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Artificial Intelligence-based Internet of Things Systems

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Preface

This book aims to bring together leading academic scientists, researchers, and research scholars to exchange and share their experiences and research results on all aspects of Internet of Things (IoT)-enabled artificial intelligence-based technologies. It also provides a premier interdisciplinary platform for researchers, practitioners, and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of AI-based IoT. This book aims to attract researchers and practitioners who are working in information technology and computer science. This book is about basics and high-level concepts regarding artificial intelligence paradigm in the context of Internet of Things. This book covers a wide range of AI-enabled IoT technologies. This book aims to explore the insight paradigm of the AI-based IoT technologies which will bring a smooth platform for the scope of industry-academia. The wide-range contents will differentiate this edited book from others. The contents include functional framework and protocols for IoT-based system, intelligent object identification, intelligent sensors, learning and analytics in intelligent IoT-enabled systems, CRISP-DM frame work, RFID technology, wearable sensors, IoT semantics, knowledge extraction, applications of linear regression, classification, vector machines and artificial neural networks for IoT devices, Bayesian learning, decision trees, deep learning frameworks, computational learning theory, multi-agent systems for IoT-based ecosystem, machine learning algorithms, nature-inspired algorithms, computational intelligence for cloud-based Internet of Things, and trustworthy machine learning for IoT-enabled system in IoT related topics. The above topics are likely to be embedded with the AI-enabled IoT technologies for future generation automation.

Chapter 1 explores IoT architecture; analyzes IoT network's technical details; and describes communication enabled technologies. Moreover, this chapter deals with various AI-based technologies integrated into IoT, edge computing, and trust models for IoT appliances. Recent AI-based projects and research challenges concludes this chapter.

Chapter 2 has formulated an overview of the IoT environment which illustrates IoT architecture, gateways, nodes, middleware, OSs, framework, protection,

storage and computation, communication or networking technologies of IoT, and interfaces for the efficient utilization of data in an ecosystem. This chapter moreover illustrates the hierarchy of the intelligence of the IoT ecosystem, which describes the process of generation of data, derivation of desired information from those raw data, processing, and manipulation.

Chapter 3 illustrates a detailed view of ML and DL applicability in WSN and IoT. This chapter also describes a complete view of various neural networks (NN) and support vector machine (SVM) types that incorporate frequent, deep neural networks, quarter and ellipsoidal SVMs, and subspace-SVM forms, which are relevant to wireless and IoT appliances. This chapter provides an in-depth summary of various communication issues in IoT that are addressed by neural networks and SVM, and application and motivation for using those techniques. Followed by intrusion detection in IoT with NN and SVM, a case study on outlier detection WSNs data and future research implementations is discussed.

Chapter 4 evaluates the different methods of machine learning that deal with the challenges posed in the handling of IoT data. Big data is generated through the communication of Internet of Things/smart devices, and this data stored at cloud. The taxonomy of machine learning algorithms is described in this chapter, explaining how different techniques are applied to data generated using IoT devices. It will also address the future problems of machine learning for IoT data analytics.

Chapter 5 aims to explore DL frameworks for IoT. The chapter begins with a discussion on the development and architecture of the DL framework. This chapter then discusses about various DL models associated with deep reinforcement learning approaches for IoT. The potential applications, including smart grid management, road traffic management, industrial sector, estimation of crop production, and detection of various plant diseases are discussed. Various design issues and challenges in implementing DL are also discussed. The findings reported in this chapter provide some insights into DL frameworks for IoT that can help network researchers and engineers to contribute further towards the development of next-generation IoT.

Chapter 6 addresses the technique that combines the capability to learn and evolve solutions for large-scale dynamic systems. The chapter deals with the extended classifier system (XCS) which is an amalgamation of reinforcement learning (RL) and genetic algorithms (GA). While RL learns the model-free problem environment, the nature-inspired GA evolves better decision-making rules and improves the existing ones. The motive is to provide intelligent computation for fog-cloud-based IoT systems through XCS. The chapter reveals how the XCS algorithm estimates the optimal number of IoT workload that is to be processed in fog, the remaining of which is transferred to the cloud. The optimal number of workloads estimated by the XCS algorithm balances the energy cost and delay in the fog-cloud based resource allocation (RA) system.

Chapter 7 integrates machine learning and IoT in a portable scale to perform high-accuracy verification system. This model uses a pre-trained convolutional neural network (CNN) on a Raspberry Pi. The CNN will analyze pixels from a signature image taken by the Pi camera to recognize abnormalities and differences and to

identify false signature. Other than requiring a secure digital authentication to operate, it also informs the user immediately on the app execution and image being scanned via a cloud-based system. The system is expected to provide on-the-spot signature verification and minimize any logistic issue that stems from faulty signature to an organization.

Chapter 8 illustrates the facilitators of Internet of Things like machine to machine (M2M), radio frequency identification (RFID), and software-defined networking (SDN). Machine to machine (M2M) is a communication system in IoT that endorses the group of devices to communicate with each other. The mobile communication system is optimized by M2M and standardized by 3GPP. The motivation of this chapter is that the communication system facilitated with IoT has performed their actions autonomously without the assistance of a human.

Chapter 9 discusses different types of framework, pros and cons of every framework, architecture, and different criteria to choose the better framework which will be useful for Internet of Things–based applications. Moreover, this chapter discusses architecture, generative models, and deep reinforcement learning for IoT applications.

Chapter 10 presents the active ongoing research in optimizing deep learning models for inference at the edge using connection-pruning, model quantization, and knowledge distillation. This chapter describes the techniques to train/retrain the deep learning models at the resource-constrained edge device using new learning paradigms such as federated learning, weight imprinting, and training smaller models on fewer data.

Chapter 11 presents a survey of techniques that have been introduced to exploit the pros and mitigate the cons of NVMs when used for designing IoT systems. This chapter classifies these techniques along several dimensions to highlight their similarities and differences. Keeping consideration that NVMs are rapidly growing in IoT systems, this chapter will encourage and motivate further researcher and scientists in the field of software technology for NVMs-based IoT.

Chapter 12 describes the digital abstraction of the physical aspects of a city using digital twin to simulate scenarios to understand behaviors of a particular event. This study analyzes the use of artificial intelligence techniques and IoT used in digital twin approaches to analyze cyber security risks in the smart city environment.

Chapter 13 discusses Cognitive Internet of Things (CIoT) which inherited numerous challenges from artificial intelligence, IoT, and cognitive systems. Therefore, the challenges of these fields should be studied to extract the challenges in designing CIoT. In the literature, there is no study on extracting the challenges considering associated technologies to CIoT. In this chapter, the challenges of the associated technologies are summarized. Then, some important challenges in designing CIoT are obtained.

Chapter 14 uses reinforcement learning techniques to find patterns of user dynamics and to determine the incentive prices. Specifically, the authors adapt the state-of-the-art reinforcement learning framework for dock-less BSS rebalancing. Different from existing research, the authors make full use of the benefits of destination incentives. In addition, they further extend the reinforcement learning

framework to docked BSSs by adding station capacities to the state space of the reinforcement learning agent. They have examined the performance of our schemes based on real-world datasets. An experiment result reveals that the hybrid incentive scheme outperforms the source-incentive-only scheme.

Chapter 15 discusses vital applications of IoT and Bayesian learning to the monitoring, messaging, and accident analysis on highways. The chapter adopts the case approach in presenting advances in IoT and cloud technologies and builds a concept around a scenario to demonstrate real-life applications and contextual relevance of Bayesian learning models.

Chapter 16 discusses the processes, challenges, and solutions concerning designing an airport smart parking system. IoT parking sensors, Open Automatic License Plate Recognition (OpenALPR) library, and the IBM cloud-based IoT platform are integrated to tackle technical challenges, including the automatic identification of plate numbers, models, and colors of vehicles in parking spaces, in both indoor and outdoor parking environments. The chapter also addresses several issues related to the system, that is, the system architecture design, the selection of sensing technologies, and hardware and software platforms, while taking into account specific characteristics of IoT and AI technologies.

Chapter 17 presents an overview of research on using end-to-end deep learning technologies for computer vision-based autonomous driving systems. It briefly discusses the ethics of autonomous driving; it also describes autonomous driving paradigms and the associated deep learning methodologies. Furthermore, it proposes an IoAT-compatible low-cost, low-latency, high-accuracy, and high-reliability CNN-LSTM based autonomous driving model that incorporates temporal information, transfer learning, and navigational command. It also provides a detailed analysis against existing models. Finally, the chapter draws its conclusions and discusses future research directions to further improve system performance.

In Chap. 18, the Bayesian learning and decision trees are presented in respect of their ability to entrench optimum intelligent prediction in IoT-enabled domain. Succinct elucidation of the potential application of an intelligent IoT-driven system is presented as a possible panacea to address some of the problems in food production cycle especially in post-harvest storage and wastage.

We are sincerely thankful to the Almighty for supporting and standing by us at all times, through thick and thin, and guiding us. Starting from the call for chapters till the finalization of chapters, all the editors have given their contributions amicably, which is a positive sign of significant teamwork. The editors are sincerely thankful to the series editors Prof. Giancarlo Fortino and Prof. Antonio Liotta for providing constructive inputs and allowing an opportunity to edit this important book. We are thankful to reviewers around the world who shared their support and stood firm toward quality chapter submission.

Kolkata, West Bengal, India — Souvik Pal
Kolkata, West Bengal, India — Debasish De
Melbourne, VIC, Australia — Rajkumar Buyya

Key Features

1. Addresses the complete functional framework workflow in AI-enabled IoT ecosystem.
2. Explores basic and high-level concepts, thus serving as a manual for those in the industry while also helping the beginners to understand both basic and advanced aspects in AI-enabled IoT ecosystem related technology.
3. Based on the latest technologies, and covering the major challenges, issues, and advances in AI-based IoT environment.
4. Explores intelligent object identification and object discovery through IoT ecosystem and its implications to the real world.
5. Explains concepts of IoT communication protocols, intelligent sensors, statistics and exploratory data analytics, nature-inspired algorithms, computational intelligence, and machine learning algorithms in IoT environment for betterment of the smarter humanity.
6. Explores intelligent data processing, deep learning frameworks, game theory, and multi-agent systems in IoT-enabled ecosystem.
7. Explores vector machines and artificial neural networks for IoT devices, and big data analytics in IoT-based environment.
8. Explores security and privacy issues and trustworthy machine learning related to data-intensive technologies in AI-based IoT ecosystem.

About the Book

The edited book *Artificial Intelligence-based Internet of Things Systems* is intended to discuss the evolution of future generation technologies through Internet of Things in the scope of artificial intelligence. The main focus of this volume is to bring all the related technologies in a single platform, so that undergraduate and postgraduate students, researchers, academicians, and industry people can easily understand the AI algorithms, machine learning algorithms, and learning analytics in IoT-enabled technologies.

This book uses data and network engineering and intelligent decision support system-by-design principles to design a reliable AI-enabled IoT ecosystem and to implement cyber-physical pervasive infrastructure solutions. This book will take the readers on a journey that begins with understanding the insight paradigm of AI-enabled IoT technologies and how it can be applied in various aspects. This proposed book will help researchers and practitioners to understand the design architecture and AI algorithms through IoT and the state-of-the-art in IoT countermeasures.

It provides a comprehensive discussion on functional framework and knowledge hierarchy for IoT, object identification, intelligent sensors, learning and analytics in intelligent IoT-enabled systems, CRISP-DM frame work, RFID technology, wearable sensors, IoT semantics, knowledge extraction, applications of linear regression, classification, vector machines and artificial neural networks for IoT devices, Bayesian learning, decision trees, deep learning frameworks, computational learning theory, multi-agent systems for IoT-based ecosystem, machine learning algorithms, nature-inspired algorithms, computational intelligence for cloud-based Internet of Things, and trustworthy machine learning for IoT-enabled systems. This book brings together some of the top IoT-enabled AI experts throughout the world who contribute their knowledge regarding different IoT-based technology aspects. This edited book aims to provide the concepts of related technologies and novel findings of the researchers through its chapter organization. The book explores AI-enabled IoT paradigms which will be utilized as a part of betterment of mankind in the future era. Specifically, the far-reaching references of various works and executions will be observed to be significant accumulations for engineers and

organizations. The primary audience for the book incorporates specialists, researchers, graduate understudies, designers, experts, and engineers who are occupied with research on Internet of Things, artificial intelligence, machine learning, and applications.

Contents

About the Editors

Souvik Pal is an associate professor in the Department of Computer Science and Engineering at Sister Nivedita University (Techno India Group), Kolkata, India. Prior to that, he was associated with Global Institute of Management and Technology; Brainware University, Kolkata; JIS College of Engineering, Nadia; Elitte College of Engineering, Kolkata; and Nalanda Institute of Technology, Bhubaneswar, India. Dr. Pal received his MTech and PhD degrees in the field of computer science and engineering from KIIT University, Bhubaneswar, India. He has more than a decade of academic experience. He is author or co-editor of more than 15 books from reputed publishers, including Elsevier, Springer, CRC Press, and Wiley, and he holds 3 patents. He is serving as a series editor for Advances in Learning Analytics for Intelligent Cloud-IoT Systems, published by Scrivener-Wiley Publishing (Scopus-indexed); Internet of Things: Data-Centric Intelligent Computing, Informatics, and Communication, published by CRC Press, Taylor & Francis Group, USA; Conference Proceedings Series on Intelligent Systems, Data Engineering, and Optimization, published by CRC Press, Taylor & Francis Group, USA. Dr. Pal has published a number of research papers in Scopus/SCI/SCIE Journals and conferences. He is the organizing chair of RICE 2019, Vietnam; RICE 2020 Vietnam; ICICIT 2019, Tunisia. He has been invited as a keynote speaker at ICICCT 2019, Turkey; ICTIDS 2019, 2021 Malaysia; and ICWSNUCA 2021, India. His professional activities include roles as associate editor and editorial board member for more than 100+ international journals and conferences of high repute and impact. His research area includes cloud computing, big data, internet of things, wireless sensor network, and data analytics. He is a member of many professional organizations, including MIEEE; MCSI; MCSTA/ACM, USA; MIAENG, Hong Kong; MIRED, USA; MACEEE, New Delhi; MIACSIT, Singapore; and MAASCIT, USA.

Debashis De obtained his MTech from the University of Calcutta in 2002 and his PhD (Engineering) from Jadavpur University in 2005. He is a professor and director of the Department of Computer Science and Engineering at Maulana Abul kalam Azad University of Technology, West Bengal (Former West Bengal University of

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Rajkumar Buyya is a Redmond Barry Distinguished Professor and director of the Cloud Computing and Distributed Systems (CLOUDS) Laboratory at the University of Melbourne, Australia. He is also serving as the founding CEO of Manjrasoft, a spin-off company of the University, commercializing its innovations in cloud computing. He served as a Future Fellow of the Australian Research Council during 2012–2016. He has authored over 625 publications and 7 textbooks including *Mastering Cloud Computing* published by McGraw Hill, China Machine Press, and Morgan Kaufmann for Indian, Chinese, and international markets, respectively. He also edited several books including *Cloud Computing: Principles and Paradigms* (Wiley Press, USA, Feb 2011). He is one of the highly cited authors in computer science and software engineering worldwide (h-index = 132, g-index = 294, 92,500+ citations). "A Scientometric Analysis of Cloud Computing Literature" by German scientists ranked Dr. Buyya as the World's Top-Cited (#1) Author and the World's Most-Productive (#1) Author in Cloud Computing. Dr. Buyya is recognized as a "Web of Science Highly Cited Researcher" for 4 consecutive years since 2016, a fellow of IEEE, and Scopus Researcher of the Year 2017 with Excellence in Innovative Research Award by Elsevier, and he has recently (2019) received "Lifetime Achievement Awards" from two Indian universities for his outstanding contributions to cloud computing and distributed systems.Software technologies for grid and cloud computing developed under Dr. Buyya's leadership have gained rapid acceptance and are in use at several academic institutions and commercial enterprises in 40 countries around the world. Dr. Buyya has led the establishment and development of key community activities, including serving as foundation chair of the IEEE Technical Committee on Scalable Computing and five IEEE/ACM conferences. These contributions and international research leadership of Dr. Buyya are recognized through the award of "2009 IEEE Medal for Excellence in Scalable Computing" by the IEEE Computer Society TCSC. Manjrasoft's Aneka Cloud technology developed under his leadership has received "2010 Frost & Sullivan New Product Innovation Award." Recently, Dr. Buyya received "Mahatma Gandhi

Award" along with gold medals for his outstanding and extraordinary achievements in the field of information technology and services rendered to promote greater friendship and cooperation between India and the world. He served as the founding editor-in-chief of the *IEEE Transactions on Cloud Computing*. He is currently serving as co-editor-in-chief of the journal *Software: Practice and Experience*, which was established 50 years ago. For further information on Dr. Buyya, please visit his cyberhome: www.buyya.com