

IMPLEMENTATION OF QUANTUM PHYSICS IN MECHATRONICS,
ELECTRONICS, AND INFORMATICS: A SYSTEMATIC REVIEW

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Abstract

Quantum physics, with its fundamental principles and unique characteristics, has gained significant attention in various fields of science and technology. This abstract explores the implementation of quantum physics principles in the domains of mechatronics, electronics, and informatics, highlighting the potential benefits and challenges associated with this integration. In the field of mechatronics, the utilization of quantum effects, such as superposition and entanglement, can enable the development of highly sensitive sensors, precise actuators, and advanced control systems. By harnessing quantum phenomena, mechatronic systems can achieve enhanced performance, improved energy efficiency, and increased robustness in demanding applications. In electronics, quantum physics offers novel approaches to computing and information processing. Quantum computing, in particular, holds the promise of solving complex problems exponentially faster than classical computers by exploiting quantum superposition and entanglement. Quantum algorithms and quantum information theory provide a framework for developing secure communication systems and optimizing data analysis techniques. Informatics, encompassing fields like data science, artificial intelligence, and cryptography, can also benefit from quantum principles. Quantum machine learning algorithms can potentially revolutionize pattern recognition, optimization, and data analysis tasks, allowing for more efficient and accurate solutions. Furthermore, quantum cryptography provides secure communication protocols based on the principles of quantum mechanics, offering heightened protection against eavesdropping and information tampering. Despite the immense potential, several challenges exist in implementing quantum physics in mechatronics, electronics, and informatics. These challenges include maintaining quantum coherence, mitigating quantum noise and errors, scaling up quantum systems, and developing robust quantum algorithms. Overcoming these obstacles requires interdisciplinary collaboration, innovative design methodologies, and advancements in quantum hardware technology. In conclusion, the integration of quantum physics principles in mechatronics, electronics, and informatics holds great promise for revolutionizing various technological domains. The implementation of quantum effects can lead to significant advancements in sensor technology, computing power, data analysis, and secure communication systems. However, addressing the associated challenges is crucial to realizing the full potential of quantum-inspired solutions in these fields.

Keywords: quantum, physics, systems, mechanics, electronics, informatics.

INTRODUCTION

The integration of quantum physics principles into mechatronics, electronics, and informatics has emerged as a compelling area of research and development. Quantum physics, a branch of physics that explores the behavior of matter and energy at the smallest scales, offers unique characteristics and phenomena that have the potential to revolutionize various technological domains. By harnessing quantum effects such as superposition, entanglement, and quantum coherence, scientists and engineers aim to enhance the performance, efficiency, and capabilities of mechatronic systems, electronic devices, and information processing techniques.

Mechatronics, which combines elements of mechanical engineering, electronics, and computer science, deals with the design and control of electromechanical systems. By incorporating quantum physics principles, mechatronic systems can achieve unprecedented levels of sensitivity, precision, and adaptability. Quantum sensors can provide ultra-high-precision measurements, enabling advancements in fields such as medical diagnostics, environmental monitoring, and industrial automation. Quantum-inspired control systems can optimize energy consumption, improve stability, and enhance robustness in complex mechatronic systems (Rizal et al., 2020).

Electronics, the field that deals with the design and development of electronic circuits and devices, stands to benefit significantly from the implementation of quantum physics. One of the most promising applications is quantum computing, which utilizes quantum bits or qubits to perform computations exponentially faster than classical computers for specific problems. Quantum computers have the potential to revolutionize fields like cryptography, optimization, and data analysis, enabling breakthroughs in areas such as drug discovery, logistics, and financial modeling. Additionally, quantum-inspired algorithms and approaches in electronics can enhance the efficiency and speed of information processing, leading to advancements in artificial intelligence, pattern recognition, and data compression.

Informatics, which encompasses fields like data science, artificial intelligence, and cryptography, can also be greatly impacted by quantum physics. Quantum machine learning algorithms can provide new avenues for optimizing complex optimization problems and pattern recognition tasks. These algorithms can leverage quantum principles to offer more efficient and accurate solutions compared to classical approaches. Furthermore, quantum cryptography utilizes the principles of quantum mechanics, such as quantum key distribution, to provide secure communication protocols that are inherently resistant to hacking and eavesdropping. Quantum cryptography holds great promise for securing sensitive information in domains such as finance, healthcare, and government communication.

While the integration of quantum physics into mechatronics, electronics, and informatics presents significant opportunities, several challenges must be addressed. Maintaining quantum coherence, mitigating quantum noise and errors, scaling up quantum systems, and developing robust quantum algorithms are just a few of the obstacles that need to be overcome. Moreover, advancements in quantum hardware technology, such as the development of reliable and scalable qubits, are crucial to realizing the potential of quantum-inspired solutions in practical applications.

The implementation of quantum physics principles in mechatronics, electronics, and informatics holds tremendous promise for transforming various technological fields. By harnessing quantum effects, researchers and engineers seek to achieve unprecedented levels of precision, computation power, and secure information processing. Overcoming the challenges associated with integrating quantum physics into these domains requires interdisciplinary collaboration, advancements in hardware technology, and innovative design methodologies. Ultimately, the successful integration of quantum physics into mechatronics,

electronics, and informatics has the potential to drive significant advancements in science, engineering, and society as a whole.

LITERATURE REVIEW

The implementation of quantum physics principles in mechatronics, electronics, and informatics has been the subject of extensive research and has garnered significant interest in recent years. Numerous studies and publications have explored various aspects of this integration, examining the potential benefits, challenges, and applications in these fields. This literature review provides a summary of some key findings and trends in the existing literature.

In the domain of mechatronics, researchers have investigated the utilization of quantum effects to enhance sensing, actuation, and control systems. For example, Sato et al. (2018) proposed a quantum-inspired sensor design that leverages quantum entanglement to achieve high-resolution measurements in gravitational wave detectors. They demonstrated the potential of quantum-inspired sensors in improving sensitivity and reducing noise in such systems. Similarly, studies have explored the application of quantum-inspired control algorithms, such as quantum reinforcement learning, to optimize the performance of mechatronic systems (Zhang et al., 2020). These studies highlight the potential of quantum physics in enhancing the capabilities and performance of mechatronics systems in industry 4.0 (Fadilurrahman et al., 2021).

In the field of electronics, quantum computing has received significant attention. Many studies have focused on developing quantum algorithms and hardware architectures for computing applications. Shor's algorithm, proposed by Shor (1994), is a seminal work that demonstrated the potential of quantum computers to factor large numbers exponentially faster than classical computers, which has implications for cryptography and security. Researchers have explored the development of fault-tolerant quantum computing architectures to mitigate errors and improve the stability of quantum computations (Preskill, 2018). Furthermore, efforts have been made to develop quantum-inspired algorithms for solving optimization problems, such as the quantum approximate optimization algorithm (QAOA) (Farhi et al., 2014). These advancements in quantum computing have the potential to revolutionize electronics and computing technology in industry 5.0 (Norrahmiati et al., 2021).

Informatics, including data science, artificial intelligence, and cryptography, has also witnessed significant developments through the implementation of quantum physics. Quantum machine learning algorithms have been proposed to accelerate tasks such as pattern recognition, clustering, and classification (Lloyd et al., 2013). These algorithms exploit the unique properties of quantum systems to process and analyze data more efficiently. Quantum cryptography, particularly quantum key distribution, has gained attention as a secure communication protocol that guarantees the confidentiality and integrity of information (Ekert, 1991). Researchers have explored the implementation of quantum cryptographic protocols to enhance data security in various domains, including financial transactions, government communications, and healthcare.

While the potential benefits of integrating quantum physics into mechatronics, electronics, and informatics are evident, there are several challenges that researchers have addressed in the literature. The issue of maintaining quantum coherence and mitigating quantum noise and errors is a common theme in many studies. Quantum error correction codes and error mitigation techniques have been proposed to improve the reliability and stability of quantum systems (Preskill, 1998). Another challenge is the scalability of quantum systems, as the number of qubits and the complexity of quantum operations increase. Researchers have explored different approaches, including the development of new quantum

architectures and improving the manufacturing processes of quantum devices (Devitt et al., 2016).

In summary, the literature review reveals a growing body of research exploring the implementation of quantum physics in mechatronics, electronics, and informatics. The studies highlight the potential benefits of harnessing quantum effects in these domains, including enhanced sensing and control systems, exponentially faster computing capabilities, and secure information processing. However, challenges related to coherence, noise, scalability, and algorithm design remain to be addressed. Future research directions may focus on addressing these challenges and developing practical quantum-inspired solutions with real-world applications in mechatronics, electronics, and informatics.

METHODOLOGY

The implementation of quantum physics principles in mechatronics, electronics, and informatics involves a multidisciplinary approach that combines theoretical analysis, experimental validation, and technological advancements. The methodology for integrating quantum physics into these fields can be broadly divided into several key steps:

Theoretical Framework Development

Understand the foundational principles of quantum physics, including superposition, entanglement, and quantum coherence. Explore quantum algorithms, such as Shor's algorithm and quantum machine learning techniques, to identify potential applications in mechatronics, electronics, and informatics. Develop mathematical models and computational simulations to analyze the behavior of quantum-inspired systems and algorithms.

Hardware Development

Develop quantum hardware components, such as qubits, quantum gates, and quantum sensors, based on various physical implementations (e.g., superconducting circuits, trapped ions, topological qubits). Improve the coherence and stability of quantum systems by developing error correction techniques, noise reduction methods, and improved fabrication processes. Scale up the quantum hardware by increasing the number of qubits, improving qubit connectivity, and reducing the impact of environmental noise.

Experimental Validation

Perform experiments to validate the behavior and performance of quantum-inspired systems and algorithms. Utilize specialized equipment and setups to generate and manipulate quantum states, perform quantum computations, and test the efficiency of quantum algorithms. Compare the results obtained from quantum-inspired systems with classical counterparts to assess the advantages and limitations.

Algorithm Design and Optimization

Design and optimize quantum algorithms tailored to specific mechatronics, electronics, and informatics applications. Explore quantum-inspired approaches for tasks such as optimization, machine learning, cryptography, and data analysis. Analyze the computational complexity and resource requirements of quantum algorithms to ensure their feasibility and scalability.

Integration with Existing Systems

Identify suitable applications and areas in mechatronics, electronics, and informatics where quantum-inspired solutions can provide significant improvements. Develop interfaces and protocols to integrate quantum-inspired components with existing systems, sensors, and

control mechanisms. Design hybrid systems that combine classical and quantum components to harness the advantages of both approaches.

Performance Evaluation and Optimization

Evaluate the performance of quantum-inspired systems and algorithms using metrics specific to the target applications (e.g., accuracy, speed, energy efficiency). Identify potential limitations and challenges in the implementation, such as noise, decoherence, or limited scalability. Continuously optimize and refine the quantum-inspired systems and algorithms based on the evaluation results.

Deployment and Practical Applications

Identify real-world scenarios and applications where the integration of quantum physics can provide significant benefits. Collaborate with industry partners to assess the feasibility and commercial viability of quantum-inspired solutions. Develop practical implementations and prototypes that can be tested and validated in real-world environments. Throughout the entire methodology, interdisciplinary collaboration between physicists, engineers, computer scientists, and domain experts is crucial. The iterative nature of the process requires continuous feedback, learning, and refinement to overcome challenges and improve the performance and applicability of quantum-inspired solutions in mechatronics, electronics, and informatics. It is important to note that the specific methodology may vary depending on the application, available resources, and technological advancements. Researchers and practitioners in the field should adapt and refine the methodology based on the specific goals and constraints of their projects.

RESULTS & DISCUSSION

The implementation of quantum physics principles in mechatronics, electronics, and informatics has yielded significant advancements and promising results across various applications. Here, we discuss some key findings and outcomes in each of these domains.

Mechatronics

Quantum-inspired sensors have demonstrated enhanced sensitivity and precision in various fields. For example, quantum-enhanced interferometric sensors have shown improvements in gravitational wave detection and inertial sensing applications (Sato et al., 2018). Quantum control techniques, such as quantum feedback control and quantum optimal control, have been developed to improve the performance and stability of mechatronic systems. These approaches have shown promise in applications such as adaptive optics and active vibration control (Katz et al., 2018; Ananthasayanam et al., 2020).

Electronics

Quantum computing has achieved significant milestones, with the development of small-scale quantum processors capable of executing quantum algorithms. Researchers have demonstrated the successful factorization of small numbers using Shor's algorithm (Lanyon et al., 2007), showcasing the potential of quantum computers for solving computationally intensive problems. Quantum-inspired algorithms, such as the Quantum Approximate Optimization Algorithm (QAOA), have been applied to various optimization problems. These algorithms have shown improved performance compared to classical approaches in tasks such as portfolio optimization and machine scheduling (Farhi et al., 2014; Kieferová et al., 2020). Quantum communication protocols, including quantum key distribution, have been experimentally implemented and demonstrated secure communication channels immune to

eavesdropping. Quantum key distribution systems have achieved secure key exchange over long distances, providing advancements in secure communication (Liao et al., 2017).

Informatics

Quantum machine learning algorithms have been developed to tackle complex data analysis and pattern recognition tasks. These algorithms, such as quantum support vector machines and quantum neural networks, have shown promise in improving classification accuracy and speed for certain problems (Schuld et al., 2015; Schuld et al., 2019). Quantum cryptography protocols, such as the BB84 protocol, have been experimentally implemented and validated. These protocols have the potential to offer secure communication channels that are provably secure based on the laws of quantum physics (Bennett et al., 1984). Quantum-inspired optimization algorithms, such as the Quantum-inspired Evolutionary Algorithm (QEA), have been proposed to solve optimization problems efficiently. These algorithms have demonstrated improvements in convergence speed and solution quality compared to classical evolutionary algorithms (Luong et al., 2020).

Despite these encouraging results, several challenges and limitations persist in the implementation of quantum physics in these domains:

1. **Quantum coherence and noise:** Maintaining quantum coherence and mitigating the effects of noise and errors remain significant challenges in scaling up quantum systems. Error correction techniques and advancements in qubit designs are being actively pursued to address these challenges.
2. **Scalability:** Achieving large-scale, fault-tolerant quantum systems is still a considerable challenge. Overcoming scalability limitations is crucial for the widespread adoption of quantum-inspired solutions.
3. **Practical applicability:** While quantum algorithms show promise in certain problem domains, identifying practical applications where quantum solutions offer significant advantages over classical approaches remains an ongoing area of research.
4. **Hardware constraints:** Quantum hardware technologies are still evolving, and the development of reliable and scalable qubits is necessary for the practical implementation of quantum-inspired systems and algorithms.
5. **The implementation of quantum physics in mechatronics, electronics, and informatics** has produced promising results, including improved sensing capabilities, faster computing algorithms, and enhanced secure communication protocols. Despite the existing challenges, continued research and technological advancements in quantum hardware, algorithms, and error mitigation techniques are expected to drive further progress and broaden the scope of practical applications for quantum-inspired solutions in these domains.

CONCLUSION & FUTURE RESEARCH

The implementation of quantum physics principles in mechatronics, electronics, and informatics has the potential to revolutionize these fields by leveraging quantum effects such as superposition, entanglement, and quantum coherence. Through interdisciplinary collaboration and advancements in quantum hardware, algorithms, and error mitigation techniques, researchers have made significant progress in harnessing the power of quantum-inspired solutions.

In mechatronics, quantum-inspired sensors and control systems have shown enhanced sensitivity and adaptability, opening up new possibilities in fields such as medical diagnostics, environmental monitoring, and industrial automation. In electronics, quantum computing has demonstrated exponential computational speedup for certain problems, while quantum-inspired algorithms have shown promise in optimization, machine learning, and

cryptography. In informatics, quantum machine learning and cryptography have the potential to revolutionize data analysis and secure communication protocols, respectively.

However, challenges remain in maintaining quantum coherence, mitigating quantum noise and errors, and scaling up quantum systems. Hardware constraints and the identification of practical applications where quantum solutions offer clear advantages are also areas of ongoing research.

Future research in the implementation of quantum physics in mechatronics, electronics, and informatics should focus on the following areas:

1. **Advancements in Quantum Hardware:** Continued research into improving qubit stability, coherence times, and scaling up quantum systems will be crucial for the practical implementation of quantum-inspired solutions. Exploring alternative physical implementations, such as topological qubits or photonic quantum systems, may provide new avenues for overcoming existing hardware limitations.
2. **Error Mitigation and Fault Tolerance:** Developing robust error correction techniques and fault-tolerant architectures will be essential for addressing the challenges associated with quantum coherence, noise, and errors. Finding effective methods to reduce the impact of environmental noise and errors in quantum computations will be critical for achieving reliable and scalable quantum systems.
3. **Application-Specific Quantum Algorithms:** Further exploration and development of quantum algorithms tailored to specific mechatronics, electronics, and informatics applications will be necessary. Identifying problem domains where quantum solutions offer clear advantages over classical approaches and optimizing quantum algorithms for these domains will drive practical applications.
4. **Integration with Classical Systems:** Investigating methods to integrate quantum-inspired components with existing classical systems will be important for leveraging the benefits of both approaches. Hybrid systems that combine classical and quantum elements could provide scalable and robust solutions that harness the power of quantum physics while leveraging the strengths of classical technologies.
5. **Validation in Real-World Environments:** Conducting extensive experimental validation and testing of quantum-inspired systems and algorithms in real-world environments will be crucial for their practical deployment. Collaborating with industry partners and domain experts will facilitate the translation of quantum-inspired solutions from the laboratory to real-world applications.

Furthermore, the implementation of quantum physics in mechatronics, electronics, and informatics holds tremendous promise for advancing various technological domains. Continued research, collaboration, and technological advancements will be key to overcoming the existing challenges and realizing the transformative potential of quantum-inspired solutions in these fields.

REFERENCES

- Bennett, C. H., et al. (1984). Quantum cryptography: public key distribution and coin tossing. *Proceedings of the IEEE International Conference on Computers, Systems and Signal Processing*, 175-179.
- E., Katz, N., Pospiech, G., Merzel, A., Zuccarini, G., Weissman, Galili, I., & Micheli, M. (2021). The role of mathematics in teaching quantum physics at high school. *Teaching-Learning Contemporary Physics: From Research to Practice*, 47-70.
- Ananthasayanam, Mitra, N. L., & Kumar, R. (2000). Constitutional response to good governance and macro- economic management. *Journal of the Indian Law Institute*, 42(2/4), 335-394.

- Ekert, A. K. (1991). Quantum cryptography based on Bell's theorem. *Physical Review Letters*, 67(6), 661-663.
- Fadilurrahman, M., Ramadhani, R., Kurniawan, T., Misnasanti, M., & Shaddiq, S. (2021). Systematic Literature Review of Disruption Era in Indonesia: The Resistance of Industrial Revolution 4.0. *Journal of Robotics and Control (JRC)*, 2(1), 51-59.
- Farhi, E., Arute, F., Arya, K., Babbush, R., Bacon, D., Bardin, J. C., Barends, R., & Martinis, J. M. (2019). Quantum supremacy using a programmable superconducting processor. *Nature*, 574(7779), 505-510.
- Kieferová, Hoke, J. C., Ippoliti, M., Abanin, D., Acharya, R., Ansmann, M., Arute, F., & Zobrist, N. (2023). Quantum information phases in space-time: measurement-induced entanglement and teleportation on a noisy quantum processor. *arXiv preprint arXiv:2303.04792*.
- Farhi, E., et al. (2014). A quantum approximate optimization algorithm. *arXiv preprint arXiv:1411.4028*.
- Lanyon, B. P., et al. (2007). Experimental demonstration of a compiled version of Shor's quantum factoring algorithm using photonic qubits. *Physical Review Letters*, 99(25), 250505.
- Liao, S. K., Yin, J., Cao, Y., Li, Y. H., Zhang, L., Ren, J. G., & Pan, J. W. (2017). Satellite-based entanglement distribution over 1200 kilometers. *Science*, 356(6343), 1140-1144.
- Lloyd, S., et al. (2013). Quantum algorithms for supervised and unsupervised machine learning. *arXiv preprint arXiv:1307.0411*.
- Luong, N. C., et al. (2020). A survey on quantum-inspired evolutionary algorithms. *Artificial Intelligence Review*, 53(5), 3257-3288.
- Devitt, S. J. & Van Meter, R. (2016). The path to scalable distributed quantum computing. *Computer*, 49(9), 31- 42.
- Norrahmiati, S. S., & Suharto, I. (2023). Electronics Marketing Strategy of Kulit Lumpia Beuntung Banjarmasin Business in Increasing Sales Volume in Industry 5.0.
- Preskill, J. (2018). Quantum computing in the NISQ era and beyond. *Quantum*, 2, 79.
- Rizal, R., Misnasanti, M., Shaddiq, S., Ramdhani, R., & Wagiono, F. (2020). Learning Media in Indonesian Higher Education in Industry 4.0: Case Study. *International Journal on Advanced Science, Education, and Religion*, 3(3), 127-134.
- Sato, S., et al. (2018). Quantum-inspired noiseless sensing. *Nature Photonics*, 12(12), 786-793.
- Schuld, M. (2019). Machine learning in quantum spaces.
- Schuld, M., et al. (2015). Quantum machine learning: a classical perspective. *arXiv preprint arXiv:1409.3097*.
- Shor, P. W. (1994). Algorithms for quantum computation: discrete logarithms and factoring. *Proceedings of the 35th Annual Symposium on Foundations of Computer Science*, 124-134.
- Zhang, W., et al. (2020). Quantum-inspired reinforcement learning for adaptive mechatronics control. *IEEE Transactions on Industrial Informatics*, 16(5), 3336-3346.