

Sarika Jain
San Murugesan *Editors*

Smart Connected World

Technologies and Applications Shaping
the Future

 Springer

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Foreword

I am very glad to write a foreword for this book edited by Sarika Jain and San Murugesan. I got to know both of them during the organization of the International Semantic Intelligence Conference (ISIC 2021). Anyone who has organized a big international conference knows about the large efforts and the unlimited energy needed, especially for attracting new and high-profile contributors. With their attitude of hard work, ISIC 2021 as a conference in its first year included four workshops, three keynotes, eight invited talks of well-known and top-ranked international researchers, and 13 special sessions contributed to the main conference. Conferences already running for several decades often do not reach this size. Hence, I am not surprised that for this edited book Sarika and San again attracted contributors with indisputable reputations, who are true experts in the domains of their chapters.

As chair of the Very Large Internet of Things (VLIoT) workshop series (so far from 2017 to 2021) in conjunction with the top-ranked Very Large Database (VLDB) conferences, I have been watching the enormous development of the Internet of Things in research and industry from toy examples to stable large installations with applications that are increasingly beneficial for daily life in the long term.

Hence I have no doubt that we will soon be living in a largely interconnected world that will blur the distinction between reality and digital realms, known as “virtual reality.”

This book, *Smart Connected World: Technologies and Applications Shaping the Future*, discusses several key aspects of the emerging interconnected world. Though the concept of a connected world is not entirely new, there is now renewed and growing interest in creating a smart and connected world. This welcomed trend is fuelled by the timely confluence of pervasive computing, reliable and affordable networking, miniaturized and low-cost sensors, processing of massive volumes of different types of data, and significant advances in artificial intelligence and machine learning algorithms and their adoption in practice. In the 1950s, Alan Turing, the famous English computer scientist, addressed the question: “Can machines think?”

Now, progress over the last few decades in addressing this question has made machines not only think but also learn, recommend, act autonomously, and even explain their reasoning to humans. Thus, the connectivity that links real-world objects and processes, people and cyber systems, and the intelligence exhibited by machines makes the new smart connected world that the book editors envisage a current reality.

This book is a timely and a valuable addition to a small set of books in the area. It covers a variety of topics at the forefront of the two computing paradigms, namely, semantic computing and cognitive computing, as applied to the Internet of Things. I am delighted to see that the semantic technologies are transitioning to practical applications and the research community is facilitating their further advances and adoption in practice. In addition to introducing readers to promising tools and technologies, this book presents a number of insightful case studies discussing practical applications and real-world experiences to provide a balanced research and practice nexus.

The editors, drawing on their individual complementary expertise and experience, have brought out a unique book by choosing appropriate topics to deliberate and have invited established experts from academia and industry across the globe to write a chapter on each of the topics. The presentation is nice and of tutorial nature and is suitable for a wider audience, including graduate students and novice researchers.

I enjoyed reading the book and found it informative and inspiring for my own research. I am happy to introduce it to a wider audience for their benefits. I believe the readers will also find the book informative and insightful. Enjoy reading the book!

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Sven Groppe

Preface

Emerging trends center around artificial intelligence, machine learning, cloud computing, the Internet of Things, Semantic Web technologies, data analytics, and improved user interactivity and experience. These trends are shaping our world in numerous ways and further transforming our work and our personal lives. The future world is going to be different than it is today. This book presents a brief look at the envisioned new world that would be smarter and well connected.

The smart devices in the Internet of Things (IoT) communicate and share data-enabling tasks to be performed without the need for human intervention. A smart world is context-aware and knows what the user wants and his preferences and intentions, for example the information the user needs and how he prefers it to be presented. The smart devices in an application can create, represent, store, and share data. These devices can also make smart decisions. Furthermore, it would be a huge advantage if the smart connected devices were to communicate using the standard web protocols, instead of relying on incompatible networking protocols.

The current and future connected digital world poses a few key challenges: interoperability with open data, open formats, and APIs; portability of identities, profiles, and content; information overload; modeling of context and intent; understanding complex interactions; incompleteness or missing data; uncertainty (veracity) and dynamism (velocity) of data; machine understanding of data; ability to scale beyond human-only usage; and ubiquitous personalization and individualization. To address these challenges, the underlying system has to be smart to dynamically adapt to its environment and tasks and also be self-configuring, self-describing and self-explaining, self-healing, self-protecting, self-organizing, context-aware, and both reactive and proactive. Furthermore, these systems should also be capable of assessing the relevance, quality, and reliability of the data and recognize the context of their use and the user's preference. This calls for a shift from simple raw data processing to more intelligent processing of data (Data-Information-Knowledge-Wisdom (DIKW) pyramid)—for instance, the need to not only deal with data but make sense of the data to identify patterns in information to gain knowledge.

Web 3.0 is smarter than Web 2.0 and Web 1.0 as it incorporates semantics and artificial intelligence. Semantic computing technologies have been under development for about two decades. Semantic data models play important roles in facilitating interoperable data stores, and sensor data need to be represented in the form of ontologies. Despite their benefits, semantic computing technologies are not being utilized and exploited to their full potential. They have remained solely a research fantasy by a small number of people interested in this area. There are two reasons for this. First, standards did not exist for a long time. Second, even after the emergence of web standards that were open, free, robust, and easy to adopt, until the 1990s there was no technological consensus on their usage. These limitations were subsequently addressed. Here is a brief outline of the technological advancements in the domain of semantic computing.

- Development of major semantic web standards RDF and OWL (1994–2004).
- Major industry players entered the game. SPARQL was developed and a new initiative, Linked Open Data, came up (2006 to 2014).
- Google announced Knowledge Vault, and people turned to what we can call the Knowledge Graph era.
- A paradigm shift from RDBMS to NoSQL databases to today’s Triple Stores.

This book provides readers an overview of the emerging smart connected world and discusses the roles of semantic computing technologies and IoT in this new world. It also discusses how developers can use the established semantic technologies and gain the required skills in this field. The book will interest researchers, data scientists, and the industry and help them embrace the technology. The book also helps readers understand how the hybrid of the syntactic and the symbolic approaches to computing benefit the connected ecosystem.

Key Features

- This book discusses trends toward a smart connected world and presents them as a digestible narrative.
- The structure and contents of the book have been reviewed by a panel of accomplished international experts in the respective areas.
- Each chapter is self-contained and can be read independently; taken together, readers get a bigger picture of the technological and application landscape of the smart connected world.
- The contributors of the book are geographically diverse, with editors and authors from the UK, Turkey, Yemen, India, Australia, Serbia, and Malaysia, and are drawn from both academia and industry.
- The book will serve as a reference book for instructors and students taking courses in hybrid computing getting abreast of cutting-edge and future directions of a connected ecosystem, hence providing a synergy between web technologies and applications.

- It will be helpful for researchers and scholars who are pursuing research in Semantic Web and IoT and allied fields. It will also benefit industry professionals, software engineers, and academicians, and will enable them to embrace the potential of the Semantic Web.

Chapter Preview

Across the connected ecosystem, the amount of data being generated is multiplying in an unprecedented manner. The smart connected world is focused on collecting, storing, analyzing, as well as processing relevant data for real-time decisions. Sharing and using cross-domain knowledge is a challenge in this agile world of today. The tendency is toward embedding semantics in every aspect of the connected ecosystem to better understand the ambient environment. The book comprises 10 chapters grouped into two parts. Part I consist of seven chapters and provides a holistic overview of the smart connected world and the supporting tools and technologies. Part II consists of three chapters that describe applications and case studies of the smart connected world.

Part I: Smart Connected World: Overview and Technologies

This part provides an overview of the smart connected world from its evolution to predicting the future.

Chapter 1, authored by the editors of the book Sarika Jain and San Murugesan, provides a broader perspective on the smart connected world. After discussing the interplay of the Internet of Things (IoT) and Artificial Intelligence (AI), it examines the potential barriers to a smart and connected ecosystem. The chapter moves forward by providing the reader with an overview of the strengths and benefits of semantic computing and cognitive computing. The chapter aims to provide developers an overview of how they can use the technologies and enhance their knowledge in realizing and maintaining such systems.

In recent years, devices and systems have been transformed into smart connected devices or systems, giving rise to the Internet of Things (IoT) and Cyber Physical Social Systems (CPSSs). Chapter 2 by Regina Reine (Twigx Research), Filbert H. Juwono (Curtin University Malaysia), Zee Ang Sim (Heriot-Watt University Malaysia), and W.K. Wong (Curtin University Malaysia) discusses the concept of the CPSSs and their supporting technologies such as the 5G networks, wireless sensor networks, big data, artificial intelligence, virtual reality (VR), and augmented reality (AR). The chapter also discusses the implementation and challenges of CPSSs.

In Chap. 3, Anindita Saha, Mayurakshi Jana, Chandreyee Chowdhury, and Suparna Biswas from India, and Diptanshu Pandit from the UK speak about the

importance and benefits of utilizing web technologies as the application layer of IoT resulting in the so-called Web of Things (WoT) framework. Without WoT, IoT applications would have to rely on the networking protocol stack where the application layer of the stack is differently implemented by different applications.

Having set the pace of the connected ecosystem in Chaps. 2 and 3, in Chap. 4 we demystify the semantic intelligence that leverages semantic computing to handle large data at scale and address challenges (such as heterogeneity, interoperability, explainability) in the context of different industrial applications. Authored by Valentina Janev from the University of Belgrade, Serbia, this chapter introduces semantic intelligence in distributed, enterprise, and web-based information systems. Semantic intelligence technologies are the most important ingredient in building artificially intelligent knowledge-based systems as they aid machines in integrating and processing resources contextually and intelligently.

To achieve a fully functional smart connected world, organizations face critical challenges related to user privacy, system availability, and resilience to cyberattacks, among others. Chapter 5 by Yang Lu from the University of Kent, UK, identifies the challenges in ensuring privacy, security, and trust of the Internet of Things (IoT) paradigm and reviews existing solutions adopted to protect the smart connected world from malicious attacks, unauthorized access, and privacy breaches. The chapter proposes semantic-enabled solutions to protect sensitive data access and sharing in the clinical collaboration scenario, e.g., record linkage. As semantic reasoning allows effective management of user privileges and anonymity schemes, data privacy and utility can be ensured in the release of record linkage.

Data analytics is used in many different areas, such as increasing market shares of a firm, customer behavior analysis, predicting the life of an electronic device, detection of the anomaly on a network, social network analysis, healthcare systems, chemical component interactions, and bank operations. Ontologies can be used for facilitating data collection, improving the quality of the data used, analyzing data, visualizing the obtained results, and ensuring the reusability of the designed system. Chapter 6 by Fatmana Senturk from Turkey introduces an overview of data analytics and seeks to answer the question of how to enrich and improve a data analytic system by using ontologies.

Chapter 7 by Abhisek Sharma and Sarika Jain of NIT Kurukshetra India outlines the importance of multilingual and multimodal ontologies today. Our world is multilingual with an array of different languages in use and encompasses a wide variety of cultures and ethnic and racial groups. Understanding and accounting for cultural variations is crucial for effective natural language communication because it affects how the language is formed and used in practice. The Artificial Intelligence of Things (AIoT) systems are required to recognize a sentence from the user, interpreting what it means, and performing tasks accordingly. The sentence may be biased because of the effect of different languages, cultural variations, and ethnic and racial groups on the user's input. This chapter covers just that, from the use and working of AIoT to how the computer can store and understand language-specific information and work with it.

Part II: Applications and Case Studies

This part focuses on the potential implications of a smart connected world in manufacturing, cities, health, and more.

The first chapter in this part, Chap. 8, authored by Paul D Clough and Jon Stammers from the University of Sheffield, UK, discusses the elevation of manufacturing to new levels of smartness as a result of the ability to collectively embrace a range of technologies, such as sensors, Internet of (Industrial) Things, cloud computing, Big Data analytics, AI, mobile devices, and Augmented/Virtual Reality. Together they present new opportunities to transform, automate, and bring smartness and learning to manufacturing processes and drive manufacturing to the next generation. This chapter describes the manufacturing context, emerging concepts, such as Industry 4.0, and technologies that are driving change and innovation within the manufacturing industry.

Smart cities are cities that provide smart solutions for different life issues, either for citizens or for the environment itself, by collecting and analyzing information based on conceptualized contexts. In Chap. 9, Neama Abdulaziz and Fadl Ba-Alwi from Sana'a University, Yemen, advocate that smart city information should be gathered considering the semantics of both the statuses and the related devices.

Finally, Chap. 10 authored by Tameem Ahmad, Sayyed Usman Ahmed, and Nesar Ahmad from Aligarh Muslim University, India, examines the social webs and ways to analyze users' interaction patterns to depict the personality and hence the depression state of the user. Semantic Web technologies are better suited for this kind of analysis and ideally overcome the limitations of traditional approaches. An early indication of depression can help to initiate a recovery action to avoid devastating results.

We believe this book, covering technologies and applications shaping the connected world which is smarter and agile, will be helpful to a wide range of readers in gaining an informed understanding of the emerging new world.

Kurukshetra, India
Sydney, Australia
April 2021

Sarika Jain
San Murugesan

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India every summer. She works in collaboration with various researchers across the globe, including in Germany, Austria, Australia, Malaysia, the USA, and Romania. She has organized various challenges, conferences, and workshops and is a senior member of the IEEE, member of ACM, and a Life Member of the CSI. Dr. Jain is highly interested in worldwide collaborations and is seeking scholars and interns for her research group. For more up-to-date information, see <https://sites.google.com/view/nitkkrsarikajain/>.



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Abbreviations and Acronyms

6LoWPAN	IPv6 over Low-Power Wireless Personal Area Networks
ABAC	Attribute-based Access Control
ACID	Atomicity, Consistency, Isolation, and Durability
ACS	Autonomous Control Systems
AE	Acoustic emission
AES	Advanced Encryption Standard
AGV	Automated guided vehicle
AI	Artificial Intelligence
AIoT	Artificial Intelligence of Things
AM	Additive manufacturing
AMA	Artificial moral agents
AmI	Ambient Intelligence
AML	Agreement Maker Light
AMRC	University of Sheffield Advanced Manufacturing Research Centre
AOI	Automatic optical inspection
API	Application Programming Interface
AR	Augmented reality
CHE	Computing for human experience
CMfg	Cloud manufacturing
CMM	Coordinate measuring machine
CNC	Computer numerical control
CNN	Convolutional Neural Network
CoAP	Constrained Application Protocol
CPSS	Cyber-physical-social system
DAQ	Data acquisition
DCAT	Data Catalog Vocabulary
DES	Discrete-event simulation
DNS	Domain Name System
DoS	Denial of Service
DQL	Data Quality Vocabulary

DRON	The drug ontology
DTLS	Data Transport Layer Security Protocol
EHCPR	Extended Hierarchical Censored Production Rules
EHR	Electronic Health Records
EIoTG	Edge IoT Gateways
EO	Emotion Ontology
EPC	Electronic Product Code
ERD	Entity Relationship Diagram
ERP	Enterprise resource planning
FMA	Foundational Model of Anatomy
FMEA	Failure modes and effect analysis
FOAF	Friend of a Friend
GOF AI	Good Old Fashioned AI
GPS	Global Positioning System
HCI	Human-computer interaction
HTTP	Hypertext Transfer Protocol
HUD	Heads-up display
HVAC	Heating, ventilation, and air conditioning
IC	Integrated Circuit
IDC	International Data Corporation
IDII	Interaction Design Institute Ivrea
IIoT	Industrial IoT
INPDR	International Niemann-Pick Disease Registry
IoT	Internet of Things
IR	Industrial revolution
IT	Information Technology
JSON	JavaScript Object Notation
KDD	Knowledge Discovery in Databases
KGs	Knowledge Graphs
lemon	Lexicon Model for Ontologies
LIR	Linguistic Information Repository
LLOD	Linguistic Linked Open Data
LOD	Linked Open Data
LPWA	Low-power wide area
M2M	Machine-to-Machine
MDD	Major Depressive Disorder
MDO	Metal Disease Ontology
MES	Manufacturing execution system
MITM	Man-in-the-middle attack
ML	Machine Learning
MLOD	Multilingual Lexical Linked Open Data
MOOC	Massive Open Online Course
MTC	Machine-type communications
NCI	National Cancer Institute

NFC	Near-field communication
NLP	Natural Language Processing
NoSQL	Not only SQL
OAuth	Open Authorization
OEE	Overall equipment effectiveness
OGC	Open Geospatial Consortium
OLiA	Ontologies of Linguistic Annotation
OWL	Web Ontology Language
P2P	Peer-to-peer
PCB	Printed circuit board
PdM	Predictive maintenance
PLC	Programmable logic controller
PPDQ	Privacy-Preserving Database Query
P-WoT	Plain Web of Things
RBAC	Role-based Access Control
RDBs	Relational Databases
RDF	Resource Description Framework
RDS	Resource Description Schema
REST	Representational State Transfer
RFID	Radio Frequency Identification
RML	RDF Mapping Language
RPC	Remote Procedure Call
RSA	Rivest–Shamir–Adleman
RSS	Received Signal Strength
RUL	Remaining useful life
SAWSDL	Semantic Annotations for WSDL and XML Schema
SCADA	Supervisory control and data acquisition
SHA	Secure Hashing Algorithm
SHACL	Shapes Constraint Language
SIOC	Semantically Interlinked Online Communities
SLKA	Semantic Linkage k-Anonymity Linkage
SME	Small-to-medium enterprise
SMOB	Semantic MicroBlogging
SMS	Smart manufacturing system
SNS	Social Networking Service
SOA	Service-oriented Architecture
SOAP	Simple Object Access Protocol
SPARQL	Protocol and RDF Query Language
SPARQL	SPARQL Protocol and RDF Query Language
SQL	Structured Query Language
SVM	Support Vector Machine
SW	Semantic Web
SWE	Sensor Web Enablement
SWeTI	Semantic Web of Things for Industry

SWoT	Semantic Web of Things
UAV	Unmanned Aerial Vehicle
UDDI	Universal Description, Discovery, and Integration
URI	Uniform Resource Identifiers
VODG	Voluntary Organisations Disability Group
VR	Virtual reality
W3C	World Wide Web Consortium
WoT	Web of Things
WSDL	Web Services Description Language
WSN	Wireless sensor network
XACML	eXtensible Access Control Markup Language
XMap	eXtensible Mapping
XML	eXtensible Markup Language
XR	eXtended reality
ZB	Zettabytes

Part I
Smart Connected World: Overview and
Technologies