
Contents

Preface	xv
Ashu TANEJA, Abhishek KUMAR, Suresh Vishnudas LIMKAR, Mariya OUAISSA and Mariyam OUAISSA	
Chapter 1. Navigating Artificial Intelligence and Digital Twin for Smart Cities	1
Wasswa SHAFIK	
1.1. Introduction	2
1.2. Artificial intelligence in smart cities	4
1.2.1. Applications of AI in smart cities	6
1.2.2. Benefits and challenges of AI implementation	6
1.2.3. Definitions and components of smart cities.	7
1.3. Digital twin technology	8
1.3.1. Concept and definition of digital twin.	9
1.3.2. Key components and functionality	10
1.4. Understanding the role of artificial intelligence in smart cities	11
1.4.1. AI-driven decision-making.	12
1.4.2. AI-enabled infrastructure management	13
1.5. The role of digital twin technologies in smart cities	14
1.5.1. Digital twins for urban planning.	15
1.5.2. Digital twins for smart infrastructure	16
1.6. Integration of AI and digital twin in smart cities	17
1.6.1. Synergies and benefits of combining AI and digital twin technologies.	18
1.6.2. Case studies and examples of successful implementations	19
1.7. Challenges and future directions	19
1.7.1. Ethical and privacy concerns.	21
1.7.2. Potential innovations and advancements	22

1.8. Conclusion	22
1.9. Reference	23
Chapter 2. Smart City Development in 6G Era: Synergizing AI and Digital Twin Technology	27
Raj Kishor VERMA and Ahmed A. ELNGAR	
2.1. Introduction	28
2.1.1. Smart cities	29
2.1.2. 6G technology.	32
2.1.3. Artificial intelligence	34
2.1.4. Digital twin	36
2.1.5. Urban development	38
2.1.6. Sustainability	41
2.2. Literature review/related work	43
2.3. Proposed diagram	45
2.3.1. Results	46
2.3.2. Seamless connectivity with 6G	47
2.3.3. Sustainability and environmental benefits	47
2.3.4. Improved public services and citizen engagement	47
2.3.5. Challenges and future directions.	48
2.4. Conclusion	50
2.5. Future and scope.	51
2.6. Challenges	52
2.7. References	53
Chapter 3. AI and Digital Twin for Smart Cities	55
Latha P, Geetha S, M. VAIDHEHI, Nalina Keerthana G and Muthu Selvi C	
3.1. Introduction	56
3.2. Digital twin security.	58
3.3. Advancing AI-driven digital twins	59
3.3.1. Factors advancing AI-driven digital twins	59
3.4. Systematic review of the research foundations	60
3.5. Understanding digital twins in a smart city context.	61
3.6. The role of AI in enhancing digital twins	62
3.7. Understanding AI and digital twin technologies	63
3.7.1. Artificial intelligence (AI)	63
3.7.2. Digital twin (DT)	63
3.8. AI-driven energy management in smart cities.	63
3.9. AI and digital twins in smart cities.	65
3.10. Foundations of AI and digital twin technologies	65
3.10.1. Artificial intelligence (AI)	65
3.10.2. Machine learning (ML)	66

3.10.3. Deep learning (DL)	66
3.10.4. Strengthening learning (RL)	66
3.11. Technology for digital twins	66
3.12. Personalizing city services through AI	66
3.13. Interplay between AI and digital twins in urban environments.	67
3.14. AI for urban planning and policy decisions	67
3.15. Ethical considerations and data privacy in smart cities	68
3.16. Understanding artificial intelligence in urban contexts	68
3.16.1. Machine learning (ML)	68
3.16.2. Advanced neural learning.	69
3.16.3. Language processing technology.	69
3.17. Urban landscape virtual models.	70
3.18. Improving public safety and emergency response.	70
3.19. AI for waste management	70
3.19.1. AI for water resource management	71
3.20. AI for urban planning and policy decisions	71
3.21. The societal impact of artificial intelligence and digital twins in urban environments.	71
3.22. Applications in smart city domains	72
3.22.1. Urban planning and development	72
3.22.2. Traffic management and transportation	73
3.22.3. Energy and sustainability management	73
3.22.4. Disaster management and emergency response.	73
3.22.5. Water, waste and environmental monitoring	74
3.22.6. Healthcare and public safety	74
3.22.7. Governance and citizen engagement.	74
3.23. AI and digital twin	75
3.23.1. Smart home	75
3.24. Smart medical	76
3.24.1. AI in smart medical care	76
3.24.2. Digital twin in healthcare	76
3.24.3. AI and digital twin integration in smart healthcare	77
3.24.4. Impact on healthcare	77
3.25. Smart agriculture	77
3.25.1. AI in smart agriculture	77
3.25.2. Applications of digital twin in agriculture.	78
3.26. Case studies.	79
3.26.1. Singapore: integrating AI with digital twins for urban efficiency	79
3.26.2. Helsinki: enhancing urban planning and sustainability.	79
3.26.3. Barcelona: revolutionizing energy management with smart grids	79

3.26.4. Rotterdam: building resilience through disaster management.	80
3.27. Applications and benefits	80
3.28. Benefits and challenges	81
3.28.1. Benefits.	81
3.28.2. Challenges	81
3.29. Case study: how the public views and accepts AI in smart cities	81
3.30. The future of AI in smart cities emerging trends and opportunities	82
3.31. Future prospects and research directions	83
3.32. Conclusion	83
3.33. References	83
Chapter 4. Security Solutions for Smart Cities Using Digital Twin	89
Shubham GUPTA and Ferdinand M. MAGTIBAY	
4.1. Overview of smart cities	89
4.1.1. Importance of digital transformation in urban areas	91
4.1.2. Security challenges in smart cities.	92
4.1.3. Role of digital twin in smart cities.	95
4.1.4. Purpose and scope of the chapter	96
4.2. Understanding digital twin technology	96
4.2.1. Concept of digital twin	97
4.2.2. Types of digital twins in smart cities	97
4.2.3. Integration with emerging technologies.	100
4.3. Security threats in smart cities and digital twins	101
4.3.1. Cybersecurity threats	101
4.3.2. Physical security threats	103
4.3.3. Privacy and ethical concerns	104
4.4. Digital twin-based security solutions for smart cities.	105
4.4.1. Real-time threat detection and response	107
4.4.2. Cybersecurity solutions using digital twins.	108
4.4.3. Physical security enhancements	109
4.4.4. Privacy-preserving mechanisms	110
4.5. Case studies and real-world implementations	110
4.5.1. Smart city security: case study of Singapore	111
4.5.2. Digital twin for critical infrastructure protection: case study of London	112
4.5.3. AI-powered digital twins in US smart cities	113
4.6. Challenges and future directions	113
4.6.1. Technical and implementation challenges	114
4.6.2. Policy and regulatory challenges	115

4.6.3. Future trends and innovations	116
4.7. Conclusion	116
4.8. References	117

Chapter 5. Building Sustainable Urban Futures with AI and Digital Twins 119

Dhruv Kumar SONI and Ashu TANEJA

5.1. Introduction	119
5.1.1. Understanding AI and digital twins in urban systems	121
5.1.2. Artificial intelligence: transforming urban systems	122
5.1.3. Digital twins: bridging the physical and digital worlds	123
5.2. The synergy between AI and digital twins.	124
5.2.1. Energy management and smart grids	125
5.3. Role of AI in sustainable smart cities	127
5.4. Case studies and real-world applications	128
5.4.1. Singapore: virtual city modeling and energy efficiency	128
5.4.2. Barcelona: smarter public services	128
5.4.3. Dubai: sustainable urban management	129
5.5. Integration with emerging technologies	129
5.6. Challenges and ethical considerations	131
5.7. Future directions	131
5.8. Conclusion	132
5.9. References	133

Chapter 6. Enhancing Urban Efficiency with AI and Digital Twin Technologies in Smart City Infrastructure 139

Sanjivani Hemant KULKARNI, Vipin KUMAR, Anupam KANWAR,
Priya DASARWAR, Monali GULHANE, Nitin RAKESH and Utku KOSE

6.1. Introduction	140
6.1.1. Introduction to smart cities.	140
6.1.2. Overview of digital twin technology	141
6.2. Theoretical background	142
6.2.1. Key concepts in AI relevant to urban applications.	142
6.2.2. Introduction to digital twins: history, development and current status.	142
6.2.3. Overview of the IoT and its integration with AI and digital twins	143
6.3. Framework and implementation	144
6.3.1. Designing an AI-enhanced digital twin model	144
6.3.2. Integration strategies for IoT data with digital twins.	145
6.3.3. Technologies and tools used in the implementation	146
6.4. Applications of AI and digital twins in smart cities.	147
6.4.1. Infrastructure management (water, power, waste management)	147

6.4.2. Traffic and transportation systems.	148
6.4.3. Public safety and emergency response	148
6.5. Results and discussion.	150
6.5.1. Presentation of results from real-world case studies or simulations.	150
6.5.2. Analysis of the impact of AI and digital twins on urban system efficiency	153
6.6. Future trends and innovations	156
6.6.1. Emerging technologies in AI and digital twins.	156
6.6.2. Predictive analysis for long-term urban planning	157
6.7. Conclusion	158
6.8. References	158
Chapter 7. Toward Smart Healthcare in Digital Twin Featuring AI for Innovation in Smart Cities and Sustainability	161
Bhupinder SINGH, Ashima JAIN and Christian KAUNERT	
7.1. Introduction	161
7.1.1. Related work	165
7.2. DT in personalized medicine	169
7.3. DT in precision medicine	171
7.3.1. State-of-the-art models and techniques	172
7.3.2. Available platforms.	174
7.3.3. Issues and challenges	175
7.4. Conclusion	178
7.5. Future scope	179
7.6. References	180
Chapter 8. Toward Smart Healthcare in Digital Twin for 6G-Powered Sustainable Ultra-Smart Cities	183
M. VAIDHEHI, C. MALATHY, Pradeep SUDHAKARAN, Aswathy K. CHERIAN, R. GEETHA and Guntupalli Manoj KUMAR	
8.1. Introduction	183
8.1.1. Overview of 6G technology	184
8.1.2. DT in healthcare	184
8.1.3. Importance of sustainability in ultra-smart cities.	185
8.2. DT in healthcare	186
8.2.1. Operational principles of DT technology for healthcare.	187
8.2.2. Influence in patient monitoring, disease prediction and treatment planning by DT	188
8.2.3. Role of AI, IoT and big data in DT healthcare	189
8.3. Healthcare systems by 6G.	190
8.3.1. Telemedicine and remote patient discussion	190

8.3.2. Haptic Internet and remote operations	191
8.3.3. Real-time patient monitoring and wearable technology	191
8.3.4. Edge computing and ultra-low latency in 6G healthcare applications.	192
8.3.5. Melding of AI-assisted diagnostics with 6G networks.	192
8.4. Sustainable ultra-smart cities and healthcare	193
8.4.1. The role of green energy and sustainable infrastructures in healthcare	193
8.4.2. Smart hospitals and intelligent patient care management	194
8.4.3. Renewable energy in healthcare	195
8.4.4. Smart hospitals and intelligent patient care management	196
8.4.5. Blockchain and cybersecurity for healthcare data privacy	197
8.5. Challenges and opportunities	199
8.5.1. Technical challenges in deploying DT healthcare systems	199
8.5.2. Regulatory and ethical considerations in smart healthcare	200
8.5.3. Case studies on regulatory and ethical considerations in smart healthcare	201
8.5.4. Opportunities for AI-driven precision medicine in ultra-smart cities	202
8.6. Future trends and research directions	203
8.6.1. Quantum computing influencing healthcare	204
8.6.2. The role of nanotechnology and biotech in 6G healthcare	205
8.6.3. Challenges in global 6G healthcare adoption.	207
8.7. Conclusion	207
8.8. References	208
Chapter 9. Smart Patient Monitoring using Wearable Devices: Applications and Future Scope	211
Garima CHOPRA, Suhaib AHMED and Shubham GUPTA	
9.1. Introduction	211
9.1.1. Overview	211
9.1.2. Evolution of wearable devices in healthcare	212
9.1.3. Significance of real-time monitoring	214
9.2. Wearable devices for healthcare monitoring	214
9.2.1. Types of wearable devices	215
9.2.2. Key features and components	216
9.2.3. Materials used in devices.	218
9.3. Applications of wearable devices in healthcare sector	220
9.3.1. Remote patient monitoring.	221
9.3.2. Early detection of diseases	221
9.3.3. Diabetes management	222
9.3.4. Wearables for neurological disorders	222

9.3.5. Sleep monitoring and mental health tracking	223
9.3.6. Rehabilitation and post-surgical recovery	223
9.3.7. Fitness and preventive healthcare	223
9.4. Case study on wearable devices for the healthcare industry	228
9.4.1. Mental health management using wearable devices	228
9.4.2. Challenges and future directions.	229
9.5. Limitations and challenges	229
9.6. Future trends and scope of wearable healthcare monitoring	230
9.6.1. Advancements in wearable sensor technologies	230
9.6.2. Role of AI in smart monitoring	231
9.6.3. Personalized and precision medicine	231
9.6.4. Integration with AR and VR	231
9.6.5. Potential in remote rural and under-served areas.	232
9.7. Conclusion	232
9.8. References	233
Chapter 10. Toward Smart Healthcare in the Digital Twin Ecosystem: Architecture, Challenges and Implementation	237
MAMTA and Shravya Reddy KARRI	
10.1. Introduction	238
10.1.1. Overview of digital twin technology.	238
10.1.2. Relevance of digital twin in healthcare	238
10.1.3. Objectives and scope of the chapter	239
10.2. Digital twin architecture for smart healthcare	240
10.2.1. Key components of digital twin systems	240
10.2.2. Integration of IoT, AI and Big Data in healthcare	241
10.2.3. Real-time data acquisition and processing	241
10.3. Applications of digital twin in healthcare	242
10.3.1. Personalized treatment and patient monitoring	243
10.3.2. Virtual testing and simulation for medical devices	243
10.3.3. Enhancing precision in surgical procedures.	244
10.3.4. Hospital operations and workflow optimization	244
10.3.5. Drug development and clinical trials	245
10.3.6. Public health and epidemic management	245
10.3.7. Mental health and cognitive care.	245
10.3.8. Personalized treatment and patient monitoring	246
10.3.9. Virtual testing and simulation for medical devices	247
10.3.10. Enhancing precision in surgical procedures	247
10.4. Challenges in implementing digital twin for healthcare.	248
10.4.1. Data security and privacy concerns	248
10.4.2. High costs of deployment and maintenance.	249
10.4.3. Interoperability issues between systems.	250

10.4.4. Ethical and legal considerations	251
10.5. Conclusion	252
10.5.1. Future prospects	252
10.5.2. Case studies and real-world examples	253
10.5.3. Insights from research projects and pilot programs	253
10.6. Future directions and opportunities	254
10.6.1. Advances in AI and machine learning for digital twins	254
10.6.2. Expanding the scope to global healthcare systems	255
10.6.3. Potential for predictive and preventive healthcare	256
10.7. Conclusion of the chapter	257
10.7.1. Key takeaways from the chapter	257
10.7.2. Role of digital twins in transforming healthcare	257
10.7.3. Call to action for future research and collaboration	258
10.8. Final thoughts	258
10.9. References	259
Chapter 11. Revolutionizing Smart Healthcare: Implementing Digital Twin Technology for Personalized Medical Solutions	265
Prashant WAKHARE, Anagha SHINDE, Navnath B. POKALE and Akanksha GOEL	
11.1. Introduction	266
11.1.1. Overview of smart healthcare	266
11.1.2. Digital twin technology in healthcare	268
11.2. Background and literature review	268
11.2.1. Smart healthcare systems	268
11.2.2. Earlier research on digital twin technology in healthcare	269
11.3. Architecture of smart healthcare in the digital twin ecosystem	271
11.3.1. Key components of the ecosystem	271
11.3.2. Data flow and interaction between components	273
11.3.3. Role of AI and machine learning in enhancing digital twin capabilities	274
11.4. Challenges in implementing digital twin in healthcare	275
11.4.1. Data privacy and security concerns	275
11.4.2. Scalability and interoperability issues	276
11.5. Implementation strategies for smart healthcare using digital twin	277
11.5.1. Building the digital twin model for healthcare applications	277
11.5.2. Integration with existing healthcare infrastructure	277
11.5.3. Real-world case studies and applications	278
11.6. Future directions and emerging trends	278
11.6.1. Integration of 6G and advanced IoT for enhanced connectivity	278
11.6.2. Personalized healthcare using digital twin technology	279

11.7. Results and discussion	280
11.8. Conclusion	284
11.9. References	284
List of Authors	287
Index.	291