Digital Object Identifier 10.1109/ACCESS.2021.3090137

EDITORIAL

IEEE ACCESS SPECIAL SECTION EDITORIAL: DATA MINING FOR INTERNET OF THINGS

It is an irrefutable fact that the Internet of Things (IoT) will eventually change our daily lives because its applications and relevant technologies have been or will be penetrating our daily lives. Also, the IoT is aimed to connect all the things (e.g., devices and systems) together via the Internet, thus making it easy to collect the data of users or environments and to find out useful information from the gathered data by using data mining technologies. As a consequence, how intelligent systems are developed for the IoT has become a critical research topic today. This means that artificial intelligence (AI) technologies (e.g., supervised learning, unsupervised learning, and semi-supervised learning) were used in the development of intelligent systems for analyzing the data captured from IoT devices or making decisions for IoT systems. It can be easily seen that AI can make an IoT system more intelligent and thus more accurate. For example, various sensors can be used for a smart home system to pinpoint the location and analyze the behavior of a human; however, with AI technologies, a more accurate prediction can be provided on the two pieces of information of a human. One of the most important uses for AI technologies is to make IoT systems more intelligent in order to provide a more convenient environment for users; thus, how to use existing AI technologies or develop new AI technologies to construct a better IoT system has attracted the attention of researchers from different disciplines in recent years. That is why, besides using existing supervised, unsupervised, semi-supervised learning algorithms, data mining algorithms, and machine learning algorithms, several recent studies have also attempted to develop new intelligent methods for the devices or systems for the IoT. All these approaches for making an IoT system more intelligent can also be found in the articles of this Special Section.

With great support from a large number of reviewers from different disciplines, organizations, and countries, we finally accepted 148 out of 443 articles submitted from 30 countries, namely, Australia, Bangladesh, Brazil, Canada, Chile, China, Colombia, Egypt, Hungary, India, Indonesia, Iran, Iraq, Italy, Japan, Malaysia, Oman, Pakistan, Poland, Portugal, Qatar, Saudi Arabia, South Korea, Spain, Taiwan, Turkey, the U.K., the United Arab Emirates, the USA, and Vietnam. The focus of this Special Section is on intelligent technologies for the IoT and their applications. The research focus of the articles in this Special Section can be divided into 13 categories: 1) smart cities, 2) agriculture, 3) healthcare, 4) human behavior and positioning, 5) social networks, 6) transportation, 7) industry, 8) education, 9) multimedia, 10) UAV and remote sensing, 11) security, privacy, and authentication, 12) effective or efficient algorithm design, and 13) system and framework design. A brief summary of these articles is given below.

The first category, about the technologies and applications of smart cities, contains 14 articles: "Channel status learning for cooperative spectrum sensing in energy-restricted cognitive radio networks," by Jin *et al.*; "Mobile fire evacuation system for large public buildings based on artificial intelligence and IoT," by Jiang; "Multi-dimensional joint prediction model for IoT sensor data search," by Zhang *et al.*; "Broken bike recycling planning for sharing bikes system," by Lu *et al.*; "Efficient and accurate target localization in underwater environment," by Ullah *et al.*; "Village-town system in suburban areas based on cellphone signaling mining and network hierarchy structure analysis," by Zhou *et al.*; "Layout design for intelligent warehouse by evolution with fitness approximation," by Zhang *et al.*; "Why customers don't revisit in tourism and hospitality industry?" by Chang *et al.*; "Performance analysis of indoor smart environmental control factors: Using temperature to control the rate of formaldehyde emission," by Chang *et al.*; "A novel framework for trash classification using deep transfer learning," by Vo *et al.*; "Seismic random noise attenuation based on PCC classification in transform domain," by Sang *et al.*; "Wind turbine fault diagnosis and predictive maintenance through statistical process control and machine learning," by Hsu *et al.*; "An adaptive Kalman filtering approach to sensing and predicting air quality index values," by Chen *et al.*; and "An implementation of high efficient smart street light management system for smart city," by Yang *et al.* Most of these articles attempted to develop better methods or systems based on IoT technologies to improve people's living environment. For example, in the article "An adaptive Kalman filtering approach to sensing and predicting air quality index values," by Chen *et al.*, an auto-regressive (AR) prediction model was presented to predict the so-called air quality index (AQI) values. Another interesting example can be found in the article "Wind turbine fault diagnosis and predictive maintenance through statistical process control and machine learning," by Hsu *et al.*, in which statistical and machine learning techniques were used to diagnose wind turbine faults. Of course,

the authors also used these technologies to predict maintenance needs by analyzing 2.8 million entries of sensor data collected from 31 wind turbines in Taiwan. In addition to the air quality and wind turbine faults prediction for the city, how to deal with the broken bikes for a bike-sharing system is also an interesting research work. In the article ''Broken bike recycling planning for sharing bikes system,'' by Lu *et al.*, an intelligent system with a multistep collection algorithm was built to collect the broken sharing bikes for recycling in a big city. For these studies, it can be easily seen that much of the research on smart cities used sensors to collect data from the environment and then developed intelligent algorithms or systems to provide better and smarter services to improve the living quality in a city.

In addition to smart cities, the so-called intelligent agriculture is another promising research topic that will directly or indirectly influence our living quality in the forthcoming days. In this Special Section, nine articles are relevant to intelligent agriculture using IoT technologies: ''Internet of Things monitoring system of modern eco-agriculture based on cloud computing,'' by Liu *et al.*; ''Theoretical basis and system establishment of China food safety intelligent supervision in the perspective of Internet of Things,'' by Fan; ''Intelligent agriculture and its key technologies based on Internet of Things architecture,'' by Chen and Yang; ''Applying big data for intelligent agriculture-based crop selection analysis,'' by Tseng *et al.*; ''Practical monitoring of undergrown pigs for IoT-based large-scale smart farm,'' by Lee *et al.*; ''The analysis of plants image recognition based on deep learning and artificial neural network,'' by Huixian; ''Internet of Things technology in ecological security assessment system of intelligent land,'' by Chen *et al.*; ''MDFC–ResNet: An agricultural IoT system to accurately recognize crop diseases,'' by Hu *et al.*; and ''An AIoT based smart agricultural system for pests detection,'' by Chen *et al.* Unlike most early studies on intelligent agriculture with IoT technologies, the focus nowadays is on improving the productivity of crops. This research topic is more diversified. Among them, identifying pests and diseases of crops are two critical research issues. In the article ''An AIoT based smart agricultural system for pests detection,'' by Chen *et al.*, the YOLOv3 was used to get the location of Tessaratoma Papillosa and then attempted to analyze the weather information stations via long short-term memory (LSTM) to predict pests. As for the diseases of crops, in the article ''MDFC–ResNet: An agricultural IoT system to accurately recognize crop diseases,'' by Hu *et al.*, a multidimensional feature compensation residual neural network model to increase the accuracy rate of a crop disease diagnosis system was presented. Another interesting study can be found in the article ''Practical monitoring of undergrown pigs for IoT-based large-scale smart farm,'' by Lee *et al.*, the focus of which was on detecting undergrown pigs via deep-learning-based computer vision techniques. Although it is not for crops, Lee *et al.* referred to it in their study as a group-housed pig farm. In this study, they proposed an automatic monitoring method for taking care of all the individual pigs in real time to avoid the economic loss caused by possible accidents.

Since most researchers believe that healthcare systems and relevant applications will be part of smart cities in the forthcoming days, this Special Section received many submissions in this research category and finally accepted 12 articles: ''Wavelet-based EEG processing for epilepsy detection using fuzzy entropy and associative Petri Net,'' by Chiang *et al.*; ''A decade of Internet of Things: Analysis in the light of healthcare applications,'' by Ud Din *et al.*; ''Robust multistage ECG identification for astronaut spacesuits with IoT applications,'' by Tseng *et al.*; ''A WPCA-based method for detecting fatigue driving from EEG-based Internet of Vehicles system,'' by Dong *et al.*; ''Internet of Things based on electronic and mobile health systems for blood glucose continuous monitoring and management,'' by Rodrigues Barata *et al.*; ''Intelligent imaging technology in diagnosis of colorectal cancer using deep learning,'' by Yang *et al.*; ''Design and implementation of wearable dynamic electrocardiograph real-time monitoring terminal,'' by Gong and Ding; ''Exploring the correlation between attention and cognitive load through association rule mining by using a brainwave sensing headband,'' by Huang *et al.*; ''A novel facial thermal feature extraction method for non-contact healthcare system,'' by Wang *et al.*; ''Colorectal disease classification using efficiently scaled dilation in convolutional neural network,'' by Poudel *et al.*; ''Contour-aware polyp segmentation in colonoscopy images using detailed upsampling encoder-decoder networks,'' by Nguyen *et al.*; and ''A deep learning H_2O framework for emergency prediction in biomedical big data,'' by Elsayad *et al.* One of the promising research trends is obviously to use machine learning algorithms to improve the accuracy of data analysis tasks. For instance, in the article ''A deep learning H_2O framework for emergency prediction in biomedical big data,'' by Elsayad *et al.*, whale optimization algorithm (WOA) and deep learning were combined to predict emergencies using biomedical big data. The WOA in this study was used to extract the subset of features to minimize the error of the classification while deep learning was used for data classification. Another main research direction in this topic is in the electroencephalography (EEG) data analysis, which can be found in the articles ''A WPCA-based method for detecting fatigue driving from EEG-based Internet of Vehicles system,'' by Dong *et al.*; ''Robust multistage ECG identification for astronaut spacesuits with IoT applications,'' by Tseng *et al.*; and ''Wavelet-based EEG processing for epilepsy detection using fuzzy entropy and associative Petri Net,'' by Chiang *et al.* A number of varying ways have been presented to improve the accuracy of data mining procedures and enhance the performance of data mining algorithms. In the article ''A WPCA-based method for detecting fatigue driving from EEG-based Internet of Vehicles system,'' by Dong *et al.*, a feature reduction method, which uses a weighted principal component analysis (WPCA) algorithm to adjust the weights of the features to speed up the computation

time of support vector machine (SVM) for EEG data analysis tasks, was presented. Finally, it can be easily seen that another research direction in healthcare is to investigate the possibility of new types of sensors or appliances, such as in the articles ''Design and implementation of wearable dynamic electrocardiograph real-time monitoring terminal,'' by Gong and Ding, and ''A novel facial thermal feature extraction method for non-contact healthcare system,'' by Wang *et al.* For instance, in the article ''Design and implementation of wearable dynamic electrocardiograph real-time monitoring terminal,'' by Gong and Ding, a wearable real-time monitoring terminal was used to gather electrocardiography (ECG) signals of people in their daily life and then an adaptive filter for data preprocessing was used to increase the accuracy of data mining.

Finding out the position of a user and understanding his or her behavior are two critical goals of modern IoT systems because these two pieces of information allow such systems to make a more precise action or decision for the user. How smart an artificial intelligence Internet of Things (AIoT) system is dependent on the precision of its actions and decisions for us. That is why the human positioning and human behavior recognition has been quite important for an IoT system in recent years. In this Special Section, we accepted 15 articles in this research category which explain why many researchers are focused on this topic and also explains why it is important for the research society of the IoT: ''Gesture recognition based on CNN and DCGAN for calculation and text output,'' by Fang *et al.*; ''A UKF-based emergency aware fusion model in a heterogeneous network for wireless body networks,'' by Li *et al.*; ''Performance test of MPMD matching algorithm for geomagnetic and RFID combined underground positioning,'' by Wang *et al.*; ''A novel high precision and low consumption indoor positioning algorithm for Internet of Things,'' by Ren *et al.*; ''A pedestrian detection method based on genetic algorithm for optimize XGBoost training parameters,'' by Jiang *et al.*; ''Time series data classification based on dual path CNN-RNN cascade network,'' by Yang *et al.*; ''Recognizing ping-pong motions using inertial data based on machine learning classification algorithms,'' by Zhang *et al.*; ''Efficient AoA-based rigid body localization via single base station for Internet of Things applications,'' by Zhou *et al.*; ''Face occlusion recognition with deep learning in security framework for the IoT,'' by Mao *et al.*; ''MeshMap: A magnetic field-based indoor navigation system with crowdsourcing support,'' by Chen *et al.*; ''Data mining analysis of overall team information based on Internet of Things,'' by Lee *et al.*; ''An intelligent identification model for the selection of elite rowers by incorporating Internet-of-Things technology,'' by Liu *et al.*; ''Enabling intelligent environment by the design of emotionally aware virtual assistant: A case of smart campus,'' by Chiu *et al.*; ''Improved genetic algorithm to optimize the Wi-Fi indoor positioning based on artificial neural network,'' by Cui *et al.*; and ''Pedestrian re-identification monitoring system based on deep convolutional neural network,'' by Qu *et al*. As for human positioning, a research trend is the realization of positioning in indoor environments via sensors or relevant appliances. For instance, in the article ''A novel high precision and low consumption indoor positioning algorithm for Internet of Things,'' by Ren *et al.*, the k-nearest neighbor (KNN) and fuzzy c-mean algorithms were used to analyze Wi-Fi signals to achieve high precision and low consumption indoor positioning. As for understanding the human behavior, an interesting study can be found in the article ''Recognizing ping-pong motions using inertial data based on machine learning classification algorithms,'' by Zhang *et al.*, in which a commercial smartwatch was first used to gather the data of acceleration, angular velocity, and magnetic induction of a human. With these pieces of information, Zhang and his colleagues used machine learning classification algorithms (e.g., k-nearest neighbor, support vector machine, naive Bayes, logistic regression, decision tree, and random forest) and deep-learning algorithms to recognize the human motion in ping-pong (also called table tennis).

Besides information on human behavior and position, with the advance of internet technology and smart handheld devices, we now have another way to understand behaviors and favors of users. It is an important reason that many more recent studies have attempted to use the information from social networks to make better marketing strategies. This Special Section contains five articles that used social network information to understand the user or used for social network environment: ''Deformable convolutional matrix factorization for document context-aware recommendation in social networks,'' by Chen *et al.*; ''An empirical study of social network activities via Social Internet of Things (SIoT),'' by Chung and Liang; ''Multi-topic misinformation blocking with budget constraint on online social networks,'' by Pham *et al.*; ''Deep learning techniques for community detection in social networks,'' by Wu *et al.*; and ''A social-aware P2P video transmission strategy for multimedia IoT devices,'' by Hsu and Tung. For example, in the article ''An empirical study of social network activities via social Internet of Things (SIoT),'' by Chung and Liang, psychological perspectives of users when they are in the social Internet of Things environment was discussed in order to better understand human activities on such a new network environment. Moreover, in the article ''A social-aware P2P video transmission strategy for multimedia IoT devices,'' by Hsu and Tung, a social-aware P2P (peer-to-peer) video transmission architecture which contains several multimedia IoT devices and a weighted fair queue (WFQ) for P2P video transmission for different queuing priority classes was presented. The simulation results show that this architecture can provide a better way to share video and watching experiences with multimedia IoT devices.

We all know that the IoT and relevant technologies will strongly impact the development of urban and future cities. Among them, transportation is an essential part of future cities if we want it trend to ''smart'' and ''intelligent.''

A recent report (https://www.greencarreports.com/news/1093560_1-2-billion-vehicles-on-worlds-roads-now-2-billion-by-2035-report) pointed out that the total number of vehicles worldwide was about 1.2 billion in 2014, and may increase to 2.5 billion by 2050. This information tells us no matter how much progress is made in a city, we will always confront the problem of having a large number of vehicles. This will bring up issues, such as carbon emissions, more traffic jams, and more traffic accidents, not only today but also in the decades to come. As such, developing good strategies, policies, infrastructures, and public transportation systems to provide a convenient traffic environment for us have become important research topics. In this Special Section, 14 articles are included that show the importance of transportation in data mining and the IoT: ''An effective order-aware hybrid genetic algorithm for capacitated vehicle routing problems in Internet of Things,'' by Lin *et al.*; ''Analysis of vehicle network architecture and performance optimization based on soft definition of integration of cloud and fog,'' by Zhou and Zhu; ''Design of traffic emergency response system based on Internet of Things and data mining in emergencies,'' by Liu and Wang; ''A generalized approach for anomaly detection from the Internet of Moving Things,'' by Tian *et al.*; ''PTCCR: A path transmission costs-based multi-lane connectivity routing protocol for Urban Internet of Vehicles,'' by Chen *et al.*; ''Data mining and optimization of a port vessel behavior behavioral model under the Internet of Things,'' by Jiang *et al.*; ''The prediction of freeway traffic conditions for logistics systems,'' by Wang *et al*., ''ASTIR: Spatio-temporal data mining for crowd flow prediction,'' by Mourad *et al.*; ''Research on adaptive iterative learning control of air pressure in railway tunnel with IoTs data,'' by Zhang *et al.*; ''Driving behavior clustering for hazardous material transportation based on genetic fuzzy *C*-means algorithm,'' by Wang and Wang; ''Operating efficiency-based data mining on intensive land use in smart city,'' by Duan *et al.*; ''Simulation of vehicle network communication security based on random geometry and data mining,'' by Wang *et al.*; ''Countermeasure study of urban traffic improvement based on the Internet of Things,'' by Wang *et al.*; and ''Interference aware service migration in vehicular fog computing,'' by Ge *et al*. Predicting traffic status has undergone a number of important changes because many kinds of prediction methods have been presented in recent years. In the article ''ASTIR: Spatio-temporal data mining for crowd flow prediction,'' by Mourad *et al.*, an attentive spatio-temporal inception ResNet (ASTIR) was presented to predict crowd flow that combines convolution-long short-term memory and attention module to better capture pattern movement changes. Simulation results show that it provides better prediction results than other prediction algorithms for the datasets of taxi Beijing and bike New York. Another study, ''The prediction of freeway traffic conditions for logistics systems,'' by Wang *et al.*, also focused on traffic prediction problems, but the focus is on freeway traffic and logistics systems. In their study, a discrete-time Markov chain was used for online traffic monitoring data to predict the probability of traffic congestion and to identify freeway bottlenecks. Moreover, an interesting study can be found in the article ''Design of traffic emergency response system based on Internet of Things and data mining in emergencies,'' by Liu and Wang, in which a traffic emergency response system based on the IoT and data mining technologies was presented to make it possible for such a system to use the flowing information of vehicles to improve rescue efficiency and urban traffic management. In the article ''Analysis of vehicle network architecture and performance optimization based on soft definition of integration of cloud and fog,'' by Zhou and Zhu, a new vehicle network architecture that adopts soft definition network (SDN) to integrate the cloud and fog servers to reduce the communication delay and energy consumption of such a system was presented. Also, because the public transportation system is part of a smart city, the article ''Research on adaptive iterative learning control of air pressure in railway tunnel with IoTs data,'' by Zhang *et al*., focused on how to adjust air and exhaust gas of the ventilation system to restrain the pressure fluctuation in the train. The simulation results show that the adaptive iterative learning control algorithm is capable of finding a better way to adjust the working frequency of the ventilator for improving the pressure of passengers on the train.

The use of data mining technologies and IoT devices is a critical research direction in different industries due to their ability to provide new opportunities to gain more profits. A common application of data mining technologies is to use data mining algorithms to find out useful information hidden in the large-scale data of machine equipment from the production line, which may be useful to increase chip yield or cycle time. Similarly, a new trend is to add more IoT devices in order to gather additional data for data mining algorithms to help companies find useful information to make a more precise plan for the whole production line. This category contains 11 articles that use different ways to enhance the performance of industry: ''The role of wearable technologies in supply chain collaboration: A case of pharmaceutical industry,'' by Shafique *et al.*; ''Concept drift detection and adaption in big imbalance industrial IoT data using an ensemble learning method of offline classifiers,'' by Lin *et al.*; ''An intelligent supply chain information collaboration model based on Internet of Things and big data,'' by Jiang; ''Data-driven reallocation of workers in engineering-to-order assembly islands: A case study,'' by Hu and Wan; ''The research on the motion state monitoring of electromagnetic valve train of engine based on Internet of Things,'' by Guo and Chang; ''Research on complex structures in space fault network for fault data mining in system fault evolution process,'' by Cui and Li; ''Construction of supply chain financial risk management mode based on Internet of Things,'' by Wang *et al*., ''A linearization model of turbofan engine for intelligent analysis towards industrial Internet of Things,'' by Gou *et al.*; ''Detecting a business anomaly based on QoS benchmarks of resource-service chains for collaborative tasks in the IoT,'' by Li *et al.*; ''Formal verification of a hybrid

machine learning-based fault prediction model in Internet of Things applications," by Souri *et al.*; and "An IoT-based cyber-physical framework for turbine assembly systems," by Hu *et al*. For instance, in the article "An IoT-based cyber-physical framework for turbine assembly systems," by Hu *et al*., IoT-based monitoring modules were used to gather data from workers, tools, and assembly process to reassign the workers, control the logistics when an unexpected event occurs, and also improve assembly task schedules. Another similar approach can be found in the article "Data-driven reallocation of workers in engineering-to-order assembly islands: A case study," by Hu and Wan, in which an effective way (i.e., linear interactive and general optimizer) was presented to reallocate the tasks of workers in engineering-to-order assembly islands when an unexpected event occurs to meet the specified dateline. Since collaboration with the whole supply chain is also a critical issue in industry, in the article "An intelligent supply chain information collaboration model based on Internet of Things and big data," by Jiang, IoT and big data technologies were adopted to construct a simulation model of the supply chain bullwhip effect based on a mathematical model of key factors of a supply chain collaboration.

Although there are only two articles, "A hybrid biological data analysis approach for students' learning creative characteristics recognition," by Chen *et al*., and "Design and evaluation of a deep learning recommendation based augmented reality system for teaching programming and computational thinking," by Lin and Chen, in the category of education in this Special Section, it does not mean this research direction is not important. On the contrary, using data mining and IoT technologies to improve learning and teaching performance has gradually become popular in recent years. In the article "A hybrid biological data analysis approach for students' learning creative characteristics recognition," by Chen *et al*., a hybrid biological data analysis tool for teachers to understand the status of student learning performance through wearable biological monitoring devices to gather student's data, such as brainwave values and echoed heartbeats, was presented. In another study, "Design and evaluation of a deep learning recommendation based augmented reality system for teaching programming and computational thinking," by Lin and Chen, a deep learning based recommendation system that uses augmented reality (AR) and learning theory to provide students from different learning backgrounds a better way to learn programming and computational thinking was presented.

Multimedia and its relevant applications have become part of our lives, therefore, many recent studies have attempted to use data mining to analyze multimedia data or integrate IoT devices to multimedia systems. Six articles about multimedia and relevant applications are included in this Special Section, indicating that it is a popular research direction: "Deep unified model for face recognition based on convolution neural network and edge computing," by Khan *et al*., "Internet of Things recognition and sensing technology in interactive display communication," by Li, "A finger-worn device for exploring Chinese printed text with using CNN algorithm on a micro IoT processor," by Su *et al*., "The application of fog computing and Internet of Things technology in music resource management model," by Zhang, "The effects of depth of field on subjective evaluation of aesthetic appeal and image quality of photographs," by Zhang *et al*., and "Parallel recurrent convolutional neural networks-based music genre classification method for mobile devices," by Yang *et al*. In the article "Parallel recurrent convolutional neural networks-based music genre classification method for mobile devices," by Yang *et al*., some time-series data classification problems are in mobile devices, such as music genre classification on mobile phones, were first pointed out. To provide a better way to deal with this kind of problem, Yang *et al.* presented a hybrid architecture by using a parallel recurrent convolutional neural network (PRCNN) to extract the spatial features and temporal frame orders in order to improve the classification results. Another study, "The application of fog computing and Internet of Things technology in music resource management model," by Zhang, attempted to develop a better management system for dance music resources. In this study, Zhang presented an improved non-dominated sorting genetic algorithm II (NSGA-II) to solve the resource allocation problem on such a system. The simulation results show that the system proposed in the article can reduce the response time and increase the throughput of the system compared to systems without such a resource management algorithm, and it is capable of providing a better experience for the user. An interesting study can be found in the article "A finger-worn device for exploring Chinese printed text with using CNN algorithm on a micro IoT processor," by Su *et al*., in which a finger-worn device (a portable device) that can be used to recognize characters on the micro IoT processor was developed. This new device contains a small camera to capture images and identify relative position of the user's finger and an audio device to output the corresponding character with a voice.

With the advance of remote sensing and unmanned aerial vehicle (UAV) technologies, it is now easy to realize applications to observe the landscape or deliver goods to users. In this Special Section, we include five articles in this category: "Secure multi-UAV collaborative task allocation," by Fu *et al*., "Multi-attention object detection model in remote sensing images based on multi-scale," by Ying *et al*., "A reinforcement one-shot active learning approach for aircraft type recognition," by Huang *et al*., "Classification for remote sensing data with improved CNN-SVM method," by Sun *et al*., and "Dynamic rendezvous node estimation for reliable data collection of a drone as a mobile IoT gateway," by Min *et al*. A fundamental study can be found in the article "Multi-attention object detection model in remote sensing images based on multi-scale," by Ying *et al.*, in which the authors propose a multi-attention object detection method (MA-FPN) based on multi-scale to make the system pay attention to the location of the object. The simulation results

shown that MA-FPN can provide better results than other deep learning algorithms in terms of the average precision. In another remote sensing study, ''Classification for remote sensing data with improved CNN-SVM method,'' by Sun *et al.*, the convolutional neural network (CNN) and support vector machine (SVM), called the CNN-SVM, were combined. The simulation results show that CNN-SVM can significantly increase the classification results of remote images compared with other deep learning algorithms in terms of the accuracy. As for the study of UAV, in the article ''Secure multi-UAV collaborative task allocation,'' by Fu *et al.*, a new framework was presented to allocate the collaborative task of multi-UAV. The authors first formulated a combinatorial optimization problem based on the concerns (e.g., lower energy consumption and collisions between the UAVs) and then used an improved clustering algorithm to deal with this optimization problem.

In the IoT era, the issues of security, privacy, and authentication have become much more important than in previous network environments because the computation ability and storage of IoT devices and systems are less than other existing network systems. For this reason, most IoT devices are weak against the attacks from hackers and abnormal user behaviors. The importance of these three issues has been found not only in many recent studies but also in the submissions to this Special Section. 26 articles relevant to these issues are included: ''Digital watermarking technique for text document protection using data mining analysis,'' by Khadam *et al.*, ''A steganography algorithm based on CycleGAN for covert communication in the Internet of Things,'' by Meng *et al.*, ''Analysis of botnet domain names for IoT cybersecurity,'' by Li *et al.*, ''Research and application of element logging intelligent identification model based on data mining,'' by Liang *et al.*, ''Cyber security threats detection in Internet of Things using deep learning approach,'' by Ullah *et al.*, ''Blockchain-driven IoT for food traceability with an integrated consensus mechanism,'' by Tsang *et al.*, ''Anti-synchronization and robust authentication for noisy PUF-based smart card,'' by Chen *et al.*, ''Group-oriented cryptosystem for personal health records exchange and sharing,'' by Wu, ''A DNA computation-based image encryption scheme for cloud CCTV systems,'' by Wu *et al.*, ''A big data mining approach of PSO-based BP neural network for financial risk management with IoT,'' by Zhou *et al.*, ''A mean quantization watermarking scheme for audio signals using singular-value decomposition,'' by Bhat *et al.*, ''DynaPro: Dynamic wireless sensor network data protection algorithm in IoT via differential privacy,'' by Li *et al.*, ''Blockchain based data integrity verification for large-scale IoT data,'' by Wang and Zhang, ''Benchmarking dynamic searchable symmetric encryption scheme for cloud-Internet of Things applications,'' by Ti *et al.*, ''Study on secrecy capacity of wireless sensor networks in Internet of Things based on the amplify-and-forward compressed sensing scheme,'' by Guo *et al.*, ''An authentication information exchange scheme in WSN for IoT applications,'' by Yang *et al.*, ''A new feature scoring method in keystroke dynamics-based user authentications,'' by Kim *et al.*, ''Traffic fingerprinting attacks on Internet of Things using machine learning,'' by Skowron *et al.*, ''A blockchain-based application system for product anti-counterfeiting,'' by Ma *et al.*, ''Vulnerability attacks of SVD-based video watermarking scheme in an IoT environment,'' by Prasetyo *et al.*, ''Ciphertext-policy hierarchical attribute-based encryption against key-delegation abuse for IoT-connected healthcare system,'' by Chen *et al.*, ''A reliable physical layer authentication algorithm for massive IoT systems,'' by Wang *et al.*, ''WS-LSMR: Malicious Web-Shell detection algorithm based on ensemble learning,'' by Ai *et al.*, ''Fog-based attack detection framework for Internet of Things using deep learning,'' by Samy *et al.*, ''CNN based malicious website detection by invalidating multiple web spams,'' by Liu and Lee, and ''Secure content-based image retrieval in the cloud with key confidentiality,'' by Li *et al.* Such a great number of articles indicates that more and more researchers focus on these research topics and that these will be an essential part of IoT devices and systems. The study, ''Fog-based attack detection framework for Internet of Things using deep learning,'' by Samy *et al.*, is a representative research that takes into account the security issues of an IoT environment. In this study, Samy and his colleagues presented an attack detection framework on the fog layer to detect several IoT cyber-attacks by using a certain number of deep learning models. The simulation results show that this framework can detect up to 99.97 cyber-attacks on an IoT environment. The focus of another study, ''Traffic fingerprinting attacks on Internet of Things using machine learning,'' by Skowron *et al.*, is on the privacy of users in an IoT environment. In this study, Skowron *et al.* first analyzed the individual devices in a victim's home network and then presented a machine learning-based pattern recognition method to detect the devices' state in order to protect the privacy of the user. In addition to security and privacy issues, the focus of the article, ''A new feature scoring method in keystroke dynamics-based user authentications,'' by Kim *et al.*, was on how to manage user authentications. In this study, Kim *et al.* presented a filter-based feature-selection method for the context of keystroke dynamics authentication. It is expected that this technology will be very useful for an IoT environment.

Developing a more effective or efficient algorithm for IoT devices or systems has been another critical research topic since the concept of the IoT was presented to the public. Compared to the approach of using a better machine, developing an effective or efficient algorithm is also a more cost-effective way for enhancing the overall performance of a system or device. There are 22 articles about how to enhance the performance of an algorithm in an IoT environment that are included in this Special Section: ''Efficient matching of multi-modal sensing nodes for collaborative sense optimization of composite events,'' by Liu *et al.*, ''Selecting hyper-parameters of Gaussian process regression based on non-inertial particle swarm optimization in Internet of Things,'' by Kang *et al.*, ''Tolerable data

transmission of mobile edge computing under Internet of Things," by Liu *et al.*, "Joint offloading and transmission power control for mobile edge computing," by Liu *et al.*, "Locally weighted adjustable parameter-based LPVG in the identification of functional regions," by Li *et al.*, "Human-centric AI for trustworthy IoT systems with explainable multilayer perceptrons," by García-Magariño, *et al.*, "Deep learning-based reasoning with multi-ontology for IoT applications," by Liu *et al.*, "HcRPC: Highly compact reachability preserving graph compression with corrections," by Bing *et al.*, "Location-based parallel sequential pattern mining algorithm," by Kim and Yi, "The analysis of node planning and control logic optimization of 5G wireless networks under deep mapping learning algorithms," by Han and Liang, "Energy consumption in point-coverage wireless sensor networks via bat algorithm," by Sangaiah *et al.*, "Performance analysis of different types of machine learning classifiers for non-technical loss detection," by Ghori *et al.*, "An intelligent algorithm for resource sharing and self-management of wireless-IoT-gateway," by Ramírez *et al.*, "Mobile edge computing based task offloading and resource allocation in 5G ultra-dense networks," by Chen *et al.*, "A coalitional graph game approach for minimum transmission broadcast in IoT networks," by Chan *et al.*, "Optimization of microservice composition based on artificial immune algorithm considering fuzziness and user preference," by Gao *et al.*, "A multi-label classification with hybrid label-based meta-learning method in Internet of Things," by Lin *et al.*, "Novel kernel orthogonal partial least squares for dominant sensor data extraction," by Chen, "A hybrid service selection and composition model for cloud-edge computing in the Internet of Things," by Hosseinzadeh *et al.*, "Application of data mining methods in Internet of Things technology for the translation systems in traditional ethnic books," by Luo and Xiang, "An N-list-based approach for mining frequent inter-transaction patterns," by Nguyen *et al.*, and "An efficient method for mining top-K closed sequential patterns," by Pham *et al*. In the article "A hybrid service selection and composition model for cloud-edge computing in the Internet of Things," by Hosseinzadeh *et al.*, a hybrid artificial neural network with particle swarm optimization, called the ANN-PSO, was presented. This algorithm is used for enhancing the QoS factors in cloud-edge computing. This combination includes supervised and unsupervised learning algorithms which can improve the reachability rate of candidate composited services and QoS factors. Because energy consumption has always been an important research issue in the IoT and wireless sensor network (WSN), in the article "Energy consumption in point-coverage wireless sensor networks via bat algorithm," by Sangaiah *et al.*, the bat algorithm (a metaheuristic algorithm) was used to select monitoring sensor nodes and information flow paths to reduce the energy consumption, thus extending the lifetime of a WSN. Moreover, for the communications between devices, in the article "An intelligent algorithm for resource sharing and self-management of wireless-IoT-gateway," by Ramírez *et al.*, Ramirez and his colleagues presented a simple but intelligent algorithm to share common resources among "things" between different types of smart appliances in an IoT environment.

The last category is the system and framework design. In this category, seven articles are included: "iDiSC: A new approach to IoT-data-intensive service components deployment in edge-cloud-hybrid system," by Chen *et al.*; "Blending big data analytics: Review on challenges and a recent study," by Amalina *et al.*; "Mobile device detection through WiFi probe request analysis," by Oliveira *et al.*; "Search engine for the Internet of Things: Lessons from web search, vision, and opportunities," by Liang *et al.*; "Collaborative filtering recommendation algorithm for heterogeneous data mining in the Internet of Things," by Gao and Ran; "Online scheduling optimization for DAG-based requests through reinforcement learning in collaboration edge networks," by Zhang *et al.*; and "A novel framework for recommending data mining algorithm in dynamic IoT environment," by Hossain *et al*. Most of them are about how to develop and design a better data mining and IoT system from a high-level perspective. For instance, in the article "Blending big data analytics: Review on challenges and a recent study," by Amalina *et al*., using big data analytics for solving problems of complex and unstructured data using technologies, such as Hadoop, Spark, and MapReduce, for different kinds of data was discussed. In the article "iDiSC: A new approach to IoT-data-intensive service components deployment in edge-cloud-hybrid system," by Chen *et al.*, an improved ant colony optimization algorithm was presented to reduce the transmission delay for IoT-data-intensive service component deployment in the edge-cloud-hybrid system. The simulation results show that the proposed ant-based algorithm can provide better performance than the genetic algorithm and the simulated annealing algorithm in an IoT environment in terms of the communication latency.

Finally, we would like to thank Professor Derek Abbott, Editor-in-Chief of IEEE ACCESS, as well as the other IEEE ACCESS staff members, for their continuous support and encouragement for the development of this Special Section. We would also like to thank the anonymous reviewers for their valuable comments and suggestions that greatly improved the quality of the articles submitted to this Special Section, as well as all the authors for submitting their articles and making this Special Section so successful. We hope that this Special Section will act as a booster to encourage more researchers from different disciplines to use intelligent technologies to make the IoT a better future for all.

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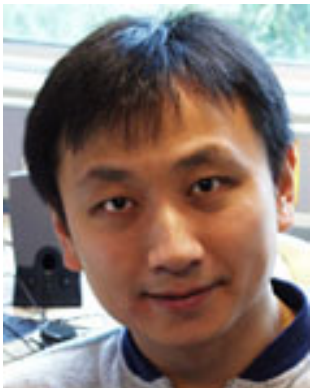

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