a number of experiments that illustrate both the expressive power of narrative world molds and their ability to steer the generation of narrative worlds."

IEEE Transactions on Cognitive and Developmental Systems

Learning Abstract Representations Through Lossy Compression of Multimodal Signals, by C. Wilmot, G. Baldassarre, and J. Triesch, *IEEE Transactions on Cognitive and Developmental Systems*, Vol. 15, No. 2, Jun. 2023, pp. 348–360.

Digital Object Identifier: 10.1109/TCDS.2021.3108478

"A key competence for open-ended learning is the formation of increasingly abstract representations useful for driving complex behavior. Abstract representations ignore specific details and facilitate generalization. Here, we consider the learning of abstract representations in a multimodal setting with two or more input modalities. We treat the problem as a lossy compression problem and show that generic lossy compression of multimodal sensory input naturally extracts abstract representations that tend to strip away modality specific details and preferentially retain information that is shared across the different modalities. Specifically, we propose an architecture that is able to extract information common to different modalities based on the compression abilities of generic autoencoder neural networks. We test the architecture with two tasks that allow: 1) the precise manipulation of the amount of information contained in and shared across different modalities and 2) testing the method on a simulated robot with visual and proprioceptive inputs. Our results show the validity of the proposed approach and demonstrate the applicability to embodied agents."

IEEE Transactions on Emerging Topics in Computational Intelligence

Multi-View Adjacency-Constrained Hierarchical Clustering, by J. Yang and C.-T. Lin, *IEEE Transactions on Emerging Topics in Computational Intelligence*, Vol. 7, No. 4, Aug. 2023, pp. 1126–1138.

Digital Object Identifier: 10.1109/TETCI.2022.3221491

"This paper explores the problem of multi-view clustering, which aims to promote clustering performance with multi-view data. The majority of existing methods have problems with parameter adjustment and high computational complexity. Moreover, in the past, there have been few works based on hierarchical clustering to learn the granular information of multiple views. To overcome these limitations, we propose a simple but efficient framework: Multi-view adjacency-Constrained Hierarchical Clustering (MCHC). Specifically, MCHC mainly consists of three parts: including the Fusion Distance matrices with Extreme Weights (FDEW); adjacency-Constrained Nearest Neighbor Clustering (CNNC); and the internal evaluation Index based on Rawls' Max-Min criterion (MMI). FDEW aims to learn a fusion distance matrix set, which not only uses complementary information among multiple views, but exploits the information from each single view. CNNC is utilized to generate multiple partitions based on FDEW, and MMI is designed for choosing the best one from the multiple partitions. In addition, we propose a parameter-free version of MCHC (MCHC-PF). Without any parameter selection, MCHC-PF can give partitions at different granularity levels with a low time complexity. Comprehensive experiments tested on eight real-world datasets validate the superiority of the proposed methods compared with the 13 current state-of-the-art methods."

IEEE Transactions on Artificial Intelligence

Building Trustworthy AI Solutions: A Case for Practical Solutions for Small Businesses, by K. Crockett, E. Colyer, L. Gerber, and A. Latham, *IEEE Transactions on Artificial Intelligence*, Vol. 4, No. 4, Aug. 2023, pp. 778–791.

Digital Object Identifier: 10.1109/TAI.2021.3137091

"Building trustworthy artificial intelligence (AI) solutions, whether in academia or industry, must take into consideration a number of dimensions including legal, social, ethical, public opinion, and environmental aspects. A plethora of guidelines, principles, and toolkits have been published globally, but have seen limited grassroots implementation, especially among small- and medium-sized enterprises (SMEs), mainly due to the lack of knowledge, skills, and resources. In this article, we report on qualitative SME consultations over two events to establish their understanding of both data and AI ethical principles and to identify the key barriers SMEs face in their adoption of ethical AI approaches. We then use independent experts to review and code 77 published toolkits designed to build and support ethical and responsible AI practices, based on 33 evaluation criteria. The toolkits were evaluated considering their scope to address the identified SME barriers to adoption, human-centric AI principles, AI life cycle stages, and key themes around responsible AI and practical usability. Toolkits were ranked on the basis of criteria coverage and expert intercoder agreement. Results show that there is not a one-size-fits-all toolkit that addresses all criteria suitable for SMEs. Our findings show few exemplars of practical application, little guidance on how to use/apply the toolkits, and very low uptake by SMEs. Our analysis provides a mechanism for SMEs to select their own toolkits based on their current capacity, resources, and ethical awareness levels – focusing initially at the conceptualization stage of the AI life cycle and then extending throughout."