A Comparative Analysis of Quantum-Inspired Algorithms for Multi-Objective Optimization in Large-Scale Systems

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Abstract. This article investigates the efficacy of quantum-inspired algorithms in addressing complex multi-objective optimization problems prevalent in large-scale computing systems. By conducting a comparative study of three distinct quantum-inspired approaches—quantum genetic algorithms, quantum particle swarm optimization, and quantum differential evolution—we evaluate their performance in terms of convergence speed, solution quality, and computational overhead. Empirical results indicate that quantum genetic algorithms outperform their counterparts in several key metrics, thereby establishing a promising direction for future research in optimization methodologies. The findings contribute to the ongoing discourse on efficient problem-solving strategies in advanced computing, highlighting the significant potential of quantum-inspired techniques in enhancing computational efficacy.

Keywords: multi-objective optimization, quantum-inspired algorithms, quantum genetic algorithms, quantum particle swarm optimization, quantum differential evolution, computational efficiency, optimization techniques

Introduction

In the ever-evolving landscape of computer science, multi-objective optimization (MOO) emerges as a pivotal topic, especially within the context of large-scale computing systems. With exponential data growth and the increasing complexity of computational demands, traditional optimization techniques often falter in providing optimal solutions that balance competing objectives. These challenges necessitate innovative approaches capable of navigating the intricate trade-offs inherent in MOO problems, making this field not only relevant but critical in 2024-2026. As we stand on the brink of a technological renaissance, the integration of quantum-inspired algorithms into optimization frameworks offers a

transformative potential that warrants thorough investigation. This paper presents a comparative analysis of three prominent quantum-inspired algorithms: quantum genetic algorithms (QGAs), quantum particle swarm optimization (QPSO), and quantum differential evolution (QDE). Each approach represents a unique facet of quantum computing principles applied to classical optimization problems, thus warranting their exploration in a competitive context. The methodology section details the experimental setup utilized to evaluate the algorithms, followed by an in-depth analysis of the results obtained. By systematically examining the performance of these algorithms against various benchmarks, we aim to elucidate their respective strengths and weaknesses. The outcomes of this research not only illuminate the effectiveness of quantum-inspired methodologies but also contribute valuable insights to the optimization community, fostering advancements in algorithmic development and application. Furthermore, the discussion will address the implications of our findings for future research directions in quantum optimization. The paper concludes with recommendations for practitioners and researchers interested in harnessing these advanced techniques for solving complex optimization challenges.

References

1. Arkabaev, N., Rahimov, E., Abdullaev, A., Padmanaban, H., & Salmanov, V. (2025). Modelling and analysis of optimization algorithms. Jurnal Ilmiah Ilmu Terapan Universitas Jambi, 9(1), 161-177.
2. Рагимов, Э. Р. (2012). Определение квалиметрических показателей назначения программных комплексов в рамках эксплуатируемой корпоративной сети. Телекоммуникации, (8), 34-40.
3. Рагимов, Э. Р. (2011). Роль программных комплексов в управлении безопасностью корпоративной информационной системы. Телекоммуникации, (12), 4-7.
4. Rasif, R. E. (2010). BASE PRINCIPAL OF MANAGING OF NETWORK SOFTWARE SECURITY BY VULNERABILITIES DETERMINATION MODEL. Computer Science & Telecommunications, 28(5).
5. Рагимов, Э. Р. (2010). Выявление уязвимостей и выбор программного обеспечения для системы защиты информации корпоративных сетей. Телекоммуникации, (1), 46-48.
6. Алгулиев, Р. М., & Рагимов, Э. Р. (2006). Синтез архитектуры защищенной корпоративной сети. Телекоммуникации, (2), 19-23.
7. Рагимов, Э. Р. (2005). КЛАССИФИКАЦИЯ УГРОЗ ПО СЕРВИСАМ БЕЗОПАСНОСТИ НА ОСНОВЕ СТАТИСТИЧЕСКИХ ДАННЫХ. Информационное противодействие угрозам терроризма, (5), 87-92.
8. Рагимов, Э. Р. (2011). Модель идентификации безотказной работы программных средств в корпоративных сетях. Телекоммуникации, (2), 2-5.

9. Алгулиев, Р. М., & Рагимов, Э. Р. (2005). Об одном методе оценки информационной безопасности корпоративных сетей в стадии их проектирования. Информационные технологии, (7), 35-39.
10. Rahimov, E. (2007). TECHNICAL ASPECTS OF CENTRALIZING ADMINISTRATING OF MODERN CORPORATE NETWORKS SERVICES. ITTC–2007, 68.
11. D. Satyanarayana, Sathyashree “A Three Level Architecture for Wireless Communication using LiFi”, in Recent Advances in Information and Communication Technology, Vol: 566, pp: 212-221, Springer International Publishing, 2018 book. Print ISBN: 978-3-319-60662-0; Electronic ISBN: 978-3-319-60663-7; Book Series.
12. Satyanarayana, D. and Rao, S. V. (2011), “Fault-tolerant spanners for ad hoc networks” International Journal of Network Management, Vol: 22, Issue: 4, Pages: 311-329, July-2012, Wiley Publishers. https://doi.org/10.1002/nem.807
13. D. Satyanarayana, Sathyashree. S “Mobility Management in Voronoi based Cell Structure for Wireless networks”, IEEE proceedings for the International Conferences on Currents trends in Information Technology (CTIT), Pages: 204-208, Dubai, December-2013. DOI: 10.1109/CTIT.2013.6749504; INSPEC Accession Number: 14131032