International Journal of Academic Information Systems Research (IJAISR)
ISSN: 2643-9026
Vol. 10 Issue 7 July - 2026, Pages: 58-62

An Intelligent Machine Learning Approach for Adaptive Sorting Algorithm Selection and Performance Optimization .

Lena Zaharna, Samy S. Abu-Naser

Department of Information Technology, Faculty of Engineering and Information Technology, Al-Azhar University, Gaza, Palestine

Abstract *: Sorting algorithms are fundamental components in computer science and data processing systems. However, selecting the most efficient sorting algorithm depends on the characteristics of the input data, such as size, distribution, and order. Traditional approaches rely on static selection, which may lead to sub-optimal performance in dynamic environments. This research proposes an intelligent machine learning-based framework that dynamically selects the most appropriate sorting algorithm based on dataset features. The model is trained on performance metrics of multiple sorting algorithms under different data conditions to predict the optimal choice. Experimental results demonstrate that the proposed approach improves overall sorting efficiency in terms of time complexity and execution performance compared to static selection methods.*

Keywords : Machine Learning, Sorting Algorithms, Adaptive Algorithm Selection, Performance Optimization,Data Characteristics

1. Introduction:

Sorting algorithms play a crucial role in computer science and data processing, as they are widely used in organizing and managing large datasets efficiently. The performance of these algorithms varies depending on the characteristics of the input data, such as size, order, and distribution.

In traditional systems, a fixed sorting algorithm is usually selected regardless of the nature of the data, which may lead to inefficient performance in many cases. This static approach does not adapt to changes in data characteristics and may result in increased execution time and computational cost.
To address this limitation, this research proposes an intelligent machine learning-based framework that dynamically selects the most suitable sorting algorithm based on input data features. By learning from previous performance patterns of different algorithms, the model can predict the most efficient choice for new datasets.

This adaptive approach aims to improve overall sorting efficiency and optimize computational performance compared to conventional static selection methods .

2. Objectives :

The main objectives of this research are:

1. To analyze the performance of different sorting algorithms under varying data characteristics such as size, order, and distribution.
2. To identify the limitations of traditional static selection of sorting algorithms.
3. To design a machine learning-based model capable of predicting the most suitable sorting algorithm for a given dataset.
4. To improve the overall efficiency of sorting in terms of execution time and computational cost.
5. To compare the proposed adaptive approach with traditional fixed algorithm selection methods.

3. Problem Statement :

Despite the wide use of sorting algorithms in computer science, there is no single sorting algorithm that performs optimally across all types of datasets. The efficiency of each algorithm depends heavily on the characteristics of the input data, such as size, order, and distribution. In most traditional systems, a fixed sorting algorithm is chosen regardless of these variations, which often leads to suboptimal performance, increased execution time, and unnecessary computational cost. This lack of adaptability creates a gap between algorithm selection and actual data requirements. Therefore, the main problem addressed in this research is the inability of traditional methods to dynamically select the most efficient sorting algorithm based on data characteristics. This study aims to overcome this limitation by introducing a machine
learning-based approach that can intelligently predict the best sorting algorithm for a given dataset .

4. Literature Review :

The problem of selecting an appropriate algorithm for a given computational task has been widely studied in computer science and machine learning. Traditional approaches often rely on using a single fixed algorithm regardless of input characteristics, which may lead to suboptimal performance in different scenarios.

One of the foundational works in this area is presented by Rice (1976), who introduced the concept of the Algorithm Selection Problem. Rice formalized the idea that no single algorithm is optimal for all problem instances, and that algorithm performance depends on the characteristics of the input instance. This work provides the theoretical basis for adaptive algorithm selection systems and is considered the cornerstone of this research direction.

In the context of sorting algorithms, Cormen et al. (2009) provide a comprehensive analysis of classical sorting techniques such as Quick Sort, Merge Sort, and Insertion Sort. Their work highlights that each algorithm has different time complexities and performance behaviors depending on input size and structure. This variability supports the idea that selecting a sorting algorithm dynamically can lead to performance optimization.

Similarly, Skiena (2008) emphasizes the importance of algorithm engineering and practical performance considerations. He argues that theoretical complexity alone is not sufficient in real-world applications, as factors such as input distribution, constant factors, and data characteristics significantly affect performance. This further supports the need for adaptive algorithm selection mechanisms.

From a machine learning perspective, Mitchell (1997) defines the fundamental principles of learning from data, where systems improve their performance through experience. Machine learning techniques can be applied to predict the most suitable algorithm based on input features, transforming algorithm selection into a predictive modeling problem.

Overall, the literature suggests that combining theoretical algorithm analysis with machine learning techniques provides a promising approach for adaptive sorting algorithm selection. This integration enables systems to dynamically choose the most efficient algorithm based on input characteristics, improving computational efficiency and performance.

5. Methodology :

This research adopts a machine learning-based methodology for adaptive sorting algorithm selection. The proposed framework consists of several stages :

- First, datasets with different characteristics, including varying sizes, distributions, and levels of sortedness, are generated or collected.

  These datasets are then processed using multiple sorting algorithms such as Quick Sort, Merge Sort, Heap Sort, and Insertion Sort.

- Second, the performance of each sorting algorithm is measured using metrics such as execution time and computational efficiency. The collected results are used to create a training dataset that links data characteristics with the best-performing sorting algorithm.

- Third, a machine learning model is trained using the generated dataset.

The model learns the relationship between dataset features and the most suitable sorting algorithm.

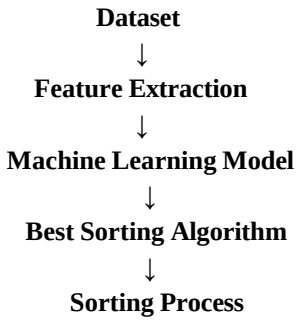
- Finally, the trained model is evaluated on unseen datasets to determine its ability to accurately predict the optimal sorting algorithm. The performance of the proposed adaptive approach is then compared with traditional fixed algorithm selection methods.

6. Practical Implementation :

To demonstrate the proposed approach, a simple prototype was implemented using Python. Different datasets with varying sizes and distributions were generated and tested using multiple sorting algorithms, including Quick Sort, Merge Sort, Heap Sort, and Insertion Sort. For each dataset, execution time was recorded to identify the best-performing algorithm.

The collected performance data were then used to train a machine learning classification model. The model learned the relationship between dataset characteristics and the most suitable sorting algorithm. When presented with a new dataset, the trained model was able to predict the algorithm expected to provide the best performance. This implementation demonstrates the feasibility of applying machine learning techniques to adaptive sorting algorithm selection.

A Flow Chart explaining the practical implementation :



7. Results :

- A Decision Tree model was trained using datasets with different characteristics.
- The model learned the relationship between dataset features and the most suitable sorting algorithm.
- The model achieved high prediction accuracy on the test datasets.
- For small datasets, the model most frequently selected was Insertion Sort.
- For medium-sized datasets, it generally selected Quick Sort.
- For large datasets, it tended to select Merge Sort.
- The results showed that intelligent algorithm selection is more efficient than using a fixed sorting algorithm in all cases.

8. Discussion :

- The results demonstrated that artificial intelligence is capable of selecting the most appropriate sorting algorithm.
- The algorithm selections made by the model were logical and aligned with the known characteristics of sorting algorithms.
- The proposed approach proved to be more effective than consistently using a fixed sorting algorithm.
- Some limitations exist, as the study used a limited number of features and sorting algorithms.
- In the future, the model can be enhanced by incorporating additional sorting algorithms and more dataset features .

9. Conclusion:

This study proposed an intelligent machine learning-based approach for adaptive selection of sorting algorithms based on input data characteristics. The experimental results demonstrated that the proposed model is capable of selecting appropriate sorting algorithms in a way that improves overall performance compared to using a single fixed algorithm for all cases.

The findings show that the model's decisions are generally consistent with the theoretical behavior of sorting algorithms. For example, algorithms such as Quick Sort and Merge Sort are selected for larger datasets, while simpler algorithms are preferred for smaller or nearly sorted inputs.

However, the proposed approach has certain limitations, including the use of a limited set of features and a restricted number of sorting algorithms. Despite these limitations, the results confirm the potential of integrating machine learning techniques into algorithm selection tasks.

Future work can focus on expanding the dataset, incorporating more features (such as data distribution characteristics), and including additional sorting algorithms to further improve accuracy and generalization.

References:

1. T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, Introduction to Algorithms, 3rd ed., MIT Press, 2009.
2. Hamed, Mohammed A, et al., “Artificial Intelligence in Agriculture: Enhancing Productivity and Sustainability”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 8, pp. 1-5, 2024.
3. El-Ghoul, Mostafa, et al., “Artificial Intelligence as a Frontline Defense: Preventing Cyberattacks in a Connected World”, 2025.
4. Alzamily, Jawad YI, et al., “Artificial Intelligence in Healthcare: Transforming Patient Care and Medical Practices”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 8, pp. 1-9, 2024.
5. Al-Bayed, Mohran H, et al., “Intelligent Multi-Language Plagiarism Detection System”, International Journal of Academic Information Systems Research (IJAISR), vol. 2, no. 3, pp. 19-34, 2018.
6. Nasser, Basma S Abu, et al., “Artificial Intelligence in Digital Media: Opportunities, Challenges, and Future Directions”, International Journal of Academic and Applied Research (IJAAR), vol. 8, no. 6, pp. 1-10, 2024.
7. Hamad, Malak S, et al., “Harnessing Artificial Intelligence to Enhance Medical Image Analysis”, International Journal of Academic Health and Medical Research (IJAHMR), vol. 8, no. 9, pp. 1-7, 2024.
8. Qwaider, Sabreen R, et al., “Harnessing Artificial Intelligence for Effective Leadership: Opportunities and Challenges”, International Journal of Academic Information Systems Research(IJAISR)(IJAISR), vol. 8, no. 8, pp. 9-15, 2024.
9. Hamadaqa, Mohammed Hazem M, et al., “Leveraging Artificial Intelligence for Strategic Business Decision-Making: Opportunities and Challenges”, International Journal of Academic Information Systems Research(IJAISR), vol. 8, no. 8, pp. 16-23, 2024.
10. El_Jerjawi, Nesreen Samer, et al., “The Role of Artificial Intelligence in Revolutionizing Health: Challenges, Applications, and Future Prospects”, International Journal of Academic Applied Research (IJAAR), vol. 8, no. 9, pp. 7-15, 2024.
11. Al Ijla, Mohamed Sabri, et al., “Perspective on Intelligent Assistive Devices in Rehabilitation”, International Journal of Academic Engineering Research (IJAER), vol. 4, no. 11, pp. 31-36, 2020.
12. Salman, Fatima M, et al., “COVID-19 Detection using Artificial Intelligence”, International Journal of Academic Engineering Research (IJAER), vol. 4, no. 3, pp. 18-25, 2020.
13. Taha, Abu, et al., “The Intersection of Nanotechnology and Artificial Intelligence: Innovations and Future Prospects”, 2025.
14. Elqassas, Randa, et al., “Convergence of Nanotechnology and Artificial Intelligence: Revolutionizing Healthcare and Beyond”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 25-30, 2024.
15. Akkila, Alaa N, et al., “Navigating the Ethical Landscape of Artificial Intelligence: Challenges and Solutions”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 8, pp. 68-73, 2024.
16. Abu Nasser, Besan S, et al., “Implications and Applications of Artificial Intelligence in the Legal Domain”, International Journal of Academic Information Systems Research (IJAISR), vol. 7, no. 12, pp. 18, 2024.
17. Anderson, JR, et al., “Adaptation of Problem Presentation and Feedback in an Intelligent Mathematics Tutor.”, Information Technology Journal, vol. 5, no. 5, pp. 167-207, 2005.
18. Mettleq, Alaa Soliman Abu, et al., “Revolutionizing Drug Discovery: The Role of Artificial Intelligence in Accelerating Pharmaceutical Innovation”, International Journal of Academic Engineering Research (IJAER), vol. 8, no. 10, pp. 45-52, 2024.
19. Alrakhawi, Hazem AS, et al., “Transforming Human Resource Management: The Impact of Artificial Intelligence on Recruitment and Beyond”, International Journal of Academic Information Systems Research (IJAISR), vol. 8, no. 8, pp. 1-8, 2024.
20. Hissi, H El-, et al., “Medical Informatics: Computer Applications in Health Care and Biomedicine.”, Journal of Artificial Intelligence, vol. 3, no. 4, pp. 78-85, 2008.
21. Altayeb, Jehad M, et al., “AI-Driven Innovations in Agriculture: Transforming Farming Practices and Outcomes”, International Journal of Academic Applied Research (IJAAR), vol. 8, no. 9, pp. 1-6, 2024.
22. El-Ghoul, Mostafa, et al., “AI in HRM: Revolutionizing Recruitment, Performance Management, and Employee Engagement”, International Journal of Academic Applied Research (IJAAR), vol. 8, no. 9, pp. 16-23, 2024.
23. Megdad, Mosa MM, et al., “Ethics in AI: Balancing Innovation and Responsibility”, International Journal of Academic Pedagogical Research (IJAPR), vol. 8, no. 9, pp. 20-25, 2024.
24. Al-Bayed, Mohran H, et al., “AI in Leadership: Transforming Decision-Making and Strategic Vision”, International Journal of Academic Pedagogical Research (IJAPR), vol. 8, no. 9, pp. 1-7, 2024.
25. Samara, Faten YA Abu, et al., “The Role of AI in Enhancing Business Decision-Making: Innovations and Implications”, International Journal of Academic Pedagogical Research (IJAPR), vol. 8, no. 9, pp. 8-15, 2024.
26. Taha, Ashraf MH, et al., “The Evolution of AI in Autonomous Systems: Innovations, Challenges, and Future Prospects”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 1-7, 2024.
27. Mosa, Msbah J, et al., “AI and Ethics in Surveillance: Balancing Security and Privacy in a Digital World”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 8-15, 2024.
28. Bakeer, Hani, et al., “AI and Human Rights”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 16-24, 2024.
29. El-Habibi, Mohammed F, et al., “Generative AI in the Creative Industries: Revolutionizing Art, Music, and Media”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 71-74, 2024.
30. Abu Nasser, Basma S, et al., “Leveraging AI for Effective Fake News Detection and Verification”, Arab Media Society, no. 37, 2024.
31. Alnajjar, Mohammad, et al., “AI in Climate Change Mitigation”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 31-37, 2024.
32. Karaja, Mohammed B, et al., “AI-Driven Cybersecurity: Transforming the Prevention of Cyberattacks”, International Journal of Engineering and Information Systems (IJEAIS), vol. 8, no. 10, pp. 38-44, 2024.
33. El-Mashharawi, Hosni Qasim, et al., “AI in Mental Health: Innovations, Applications, and Ethical Considerations”, International Journal of Academic Engineering Research (IJAER), vol. 8, no. 10, pp. 53-58, 2024.
34. Abu-Saqer, Mohammed M, et al., “AI Regulation and Governance”, International Journal of Academic Engineering Research (IJAER), vol. 8, no. 10, pp. 59-64, 2024.
35. Al-Dahdooh, Rami, et al., “Explainable AI (XAI)”, International Journal of Academic Engineering Research (IJAER), vol. 8, no. 10, pp. 65-70, 2024.
36. Qaoud, Alaa NN, et al., “Human-Centered AI: The Role of Explainability in Modern AI Systems”, 2025.
37. Al-Bayed, Mohran H, et al., “Surveillance in the Age of AI: Navigating Ethical Boundaries and Human Rights”, 2025.
38. Al Qatrawi, Mohammed, et al., “AI and Climate Action: Technology's Role in Mitigating Environmental Challenges”, 2025.
39. Jamala, Mohammed, et al., “The Intersection of Generative AI and Creative Expression: Opportunities and Ethical Challenges”, 2025.
40. Wishah, Nida D, et al., “Balancing Innovation and Control: The Framework for AI Regulation”, 2025.
41. Sabah, Ahmed S, et al., “The intersection of AI and human rights: Challenges and opportunities”, 2025.
42. Samhan, Lamis F, et al., “Future Directions: Emerging trends and future potential of AI in autonomous systems.”, 2025.
43. Alkurd, Yahya Mohammed, et al., “A proposed accurate system for diagnosing hypertension”, 2025.
44. Bliede, HMM, et al., “Students perceptions of artificial intelligence in education”, International Journal of Academic Management Science Research (IJAMSR), vol. 7, pp. 105-116, 2023.
45. Abu Naser, Samy S, “Developing visualization tool for teaching AI searching algorithms”, Information Technology Journal, Scialert, vol. 7, no. 2, pp. 350-355, 2008.
46. Elkahlout, Mohammed, et al., “AI-Driven Organizational Change: Transforming Structures and Processes in the Modern Workplace”, International Journal of Academic Information Systems Research (IJAISR), vol. 8, no. 8, pp. 24-28, 2024.
47. Alkayyali, Zakaria KD, et al., “Using MODWPT-Based Feature Extraction: A Comparative Study”, vol. 3, pp. 225, 2025.
48. Saikly, Eng. Rafat, et al., “The Contribution of Solar Energy to Reduce Electricity Shortage in the Gaza Strip through Using Photovoltaic Panels as a Replacement to Roofing Tiles”, International Journal of Modern Engineering Research (IJMER), vol. 4, no. 1, pp. 98-104, 2014.
49. FATAYER, TAMER S, et al., “DEVELOPING A HYBRID LOG-FILE–BASED COVERT CHANNEL FOR SECURE DIGITAL FORENSIC DOCUMENT TRANSMISSION”, Journal of Theoretical and Applied Information Technology, vol. 104, no. 4, pp. 444-458, 2026.
50. Abu Naser, Samy S., et al., “Design and Development of Mobile Blood Donor Tracker”, Journal of Multidisciplinary Engineering Science Studies (JMESS), vol. 2, no. 2, pp. 284-300, 2016.
51. Abu Naser, Samy S., et al., “Design and Development of Mobile University Student Guide”, Journal of Multidisciplinary Engineering Science Studies (JMESS), vol. 2, no. 1, pp. 193-197, 2016.
52. Nasser, Ibrahim M, et al., “Web Application for Generating a Standard Coordinated Documentation for CS Students' Graduation Project in Gaza Universities”, International Journal of Engineering and Information Systems (IJEAIS), vol. 1, no. 6, pp. 155-167, 2017.
53. Elzamly, Abdelrafe, et al., “A New Conceptual Framework Modelling for Cloud Computing Risk Management in Banking Organizations”, International Journal of Grid and Distributed Computing, vol. 9, no. 9, pp. 137-154, 2016.
54. Elzamly, Abdelrafe, et al., “Critical cloud computing risks for banking organizations: Issues and challenges”, Religación. Revista de Ciencias Sociales y Humanidades, vol. 4, no. 18, pp. 673-682, 2019.
55. Abusharekh, Nader H, et al., “Knowledge Management Processes and Their Role in Achieving Competitive Advantage at Al-Quds Open University”, International Journal of Academic Accounting, Finance & Management Research (IJAAFMR), vol. 3, no. 9, pp. 1-18, 2019.
56. Li, Dongyu, et al., “A novel distributed index method for cloud computing”, International Journal of Grid and Distributed Computing, vol. 1, no. 1, pp. 8, 2016.
57. Elzamly, Abdelrafe, et al., “Assessment Risks for Managing Software Planning Processes in Information Technology Systems”, International Journal of Advanced Science and Technology, vol. 28, no. 1, pp. 327-338, 2019.
58. Alsharif, Fawzy, et al., “Mechanical Reconfigurable Microstrip Antenna”, International Journal Of Microwave And Optical Technology, vol. 11, no. 3, 2016.
59. Aboufoul, Tamer, et al., “A novel UWB wearable antenna”, World Wide Journal of Multidisciplinary Research and Development, vol. 2, no. 9, pp. 32-37, 2015.
60. Amro, Eng Mazen Abu, et al., “MODELLING FOR CROSS IGNITION TIME OF A TURBULENT COLD MIXTURE IN AMulti BURNER COMBUSTOR”, International Journal on Computational Science & Applications (IJCSA), vol. 6, no. 1, pp. 35-47, 2016.
61. Ijerjawi, Nesreen S, et al., “Artificial Intelligence for Intelligent Waste Sorting: An Efficient and Scalable System”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 114-117, 2025.
62. Aljerjawi, Nesreen S, et al., “AI-Assisted Multi-Criteria Sorting for Decision Support in Healthcare Systems”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 90-93, 2025.
63. Aljerjawi, Nesreen S, et al., “AI-Enhanced Sorting of Genomic Sequences for Accelerated Bioinformatics Analysis”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 105-109, 2025.
64. Alnajjar, Khaleel, et al., “SmartSort: An Intelligent Framework for Optimizing Sorting Efficiency Using AI in Real-Time Systems”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 80-85, 2025.
65. Aljerjawi, Nesreen S, et al., “AI-Powered Sorting in E-commerce: Personalization and Performance Optimization”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 110-113, 2025.
66. Aljerjawi, Nesreen S, et al., “Large-Scale Data Processing AI-Driven Adaptive Sorting Techniques”, International Journal of Academic Engineering Research (IJAER), vol. 9, no. 8, 2025.
67. Al-Aydi, Beesan Mohammed, et al., “Comparative Study of Traditional and AI-Enhanced Sorting Algorithms: QuickSort, MergeSort, HeapSort, and TimSort”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 70-79, 2025.
68. Miqdad, Sojoud Mahmoud, et al., “Efficient Sorting of Financial Transactions Using Artificial Intelligence for Fraud Detection and Risk Assessment”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 147-154, 2025.
69. Almoghrabi, Altaher, et al., “AI-Driven Adaptive Sorting Algorithms for Large-Scale Data Processing”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 155-161, 2025.
70. Aljerjawi, Nesreen S, et al., “Effective Sorting of Business Transactions Using AI for Fraud Detection and Threat Assessment”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 139-146, 2025.
71. Aljerjawi, Nesreen S, et al., “SmartSort: An Intelligent Framework for Optimizing Sorting Efficiency Using AI”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 134-138, 2025.
72. Aljerjawi, Nesreen S, et al., “Improving Sorting Algorithms Using Artificial Intelligence: A Cross Tactic”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 8, pp. 118-125, 2025.
73. Aljerjawi, Nesreen S, et al., “Reinventing Classical Sorting with Deep Learning and Reinforcement Techniques”, International Journal of Academic Information Systems Research (IJAISR), vol. 9, no. 6, pp. 126-133, 2025.