NEXT–GENERATION COMPUTING AND COMMUNICATION ENGINEERING

COMPUTATIONAL INTELLIGENT TECHNIQUES IN MECHATRONICS

Edited By
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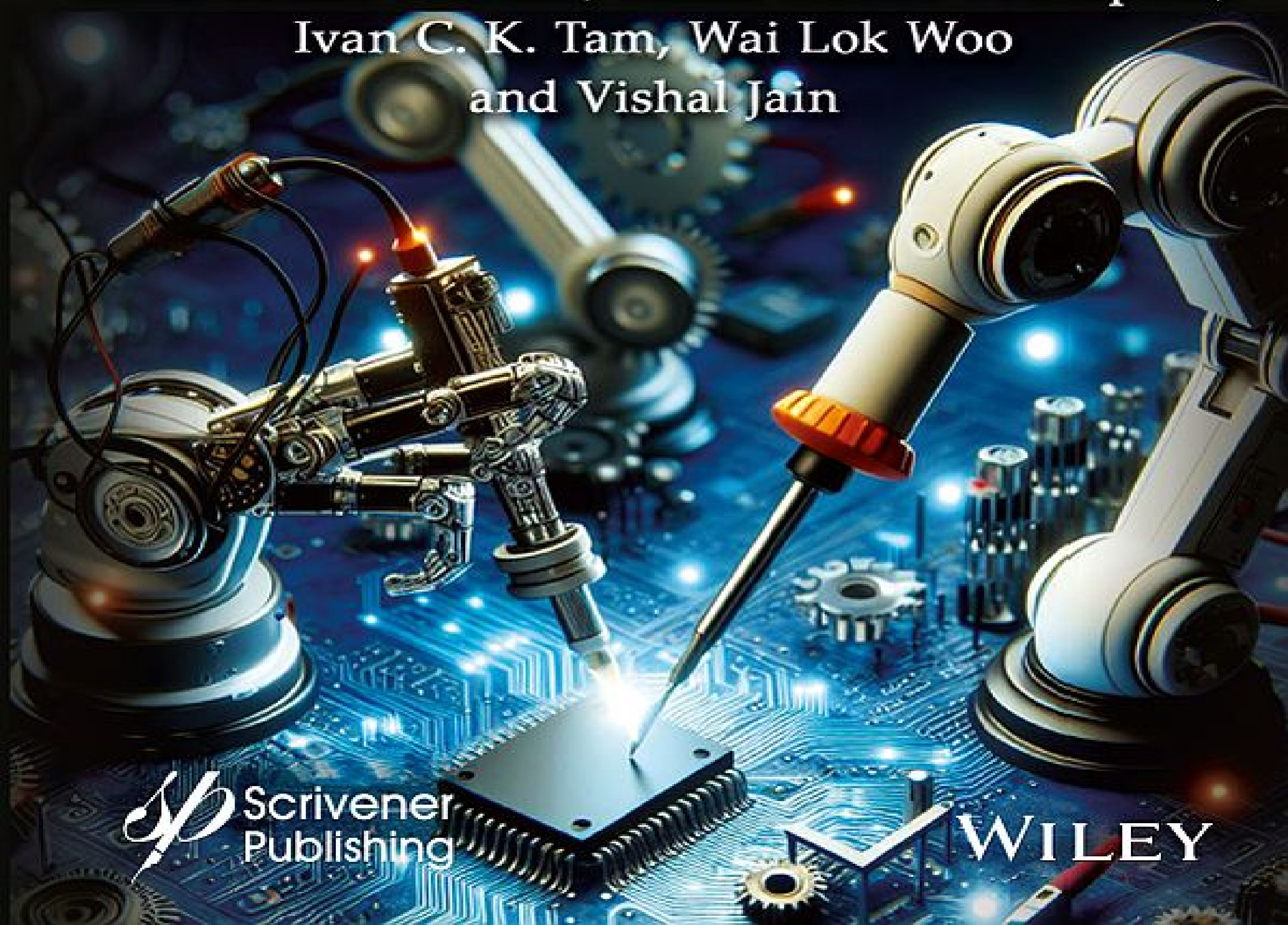

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Preface

Mechatronics has been a revolutionary force in engineering and medical robotics over the past decade. It will lead to a major industrial revolution and affect research in every field of engineering. This book covers the basics of mechatronics, computational intelligence approaches, simulation and modeling concepts, architectures, nanotechnology, real-time monitoring and control, different actuators, and sensors. This resource is important for research and development departments in academia, government, and industry, and as a reference source in university libraries. This book explains clearly and comprehensively the engineering design process at different stages. As the historical divisions between the various branches of engineering and computer science become less clearly defined, mechatronics may provide a roadmap for nontraditional engineering students studying within the traditional university structure. This book covers all the algorithms and techniques found in mechatronics engineering, well explained with real-time examples, especially lab experiments that will be very informative to students and scholars.

Chapter 1 of this book provides an overview of promising AI approaches for modern mechatronics, along with the key benefits. The second chapter discusses classical thermodynamics and heat transfer principles that can optimize the blueprint, performance, and regulation of mechatronic apparatus.

Chapter 3 explores the role of data acquisition, sensors, and actuators in the mechatronics industry, while Chapter 4 discusses the challenges and opportunities in employing these techniques. Furthermore, it proposes future research directions to optimize mechatronic systems.

Chapter 5 highlights the potential of RL for the future of adaptive mechatronics, fostering a new era of intelligent and versatile systems that can adapt, learn, and excel in diverse and dynamic scenarios. The sixth chapter shows a study of how important PLCs are to advancing the mechatronics sector and enabling more advanced forms of industrial automation.

Chapter 7 discusses fuzzy logic and its applications in mechatronic control systems, while Chapter 8 highlights the need for addressing ethical considerations and ensuring responsible deployment for the widespread acceptance and success of autonomous systems in the real world. Chapter 9 explores this intersection by considering the key components, challenges, and benefits of integrating AI in self-driving transportation systems. This section also highlights the advancements made in the field, current state of the art, and potential future directions.

Chapter 10 illustrates how mechatronics-based power quality solutions have increased industrial productivity, and may result in smart and strong industrial infrastructures. The eleventh chapter delves into prospects, challenges, and emerging trends, underscoring the potential of neural networks and fuzzy logic to shape the future of autonomous electric transportation.

Chapter 12 explores the transformative impact of integrating artificial intelligence (AI) techniques within the field of mechatronics, showcasing the synergistic potential that emerges when advanced AI technologies are harnessed to enhance the functionality, adaptability, and intelligence of mechatronic systems. Then, Chapter 13 delves into the intriguing area of human-robot interaction and emotional intelligence, showcasing how AI enhances interaction and emotional understanding between humans and machines.

Chapter 14 proposes a way by which a driver can be alerted to drowsiness in order to reduce the numbers of road accidents, while Chapter 15 proposes the model of a multi-featured robot that can send live surveillance and notifications if human motion is detected. Finally, Chapter 16 highlights the latency of mechatronics in altering the current agriculture practices including productivity, and sustainability.

In conclusion, we offer our heartfelt thanks to all the contributors who have made this book a reality. Your expertise, dedication, and passion have enriched every page, creating a comprehensive and insightful collection. Without your valuable insights and commitment to excellence, this project would not have been possible. Your contributions have not only elevated the quality of this book but have also left a lasting impact on the field. Additionally, we have greatly appreciated the dedicated support and valuable assistance rendered by Martin Scrivener and the Scrivener Publishing team during the publication of this volume.

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1
AI in Mechatronics

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Abstract

The chapter "AI in Mechatronics" provides a comprehensive overview of how artificial intelligence (AI) techniques can enhance mechatronic systems; it covers core AI approaches, including machine learning, computer vision, soft computing methods, natural language processing, AI planning, and intelligent system design tools. Key real-world applications across areas like manufacturing automation, robotics, vehicles, and human–machine interaction are analyzed. The integration of data-driven and knowledge-based AI methods can endow mechatronics with advanced capabilities around autonomy, environmental perception, reasoning, control, and human collaboration. This creates intelligent self-optimizing systems that continue learning and adapting. Current challenges around model accuracy, data availability, security, and algorithmic transparency are discussed along with emerging opportunities in embedded intelligence and bio-inspired robotics. Overall, the synergistic fusion of AI and mechatronics promises to transform technological systems across industrial and societal domains by enhancing automation, augmenting human capabilities, and enabling next-generation smart mechanized assistants.

***Keywords*:** Machine learning, human–robot collaboration, computer vision, robotic systems, natural language processing, manufacturing automation, self-driving vehicles

1.1 Introduction to AI Techniques for Mechatronics

Mechatronics refers to the synergistic integration of mechanical, electrical, and computer engineering to design smart systems and products capable of exhibiting both information-processing and physical-action capabilities. It combines the core disciplines of mechanics, electronics, control systems, and computing to create high-performance systems with built-in intelligence.

Although mechatronics has its origins in industrial robotics and manufacturing automation, it has grown tremendously in scope and adoption over the past few decades. Today, mechatronic systems and principles are utilized in a diverse range of applications including automotive systems, aerospace systems, industrial production systems, defense systems, material handling systems, healthcare systems, and consumer product design. Figure 1.1 shows the flowchart depicting the design methodology for mechatronics systems, mechatronics integrates various engineering disciplines.

Modern mechatronic systems incorporate sensors, actuators, microprocessors, control systems, and mathematical modeling into product design. This facilitates features like automation, precision, efficiency, adaptability, reconfigurability, safety, reliability, and productivity. For example, an automated robotic manufacturing system may use servo motors and drives for motion control, various sensors for inspection and feedback, PLCs or microcontrollers for regulated actuation and monitoring, and sophisticated control software for supervision, analysis, and coordination [1].

With rapid advances in artificial intelligence (AI) and machine learning, integrating AI techniques into mechatronic systems has become an active area of innovation and research. AI can endow mechatronics with higher levels of intelligence, autonomy, perception, and decision-making capabilities to create smart, self-optimizing systems. This introductory chapter provides an overview of promising AI approaches for modern mechatronics along with the key benefits.

1.1.1 Overview of Key AI Approaches

Several AI techniques hold promise for advancing mechatronics.

- **Machine Learning:** This allows systems to automatically learn and improve from data without being explicitly programmed. Algorithms identify patterns and build models based on training data. Supervised, unsupervised, and reinforcement learning methods can be used for tasks like prediction, classification, and control optimization in mechatronic systems.

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