Guest Editorial: Special Section on Advanced Deep Learning Algorithms for Industrial Internet of Things

NOWADAYS the industrial Internet of Things (IIoT) has been widely utilized in various fields (e.g., smart transportation, smart home, smart manufacturing). However, there are still some challenges, which hinder the further large-scale application of IIoT. Specifically, the data in IIoT are with a certain redundancy, while transmitting and processing these redundant data consume energy unnecessarily. Therefore, these redundant data should be compressed or removed. Conventionally, machine learning algorithms are used to process these redundant data in IIoT. However, with the growing diversity of IIoT and complexity of mobile network architectures, as well as increasing volume of data with increased dimensions and dynamics, they have made monitoring and managing a multitude of IIoT elements extremely difficult using machine learning algorithms. As we all know, deep learning algorithms can solve more complicated problems, unsolvable by machine learning algorithms, and produce high accurate results. Thus, machine learning algorithms are being replaced by advanced deep learning algorithms in various fields of IIoT. Incorporating advanced deep learning algorithms into IIoT can provide radical innovations in data analysis and pathbreaking industry applications.

Therefore, this special section aims to solicit original papers with novel contributions on advanced deep learning algorithms for various fields of IIoT. Based on the reviewers' feedback, as well as the evaluations of editors, 14 articles are selected in this special section from more than 100 submissions. The 14 article which cover broad topics are introduced briefly as follows.

In diverse applications of IIoT, the six degrees of freedom (6-DoF) information is essential, which determines the attitude and position of 3-D object. The article, "Robust 6-DoF Estimation for IIoT Based on Multi-branch Network" authored by Yang *et al.* proposed a completely new and universal multibranch network for estimating the six degrees of freedom (6-DoF). Compared with the traditional method, it owns higher accuracy and lower estimation error under occlusion.

Nowadays, information overload issue is gradually exposed in IoT, calling for research works on recommender system in advance for IoT scenarios. The article, "A Deep Graph Neural Network-based Mechanism for Social Recommendations" authored by Guo *et al.* proposed a deep graph neural network-based social recommendation framework (GNN-SoR) in IoT scenarios. A large amount of experiments are conducted on three real-world datasets to verify efficiency and stability of the proposed GNN-SoR.

As we know, it is a big challenge to recognize facial expression of vision IIoT systems more effectively. The article "Facial Expression Recognition of IIoTs by Parallel Neural Networks Combining Texture Features," authored by Xi *et al.* proposed a parallel neural network combining texture features, which can be applied in facial expression recognition. Experimental results prove the proposed method has a high recognition rate and strong robustness compared to competitive algorithms.

Healthcare applications are becoming flexible and scalable with the assimilation of information and communication technologies in recent years. It is very important to design a data processing and storage framework. Therefore, the article "Concurrent Healthcare Data Processing and Storage Framework using Deep-Learning in Distributed Cloud Computing Environment," authored by Yan *et al.* designed a concurrent healthcare data processing and storage framework using deep learning algorithms in cloud environment. The simulation analysis using the metrics discontinuous indexing, replicated data, retrieval time, and cost proves the reliability of the proposed framework.

As one of the most important applications of IIoT, intelligent transportation system aims to improve the efficiency and safety of transportation networks. The article "Variational Graph Neural Networks for Road Traffic Prediction in Intelligent Transportation Systems," authored by Zhou *et al.* proposed a novel Bayesian framework entitled Variational Graph Recurrent Attention Neural Networks (VGRAN) for robust traffic forecasting. Extensive experiments conducted on two real-world traffic datasets demonstrate that the proposed VGRAN model outperforms state-of-the-art approaches while capturing innate ambiguity of the predicted results.

IoT is making objects smarter and more autonomous, and also accelerating the development of online education. Content preparation for online education usually involves recording the classes. The article "Automation of Recording in Smart Classrooms via Deep Learning and Bayesian Maximum a Posteriori Estimation of Instructor's Pose" authored by Haghighi *et al.* proposed a deep learning-based solution to automate the process of recording for classrooms. Experimental results prove its reliability and receive a high accuracy.

As an essential part of IoT, monocular depth estimation (MDE) predicts dense depth maps from a single RGB image captured by monocular cameras. Past MDE methods almost focus on improving accuracy at the cost of increased latency,

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power consumption, and computational complexity, failing to balance accuracy and efficiency. In order to solve this challenge., the article "Efficient Monocular Depth Estimation for Edge Devices in Internet of Things" authored by Tu *et al.* designed a pruned and optimized MDE model for precise depth sensing on edge devices. Extensive experiments confirm that the designed model is effective for images of different sizes on two public datasets.

At present, the massive data in IIoT promote the development of deep learning-based health monitoring for smart manufacturing. Since monitoring data for mechanical fault diagnosis collected on different working conditions or equipment have domain mismatch, models trained with training data may not work in practical applications. In order to overall the challenge, the article "Intelligent Fault Diagnosis by Fusing Domain Adversarial Training and Maximum Mean Discrepancy via Ensemble Learning" authored by Li *et al.* proposed an intelligent fault diagnosis method based on an improved domain adaptation method with the help of deep learning algorithms. Experimental results indicate that the proposed method is effective and applicable in diagnosing faults with domain mismatch.

Real-time multimedia applications have gained immense popularity in IIoT. Due to the impact of the complex industrial environment, the transmission of video streaming is usually unstable. In view of this challenge, the paper entitled "Edge Computing-Enabled Deep Learning for Real-time Video Optimization in IIoT" authored by Dou *et al.* proposed a real-time video streaming optimization method by reducing the number of video frames transmitted in IIoT environment. Extensive experiments are conducted to validate the effectiveness, and dependability of the method.

Currently, the evolution toward IIoT, or so-called Industry 4.0, is already evident. The multipath communication problem in this field is still a challenge. The article "Multipath Communication with Deep Q-Network for Industry 4.0 Automation and Orchestration" authored by Pokhrel *et al.* designed a novel multipath communication framework for Industry 4.0 using Deep Q-Network to achieve human-level intelligence in networking automation and orchestration. The simulation result demonstrates that the proposed scheme significantly outperforms the baseline schemes.

Extensive interconnection of industrial systems with corporate systems in IIoT networks exposes the industrial domain to severe cyber-risks. For this problem, the article "An Adaptive Trust Boundary Protection for IIoT Networks Using Deep Learning Feature Extraction based Semi-Supervised Model" authored by Hassan *et al.* proposed an adaptive trust boundary protection for IIoT networks using a deep-learning model. Extensive experimental analysis of the attack models and results shows that the proposed approach significantly improves identification of attacks over conventional security control techniques.

IoT services rely on a heterogeneous cloud network for serving user demands ubiquitously. Service data management is a complex task in this heterogeneous environment. Therefore, the article "Machine Learning Assisted Information Management Scheme in Service Concentrated IoT" authored by Manogaran *et al.* proposed a machine learning aided information management scheme for handling data to ensure uninterrupted user request service. The proposed data management scheme ensures less replication and minimum service response time irrespective of the request and device density.

With the development of Internet of Medical Things, the task of reading and processing for medical images is increasing. Therefore, it is very important to design intelligent algorithms to complete the task. The article "Parallel Deep Learning Algorithms with Hybrid Attention Mechanism for Image Segmentation of Lung Tumors" authored by Hu *et al.* proposed a parallel deep learning algorithm with hybrid attention mechanism for image segmentation of lung tumors. The experimental results prove that the proposed method performs well in image segmentation of lung tumors compared with other baseline methods.

Recent trend focuses on using heterogeneous graph of things (HGoT) to represent things and their relations in IoT, thereby facilitating the applying of advanced learning frameworks, i.e., deep learning. Nevertheless, this is a challenging task since the existing deep learning models are hard to accurately express the complex semantics and attributes for those heterogeneous nodes and links in HGoT. To address this issue, the article "Attention-Aware Encoder-Decoder Neural Networks for Heterogeneous Graphs of Things" authored by Li *et al.* developed an Attention-Aware Encoder-Decoder Graph Neural Networks for HGoT, termed as HGAED. Extensive experiments on three real-world datasets demonstrate the superior performance of HGAED over state-of-the-art baselines.

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