Preface

Quantum computing (QC) can process calculations tenfold quicker than traditional computing by utilizing the unique characteristics of quantum bits or qubits. The three fundamental ideas of quantum mechanics – superposition, entanglement, and interference – give QC its particular strength. A qubit can store quantum information in a state of superposition, which combines all of the qubit's potential configurations. Computational spaces can be made complex and multidimensional by using multiple qubits in superposition. These spaces allow for many representations of complex problems.

Changes to one qubit directly affect the other when two qubits are entangled. Probabilistic waves exist in an environment of entangled qubits in a superposition state. When multiple waves peak at the same result, they might compound on top of one another or cancel each other out when peaks and troughs intersect. Both of these are examples of interference. To put it succinctly, QC creates new opportunities.

This paradigm shift in computation can solve complex problems pronounced difficult by classical computers. Quantum computing is being explored across different industry verticals. High-performance computing is indispensable for high-end scientific, technical, mathematical and physics problems. These high-performance problems will be addressed easily and speedily through fault-tolerant quantum computing. Besides ensuring high-performance capability for next-generation computing requirements, QC offers significant security, blockchain, 6G communication, and AI potential. Precisely speaking, *QC promises noteworthy breakthroughs in performing process optimization and enhancing the security and privacy of data transmission over any network.*

Modeling the behavior of individual atoms in a molecule turns out to be a complex problem. Similarly, identifying subtle fraud patterns in real-time financial transactions is another complex problem. Some real-world problems are truly complex to be encoded and solved through classical computers. Thus, high-performance computing has to be taken to the next level. Supercomputing is one powerful approach.

Supercomputers are being used to accomplish hugely complex computations. Supercomputers are large-scale classical computers with thousands of central and graphic processing units (CPUs and GPUs). When scientists and engineers encounter difficult problems, they turn to supercomputers. A big cluster of distributed CPUs and GPUs is being leveraged, especially for creating and fine-tuning general-purpose and purpose-specific large language models (LLMs). Such centralized and distributed supercomputers are being utilized for solving intractable problems. Supercomputers are binary code-based machines reliant on the last-century transistor technology, so they struggle to solve certain kinds of problems. In a nutshell, even a supercomputer falters and fails to solve problems with a high degree of complexity.

However, as the quantum computing phenomenon is soliciting a lot of attention from worldwide researchers and practitioners, there is a glimmer of hope that in future, for solving high-end AI requirements, quantum computers with large numbers of qubits will be used. Quantum computers are also expected to challenge the current

cryptography methods and introduce new possibilities for ensuring complete private communication.

Our ability to study, simulate, and work with other quantum systems will be aided by quantum computers. This competency, influenced by quantum mechanics, will enhance our comprehension of physics. The findings have implications for designing objects engineered at a scale where quantum physics is relevant. In other words, once quantum computers are in use, we will have innovations in computer chips, communication devices, energy technologies, scientific instruments, sensors, clocks, and materials that are groundbreaking and setting trends. According to IBM, quantum physics underpins the real world. Our finest tools for comprehending it should, in many cases, be computers that perform calculations utilizing the quantum states of quantum bits.

Artificial intelligence (AI), quantum computing, and 6G technologies are evolving fast to bring in a suite of evolutionary and revolutionary advancements for the information processing and communication industry. With the broader acceptance and adoption of the Internet of Things (IoT) paradigm, market researchers, analysts, and watchers estimate that there will be trillions of digitized objects and billions of connected embedded systems. When interacting and collaborating, such a humungous number of digitized sensors and actuators can easily result in zettabytes of data. QC is being presented as the way forward to make sense of such big data. The IoT devices are typically the data generator and collector; 5G and 6G in future will be the primary data carrier. AI is the modern data cruncher to emit actionable insights in time. Quantum computing is the next-generation IT infrastructure to host and run data and process-intensive AI models.

By fusing quantum computing, AI and 6G technologies, it is possible to envisage and realize newer possibilities beyond what each field can achieve individually. For 6G, quantum computing can potentially optimize network resource allocation, improve channel estimation, enhance security mechanisms, and enable advanced algorithms for intelligent network management. Furthermore, quantum entanglement's inherent secure communication capabilities can offer novel solutions for encryption, data privacy, and secure transmission in 6G networks, succulently mitigating emerging security challenges.

Quantum computing is being proclaimed as a next-generation technology for the total society. With the faster maturity and stability of enabling theories, techniques and tools, it is safe to pronounce that quantum computing will become the new normal in the coming decades. The greater awareness, adoption, and adaptation of digital technologies (the IoT, AI, cybersecurity, cloud-native computing, 6G, etc.) has inspired national governments across the world to form special missions to fast-track the research initiatives and implementations to smoothen the path for quantum computing to flourish.

This book will discuss the trends and transitions happening in the enigmatic and energetic quantum computing space. How digitization and digitalization technologies are being succulently empowered through quantum computers is to be explained easily.