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Machine Learning for Smart Environments/Cities

An IoT Approach

Springer

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ISSN 1868-4394 ISSN 1868-4408 (electronic)
Intelligent Systems Reference Library
ISBN 978-3-030-97515-9 ISBN 978-3-030-97516-6 (eBook)
https://doi.org/10.1007/978-3-030-97516-6

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The Internet of Things (IoT) consists of numerous "things" that are connected and managed across the Internet. Machine Learning is a research field that focuses on the development of predictive computer-aided applications which are not explicitly programmed. IoT and Machine Learning are mutually contributing to the advancement of technologies involved in smart city and smart environment development. Furthermore, the use of such communication and computing technologies is enabled by miniaturized microcontrollers, sensors, and actuators, which have a lower cost and greater energy efficiency.

Thus, IoT and ML provide smart cities and smart environments with countless advantages by enabling interaction with the physical world through interoperable applications, supported by smart city and smart environment systems. These applications aim to improve the citizens' quality of life.

This book aims to introduce Machine Learning and its applications for smart environments/cities supported by IoT technologies. Its chapters have been written by researchers located in different countries across the globe. The book consists of 12 chapters. Chapter 1 presents an introduction to the book scope and main topics. The rest of the chapters are organized into two parts. On the one hand, Part I comprises Chaps. 2–6 and focuses on smart environments. On the other hand, Part II comprises Chaps. 7–12 and presents relevant studies on smart cities. These chapters have been contributed by several authors from across the globe, namely Australia, Brazil, Colombia, Germany, Ghana, Italy, Malaysia, Portugal, Spain, Turkey, the Netherlands, and the USA. This makes the content of the book geographically diverse, as its authors come from 12 different countries, spread over 6 different continents.

The advent of the IoT and Machine Learning in recent decades has brought about developments in smart sensing and actuating technologies, which have been adopted in so-called smart environments, such as smart homes, smart farms, and other smart city settings. In this regard, keeping track of applications that use IoT and Machine Learning for smart environments has become an important aspect of research. A lot of research effort has been put into reviewing aspects of smart environments/cities, such as technologies, architectures, and security. However, there is not enough research on approaches that would combine IoT and Machine Learning in

smart environments/cities. Chapter 1 "**An Introduction and Systematic Review on Machine Learning for Smart Environments/Cities: An IoT Approach**" presents a systematic review of the combination of IoT and Machine Learning in smart environments/cities. Furthermore, recommendations for the implementation of IoT and Machine Learning in smart environments/cities are presented. It is expected that the recommendations may be used as a basis for the successful implementation of IoT and Machine Learning in smart environments/cities.

Chapter 2 "**Model-Based Digital Threads for Socio-Technical Systems**" defines the MBSE-based methodology for the creation and maintenance of the digital thread of physical systems and their digital twins. The authors illustrate this with a case study in which the proposed methodology has been applied to design a digital thread of a Traffic Monitoring System (TMS) for a smart city. The methodology uses the SysML (Systems Modeling Language), which is adequate for the specification of socio-technological (cyber-physical) systems, such as TMSs. This digital thread represents both the physical and virtual entities of the system, enabling the development of digital twins for simulating, testing, monitoring, and/or maintaining the system. SysML is currently being redesigned, and the new SysML v2 aims to offer precise and expressive language capabilities to improve support to system specification, analysis, design, verification, and validation. The chapter also discusses how SysML v2 is expected to facilitate the development of digital threads for socio-technological systems, such as TMSs.

Since the beginning, smart cities have been predicated on the concept of IoT; however, there is a gap between theory and practice, making effective implementation challenging. Smart cities are not just for urban dwellers; they are also for suburban dwellers who need effective methods and systems to foster a higher quality of life. The principal pollutants that are the subject of this study are industrial suburbs. Chapter 3 "**IoT Regulated Water Quality Prediction Through Machine Learning for Smart Environments**" presents research on data from recycled wastewater obtained from industrial use, which would otherwise be dumped directly into rivers. The authors used IoT sensors to gather data which has enabled the inspection of water and the maintenance of its quality. The data were used to measure a series of factors that indicate and influence water quality; they were utilized to calculate the water quality index. Finally, three Machine Learning algorithms were used to train and predict this quality index.

Chapter 4 "**The Power of Augmented Reality for Smart Environments: An Explorative Analysis of the Business Process Management**" contains an explorative analysis of the use of augmented reality for smart environments. It demonstrates that augmented reality improves business process management in numerous fields, such as military, medicine, architecture, automotive, and retail. Additionally, the study furnishes historical evidence for the evolution of augmented reality for smart environments, reviews the contributions of top research in this field, and evidences the effect of augmented reality on the business process and on the transformation of the business environment into a smart environment through IoT devices. This type of devices is capable of monitoring important variables in the users' environments, from a value co-creation perspective. Indeed, there is evidence of the use of augmented

reality in Information Management, Planning and Control, Change Process, Knowledge Management, Performance Management, People, and Customer Management. Finally, the chapter reveals how this technology can support innovative practices in business processes. In the search for competitive advantage, firm managers could indeed exploit this research to explore the impact of smart components on the improvement of smart environments investigating new industries.

IoT technologies are an opportunity for humanity to provide a wide range of e-educational technologies that have the potential to change educational systems. For example, students can now access online labs and libraries on their smart devices, which increases productivity in learning activities. Thanks to the rapid growth of information and communication technologies, online learning is now a practical choice, provided there is Internet availability. By combining real and virtual aspects in the learning process, IoT will allow for the expansion of learning contexts. The adoption of IoT can provide a wide range of e-educational technologies that have the potential to cover the shortfalls of the current education system. Through IoT, students can interact with their colleagues and teachers, share ideas, and find answers to problems. Chapter 5 "**Internet of Things Applications for Smart Environments**" considers IoT in education, the benefits of IoT technology in e-learning, online self-study, smart collaboration, IoT and e-learning, smart homes, smart home service adoption, and critical factors for smart home service.

A smart environment should be self-aware, using IoT technologies applied to health, education, and justice. Following the COVID-19 pandemic, the gains from applying technologies in healthcare and medical decision-making environments became evident. Chapter 6 "**Exploring Interpretable Machine Learning Methods and Biomarkers to Classifying Occupational Stress of the Health Workers**" focuses on the monitoring of stress in healthcare professionals through wearable devices, using biomarkers and Machine Learning to develop models that can aid in decision making. Challenges related to Explainable Artificial Intelligence are also addressed, as well as to the definition of stress classification, enabling the identification of impact on health professionals. An intelligent system is proposed to recommend actions in response to the professionals' stress level, in a way that is explainable, transparent, and feasible. This is an outstanding solution that may be adopted by the managers of health centers. Challenges related to information security and to the privacy of the health professionals are also discussed.

Chapter 7, "**Smart Cities, The Internet of Things, and Corporate Social Responsibility**" explores a plethora of IoT studies to identify how such technologies improve operational efficiency and infrastructure service and create an ecosystem in which the economic, environmental, and societal challenges associated with increased urbanization and smart cities may be addressed. Their inherent risks, issues, and challenges are also explored. Building on CSR literature, the author argues for a re-orientation of the smart city design toward decisional and governance process(es), and a shift away from technocentric and top-down approaches. A call is made for increased collaboration between decision-makers, community, and citizens in IoT implementation. A top-down/bottom-up multi-staged collaborative approach is proposed for evolving Corporate Social Responsibility governance

and engagement. It recognizes the importance of creating shared value, in the selection and deployment of IoT devices. Consequentially, addressing and resolving the challenges faced by communities and citizens in the adoption of IoT in smart cities.

Chapter 8 "**Intelligent Techniques for Optimization, Modelling and Control of Power Management Systems Efficiency**" analyzes the issue of climate change and smart grid, from the point of view of efficiency in power converters. Power distribution in the Spanish electric system has changed over the years and will further change with the introduction of the smart grid, opening up new possibilities for the distribution of energy. Power electronics aim to interconnect the different parts of the electric system and control the energy flow from point to point. In addition, the main objective of smart cities is efficiency and the optimal use of energy. Power converters are a crucial element, as they interconnect electricity generators with electricity consumers. The introduction of Machine Learning and AI in this field helps to optimize the switching converter, allowing for the reduction of power loss.

Chapter 9 "**Intelligent Simulation and Emulation Platform for Energy Management in Buildings and Microgrids**" presents a Multi-Agent-based Real-Time Infrastructure for Energy (MARTINE). MARTINE is a platform that enables the study of the physical components of buildings and microgrids, including emulation capabilities, multi-agent and real-time simulation, and intelligent decision support models and services, based on Machine Learning approaches. MARTINE enables the study and management of energy resources, considering both physical and intelligent virtual components. Hence, it provides a real platform for the continuous improvement of the synergies between IoT and Machine Learning solutions.

Smart cities collect data using IoT technology and use the information obtained from this data to manage resources and services efficiently. Thus, the living conditions of the people living in the cities are facilitated by the quality services offered to them. Chapter 10 "**Machine Learning Applications and Security Analysis in Smart Cities**" presents smart city IoT applications; especially, smart parks, smart buildings, smart homes, smart health, smart business, and smart environment applications are widely used. It is possible to benefit from Machine Learning methods depending on the data obtained while developing these applications. With these methods, routine operations, especially for the city administration, can be made more practical and rational. However, while everything is smart, environmental influences should be taken into account. Systems that can be implemented in smart cities with the smart environment should be completely sensitive to the environment. The protocols used for the communication of data of IoT applications developed in smart environments and cities must be secure in terms of security.

Chapter 11 "**Recent Developments of Deep Learning in Future Smart Cities: A Review**" reviews the use of Deep Learning techniques in Artificial Intelligence applications, oriented toward multiple smart city domains, including smart transportation, smart services, smart governance, environment, security, and public safety. The difficulties associated using Deep Learning on smart city data have also been addressed.

This chapter is concluded by describing a series of Deep Learning techniques that help to better understand the smart city concept and follow the current trends in smart cities.

Chapter 12 "**Smart and Sustainable Cities in Collaboration with *IoT*: The Singapore Success Case**" explores the collaboration of the IoT paradigm with the Sustainable and Smart Cities (SSC) concept and looks at their success cases. The need for an adequate flow of information is emphasized, so that the state of a particular urban area may be known in real time. Accordingly, the challenges in the interconnection of highly sensitive sensors, as well as the transfer of data, require a hybrid cloud architecture that would allow for the large-scale processing of daily citizen data and for the prediction of environmental factors. However, the conceptualization and creation of an SSC must be considered in technological, scientific, social, and state policies, aspects that translate into Governance, Mobility, Sustainability, Economic Development, Intellectual Capital, and Quality of Life. Moreover, adding to the technological utopia, the modern concept of economic and social development entails the creation of an SSC for the promotion of entrepreneurship, innovation, and social justice: a new dimension of urban resilience focused on a city caring society.

Recent advances and comprehensive reviews have been included, aiming to provide background for future research initiatives. It is hoped that the book will be of support in the research and development of future IoT architectures for smart environments/cities. Finally, we thank everyone involved in this project for their contribution and for giving us the opportunity to edit this book. Furthermore, we would like to thank all the professionals from Springer who have worked with us, in particular, Prof. Lakhmi C. Jain, for their help and support during the development of this book.

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About This Book

This book introduces Machine Learning and its applications in smart environments/cities. At this stage, a comprehensive understanding of smart environment/city applications is critical for supporting future research. This volume includes chapters written by researchers from different countries across the globe and identifies critical threads in research and also gaps that open up new and challenging lines of research for the future. Recent advances are discussed, and thorough reviews introduce readers to critical domains. The discussion on key research topics presented in this book will accelerate smart city and smart environment implementations based on IoT technologies. Consequently, this book will support future research activities aimed at developing future IoT architectures for smart environments/cities.

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About the Editors

Gonçalo Marques holds a Ph.D. in Computer Science Engineering and is Member of the Portuguese Engineering Association (Ordem dos Engenheiros). He is currently working as Assistant Professor lecturing courses on programming, multimedia, and database systems. Furthermore, he worked as Software Engineer in the Innovation and Development Unit of Groupe PSA automotive industry from 2016 to 2017 and in the IBM group from 2018 to 2019. His current research interests include Internet of Things, Enhanced Living Environments, Machine Learning, e-health, telemedicine, medical and healthcare systems, indoor air quality monitoring and assessment, and wireless sensor networks. He has more than 80 publications in international journals and conferences, is a frequent reviewer of journals and international conferences, and is also involved in several edited books projects.

Alfonso González-Briones holds a Ph.D. in Computer Engineering from the University of Salamanca since 2018; his thesis obtained the second place in the 1st SENSORS+CIRTI Award for the best national thesis in Smart Cities (CAEPIA 2018). At the same university, he obtained his Bachelor of Technical Engineer in Computer Engineering (2012), Degree in Computer Engineering (2013), and Master in Intelligent Systems (2014). He was Project Manager of Industry 4.0 and IoT projects in the AIR Institute, Lecturer at the International University of La Rioja (UNIR), and also a "Juan De La Cierva" Postdoc at University Complutense of Madrid. Currently, he is Assistant

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José Manuel Molina López is Full Professor at the Universidad Carlos III de Madrid. He joined the Computer Science Department of the Universidad Carlos III de Madrid in 1993. Currently, he coordinates the Applied Artificial Intelligence Group (GIAA). His current research focuses on the application of soft computing techniques (NN, Evolutionary Computation, Fuzzy Logic, and Multi-agent Systems) to radar data processing, air traffic management, e-commerce, and ambient intelligence. He has authored up to 100 journal papers and 200 conference papers. He received a degree in Telecommunications Engineering in 1993 and a Ph.D. degree in 1997 both from the Universidad Politécnica de Madrid.