Guest Editorial
Special Issue on Internet of Things for Smart Health and Emotion Care

AS AN information carrier, the Internet of Things (IoT) based on the Internet and sensing equipment makes all physical objects form an interconnected network. The 5th generation mobile networks (5G) technology has many advantages, such as high data rates, reduced latency, energy savings, reduced costs, increased system capacity and large-scale device connectivity, realize the real-time data collection, transmission, analysis, management, and application in the era of global Internet of Everything. In order to quickly respond to people's daily requirements and provide the smart application based on artificial intelligence technology in various scenarios, the number of IoT devices will further increase. The integration of mobile-edge computing (MEC) and IoT is imperative, especially in industries needing real-time data computing, such as smart home, public security, automobile transportation, smart health, emotion care, etc. As a new form of IoT terminal combining 5G and MEC, wearable device based on intelligent fabrics plays an important role in smart health and emotion care, which is one of the potential development directions of the next generation of intelligent medical and rehabilitation systems.

Wearable sensors can collect multimodal data, such as physiological data of the human body and psychological data closely related to emotion, including ECG, EEG, blood pressure, blood oxygen, voice, and expression data. Combining with conventional sensor data, such as video, audio, and speech text data, significant health characteristics can be obtained using deep learning technology. With the help of professional medical knowledge, the medical knowledge graph and corresponding inference algorithms positioning different scenes will be constructed. In real application scenarios, patients' symptoms are extracted from the data collected by the IoT, and corresponding treatment plans are provided to serve smart health. For patients with mental illness, emotion care can be achieved through sentiment analysis.

This special issue aims to research the state-of-the-art developments, new architecture, and novel algorithms of the IoT for smart health and emotion care applications. It will bring together academic and industrial researchers to discuss technical challenges and recent results related to intelligent networks, in order to meet the demanding requirements needed for user experience, efficiency, and performance in a complex network environment, novel design, configuration, and optimization for communications and networking. In response to the call for contributions, we have received many paper submissions. After a careful review process, 21 outstanding articles have been collected for this special issue.

Li *et al.* propose using smartphone usage data to detect group health conditions, such as the severity of Covid-19, in their article "The impact of Covid-19 on smartphone usage." The outbreak of Covid-19 affects users' smartphone usage behaviors in terms of memory usage, CPU usage, and network usage, as demonstrated by a real-world data set. A deep-learning-based model is proposed for detecting the Covid-19 outbreak stage from smartphone data, with Macro-F1 and Micro-F1 both scoring over 0.8.

In the article "Learning your heart actions from pulse: ECG waveform reconstruction from PPG," Zhu *et al.* study the relation between electrocardiogram (ECG) and photoplethysmogram (PPG) and infer the waveform of ECG via the PPG signals that can be obtained from affordable wearable IoT devices for mobile health. In order to address this inverse problem, a transform is proposed to map the discrete cosine transform (DCT) coefficients of each PPG cycle to those of the corresponding ECG cycle based on their proposed cardiovascular signal model. The proposed method is evaluated with different morphologies of the PPG and ECG signals on three benchmark data sets with a variety of combinations of age, weight, and health conditions using different training setups. Experimental results show that the proposed method can achieve a high prediction accuracy greater than 0.92 in averaged correlation for each data set when the model is trained subject-wise. With a signal processing and learning system that is designed synergistically, the authors are able to reconstruct ECG signals by exploiting the relation of these two types of cardiovascular measurement. The reconstruction capability of the proposed method can enable low-cost ECG screening from affordable wearable IoT devices for continuous and long-term monitoring. This work may open up a new research direction to transfer the understanding of the clinical ECG knowledge base to build a knowledge base for PPG and data from wearable devices.

The article "Digital twin for intelligent context-aware IoT healthcare systems," written by Elayan *et al.*, proposes a digital twin framework for building smart healthcare systems that aid in continuous monitoring and improvement of healthcare operations using IoT. The implementation of a heart disease diagnostic system has demonstrated that integrating DT with the healthcare field would improve healthcare processes by

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bringing patients and healthcare professionals together in an intelligent, comprehensive, and scalable ecosystem. Moreover, the application of the ECG classifier inspires to apply AI with different human body metrics for continuous monitoring and abnormalities detection. Finally, deep learning algorithms handle ECG data better than traditional ML algorithms.

The article "Convolutional network embedding of text-enhanced representation for knowledge graph completion," written by Zhao *et al.*, proposes a novel joint representation learning model that introduces text description information and extracts reliable feature information from text data by using a convolutional neural network (CNN) model. The experimental results reveal that the proposed joint representation learning model performs well in the basic prediction task and can fully utilize the effective feature obtained from the text to enhance structural representation learning.

The article "Smart health of ultrasound telemedicine based on deeply represented semantic segmentation," written by Shen *et al.*, proposes a robust deep learning framework for the segmentation of cardiac ultrasound imaging sequences over the IoT platform. This framework over the IoT platform is evaluated over two echocardiographic data: 1) public data set (CAMUS) and 2) self-made data set (total 18 906 images from 160 patients). Sufficient experiments show that this framework is prominent in generalization and robustness, surpassing other state-of-the-art methods.

The article "An intelligent end–edge-cloud architecture for visual IoT-assisted healthcare systems," written by Yang *et al.*, proposes an intelligent end–edge-cloud architecture for visual IoT-assisted healthcare systems, including computation model of end intelligence, edge intelligence, and cloud intelligence. The architecture analyzes the end–edge-cloud collaboration system from the perspective of intelligence for the first time, which can improve the intelligence level of the next-generation smart healthcare.

The article "Ahed: A heterogeneous-domain deep learning model for IoT-enabled smart health with few-labeled EEG data," authored by Chu *et al.*, proposes a heterogeneous-domain deep learning model to extract informative features of few-labeled EEG signals in an intelligent health system. The authors empirically and theoretically prove the advantage of training the consistency-regularized network jointly with labeled and unlabeled data. Furthermore, case studies demonstrate that the proposed methods achieve superior performance over many challenging settings.

In the article "Confident information coverage hole prediction and repairing for healthcare big data collection in large-scale hybrid wireless sensor networks," Feng *et al.* propose two energy-efficient algorithms to solve coverage hole repairing for healthcare big data collection in large-scale hybrid wireless sensor networks, by leveraging the novel confident information coverage model. Simulation results show that the proposed algorithms have better performance than peer algorithms.

The article "IoT-based smart health system for ambulatory maternal and fetal monitoring," authored by Marques *et al.*, presents a comprehensive IoT-based solution for maternal and fetal multiple monitoring, considering multiple sensors, such as heart rate, temperature, blood pressure, and oxygen saturation. Two subsystems are implemented. The first one is an emergency subsystem at the first level and installed on clinical premises. The second level is a feature extraction and artificial intelligence diagnostic support system running on the cloud. Different classifiers are evaluated, and a proposed CNN presents the best results, with the F1-score ranging from 0.74 to 0.91. The results are validated based on the diagnosis provided by two specialists and show that the proposed system is a viable solution for maternal and fetal ambulatory monitoring based on IoT.

In the article "Medical-level suicide risk analysis: A novel standard and evaluation model," Wang *et al.* propose a novel medical-level suicide risk standard to monitor suicide risk of the text sent by the smart terminal. Meanwhile, a Bert evaluation model based on knowledge perception is established for the classification of risk level. Experimental results show that the classification standard and evaluation model can be effectively used for the identification and early warning of suicide risk, which can discover high suicide risk groups to reduce the occurrence of suicide.

The article "sEMG-based dynamic muscle fatigue classification using SVM with improved whale optimization algorithm" by Liu *et al.* proposes a classification model incorporating support vector machine (SVM) and improved whale optimization algorithm (WOA) to accommodate the muscle fatigue prediction in dynamic conditions. Wearable sensors are used to collect physiological data (sEMG) of the human body and multidomain features are fused to classify the muscle fatigue. From this study, patients' tiredness can be extracted from the collected EMG data, and corresponding treatment plans can be automatically optimized.

In the article "HeDI: Healthcare device interoperability for IoT-based eHealth platforms," Pathak *et al.* propose and develop healthcare device interoperability (HeDI)—a system to enable device interoperability in IoT-enabled in-home healthcare monitoring platforms. The system consists of multiple sensors, each connected wirelessly to an edge device, acting as a wireless communication gateway to a remote server. The system initiates information handshaking between the sensor adapters and edge device at the beginning of the operation, which is later used to detect the sensor settings to process the data received from the sensor. The system is scalable and dynamically accommodates multiple sensors without any predefined ontologies at the edge device. The implementation of the system avoids dependencies on a system's physical ports. The low form factor and wireless connectivity of the adapter make the system portable and convenient for in-home health monitoring. Additionally, the system allows multiple homogeneous sensors to operate at the same time in the same system. The authors implement and evaluate their system with a 3-lead ECG, pulse, and temperature sensors against two different network configurations—Star and Mesh. They use the data set generated from their implemented system for performance analysis. The network-level analysis of their system shows an average packet delivery ratio of 0.92 for star network configuration and 0.98 for mesh network configuration, ensuring the reliability of performance and its suitability for healthcare monitoring systems.

In the article "Dynamic contract design for federated learning in smart healthcare applications," Lim *et al.* propose a federated-learning (FL)-based approach to enable privacy-preserving collaborative model training at the edge of the network across distributed IoT owners, i.e., users. However, the users in the FL network may have different willingness to participate (WTP), a hidden information unknown to the model owner. Furthermore, the development of applications typically requires sustained user participation, e.g., for the continuous collection of data, during which the user WTP may change over time. As such, we leverage on the dynamic contract design to consider a two-period incentive mechanism that satisfies the intertemporal incentive compatibility (IC), such that the self-revealing mechanism of the contract holds across both periods.

In the article "LSTM-based emotion detection using physiological signals: IoT framework for healthcare and distance learning in COVID-19," Awais *et al.* propose an integrated IoT framework which enables wireless communication of physiological signals to data processing hub where long short-term memory (LSTM)-based emotion recognition is performed. The proposed framework offers real-time communication and recognition of emotions which enables health monitoring and distance learning support amidst pandemics. In this study, the achieved results are very promising. In the proposed IoT protocols, TS-MAC and R-MAC, the ultra-low latency of 1 ms is achieved. R-MAC also offers improved reliability in comparison to state of the art. In addition, the proposed deep learning scheme offers a high performance (f-score) of 95%. The achieved results in communications and AI match the interdependency requirements of deep learning and IoT frameworks, thus ensuring the suitability of the proposed work in distance learning, student engagement, healthcare, emotion support, and general wellbeing.

In the article "High-performance isolation computing technology for smart IoT healthcare in cloud environments," Zhang *et al.* propose a copyright protection scheme based on blockchain, which can integrate with existing centralized copyright protection solutions and make use of their data to construct, improve, and strengthen its blockchain knowledge base and further smoothly evolve to be a decentralized scheme, where there is no central party with absolute power to inappropriately control or operate on the copyright transaction. Moreover, by the tamper-resistant feature of blockchain, it is impossible for attackers to alter any content of any transaction once it is recorded on the blockchain within a block. What is more, the information recorded on the blockchain will be the reliable evidence in court once infringement happens.

In the article "Game theory for anti-jamming strategy in multichannel slow fading IoT networks," a defending strategy against jamming attacks in health monitoring IoT networks is proposed. This strategy operates in orthogonal frequency-division multiplexing (OFDM) channels and takes into consideration the effect of slow fading channels in the strategy design. Specifically, the jamming combating problem is formulated as a Colonel Blotto game where the equilibrium defines the minimization of the worst case jamming effect on the IoT sensors communications. Then, the optimal power allocation strategy for all the potential jammer power ranges is derived by investigating the Nash equilibrium (NE) of the game. This proposed strategy is shown to be efficient in combating jamming attacks while minimizing the IoT sensors power consumption.

The article "Emotion recognition for cognitive edge computing using deep learning" proposes an emotion recognition system from facial images based on edge computing. A CNN model is proposed to recognize emotion. The model is trained in a cloud during off time and downloaded to an edge server. During testing, an end device such as a smartphone captures a face image and does some preprocessing, which includes face detection, face cropping, contrast enhancement, and image resizing. The preprocessed image is then sent to the edge server. The edge server runs the CNN model and infers a decision on emotion. The decision is then transmitted back to the smartphone. Two data sets, JAFFE and CK+, are used for the evaluation. Experimental results show that the proposed system is energy efficient, has less learnable parameters, and good recognition accuracy.

In the article, "Applying cross-modality data processing for infarction learning in medical Internet of Things," Xu *et al.* propose a novel spatiotemporal two-streams generative adversarial network (SpGAN) as a cross-modality data processing approach to deploy the medical IoT in infarction learning. Our SpGAN remotely converts diagnostic valuable contrast-enhanced images (the "gold standard" for infarction learning, but it requires the injection of contrast agents) directly from raw nonenhanced cine MR images. This converting allows physicians to remotely perform infarction observation and analysis to break through the limitations of time and space by building a cloud computing platform of IoT15-based MRI devices. Importantly, this converting offers a low-risk IoT-based manner to eliminate the potential fatal risk caused by contrast agent injection in the current infarction learning workflow. Specifically, SpGAN consists of: 1) a spatiotemporal two-stream framework as an encoding–decoding model to achieve data converting and 2) a spatiotemporal pyramid network that enhances those features which are responsible to the infarction learning during encoding to improve decoding performance. Real IoT23-based remote diagnosis experiments performed on 230 patients demonstrate that SpGAN provides high-quality converted images for infarction learning and promotes the in-depth application and deployment of IoT in the medical field.

In the article, "Anchored user selection for traffic offloading optimization in D2D-aided mobile-edge computing," Wang *et al.* first propose a network representation model, named MPPT, to regard the multidimensional relations as a probability in a third-order (3-D) tensor space. Then, a mobile D2D social community is derived by integrating an edge base station (BS) and the nearby D2D users. The authors introduce the problem of adaptive anchored (k, r)-core to maintain the stability of multiple D2D communities. It aims to adaptively select and retain a set of critical users for each network with the constraints of limited resources, whose participation is critical to the overall stability of the network, so that the maximum number of users of all networks will remain engaged. Finally, the authors devise a probability-based onion layers anchored (*k*, *r*)-core (P-OLAK) algorithm to identify the anchor users. The large-scale data-set-based experimental results show the superiorities of the proposed methods.

The article "Deep learning methods in Internet of Medical Things for valvular heart disease screening system" presents STM32 as the main Internet of Medical Things controller, which is combined with IoT devices—a sphygmomanometer cuff, temperature sensor, and pulse sensor—for instrument control and data acquisition. With this, the authors develop a valvular heart disease screening system. This system structure incorporates deep learning to develop fitting models and analysis. In the experiment, blood flow is blocked temporarily and released to observe changes in surface temperature of fingertip skin, and the blood supply capability of the heart is judged indirectly based on the curve of the temperature change. Eighteen subjects are tested in this experiment, and one subject has cardiac valve insufficiency and arrhythmia. This experiment obtains the temperature curve variation data from the healthy subjects successfully and identifies the temperature curve irregularities of the patient with cardiac valve insufficiency. This subject's range of temperature throughout the three test steps is smaller than that of most of the other subjects, within 0.52 °C. In addition, in the course of blocking and releasing blood, the overall temperature curve goes down, while some curves rise first before dropping slowly. The data analysis results show that the temperature curve variation and values of Subject 2 are similar to those of Subject 10, which may point to the incidence of valvular heart disease. This valvular heart disease screening system can successfully analyze and judge the characteristic signal values of the patients with valvular heart disease.

Finally, in the article "MEC-enabled hierarchical emotion recognition and perturbation-aware defense in smart cities," Zhao *et al.* propose a hierarchical emotion recognition system for resource-constrained IoT devices. Moreover, the authors clarify that the DNN-based emotion recognition system exposes obvious vulnerability to perturbation, thereby, proposed a proactive perturbation-aware defense mechanism. The results demonstrate the state-of-the-art performance on the publicly available LIRIS-CSE data set, as well as the effective defense performance against known and unknown perturbation.

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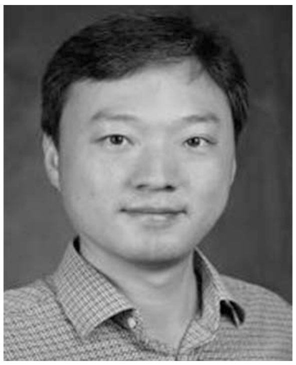

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