COGNITIVE DATA SCIENCE **IN SUSTAINABLE COMPUTING**

SERIES EDITOR: **ARUN KUMAR SANGAIAH**

ARTIFICIAL INTELLIGENCE IN FUTURE MINING

VOLUME EDITORS
AMIR RAZMJOU AND MOHSEN ASADNIA

Artificial Intelligence in Future Mining explores the latest developments in the use of artificial intelligence (AI) in mining and how it will impact the industry's future. The application of data science and AI in future mining involves using advanced technologies to optimize operations, improve decision-making, and enhance safety and sustainability in the industry. After a brief history of AI in mining, the editors look closely at different AI techniques used in mining. The following chapters explore ocean mining, brine mining, and urban mining. With an eye towards sustainability, the editors then review the future of wastewater mining and green mining. This book wraps up with chapters on safety and risk, resource planning, and a larger discussion of the opportunities and challenges of mining with AI in the future. This book is a must-have for researchers and professionals who find themselves at the intersection of mining, engineering, and data science.

KEY FEATURES

- Case studies on the application of data processing, the Internet of Things, and AI in environmental sensing
- Each chapter ends with an in-depth discussion of the future implications of AI on the mining industry

ELSEVIER

ACADEMIC PRESS

An imprint of Elsevier
elsevier.com/books-and-journals

ISBN 978-0-443-28911-8

List of contributors xiii
Preface xvii
Introduction xix

1. The evolution of artificial intelligence in mining
Hamid Sarkheil, Mohammad Delnavaz and Javad Farahbakhsh

1.1 Introduction 2
1.1.1 Definition of artificial intelligence and its significance in the mining industry 4
1.1.2 Brief overview of the history of mineral mining and technological advancements 5
1.2 Early applications of artificial intelligence in mining 6
1.2.1 Historical overview of early artificial intelligence and automation in mining 7
1.2.2 Early attempts at data analysis and optimization in mineral mining 8
1.3 Applications of artificial intelligence in mineral mining method selection 10
1.4 Artificial intelligence application for operation automation in mineral mining 11
1.4.1 Application of artificial intelligence in mineral prospecting and exploration 12
1.4.2 Application of artificial intelligence in mine planning 13
1.4.3 Application of artificial intelligence in machine operation in mineral mining 15
1.4.4 Application of artificial intelligence in drilling and blasting in mineral mining 16
1.4.5 Application of artificial intelligence in mineral processing 17
1.4.6 Application of artificial intelligence in environmental issues in mineral mining 18
1.5 Artificial intelligence in ethical and green mineral processing 20
1.6 The climate-smart mining 21
1.6.1 Climate mitigation in climate-smart mining: strategies and impact 24
1.6.2 Climate adaptation strategies in climate-smart mining: building resilience for sustainable resource extraction 26

1.6.3 Reducing material impacts in climate-smart mining: strategies for sustainable resource extraction 28
1.6.4 Creating marketing opportunities in climate-smart mining: sustainable resource extraction in a green economy 29
1.6.5 Renewable energy integration in climate-smart mining: a path to sustainable resource extraction 32
1.6.6 Resource efficiency in climate-smart mining: optimizing sustainable resource extraction 34
1.6.7 Reuse and recycling of low-carbon minerals in climate-smart mining: towards a circular resource economy 37
1.6.8 Leveraging carbon finance instruments in climate-smart mining: a path to sustainable resource extraction 38
1.6.9 Energy efficiency in the mineral value chain: a cornerstone of climate-smart mining 40
1.6.10 Innovation waste solutions in climate-smart mining: advancing sustainable resource extraction 43
1.6.11 Low-carbon mineral supply chain management: a key driver of climate-smart mining 45
1.6.12 Robust geological data management: a cornerstone of climate-smart mining 48
1.6.13 Gender and multistakeholder engagement: key drivers of climate-smart mining 50
1.6.14 Strong governance and regulatory framework: cornerstones of climate-smart mining 55
1.6.15 Forest-smart mining with landscape management: a cornerstone of climate-smart mining 60
1.6.16 De-risking investments for low-carbon minerals: a key driver of climate-smart mining 62
References 67

2. Advances in acid mine drainage management through artificial intelligence

Mokhinabonu Mardonova, Muhammad Kashif Shahid, Rouzbeh Abbassi, Jun Wei Lim, Shukra Raj Paudel and Bandita Mainali

2.1 Introduction 78
2.2 Acid mine drainage processes 79
2.2.1 Formation and characteristics 79
2.2.2 Sources 83
2.2.3 Mine impacted water classification 85
2.2.4 Environmental impact control and prevention 93
2.3 Management of acid mine drainage processes 95
2.3.1 Acid mine drainage management challenges 95
2.3.2 Corporate governance and frameworks 100

2.3.3 Classification frameworks for mine waste materials 102
2.4 Circular economy and resource recirculation 110
2.4.1 Water 111
2.4.2 Sulfuric acid, metals, and rare earth elements 113
2.4.3 Sludge and mining residues reuse 114
2.5 Sustainability and environmental impact assessment aspects 114
2.5.1 Sustainability and climate change in acid mine drainage 114
2.5.2 Considerations in emission analysis of acid mine drainage treatment 121
2.6 Artificial intelligence in acid mine drainage risk prediction 124
2.6.1 Operational approaches to acid mine drainage prediction 127
2.6.2 Artificial intelligence 144
2.7 Conclusions 156
References 157

3. Advancing mining maintenance: integrating machine learning for proactive corrosion management
Jacques Lepage, Kaveh Ghouchani, Javad Mohammadpour, Fatemeh Salehi and Rouzbeh Abbassi

3.1 Introduction 179
3.2 Pipeline corrosion in mining 181
3.3 Internal corrosion 181
3.4 External corrosion 182
3.5 Machine learning application 183
3.6 Overview of adopted machine learning techniques 184
3.7 Supervised machine learning algorithms 184
3.7.1 Neural networks and deep learning 185
3.7.2 Ensemble, tree-based, and boosting methods 185
3.7.3 Regression algorithms 185
3.7.4 Support vector methods 186
3.7.5 Time series and similarity-based methods 186
3.8 Unsupervised machine learning algorithm 187
3.9 Reinforcement machine learning algorithm 187
3.10 Machine learning techniques in corrosion modeling 187
3.11 Conclusions 190
References 190

4. Revolutionizing brine mining through artificial intelligence-assisted techniques
Arash Khosravi, Maryam Ashkpour and Farideh Abdollahi

4.1 Introduction 196
4.2 Types and definitions of brine resources and brine mining techniques 197
4.2.1 Categories of brine resources 197
4.2.2 Industrial processes for brine mining 201

4.3 Principles and benefits of artificial intelligence-assisted brine mining 203
4.3.1 General concept of artificial intelligence-techniques 204
4.3.2 Increasing efficiency and productivity using artificial intelligence-techniques 206
4.3.3 Cost reduction 208
4.3.4 Improving safety and environmental sustainability 208
4.4 Artificial intelligence-assisted techniques in brine mining case studies 210
4.4.1 Exploration and production 211
4.4.2 Robotics and automation 212
4.4.3 Monitoring, controlling and predictive maintenance 214
4.4.4 Characterization of brine 215
4.5 Challenges and limitations of artificial intelligence-assisted brine mining techniques 217
4.5.1 Data availability and quality 217
4.5.2 Technical expertise and training 218
4.6 Future directions for artificial intelligence-assisted brine mining techniques 218
4.6.1 Integration with other technologies 219
4.6.2 Collaboration and knowledge sharing 219
4.6.3 Regulatory frameworks and standards 219
Acknowledgments 220
References 220

5. Urban mining and artificial intelligence: challenges and opportunities 229
Sorour Ayoubian Markazi, Shokat Akbarnezhad, Negar Karimian Ardestani and Milad Razbin

5.1 Introduction 229
5.2 Importance of urban mining 231
5.3 Resources of urban mining 232
5.3.1 E-waste in urban mining 232
5.3.2 Water/wastewater treatment in urban mining 233
5.3.3 Building in urban mining 235
5.4 Artificial intelligence approach in urban mining 236
5.5 Conclusion 244
References 245

6. Wastewater mining: a new frontier for artificial intelligence in mining 249
Hoda Khoshvaght and Mehdi Khiadani

6.1 Introduction 249
6.2 Understanding mining wastewater 252
6.2.1 Overview of mining wastewater 253
6.2.2 Mining wastewater characteristics 254

6.2.3 Environmental impact of mining activities and wastewater 255
6.2.4 Economic benefit of mining wastewater 259
6.2.5 Mining wastewater treatment techniques 264
6.3 Role of artificial intelligence in mining wastewater 271
6.3.1 Artificial intelligence in process controlling and optimization 272
6.3.2 Artificial intelligence in outlier detection 273
6.3.3 Artificial intelligence in water quality monitoring 281
6.3.4 Artificial intelligence in mineral extraction 284
6.3.5 Popular artificial intelligence algorithm in water and wastewater research 285
6.3.6 Artificial intelligence case studies in mining 286
6.4 Challenges and future directions 289
6.4.1 Challenges 289
6.4.2 Future directions 289
6.5 Conclusions 294
AI disclosure 295
Abbreviations 295
References 297

7. Green mining with artificial intelligence: a path to sustainability 309
Mahdi Pouresmaieli, Yasaman Boroumand, Meysam Habibi, Reza Maleki, Mohammad Ataei and Ali Nouri Qarahasanlou

7.1 Introduction 310
7.1.1 The notion of sustainable development 311
7.1.2 Necessity of sustainable mining 312
7.1.3 Mining's effects on metrics for sustainable development 312
7.2 Sustainable development goal-based artificial intelligence and Internet of Things introduction in the mining sector 314
7.2.1 Advanced mining automation 318
7.3 Artificial intelligence/Internet of Things's impact on sustainable development goal in the mining sector 321
7.4 Effect of Internet of Things and artificial intelligence on robots and automation in the mining sector according to sustainable development 322
7.4.1 Robotics and automation's effects on economic metrics in mining operations 323
7.4.2 Robotics and automation's effects on social metrics in mining operations 324
7.4.3 The effect of robots and automation on environmental indicators in mining operations 327
7.5 Capabilities and limitations of artificial intelligence in sustainable development for mine designing and planning 329
7.5.1 Feature engineering and artificial intelligence for sustainable development in mine planning and design 331

7.5.2 Data preprocessing and artificial intelligence feature engineering 334
7.5.3 Feature selection in materials 334
7.5.4 Artificial intelligence usage and its effect on sustainable development 336
7.6 The future of robotics and automation in mining 343
7.7 Discussion 344
7.8 Conclusion 345
References 347

8. Enhancing safety and minimizing risk in mining processes with artificial intelligence 355
Armaghan Javid, Mohammad Zarkesh, Yasaman Boroumand and Mohammad Al-Fawa'reh

8.1 Introduction 355
8.1.1 Challenges and risks associated with mining processes 356
8.1.2 Role of artificial intelligence in revolutionizing safety practices 357
8.2 Real-time monitoring and predictive analytics 358
8.2.1 Artificial intelligence-powered sensors for real-time data collection 358
8.2.2 Predictive analytics for identifying potential safety hazards 363
8.2.3 Vision-based data analysis 369
8.3 Autonomous vehicles and equipment for hazardous environments 372
8.3.1 Benefits of autonomous vehicles and equipment in dangerous areas 373
8.3.2 Reducing human exposure to risky tasks through automation 374
8.3.3 Different types of autonomous vehicles and equipment used in mining 375
8.3.4 AI-driven navigation and obstacle avoidance systems 376
8.4 Conclusion 377
References 378

9. The future of the mining industry with artificial intelligence 383
Walid K. Hasan, Mohammad Al-Fawa'reh, Matt Madelatparvar and Nima Fakhralmobasheri

9.1 Introduction 384
9.2 Recent advancements in artificial intelligence and autonomous solutions in mining operations 385
9.2.1 Automating extraction: robotics and artificial intelligence in underground mining 386

9.2.2 Artificial intelligence for autonomous mining trucks and uncrewed vehicles 387
9.2.3 Connected quarries: Internet of Things and data integration for mining efficiency 389
9.2.4 Waste to wealth: artificial intelligence-enabled solutions for efficient tailings management 390
9.3 Optimizing operations 390
9.4 Hazard management 390
9.5 Potential applications of artificial intelligence in mining industry 392
9.5.1 Automating extraction: robotics and artificial intelligence in underground mining 392
9.5.2 Connected quarries: Internet of Things and data integration for mining efficiency 395
9.5.3 Waste to wealth: artificial intelligence-enabled solutions for efficient tailings management 397
9.5.4 Challenges in implementing artificial intelligence in mining industry 399
9.5.5 Automating extraction: robotics and artificial intelligence in underground mining 399
9.5.6 Autonomous mining trucks and uncrewed vehicles 400
9.5.7 Connected quarries: Internet of Things and data integration for mining efficiency 401
9.6 Conclusion and future directions 402
References 403

Index 409