

a survey on quantum computing technology

A Survey on Quantum Computing Technology: A Comprehensive Overview

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Keywords: quantum computing, quantum technology, quantum algorithms, quantum annealing, quantum supremacy, qubit, superposition, entanglement, quantum error correction, quantum hardware, quantum software, a survey on quantum computing technology, future of quantum computing.

Abstract: This article provides a comprehensive survey on quantum computing technology, exploring its fundamental principles, current advancements, and future potential. We delve into various quantum computing architectures, algorithms, and the challenges that need to be addressed for widespread adoption. This survey on quantum computing technology aims to provide a balanced perspective, covering both the exciting possibilities and the significant hurdles that lie ahead.

1. Introduction: Understanding the Quantum Leap

The field of quantum computing is rapidly evolving, promising to revolutionize various sectors, from drug discovery and materials science to financial modeling and artificial intelligence. A survey on quantum computing technology, like this one, is crucial for understanding the current state-of-the-art and potential future developments. Unlike classical computers that rely on bits representing 0 or 1, quantum computers leverage the principles of quantum mechanics, employing qubits that can exist in a superposition of both 0 and 1 simultaneously. This, combined with phenomena like entanglement, allows quantum computers to perform certain calculations exponentially faster than their classical counterparts. This survey on quantum computing technology will unpack these concepts further.

2. Fundamental Principles: Qubits and Quantum Phenomena

At the heart of any discussion on a survey on quantum computing technology

lies the understanding of qubits. These fundamental units of quantum information exploit quantum phenomena like superposition and entanglement. Superposition allows a qubit to exist in multiple states simultaneously, while entanglement links the fates of multiple qubits, regardless of the physical distance separating them. These properties are the foundation of quantum algorithms' enhanced computational power. Understanding these principles is paramount for anyone engaging with a survey on quantum computing technology.

3. Quantum Computing Architectures: A Diverse Landscape

Several approaches are being pursued in the development of quantum computers. A survey on quantum computing technology would be incomplete without exploring this diverse landscape:

Superconducting Qubits: This dominant approach utilizes superconducting circuits cooled to extremely low temperatures to create and manipulate qubits. Companies like Google, IBM, and Rigetti are heavily invested in this technology.

Trapped Ions: This approach uses individually trapped ions as qubits, manipulated using lasers. IonQ and Honeywell are notable players in this space.

Photonic Qubits: Photons, particles of light, are used as qubits in this approach, leveraging their inherent stability and ease of transmission.

Neutral Atoms: Similar to trapped ions, this approach uses neutral atoms as qubits, offering potential scalability advantages.

Quantum Annealing: A specialized approach, quantum annealing focuses on finding the global minimum of a complex energy landscape. D-Wave Systems is the leading company in this area. A survey on quantum computing technology should differentiate between this specialized approach and universal quantum computers.

4. Quantum Algorithms: Unlocking Computational Power

The power of quantum computers lies not just in their hardware but also in the algorithms designed to exploit their unique capabilities. A survey on quantum computing technology must highlight some key algorithms:

Shor's Algorithm: This algorithm can factor large numbers exponentially faster than the best known classical algorithms, posing a significant threat to current encryption methods.

Grover's Algorithm: This algorithm provides a quadratic speedup for searching unsorted databases compared to classical algorithms.

Quantum Simulation: Quantum computers can simulate quantum systems with unprecedented accuracy, opening doors for advancements in materials science and drug discovery.

5. Challenges and Roadblocks: The Path to Practical Quantum Computing

Despite the significant progress, several challenges hinder the widespread adoption of quantum computing. A survey on quantum computing technology must acknowledge these critical hurdles:

Qubit Coherence: Maintaining the delicate quantum states of qubits for extended periods is crucial. Decoherence, the loss of quantum information, remains a significant obstacle.

Scalability: Building large-scale, fault-tolerant quantum computers is a monumental engineering challenge.

Error Correction: Developing robust error correction techniques is vital for ensuring the accuracy of quantum computations.

Quantum Software Development: The development of quantum algorithms and software tools is still in its nascent stages.

6. Applications and Impact: Transforming Industries

The potential applications of quantum computing are vast and far-reaching. A survey on quantum computing technology should showcase the transformative impact it promises to have across various sectors:

Drug Discovery and Development: Simulating molecular interactions to design new drugs and therapies.

Materials Science: Discovering novel materials with enhanced properties.

Financial Modeling: Developing more accurate and efficient financial models.

Artificial Intelligence: Boosting the performance of machine learning algorithms.

Cryptography: Developing new cryptographic techniques resistant to quantum attacks.

7. Current State and Future Outlook: A Survey on Quantum Computing Technology's Trajectory

A survey on quantum computing technology needs to assess the current

landscape, with multiple companies and research institutions actively pursuing different quantum computing approaches. While fully fault-tolerant, large-scale quantum computers are still years away, the progress made is significant. The next decade will likely witness the emergence of more powerful quantum computers, capable of tackling increasingly complex problems.

8. Conclusion

This survey on quantum computing technology has provided a comprehensive overview of this rapidly evolving field, covering its fundamental principles, architectural approaches, algorithmic advancements, challenges, and potential applications. While significant hurdles remain, the potential benefits of quantum computing are undeniable. Continued research and development are crucial to realizing the transformative potential of this revolutionary technology. The future of computing is quantum, and a survey on quantum computing technology like this one is a vital guide to navigating this exciting frontier.

FAQs

1. What is the difference between a classical computer and a quantum computer? Classical computers use bits representing 0 or 1, while quantum computers use qubits that can be 0, 1, or a superposition of both.
1. What is quantum supremacy? Quantum supremacy refers to the point when a quantum computer can solve a problem that is practically impossible for even the most powerful classical computers.
1. What are the major challenges in building quantum computers? Maintaining qubit coherence, scaling up the number of qubits, and developing effective error correction techniques are major challenges.
1. What are the potential applications of quantum computing? Potential applications span drug discovery, materials science, financial modeling, artificial intelligence, and cryptography.

1. How long will it take before quantum computers become widely available? Fully fault-tolerant, large-scale quantum computers are still years away, but smaller, specialized quantum computers are already being used for certain applications.
1. What is quantum annealing? Quantum annealing is a specialized type of quantum computing designed to solve optimization problems.
1. What is the role of quantum algorithms? Quantum algorithms are designed to exploit the unique capabilities of quantum computers to solve problems more efficiently than classical algorithms.
1. What is qubit coherence? Qubit coherence refers to the ability of a qubit to maintain its quantum state without being disturbed by its environment.
1. What is the difference between different types of qubits (superconducting, trapped ions, etc.)? Different types of qubits have different strengths and weaknesses in terms of coherence times, scalability, and controllability.

Related Articles:

1. "Quantum Computing: Progress and Prospects" (Nature): A review article summarizing the current state of quantum computing research and development.
1. "Quantum Algorithm Implementations for Beginners" (arXiv): A tutorial introducing the implementation of quantum algorithms on different quantum computing platforms.
1. "Quantum Error Correction: An Overview" (Review of Modern Physics): A

detailed review of quantum error correction techniques.

1. "A Survey of Quantum Annealing" (IEEE Transactions on Computers): A comprehensive survey on the principles and applications of quantum annealing.
1. "Quantum Computing for Finance" (Journal of Financial Econometrics): An exploration of the applications of quantum computing in the financial industry.
1. "Quantum Simulation of Molecular Systems" (Science): A discussion on the use of quantum computers to simulate molecular systems.
1. "Quantum Machine Learning: A Brief Overview" (Quantum Information Processing): An introduction to the field of quantum machine learning.
1. "The Future of Quantum Computing" (MIT Technology Review): A perspective on the potential future impact of quantum computing.
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exercises. The first five present the mathematical tools required for a full comprehension of various aspects of quantum mechanics, classical information, and coding theory. Chapter 6 deals with the manipulation and transmission of information in the quantum realm. Chapters 7 and 8 discuss experimental implementations of quantum information ideas using photons and atoms. Finally, chapters 9 and 10 address ground-breaking applications in cryptography and computation.

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classical telecom world, corresponding quantum-based solutions, bridging the gap between pure theory and engineering practice. This book provides telecommunications engineers, as well as graduate students and researchers in the fields of computer science and telecommunications, with a wide overview of quantum computing & communications and a wealth of essential, practical information.

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L.-C. Tang, 2023-08-09 The field of industrial engineering (IE) has a very wide scope, from production processes and automation to supply chain management, but the scope of IE techniques has expanded beyond the traditional domains of application, and is now relevant to areas that matter most to society at large. This book presents the proceedings of ICIEA 2023, the 10th International Conference on Industrial Engineering and Applications, held in Phuket, Thailand, from 4 to 6 April 2023. The conference was conducted in hybrid mode, with close to 100 delegates attending in person and about 50 participants attending online. A total of 272 submissions were received for the conference, of which 120 were accepted for presentation with 83 of those published here as full papers. These papers cover a wide range of topics within the scope of industrial and systems engineering, including but not limited to: supply chain and logistics; quality and reliability; advanced manufacturing; and production scheduling to ergonomics and man-machine systems interfaces. In particular, a significant number of papers are devoted to machine learning techniques and applications beyond the traditional manufacturing sector, to include healthcare, sustainability assessment, and other social issues. Offering an overview of recent research and novel applications, the book will be of interest to all those whose work involves the application of industrial engineering techniques.

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online format due to the COVID-19 pandemic. The total of 95 full papers presented in these proceedings was carefully reviewed and selected from 341 submissions. The papers were organized in topical sections as follows: Part I: Best paper awards; public-key cryptanalysis; symmetric key cryptanalysis; quantum security; Part II: physical attacks, leakage and countermeasures; multiparty computation; enhanced public-key encryption and time-lock puzzles; real-world protocols; Part III: NIZK and SNARKs; theory; symmetric-key constructions; homomorphic encryption and encrypted search; Part IV: Lattice cryptanalysis; post-quantum cryptography; advanced encryption and signatures; zero-knowledge proofs, threshold and multi-signatures; authenticated key exchange.

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modern techniques for cyber security, such as blockchain for modern security, quantum cryptography, and forensic tools. Also, it provides a comprehensive survey of cutting-edge research on the cyber security of modern networks, giving the reader a general overview of the field. It also provides interdisciplinary solutions to protect modern networks from any type of attack or manipulation. The new protocols discussed in this book thoroughly examine the constraints of networks, including computation, communication, and storage cost constraints, and verifies the protocols both theoretically and experimentally. Written in a clear and comprehensive manner, this book would prove extremely helpful to readers. This unique and comprehensive solution for the cyber security of modern networks will greatly benefit researchers, graduate students, and engineers in the fields of cryptography and network security.

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