

# Topics in Artificial Intelligence Applied to Industry 4.0

Edited by

Mahmoud Ragab AL-Refaey · Amit Kumar Tyagi  
Abdullah Saad AL-Malaise AL-Ghamdi · Swetta Kukreja



WILEY



## **Topics in Artificial Intelligence Applied to Industry 4.0**



# Topics in Artificial Intelligence Applied to Industry 4.0

*Edited by*

*Mahmoud Ragab AL-Refaey*

*Information Technology Department, Faculty of Computing and Information Technology (FCIT),  
King Abdulaziz University (KAU), Jeddah, Saudi Arabia*

*Mathematics Department, Faculty of Science, Al-Azhar University, Naseir City, Cairo, Egypt*

*Amit Kumar Tyagi*

*Department of Fashion Technology, National Institute of Fashion Technology, New Delhi, India*

*Abdullah Saad AL-Malaise AL-Ghamdi*

*Information Systems Department, Faculty of Computing and Information Technology (FCIT), King  
Abdulaziz University (KAU), Jeddah, Saudi Arabia*

*Information Systems Department, School of Engineering, Computing and Design, Dar Al-Hekma University,  
Jeddah, Saudi Arabia*

*Swetta Kukreja*

*Department of Computer Science and Engineering, Amity University, Mumbai, Maharashtra, India*

**WILEY**

This edition first published 2024  
© 2024 John Wiley & Sons Ltd

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>

The right of Mahmoud Ragab AL-Refaey, Amit Kumar Tyagi, Abdullah Saad AL-Malaise AL-Ghamdi, and Swetta Kukreja to be identified as the authors of the editorial material in this work has been asserted in accordance with law.

*Registered Offices*

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at [www.wiley.com](http://www.wiley.com)

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Trademarks: Wiley and the Wiley logo are trademarks or registered trademarks of John Wiley & Sons, Inc. and/or its affiliates in the United States and other countries and may not be used without written permission. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc. is not associated with any product or vendor mentioned in this book.

*Limit of Liability/Disclaimer of Warranty*

While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

***Library of Congress Cataloging-in-Publication Data applied for:***

Hardback ISBN: 9781394216116

Cover Design: Wiley

Cover Image: © VicenSanh/Adobe Stock Photos

Set in 9.5/12.5pt STIXTwoText by Straive, Pondicherry, India

## Contents

<b>About the Editors</b>	<i>xv</i>
<b>List of Contributors</b>	<i>xvii</i>
<b>Preface</b>	<i>xxi</i>
<b>Acknowledgment</b>	<i>xxiii</i>
<b>1 Introduction to Industry 4.0 and Its Impacts on Society</b>	<b>1</b>
<i>Shrikant Tiwari, Kanchan Naithani, Arun K. Singh, Virendra K. Verma, Ramesh S. Wadawadagi, and Bireshwar D. Mazumdar</i>	
1.1	Introduction 1
1.1.1	Overview of the Major Technological Advancements Driving the Revolution 2
1.1.2	Importance of Studying and Understanding the Impacts of the Fourth Industrial Revolution 2
1.2	The Technological Advancements of the Fourth Industrial Revolution 3
1.2.1	Discussion of the Potential Benefits and Drawbacks of Each Technology 4
1.2.2	Examples of How These Technologies Are Already Being Used in Various Industries 4
1.3	Impacts on the Economy 5
1.3.1	The Potential Impacts of the Fourth Industrial Revolution on the Economy 6
1.3.2	Analysis of Fourth Industrial Revolution Is Changing the Nature of Work and Engages in Economic Activities 7
1.3.3	Discussion of How Businesses and Governments Can Prepare for and Adapt to These Changes 8
1.4	Impacts on Society 9
1.4.1	Discussion of How the Fourth Industrial Revolution Is Impacting Society 9
1.4.2	Analysis of How Individuals and Communities Can Best Adapt to These Changes 10
1.4.3	Examples of How the Fourth Industrial Revolution Is Being Used to Address Social Challenges and Promote Social Good 10
1.5	Ethics and Governance 11
1.5.1	Discussion of the Ethical and Governance Challenges Posed by the Fourth Industrial Revolution 11
1.5.2	Analysis of the Role of Government, Businesses, and Individuals in Addressing These Challenges 12
1.5.3	Examples of Best Practices in Ethical and Responsible Technology Development and Deployment 13
1.6	Future Directions 13
1.6.1	Potential Future Directions of the Fourth Industrial Revolution 14
1.6.2	Analysis of the Fourth Industrial Revolution 14
1.6.3	Discussion of the Fourth Industrial Revolution in a Positive and Equitable Way 15
1.7	Conclusion 15
1.7.1	Reflection on the Importance of Studying the Fourth Industrial Revolution and Its Impacts on Society 16
1.7.2	Fourth Industrial Revolution in a Way That Benefits All Members of Society 16
	References 16
<b>2 Digital Transformation Using Industry 4.0 and Artificial Intelligence</b>	<b>19</b>
<i>M. Keerthika, M. Pragadeesh, M. Santhiya, G. Belshia Jebamalar, and Harish Venu</i>	
2.1	Introduction 19
2.2	Industry 4.0 Technologies 20
2.3	AI Features in Industry 4.0 22

2.3.1	Machine Learning	22
2.3.2	Deep Learning	23
2.3.3	Natural Language Processing	24
2.3.4	Computer Vision	24
2.4	Industry 4.0 and XAI	24
2.5	Industry 4.0 Integration Using an XAI-Based Methodology with AI	24
2.5.1	Intelligent Communities	26
2.5.2	Smart Industries	27
2.5.3	Adaptive Production	27
2.5.4	Intelligent Health Care	27
2.5.5	Human-Computer Interaction	28
2.5.6	Prevention-based Maintenance	28
2.5.7	Intuitive Assistance	28
2.5.8	Smart Gadgets	28
2.5.9	Commercial Robotics	28
2.5.10	Digital-Privacy and Security	28
2.5.11	Intelligent Transportation	29
2.6	Case Studies for Industry 4.0	29
2.6.1	Analytics of Big Data	29
2.6.2	Intelligent Robotics	29
2.6.3	Cloud-Based Computing	29
2.6.4	Digital Industry 4.0 and IoT	29
2.6.5	Standard Product Lifecycle Management Packages and Industry 4.0	30
2.6.6	Internet of Things and Product Lifecycle Management	30
2.6.7	Leveraging 3D Printing	30
2.6.8	Technologies for Cybersecurity	30
2.7	Challenges of Industry 4.0	31
2.8	Advantages of Intelligent Factory	31
2.8.1	Positive Effects of Industrial Revolution 4.0	32
2.9	Discussion and Emerging Trends	32
2.10	Conclusion	33
	References	34
<b>3</b>	<b>Industry 4.0: Design Principles, Challenges, and Applications</b>	<b>39</b>
	<i>K.K. Girish, Sunil Kumar, and Biswajit R. Bhowmik</i>	
3.1	Introduction	39
3.2	Organization of Chapter	40
3.3	Industrial Revolutions	40
3.4	Generations of Industrial Revolutions	40
3.4.1	First Industrial Revolution	41
3.4.2	Second Industrial Revolution	41
3.4.3	Third Industrial Revolution	42
3.5	Transformation to Industry 4.0	43
3.6	Characteristics of Industry 4.0	43
3.7	Technologies Under Industry 4.0	44
3.7.1	Cyber-Physical Systems	44
3.7.2	Internet of Things	46
3.7.3	Big Data and Analytics	46
3.7.4	Cloud Technology	47
3.7.5	Artificial Intelligence	48
3.7.6	Blockchain	49
3.7.7	Simulation and Modeling	50

3.7.8	Visualization Technology	50
3.7.9	Automation and Industrial Robots	51
3.7.10	Additive Manufacturing	52
3.8	Design Principles of Industry 4.0	53
3.8.1	Interoperability	54
3.8.2	Virtualization	54
3.8.3	Real-Time Capability	55
3.8.4	Service Orientation	55
3.8.5	Modularity	55
3.8.6	Information Transparency	56
3.8.7	Decentralization	56
3.8.8	Smart Product	56
3.8.9	Corporate Social Responsibility	56
3.8.10	Technical Assistance	57
3.8.11	Resource Efficiency	57
3.9	Applications of Industry 4.0	57
3.10	Trends in Industry 4.0	58
3.11	Challenges of Industry 4.0	59
3.12	Related Works	61
3.13	Paradigm Shift Toward Industry 5.0	62
3.14	Future Challenges and Research	63
3.15	Conclusion	64
	References	64
<b>4</b>	<b>Detection from Chest X-Ray Images Based on Modified Deep Learning Approach</b>	<b>69</b>
	<i>Jyoti Dabass, Manju Dabass, and Ananda K. Behera</i>	
4.1	Introduction	69
4.2	Related Works	70
4.2.1	Significance of the Study	71
4.3	Research Methodology	71
4.3.1	Dataset Description	72
4.3.1.1	TB X 11K Dataset	72
4.3.1.2	Montgomery County Chest X-Ray Dataset	72
4.3.1.3	Shenzhen Chest X-Ray Dataset	72
4.3.1.4	DA and DB Chest X-Ray Dataset	72
4.3.2	Data Preprocessing	73
4.3.2.1	Lung Image Segmentation	73
4.3.2.2	Contrast-Limited Adaptive Histogram Equalization	73
4.3.2.3	High-Frequency Emphasis Filter	73
4.3.2.4	Bilateral Filter	74
4.3.2.5	Data Augmentation	74
4.3.3	Transfer Learning	74
4.3.3.1	Fine-Tuning a CNN Model	74
4.3.3.2	EfficientNet-B0 Model	75
4.3.3.3	SqueezeNet Model	76
4.3.4	Experimental Approaches	76
4.3.4.1	Approach 1: Sum of Probabilities Ensemble	76
4.3.4.2	Approach 2: Stacked Generalization Ensemble	77
4.3.5	Evaluation Metrics	78
4.4	Results and Discussions	80
4.4.1	Data Preparation	80
4.4.2	Image Enhancements	80

4.4.2.1	Applying Bilateral Filter to the Image	80
4.4.3	Image Augmentation	80
4.4.3.1	Lung Segmentation and Region of Interest Extraction	81
4.4.4	Pretrained Model Fine-tuning	82
4.4.5	Model Hyperparameter Selection	82
4.4.6	Model Callbacks	82
4.4.7	Model Training	83
4.4.8	Ensemble Model Development	83
4.4.9	Model Evaluation	83
4.4.10	U-Net Model Performance	83
4.4.11	Performance of Fine-Tuned Model	84
4.4.12	EfficientNet-B0 Model Performance	84
4.4.13	ChexNet Model Performance	85
4.4.14	SqueezeNet Model Performance	85
4.4.15	Performances of Ensemble Models	85
4.4.16	Performance Analysis of Sum of Probabilities Ensemble Model	85
4.4.17	Performance Analysis of Stacked Generalization Model	86
4.4.18	Overall Results of Model Building	86
4.4.19	Selection of Best Model	88
4.4.20	Comparison of Research Findings on TBX11K Dataset	89
4.4.21	Comparison of Model Performance with Other Binary Classification Models	89
4.5	Conclusions	89
	References	90
<b>5</b>	<b>Smart Technologies in Manufacturing Industries: A Useful Perspective</b>	<b>93</b>
	<i>V.M. Gobinath, A. Kathirvel, S.K. Rajesh Kanna, and K. Annamalai</i>	
5.1	Introduction	93
5.2	Literature Review	95
5.3	Materials and Methods	95
5.3.1	Manufacturing-Led Design	95
5.3.2	3D Printing	96
5.3.3	CNC Machining	97
5.3.4	Cloud Computing and Storage	98
5.3.5	Internet of Things	99
5.3.6	Cyber-Physical Production Systems	100
5.3.7	Sensors and Automatic Identification	102
5.3.8	Big Data Analytics	103
5.3.9	Blockchain Technology	103
5.3.10	Artificial Intelligence	103
5.4	Discussion	104
5.4.1	Present and Future Challenges	104
5.4.1.1	Technical Staff	104
5.4.1.2	Difficult to Handle Huge Data Analytic and Management Techniques	104
5.4.1.3	System Integration	104
5.4.1.4	Big Data Analytic Tools	104
5.4.1.5	Robustness and Security Issue	105
5.4.1.6	Use of Wireless Technologies and Different Protocols	105
5.4.1.7	Invention of Specific Operating System	105
5.4.1.8	Supply Chain Is Complex	105
5.4.1.9	Customer Trust Involvement	105
5.5	Conclusion	105
	References	105

<b>6</b>	<b>Blockchain Technology for Industry 4.0</b>	<b>107</b>
	<i>Rajiv Kumar Berwer, Sanjeev Indora, Dinesh Kumar Atal, and Vivek Yadav</i>	
6.1	Introduction	107
6.1.1	Definition and Overview of Industry 4.0	107
6.1.2	Introduction to Blockchain Technology and Its Key Characteristics	108
6.1.3	Significance and Rationale for Integrating Blockchain in Industry 4.0	110
6.2	Key Concepts of Blockchain	110
6.2.1	Distributed Ledger Technology and Decentralized Consensus Mechanisms	110
6.2.2	Smart Contracts and Their Role in Automating Processes	111
6.2.3	Public Versus Private Blockchains: Trade-Offs and Considerations	112
6.2.4	Interoperability and Standardization Challenges	113
6.3	Blockchain in Data Privacy and Security	114
6.3.1	Ensuring Data Privacy in a Decentralized Ecosystem	114
6.3.2	Immutable and Tamper-Proof Records for Enhanced Data Integrity	114
6.3.3	Secure Peer-to-Peer Communication and Encryption Protocols	115
6.3.4	Self-Sovereign Identity and User-Controlled Data Sharing	116
6.4	Cybersecurity in the Era of Industry 4.0	116
6.4.1	Blockchain as a Security Layer for IoT Devices and Networks	117
6.4.2	Prevention of Unauthorized Access and Tampering of Data	117
6.5	Supply Chain Management and Traceability	117
6.6	Blockchain-Enabled Smart Manufacturing	118
6.7	Overcoming Challenges in Blockchain Implementation	119
6.8	Real-World Applications of Blockchain in Industry 4.0	119
6.9	Future Trends	120
6.10	Conclusion	120
	Declarations	121
	References	121
<b>7</b>	<b>Unifying Technologies in Industry 4.0: Harnessing the Synergy of Internet of Things, Big Data, Augmented Reality/ Virtual Reality, and Blockchain Technologies</b>	<b>127</b>
	<i>K. Logeswaran, S. Savitha, P. Suresh, K.R. Prasanna Kumar, M. Gunasekar, R. Rajadevi, M.K. Dharani, and A.S. Jayasurya</i>	
7.1	Introduction to Industry 4.0	127
7.1.1	Evolution of Industrial Revolutions	127
7.1.1.1	First Industrial Revolution	128
7.1.1.2	Second Industrial Revolution	128
7.1.1.3	Third Industrial Revolution	128
7.1.1.4	Fourth Industrial Revolution (Industry 4.0)	129
7.1.2	Components and Technologies of Industry 4.0	130
7.1.3	Industry 4.0 Architecture	130
7.1.4	Benefits and Opportunities of Industry 4.0	133
7.1.5	Challenges and Implications of Industry 4.0	133
7.1.5.1	Workforce Transformation	133
7.1.5.2	Cybersecurity Risks and Data Privacy	133
7.1.5.3	Ethical Considerations	134
7.1.5.4	Infrastructure and Investment Requirements	134
7.2	Internet of Things	134
7.2.1	Notion of IoT	134
7.2.1.1	Concept of IoT	134
7.2.2	Role of IoT in Industry 4.0	135
7.2.3	IoT Applications in Manufacturing and Supply Chain	135
7.2.4	Challenges and Opportunities of IoT Implementation	136
7.3	Big Data	136

7.3.1	Understanding Big Data and Its Characteristics	137
7.3.2	Big Data Analytics in Industry 4.0	137
7.3.3	Utilizing Big Data for Predictive Maintenance and Optimization	138
7.4	Augmented Reality and Virtual Reality	138
7.4.1	Introduction to AR and VR	138
7.4.1.1	AR Architecture	138
7.4.1.2	VR Architecture	139
7.4.2	Role of AR and VR in Industry 4.0	140
7.5	Blockchain	140
7.5.1	Fundamentals of Blockchain Technology	140
7.5.2	Architecture of Blockchain	141
7.5.3	Enhancing Security and Trust in Industry 4.0 with Blockchain	142
7.6	Convergence of IoT, Big Data, AR/VR, and Blockchain in Industry 4.0	142
7.6.1	Interplay and Integration of Technologies	143
7.6.2	Use Cases and Examples of Combined Implementations	143
7.6.3	Benefits and Synergies of Technology Convergence	144
7.7	Conclusion	145
	References	145
<b>8</b>	<b>Industry 4.0 in Manufacturing, Communication, Transportation, and Health Care</b>	<b>149</b>
	<i>Mani D. Choudhry, Jeevanandham Sivaraj, Sundarrajan Munusamy, Parimala D. Muthusamy, and V. Saravanan</i>	
8.1	Introduction	149
8.1.1	Technological Trends of Industry 4.0	151
8.2	Diversified Applications of Industry 4.0	153
8.2.1	Background Analysis	153
8.2.2	Industry 4.0 in Manufacturing	155
8.2.3	Industry 4.0 and Communication Services	157
8.2.4	Industry 4.0 in Transportation	159
8.2.5	Industry 4.0 in Health Care	160
8.2.5.1	On-Demand Health Care	161
8.2.5.2	Telemedicine Market	161
8.2.5.3	Data Privacy and Cybersecurity in Medicine and Health Care	162
8.2.5.4	Big Data Analytics in Health Care	162
8.2.5.5	Wearable Medical Devices	162
8.3	Conclusion	162
	References	163
<b>9</b>	<b>Transforming Education Management in the Industry 4.0 Era: Harnessing the Power of Cloud-Based Blockchain</b>	<b>167</b>
	<i>Sovers Singh Bisht, Garima Jain, Priyanka Chandani, and Vinod M. Kapse</i>	
9.1	Introduction	167
9.1.1	Contribution	169
9.2	Revolutionizing Education Through Technology: The Power of Innovation and Connectivity	169
9.2.1	What Is a Chain of Blocks (Blockchain), and How Does It Work?	169
9.2.2	Blockchain Utilization	170
9.2.3	Blockchain in Education: Revolutionizing Learning, Credentialing, and Industry 4.0	170
9.2.4	Realities: Utilizing Blockchain in Education in the Industry 4.0 Era	171
9.2.5	Blockchain, Cloud Computing, and Industry 4.0: Transforming Education and Beyond	171
9.3	Blockchain Application in Education with Industry 4.0: Revolutionizing Learning, Credentialing, and Collaboration	172
9.4	Blockchain Solution Providers for Education in the Era of Industry 4.0	174

9.5	Navigating the Challenges: Implementing Blockchain in Education Within the Industry 4.0 Landscape	177
9.6	A Vision for the Future	178
9.7	Conclusion	179
	References	179
<b>10</b>	<b>Future Professions in Agriculture, Medicine, Education, Fitness, Research and Development, Transport, and Communication</b>	<b>181</b>
	<i>Mohan Singh, Manoj Joshi, Kapil D. Tyagi, and Vaibhav B. Tyagi</i>	
10.1	Introduction	181
10.1.1	Artificial Intelligence	181
10.1.2	Applications of AI	182
10.1.3	AI Roadmap in Industry 4.0	182
10.2	Literature Review	182
10.3	AI Impact on Future Professions	186
10.4	Role Model of AI in Industry 4.0	187
10.5	AI in Agriculture	187
10.5.1	Applying AI in Agriculture	188
10.5.2	Role of AI in Challenges of Agriculture	188
10.6	AI in Medicine	189
10.6.1	Applying AI in Medicine	190
10.7	Role of AI in Challenges of Medicine	190
10.8	AI in Education	191
10.8.1	Applying AI in Education	192
10.8.2	Role of AI in Challenges of Education	193
10.9	AI in Fitness	194
10.9.1	Applying AI in Fitness	194
10.9.2	Role of AI in Challenges of Fitness	195
10.10	AI in R&D	196
10.10.1	Applying AI in R&D	196
10.10.2	Role of AI in Challenges of R&D	197
10.11	AI in Transport	197
10.11.1	Applying AI in Transport	198
10.11.2	Role of AI in Challenges of Transport	198
10.11.3	AI in Communication	199
10.11.4	Applying AI in Communication	199
10.11.5	Role of AI in Challenges of Communication	200
10.12	AI Market Growth in Future Profession	200
10.13	Conclusion	201
	References	201
<b>11</b>	<b>Cybersecurity Issues and Challenges in Quantum Computing</b>	<b>203</b>
	<i>R. Rahul, S. Geetha, Soniya Priyatharsini, K. Mehata, Ts. Sundaresan Perumal, N. Ethiraj, and S. Sendilvelan</i>	
11.1	Introduction	203
11.2	Cybersecurity Issues and Challenges in Quantum Computer	206
11.2.1	Quantum Key Distribution	208
11.2.2	Post-Quantum Cryptography	209
11.2.3	Quantum Attacks	209
11.2.4	Algorithmic Design	211
11.2.5	Standardization	212
11.2.6	Quantum-Aware Infrastructure	214
11.2.7	Quantum Security Standards and Policy	214

11.2.8	Implementation Challenges	216
11.3	General Solutions	217
11.4	Conclusion	219
	References	220
<b>12</b>	<b>Security, Privacy, Trust, and Other Issues in Industries 4.0</b>	<b>223</b>
	<i>Ambeshwar Kumar, Manikandan Ramachandran, M. Manjula, Monika Agarwal, Pooja, and Utku Köse</i>	
12.1	Introduction	223
12.1.1	Integration of Modern Technologies	223
12.1.2	Globalization and Emerging Issues	224
12.1.3	Cybersecurity 4.0	225
12.2	Security Fog Computing	226
12.2.1	Fog Computing in Industrial Internet of Things	226
12.2.1.1	Working of Industrial Internet of Things	226
12.2.2	Plant Safety and Security Including Augmented Reality and Virtual Reality	227
12.2.3	Augmented Reality Security and Privacy Issues	227
12.2.3.1	Augmented Reality Concerns	227
12.2.3.2	Virtual Reality Concerns	228
12.2.3.3	Examples	228
12.2.4	Safety Application	228
12.2.4.1	WirelessHART and Analytics	228
12.2.4.2	Maximize Plant Safety	228
12.3	IoT Challenges	228
12.3.1	Privacy and Security Concerns of Industrial Internet of Things	228
12.3.2	Security-Related Issues in Industry 4.0	229
12.3.3	Side-Channel Attacks	230
12.3.3.1	Types of Side-Channel Attacks	230
12.3.4	Spear Phishing	231
12.3.5	Cyberterrorism	231
12.4	Security Threats and Solutions of Industrial Internet of Things	232
12.4.1	Spoofing	233
12.4.2	Data Tempering	233
12.4.3	Malicious Code Injection	233
12.5	Conclusion	236
	References	236
<b>13</b>	<b>Designing a Quantum Computer to Gear up Artificial Intelligence for Industry 4.0</b>	<b>239</b>
	<i>K. Pradheep Kumar, Neha Sharma, and Juergen Seitz</i>	
13.1	Introduction	239
13.2	Literature Survey	240
13.3	Proposed Work	241
13.3.1	Motivation for Quantum Computers in Industry 4.0 Revolution	241
13.3.1.1	Cryo-cooling Unit	241
13.3.1.2	Qubit Container	241
13.3.1.3	Qubit Functional Unit	242
13.3.1.4	Quantum Data Plane	242
13.3.1.5	Quantum Control Plane	242
13.3.1.6	Quantum ALU	243
13.3.1.7	Quantum Memory Unit	243
13.3.1.8	Quantum Display Unit	243
13.3.2	Working of the Quantum Computer	243
13.3.2.1	Algorithm	243

13.3.2.2	Qubit Proportion Combinations	243
13.3.3	Datasets and Qubit Processing Requirement	245
13.3.3.1	Quantum Datasets	245
13.3.3.2	Lattice Cube Formation	245
13.3.3.3	Threshold of Quantum Cube	247
13.3.3.4	Randomized Quantum Dataset Generator	247
13.3.3.5	Significance of Threshold Computation	247
13.3.4	Optimizations for Quantum Computer	248
13.3.4.1	Cryo-Cooling Unit Backup Power	248
13.3.4.2	Qubit Balancing	248
13.3.4.3	Quantum Memory Optimization	249
13.3.4.4	Significance of Overall Optimality	249
13.3.4.5	Complexity in Quantum Cubes	250
13.3.5	Dataset Complexity	250
13.3.6	Green Quantum Computing and Its Importance for Industry 4.0	250
13.4	Simulation Results	250
13.4.1	Processing Time	251
13.4.2	Memory Consumption	252
13.5	Conclusion and Future Work	254
	References	254
<b>14</b>	<b>Opportunities in Neural Networks for Industry 4.0</b>	<b>257</b>
	<i>Rodrigo de Paula Monteiro, José P.G. de Oliveira, Sérgio C. Oliveira, and Carmelo J.A.B. Filho</i>	
14.1	Introduction: Why Is Machine Learning Interesting to Industry 4.0?	257
14.2	Machine Learning	257
14.3	Challenges in Industry 4.0 That Can Benefit from Using Machine Learning	259
14.3.1	Fault Detection and Diagnosis	259
14.3.2	Predicting Remaining Useful Lifetime	259
14.3.3	Predictive Maintenance	260
14.3.4	Optimizing Energy Consumption	260
14.3.5	Cybersecurity	261
14.3.6	Soft Sensors	262
14.4	Some Cases of Success Deploying ML in Industry 4.0	262
14.4.1	Detecting Defects in Sanitary Ware with Deep Learning	262
14.4.2	Detection of Anomalies in Embedded System Using Electrical Signature	264
14.5	Conclusions and Final Remarks	267
	References	267
<b>15</b>	<b>A Smarter Way to Collect and Store Data: AI and OCR Solutions for Industry 4.0 Systems</b>	<b>271</b>
	<i>Ajay R. Nair, Varun D. Tripathy, R. Lalitha Priya, Manigandan Kashimani, Guru Akaash N. Janthapur, Nusrat J. Ansari, and Igor Jurcic</i>	
15.1	Introduction	271
15.2	Background	271
15.3	Architecture of Wireless Extraction of Display Panel	273
15.3.1	Block Diagram	273
15.3.2	Modular Diagram	274
15.3.3	Equations Applied	275
15.4	ESP32 Cam Module	275
15.4.1	Why Is the ESP32-CAM-MB USB Programmer Preferred over the FTDI Programmer?	276
15.4.2	So How Is the ESP32-CAM-MB USB Programmer Used?	277
15.5	Wireless LAN Network Setup	277
15.6	Optical Character Recognition for Text Detection and Text Recognition	278

- 15.6.1 KerasOCR's Text Detector – CRAFT Model 278
- 15.6.2 Training Custom KerasOCR Models 279
- 15.6.3 EasyOCR Architecture 279
- 15.6.4 Training of Custom EasyOCR Model 280
- 15.6.5 Real-Time Streaming Using IP Webcam 281
- 15.6.6 Processing the Data 281
- 15.7 Working of the Model 282
  - 15.7.1 Creating a Class for Handling Web Camera Stream 282
  - 15.7.2 Using the Web Camera Stream Class 283
  - 15.7.3 Detecting Texts or Selecting Regions of Interest 283
  - 15.7.4 Cropping Selected ROIs from an Image 284
  - 15.7.5 Performing Optical Character Recognition on the Cropped Images 284
- 15.8 Application GUI 284
- 15.9 Conclusion 287
  - References 287

**Index** 289

## About the Editors



**Mahmoud Ragab AL-Refaey** obtained his Ph.D. degree from the Faculty of Mathematics and Natural Sciences at the Christian-Albrechts-University in Kiel (CAU), Schleswig-Holstein, Germany.

He received his B.S.C. degree in Statistics Computer Science from Mansoura University in Mansoura, Egypt. He is a professor of data science at the Department of Information Technology, Faculty of Computing and Information Technology, King Abdulaziz University in Jeddah, Saudi Arabia and the Mathematics Department, Faculty of Science, Al Azhar University in Cairo, Egypt. He worked in different research groups at various universities such as the Combinatorial Optimization and Graph Algorithms Group (COGA), Faculty of Mathematics and Natural Sciences, Berlin University of Technology in Berlin, Germany; Faculty of Informatics and Computer Science at the British University in Egypt BUE; Integrated Communication Systems Group at Ilmenau University of Technology TU Ilmenau, in Thüringen, Germany. Now he is a researcher at various centers

such as: University of Oxford Centre for Artificial Intelligence in Precision medicines; Center of Research Excellence in Artificial Intelligence and Data Science; Center of Excellence in Smart Environment Research at King Abdulaziz University, Jeddah, Saudi Arabia. He has published over 100 papers in refereed high-impact journals, books, and patents. His research focuses on: AI, Deep learning, Optimization, Mathematical Modeling, Data Science, Neural Networks, Time series analysis, and decision support systems.



**Amit Kumar Tyagi** is working as an assistant professor at the National Institute of Fashion Technology, New Delhi, India. Previously, he worked as an assistant professor (Senior Grade 2) and senior researcher at Vellore Institute of Technology (VIT), Chennai Campus, Chennai, Tamil Nadu, India, for the period of 2019–2022. He received his PhD degree (full-time) in 2018 from Pondicherry Central University, Puducherry, India. Regarding his academic experience, he joined Lord Krishna College of Engineering, Ghaziabad (LKCE) for the periods of 2009–2010 and 2012–2013. He was an assistant professor and head of research at Lingaya's Vidyapeeth (formerly known as Lingaya's University), Faridabad, Haryana, India, for the period of 2018–2019. His supervision experience includes more than 10 master's dissertations and one PhD thesis. He has contributed to several projects such as AARIN and P3- Block to address some of the open issues related to privacy breaches in vehicular applications (such as parking) and medical cyber-physical systems (MCPS). He has published over 100 papers in refereed high-impact journals, conferences, and books, with some of his articles receiving best paper awards. Also, he has filed more than 20 patents (nationally and internationally) in the areas

of deep learning, the Internet of Things, cyber-physical systems, and computer vision. He has edited more than 20 books for IET, Elsevier, Springer, CRC Press, and so on. Furthermore, he has authored three books on the Internet of Things, intelligent transportation systems, and vehicular ad hoc networks with BPB Publication, Springer, and IET publisher,

respectively. He is a winner of the Faculty Research Award for the years 2020, 2021, and 2022 (consecutively three years), given by Vellore Institute of Technology, Chennai, India. Recently, he has received the best paper award for a paper titled “A Novel Feature Extractor Based on the Modified Approach of Histogram of Oriented Gradient” at ICCSA 2020 in Italy, Europe. His current research focuses on next-generation machine-based communications, blockchain technology, smart and secure computing, and privacy. He is a regular member of the ACM, IEEE, MIR Labs, Ramanujan Mathematical Society, Cryptology Research Society, and Universal Scientific Education and Research Network, CSI, and ISTE.



**Abdullah Saad AL-Malaise AL-Ghamdi** is a professor of software & systems Engineering and AI, associated with Faculty of Computing and Information Technology (FCIT) at King Abdulaziz University (KAU), Jeddah, Saudi Arabia. He is a professor at the Information Systems Department, School of Engineering, Computing and Design, Dar Al-Hekma University, in Jeddah, Saudi Arabia. He received his PhD. degree in computer science from George Washington University, USA, in 2003. He is a member of the Scientific Council and holds the position of secretary general of the scientific council at KAU. In addition, he is working as the head of Consultant’s unit at the Vice-President for Development Office, as a consultant to the vice-president for Graduate Studies & Scientific Research at KAU. Previously, he has worked as the head of the IS Department, vice dean for Graduate Studies and Scientific Research, and head of the Computer Skills Department at FCIT. Recently he is a researcher at various centers such as: University of Oxford Centre for Artificial Intelligence in Precision Medicines; Center of Research Excellence in Artificial Intelligence and Data Science; Center of

Excellence in Smart Environment Research at King Abdulaziz University, Jeddah, Saudi Arabia. He has supervised many MSc & PhD students who are now successful in and outside academia. He has published many papers in refereed high-impact journals, books, and patents. His main research areas are software engineering and systems, artificial intelligence, data analytics, business intelligence, and decision support systems.



**Swetta Kukreja** is working as an associate professor in the Department of CSE at Amity University, Mumbai. She has more than 10 years of teaching and research experience. She has completed her PhD from Lingaya’s University, Faridabad. She had served as an editor for many international conferences and journals. She has many publications (including patents) in national and international conferences and journals and has also served as a reviewer for the same. She is a member of ACM and IEEE.

## List of Contributors

### **Monika Agarwal**

Computer Science and Engineering  
Dayananda Sagar University  
Bengaluru, Karnataka, India

### **Abdullah Saad AL-Malaise AL-Ghamdi**

Information Systems Department, Faculty of Computing  
and Information Technology (FCIT)  
King Abdulaziz University (KAU)  
Jeddah, Saudi Arabia

Information Systems Department  
School of Engineering, Computing and Design  
Dar Al-Hekma University  
Jeddah, Saudi Arabia

### **K. Annamalai**

VIT University  
Chennai, Tamil Nadu, India

### **Nusrat J. Ansari**

Computer Science Department  
Vivekanand Education Society's Institute of Technology  
Mumbai, Maharashtra, India

### **Dinesh Kumar Atal**

Department of Biomedical Engineering  
Deenbandhu Chhotu Ram University of Science and  
Technology  
Sonapat, Haryana, India

### **Ananda K. Behera**

Artificial Intelligence and Machine Learning Programme  
Liverpool John Moores University  
Liverpool, UK

### **Rajiv Kumar Berwer**

Department of Computer Science and Engineering  
Deenbandhu Chhotu Ram University of Science and  
Technology  
Sonapat, Haryana, India

### **Biswajit R. Bhowmik**

BRICS Laboratory  
Department of Computer Science and Engineering  
National Institute of Technology Karnataka  
Mangalore, Karnataka, India

### **Sovers Singh Bisht**

Noida Institute of Engineering and Technology  
Greater Noida, Uttar Pradesh, India

### **Priyanka Chandani**

Noida Institute of Engineering and Technology  
Greater Noida, Uttar Pradesh, India

### **Mani D. Choudhry**

Department of Information Technology  
KGiSL Institute of Technology  
Coimbatore, Tamil Nadu, India

### **Jyoti Dabass**

DBT Centre of Excellence Biopharmaceutical  
Technology, IIT  
New Delhi, India

### **Manju Dabass**

EECE Department  
The Northcap University  
Gurugram, Haryana, India

### **José P.G. de Oliveira**

Polytechnic School of Pernambuco  
University of Pernambuco  
Recife, Pernambuco, Brazil

### **M.K. Dharani**

Department of AI  
Kongu Engineering College  
Erode, Tamil Nadu, India

***N. Ethiraj***

Dr. M.G.R. Educational and Research Institute  
Chennai, Tamil Nadu, India

***Carmelo J.A.B. Filho***

Polytechnic School of Pernambuco  
University of Pernambuco  
Recife, Pernambuco, Brazil

***S. Geetha***

Dr. M.G.R. Educational and Research Institute  
Chennai, Tamil Nadu, India

***K.K. Girish***

BRICS Laboratory  
Department of Computer Science and Engineering  
National Institute of Technology Karnataka  
Mangalore, Karnataka, India

***V.M. Gobinath***

Rajalakshmi Institute of Technology  
Chennai, Tamil Nadu, India

***M. Gunasekar***

Department of Information Technology  
Kongu Engineering College  
Erode, Tamil Nadu, India

***Sanjeev Indora***

Department of Computer Science and Engineering  
Deenbandhu Chhotu Ram University of Science and  
Technology  
Sonapat, Haryana, India

***Garima Jain***

Noida Institute of Engineering and Technology  
Greater Noida, Uttar Pradesh, India

***Guru Akaash N. Janthalur***

Computer Science Department  
Vivekanand Education Society's Institute of Technology  
Mumbai, Maharashtra, India

***A.S. Jayasurya***

Department of Electrical and Electronics  
Universiti Teknologi Petronas  
Perak, Malaysia

***G. Belshia Jebamalar***

Department of Computer Science and Engineering  
S.A. Engineering College  
Chennai, Tamil Nadu, India

***Manoj Joshi***

Department of ECE  
JSS Academy of Technical Education  
Noida, Uttar Pradesh, India

***Igor Jurcic***

Telecommunications and Informatics Department  
HT ERONET  
Mostar, Bosnia and Herzegovina

***S.K. Rajesh Kanna***

Rajalakshmi Institute of Technology  
Chennai, Tamil Nadu, India

***Vinod M. Kapse***

Noida Institute of Engineering and Technology  
Greater Noida, Uttar Pradesh, India

***Manigandan Kashimani***

Computer Science Department  
Vivekanand Education Society's Institute of Technology  
Mumbai, Maharashtra, India

***A. Kathirvel***

Panimalar Engineering College  
Chennai, Tamil Nadu, India

***M. Keerthika***

Department of Computer Science and Engineering  
Rajalakshmi Engineering College  
Chennai, Tamil Nadu, India

***Utku Köse***

Computer Engineering  
Suleyman Demirel University  
Kaskelen, Kazakhstan

***Swetta Kukreja***

Department of Computer Science and Engineering  
Amity University  
Mumbai, Maharashtra, India

***Ambeshwar Kumar***

Computer Science and Engineering  
GITAM University  
Visakhapatnam, Andhra Pradesh, India

***K. Pradheep Kumar***

Department of CSIS  
BITS Pilani  
Pilani, Rajasthan, India

**K.R. Prasanna Kumar**

Department of Information Technology  
Kongu Engineering College  
Erode, Tamil Nadu, India

**Sunil Kumar**

BRICS Laboratory  
Department of Computer Science and Engineering  
National Institute of Technology Karnataka  
Mangalore, Karnataka, India

**R. Lalitha Priya**

Computer Science Department  
Vivekanand Education Society's Institute of Technology  
Mumbai, Maharashtra, India

**K. Logeswaran**

Department of AI  
Kongu Engineering College  
Erode, Tamil Nadu, India

**M. Manjula**

Computer Science and Engineering  
Dayananda Sagar University  
Bengaluru, Karnataka, India

**Bireshwar D. Mazumdar**

Department of Computer Science and Engineering  
Faculty of Engineering and Technology  
United University Prayagraj  
Allahabad, Uttar Pradesh, India

**K. Mehata**

Dr. M.G.R. Educational and Research Institute  
Chennai, Tamil Nadu, India

**Rodrigo de Paula Monteiro**

Polytechnic School of Pernambuco  
University of Pernambuco  
Recife, Pernambuco, Brazil

**Sundarrajan Munusamy**

Department of Networking and Communications  
SRM Institute of Science & Technology  
Chennai, Tamil Nadu, India

**Parimala D. Muthusamy**

Department of Electronics and Communication  
Engineering  
Velalar College of Engineering and Technology  
Erode, Tamil Nadu, India

**Ajay R. Nair**

Computer Science Department  
Vivekanand Education Society's Institute of Technology  
Mumbai, Maharashtra, India

**Kanchan Naithani**

School of Computing Science and Engineering  
Galgotias University  
Greater Noida, Uttar Pradesh, India

**Sérgio C. Oliveira**

Polytechnic School of Pernambuco  
University of Pernambuco  
Recife, Pernambuco, Brazil

**Ts. Sundaresan Perumal**

Universiti Sains Islam Malaysia  
Bandar Baru Nilai  
Negeri Sembilan, Malaysia

**Pooja**

Computer Science and Engineering  
Dayananda Sagar University  
Bengaluru, Karnataka, India

**M. Pragadeesh**

Department of Information Technology  
Rajalakshmi Engineering College  
Chennai, Tamil Nadu, India

**Soniya Priyatharsini**

Dr. M.G.R. Educational and Research Institute  
Chennai, Tamil Nadu, India

**Mahmoud Ragab AL-Refaey**

Information Technology Department, Faculty of  
Computing and Information Technology (FCIT)  
King Abdulaziz University (KAU)  
Jeddah, Saudi Arabia

Mathematics Department  
Faculty of Science  
Al-Azhar University  
Naseir City, Cairo, Egypt

**R. Rahul**

Dr. M.G.R. Educational and Research Institute  
Chennai, Tamil Nadu, India

**R. Rajadevi**

Department of AI  
Kongu Engineering College  
Erode, Tamil Nadu, India

***Manikandan Ramachandran***

School of Computing  
SASTRA Deemed University  
Thanjavur, Tamil Nadu, India

***M. Santhiya***

Department of Computer Science and Engineering  
Rajalakshmi Engineering College  
Chennai, Tamil Nadu, India

***V. Saravanan***

Department of Computer Science  
College of Engineering and Technology  
Dambi Dollo University  
Dambi Dollo, Oromia Region, Ethiopia

***S. Savitha***

Department of CSE  
K.S.R. College of Engineering  
Tiruchengode, Tamil Nadu, India

***Juergen Seitz***

Duale Hochschule Baden-Württemberg  
Wirtschaftsinformatik, Heidenheim, Germany

***S. Sendilvelan***

Dr. M.G.R. Educational and Research Institute  
Chennai, Tamil Nadu, India

***Neha Sharma***

Tata Consultancy Services  
Pune, Maharashtra, India

***Arun K. Singh***

Department of Computer Science & Engineering  
Greater Noida Institute of Technology  
Greater Noida, Uttar Pradesh, India

***Mohan Singh***

Department of ECE  
G.L. Bajaj Institute of Technology and Management  
Greater Noida, Uttar Pradesh, India

***Jeevanandham Sivaraj***

Department of Information Technology  
Sri Ramakrishna Engineering College  
Coimbatore, Tamil Nadu, India

***P. Suresh***

Department of Database Systems  
School of Computer Science and Engineering  
Vellore Institute of Technology  
Vellore, Tamil Nadu, India

***Shrikant Tiwari***

School of Computing Science and Engineering  
Galgotias University  
Greater Noida, Uttar Pradesh, India

***Varun D. Tripathy***

Computer Science Department  
Vivekanand Education Society's Institute of Technology  
Mumbai, Maharashtra, India

***Amit Kumar Tyagi***

Department of Fashion Technology  
National Institute of Fashion Technology  
New Delhi, India

***Kapil D. Tyagi***

Department of ECE  
Jaypee Institute of Information Technology  
Noida, Uttar Pradesh, India

***Vaibhav B. Tyagi***

Department of ECE  
ISBAT University  
Kampala, Uganda

***Harish Venu***

Institute of Sustainable Energy (ISE)  
Universiti Tenaga Nasional  
Putrajaya Campus, Malaysia

***Virendra K. Verma***

Department of Industrial & Production Engineering  
Institute of Engineering and Rural Technology (IERT)  
Allahabad, Uttar Pradesh, India

***Ramesh S. Wadawadagi***

Department of Information Science and Engineering  
Nagarjuna College of Engineering  
Bengaluru, Karnataka, India

***Vivek Yadav***

Expresslending Pty Ltd  
Melbourne, Victoria, Australia

## Preface

Industries, as we all know, are the ones that produce goods and services for society. Workers in the textile industry design, fabricate, and sell cloth. The tourist industry includes all the commercial aspects of tourism. The automobile industry makes cars and car parts. The food service industry prepares food and delivers it to hotels, schools, and other big facilities. “Industry” comes from the Latin “*industria*,” which means “diligence, hard work,” and the word is still used with that meaning. Generally, the industry has been through various evolutions during the last three decades. The industry started in the eighteenth century; that is, in 1784, the first power loom was developed. Hence, Industry 1.0 was all about mechanization with water and steam. In the next phase of the industry revolution, that is, Industry 2.0, the electrification of the industry took place. It started from 1900 to 1950. During this revolution, the “Assembly Line was developed.” Further, Industry 3.0 is about the automation of data. During this revolution, the adoption of computers and automation, enhanced by smart and autonomous systems, is fueled by data and machine learning. All the data that was available manually began to be stored disks. Industry 3.0 was a major revolution in terms of automating things, and even operational technologies came into existence, but there was still a felt need to merge information technology with operational technology to truly digitize the world. This would be called “the Digital Transformation” in the true sense, and the resolution happening in Industry 4.0 is to move toward that direction.

Later, Industry 4.0 is to improve manufacturing efficiency; it is about transforming the way your entire business operates and grows. It is associated with cyber-physical system, in which digital technologies can create virtual versions of real-world installations, processes, and applications. This can then be robustly tested to make cost-effective, decentralized decisions. These virtual copies can then be created in the real world and linked via the Internet of Things (IoT), allowing cyber-physical systems to communicate and cooperate with each other and human staff to create a joined-up real-time data exchange and automation process for Industry 4.0 manufacturing. This should allow for digital transformation and automated and autonomous manufacturing with joined-up systems that can cooperate with each other. This technology will help solve problems and track processes while increasing productivity. It also primarily focuses on the use of large-scale machine-to-machine communication and IoT deployments to provide increased automation, improved communication, and self-monitoring, as well as smart machines that can analyze and diagnose issues without the need for human intervention. The idea of connected manufacturing or smart factories is becoming increasingly ubiquitous. Factories and their machines across the globe are getting smarter as connected products and systems operate as part of a larger, more responsive, and agile information infrastructure. The aim is to harvest benefits and improvements in efficiency and profitability, increased innovation, and better management of safety, performance, and environmental impact. This book will provide a complete experience of industrial revolution and its progress toward emerging technology.

*Mahmoud Ragab AL-Refaey*  
*Amit Kumar Tyagi*  
*Abdullah Saad AL-Malaise AL-Ghamdi*  
*Swetta Kukreja*



## Acknowledgment

First of all, we would like to extend our gratitude to our family members, friends, and supervisors, who stood with us as advisors in completing this book. Also, we would like to thank our almighty God, who inspires us to write this book. We also thank Wiley Publishers, who have provided their continuous support all the time, and our colleagues, authors with whom we have worked together inside the college/university and others outside of the college/university, who have provided their continuous support towards completing this book on *Topics in Artificial Intelligence Applied to Industry 4.0*.

Further, the authors also gratefully acknowledge the support provided by the Faculty of Computing and Information Technology (FCIT) and King Abdulaziz University (KAU), Jeddah, Saudi Arabia, to produce this book. Furthermore, we thank the School of Engineering, Computing and Design, Dar Al-Hekma University, Jeddah, Saudi Arabia, for their support in performing this book.

We also acknowledge the support provided by the Department of Fashion Technology, National Institute of Fashion Technology, New Delhi, and the Department of Computer Science and Engineering, Amity University Mumbai, India.

Lastly, we would like to thank our respected madam Prof. G. Aghila, Prof. Siva Sathya, Manisha Kinnu (IRS), our respected sir Prof. N Sreenath, and Prof. Aswani Kumar Cherukuri for giving their valuable inputs and helping us in completing this book with Wiley Publisher.

Once again, thanks to all.

*Mahmoud Ragab AL-Refaey*  
*Amit Kumar Tyagi*  
*Abdullah Saad AL-Malaise AL-Ghamdi*  
*Swetta Kukreja*



## 1

## Introduction to Industry 4.0 and Its Impacts on Society

Shrikant Tiwari<sup>1</sup>, Kanchan Naithani<sup>1</sup>, Arun K. Singh<sup>2</sup>, Virendra K. Verma<sup>3</sup>, Ramesh S. Wadawadagi<sup>4</sup>, and Bireshwar D. Mazumdar<sup>5</sup>

<sup>1</sup> School of Computing Science and Engineering, Galgotias University, Greater Noida, Uttar Pradesh, India

<sup>2</sup> Department of Computer Science & Engineering, Greater Noida Institute of Technology, Greater Noida, Uttar Pradesh, India

<sup>3</sup> Department of Industrial & Production Engineering, Institute of Engineering and Rural Technology (IERT), Allahabad, Uttar Pradesh, India

<sup>4</sup> Department of Information Science and Engineering, Nagarjuna College of Engineering, Bengaluru, Karnataka, India

<sup>5</sup> Department of Computer Science and Engineering, Faculty of Engineering and Technology, United University Prayagraj, Allahabad, Uttar Pradesh, India

### 1.1 Introduction

The ongoing Fourth Industrial Revolution (4IR) is characterized by the continuous transformation of society and the economy through technological advancements [1, 2]. This revolution encompasses breakthroughs in artificial intelligence (AI), robotics, the Internet of Things (IoT), and other digital technologies. What sets it apart from previous revolutions is not only the creation of new machines or processes but also the integration of these technologies into existing systems and the development of previously unimaginable systems [3].

The potential impacts of the 4IR on society and the economy are extensive and profound [4]. While these new technologies have the potential to improve productivity, efficiency, and quality of life for many, they also raise important questions regarding the equitable distribution of benefits and the potential exclusion of certain groups.

This chapter serves as an introduction to the 4IR and its societal impact. It explores the technological advancements driving this revolution, examines its potential effects on the economy and society, and addresses the ethical and governance considerations that arise in this era of technological progress.

The objective of this exploration is to deepen our understanding of the 4IR and its implications for society and the economy. Additionally, it explores how individuals, businesses, and governments can collaborate to shape this revolution in a way that maximizes its potential benefits while mitigating any negative consequences.

The 4IR refers to the current phase of technological advancements, encompassing AI, robotics, the IoT, and other digital technologies [5]. Coined by Klaus Schwab in his 2016 book *The Fourth Industrial Revolution*, it builds upon the transformative changes initiated by previous industrial revolutions [6].

The First Industrial Revolution introduced mechanization and steam power, while the Second Industrial Revolution brought electricity and mass production [7]. The Third Industrial Revolution, known as “the digital revolution,” introduced computers and digital technology. However, the 4IR is distinctive because it integrates and converges technologies across all aspects of life [8]. It blurs the boundaries between physical, digital, and biological systems, enabling unprecedented levels of automation, connectivity, and data analysis. This integration has the potential to revolutionize industries, boost productivity, and create new avenues for economic growth.

The anticipated impact of the 4IR on society and the economy is profound. It is crucial for us to understand its implications and foster collaboration to ensure the equitable distribution of its benefits.

### 1.1.1 Overview of the Major Technological Advancements Driving the Revolution

The ongoing 4IR is characterized by remarkable technological advancements that are profoundly reshaping our lifestyles and work dynamics [9]. These advancements include:

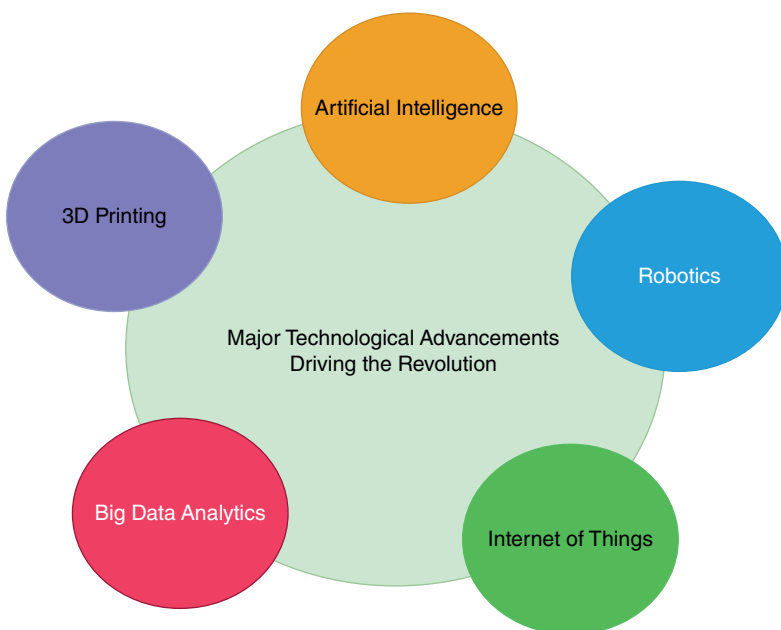
- **Artificial Intelligence:** AI encompasses machines capable of performing tasks that traditionally require human intelligence, such as speech recognition, decision-making, and experiential learning. It continues to evolve and finds applications in various fields, including autonomous vehicles, personalized medicine, and intelligent virtual assistants.
- **Robotics:** Robotics involves the use of robots and automated systems to perform tasks that typically require human intervention. Advances in robotics enable increased levels of automation in industries such as manufacturing, logistics, and more.
- **Internet of Things:** The IoT is a network that connects physical objects embedded with sensors, software, and other technologies, enabling data exchange and collection. It promotes connectivity and data analysis, leading to valuable insights and efficiencies in sectors such as health care, agriculture, and transportation.
- **Big Data Analytics:** Big data refers to vast amounts of data generated by the IoT, social media, and other sources. Big data analytics involves employing advanced analytical techniques to extract insights and value from this data. It empowers organizations to make informed decisions and optimize their operations.
- **3D Printing:** 3D printing involves the layer-by-layer creation of physical objects. Advances in 3D printing technology allow to produce intricate and precise objects, unlocking new possibilities in health care, aerospace, manufacturing, and other industries.

These advancements in the 4IR are revolutionizing various sectors and presenting exciting opportunities for innovation and growth (refer to Figure 1.1). They have the potential to reshape our society and economy in profound ways, driving us toward a more interconnected and technologically advanced future.

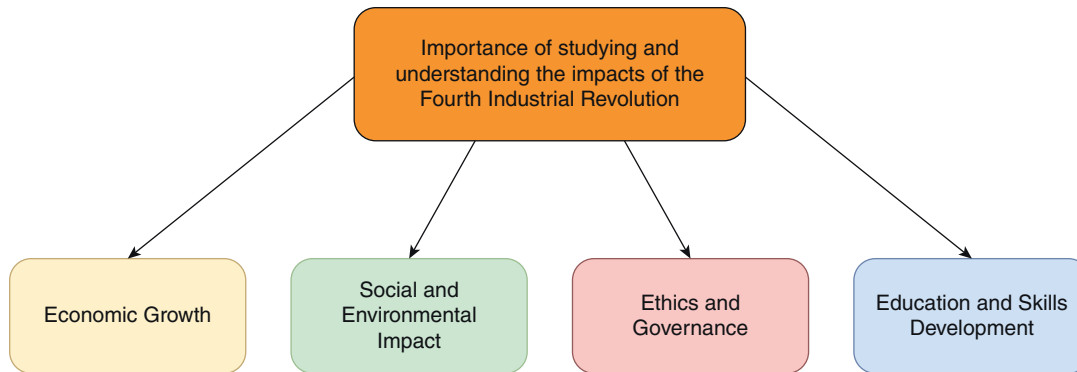
### 1.1.2 Importance of Studying and Understanding the Impacts of the Fourth Industrial Revolution

Studying and understanding the impacts of the 4IR is critical for several reasons [6, 10]:

- **Economic Growth:** The 4IR has the potential to drive substantial economic growth by fostering innovation, creating new employment opportunities, and enhancing productivity. A deep understanding of the opportunities presented by these technological advancements enables businesses and governments to capitalize on them, leading to sustainable economic growth.



**Figure 1.1** Major technological advancements driving the revolution.



**Figure 1.2** Importance of studying and understanding the impacts of the Fourth Industrial Revolution.

- **Social and Environmental Impact:** The 4IR carries the potential for significant social and environmental consequences. It may exacerbate income inequality, contribute to job displacement through automation, and have adverse environmental effects. By comprehending the potential negative impacts of these technologies, we can develop policies and strategies to address and mitigate these challenges effectively.
- **Ethics and Governance:** The 4IR raises crucial ethical and governance considerations. Privacy, security, and accountability become paramount concerns in a technologically advanced era. A thorough understanding of these considerations empowers us to establish ethical frameworks and governance structures that ensure responsible development and use of these technologies.
- **Education and Skills Development:** The 4IR transforms the skill sets and educational requirements needed for the workforce of the future. Understanding the evolving demands and identifying the necessary skills equip us to prepare individuals and communities for the changing nature of work, fostering adaptability and lifelong learning.

In summary, studying and comprehending the impacts of the 4IR are vital to optimize the benefits of these technological advancements while minimizing their negative consequences. By doing so, we can create a more equitable, sustainable, and prosperous future for all (refer to Figure 1.2).

## 1.2 The Technological Advancements of the Fourth Industrial Revolution

The 4IR represents a wave of transformative technological advancements that are fundamentally reshaping our lives and work dynamics [7, 11]. These advancements encompass a range of key technologies, which include the following:

- **Artificial Intelligence:** AI enables machines to perform tasks that traditionally require human intelligence, such as speech recognition, decision-making, and experiential learning. Ongoing advancements in AI have led to its application in various domains, including autonomous vehicles, personalized medicine, and intelligent virtual assistants.
- **Robotics:** Robotics involves the use of robots and automated systems to perform tasks that typically require human intervention. Advances in robotics have facilitated increased levels of automation in industries such as manufacturing, logistics, and beyond.
- **Internet of Things:** The IoT consists of a network of physical objects embedded with sensors, software, and other technologies for data collection and exchange. It enables enhanced connectivity and data analysis, leading to valuable insights and efficiencies in sectors like health care, agriculture, and transportation.
- **Big Data Analytics:** Big data refers to vast amounts of data generated by the IoT, social media, and other sources. Big data analytics involves employing advanced techniques to extract insights and value from this data. Organizations leverage these insights to make informed decisions and optimize their operations.
- **3D Printing:** 3D printing is an additive manufacturing process that constructs physical objects layer by layer. Advancements in 3D printing technology enable the production of intricate objects with exceptional precision, unlocking new possibilities in health care, aerospace, manufacturing, and more.

- **Blockchain:** Blockchain is a distributed ledger technology that enables secure and transparent transactions without intermediaries. It has the potential to transform various industries, including finance, supply chain management, and real estate.
- **Augmented Reality (AR) and Virtual Reality (VR):** AR and VR technologies provide immersive experiences that blend the physical and digital realms. These technologies find applications in fields such as education, entertainment, and retail.

These technological advancements are reshaping industries, creating new opportunities for growth. However, they also give rise to critical ethical and governance considerations. Understanding these advancements and their potential impact is crucial for individuals, businesses, and governments as we navigate the 4IR and strive to maximize its benefits while addressing its challenges.

### 1.2.1 Discussion of the Potential Benefits and Drawbacks of Each Technology

The key technologies driving the 4IR present both potential benefits and drawbacks [12]:

- **Artificial Intelligence**  
Benefits: AI has the potential to enhance decision-making, improve efficiency, and enable better understanding of complex data. It offers applications in various fields, including health care and finance.  
Drawbacks: Ethical concerns regarding bias and discrimination in AI decision-making processes exist. There are also concerns about job displacement as AI and automation become more prevalent.
- **Robotics**  
Benefits: Robotics can increase efficiency, reduce costs, and improve safety in industries like manufacturing and logistics. It enables the completion of tasks that are dangerous or difficult for humans.  
Drawbacks: Job displacement is a concern as robotics and automation advance. Safety and ethical considerations in the development and deployment of robots require attention.
- **3D Printing**  
Benefits: 3D printing enables faster, cheaper, and more customizable production of products. It has the potential to reduce waste and improve sustainability.  
Drawbacks: 3D printing is still relatively costly compared to traditional manufacturing methods. The quality of printed products may not always meet the standards of traditional manufacturing.
- **Internet of Things**  
Advantages: The IoT offers real-time insights and improved efficiency across industries. It enhances resource monitoring and management, promoting energy and water conservation.  
Disadvantages: Security and privacy concerns arise as more devices become interconnected, necessitating robust data protection measures. Increased energy usage associated with the IoT raises environmental concerns.
- **Blockchain**  
Advantages: Blockchain enhances transparency, security, and efficiency in industries like finance, supply chain management, and real estate. It enables peer-to-peer transactions, reducing reliance on intermediaries.  
Disadvantages: Energy consumption, especially with cryptocurrencies, poses environmental challenges. Scalability and interoperability of blockchain systems require attention.

Understanding the potential benefits and drawbacks of these technologies is crucial as we navigate the 4IR (refer to Figure 1.3). It allows for informed decision-making regarding their development and deployment, enabling us to harness their advantages while addressing the associated challenges.

### 1.2.2 Examples of How These Technologies Are Already Being Used in Various Industries

The key technologies of the 4IR are already being applied in various industries, leading to transformative outcomes [12]:

- **Artificial Intelligence**  
Health Care: AI assists in disease diagnosis, treatment development, and improving patient outcomes. It analyzes medical images, predicts high-risk individuals, and enables proactive interventions.  
Finance: AI enhances fraud detection, risk management, and customer service in the financial industry. AI-powered chatbots offer personalized financial advice and efficient customer support.