International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Review Article)

Check for updates

Extraction of value and impact from IoT big data sets: A qualitative exploration of current methodologies and future directions

Oluwaseyi Olakunle Mokuolu *

Department of Information Technology, University of the Cumberlands, Kentucky, U.S.A.

International Journal of Science and Research Archive, 2024, 13(01), 503–507

Publication history: Received on 30 July 2024; revised on 08 September 2024; accepted on 10 September 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.1.1669

Abstract

Integrating the Internet of Things (IoT) with big data analytics has created transformative opportunities across various domains, including smart cities, healthcare, and industrial automation. However, the challenges of extracting value from the vast and heterogeneous IoT data sets are significant. This study aims to explore methods for maximizing value extraction from IoT-generated big data and evaluate their impact on decision-making processes. A systematic literature review was conducted, and an exploratory qualitative methodology was employed to assess existing frameworks and propose improvements. The results highlight the importance of edge computing, machine learning algorithms, and data processing architectures in managing IoT data effectively. Additionally, the study identifies gaps in current research and suggests future directions to enhance the practical application of IoT big data analytics.

Keywords: IoT; Big data; Edge computing; Machine learning; Data analytics; Value extraction

1. Introduction

The rapid expansion of the Internet of Things (IoT) has resulted in the proliferation of connected devices that generate massive volumes of data; this phenomenon has introduced new possibilities for optimizing processes, improving decision-making, and creating innovative services across various sectors [1, 2, 3, 4, 5]. However, the sheer volume, velocity, and variety of IoT-generated big data often pose significant challenges in extracting meaningful value from these data sets [6, 7].

Still, effectively harnessing IoT data can enhance business intelligence, predictive analytics, and automation; nevertheless, the heterogeneity and complexity of these data require advanced methodologies and architectures to ensure efficient processing and utilization [7, 8].

This study aims to explore the methodologies for extracting value from IoT big data sets and assesses their impact on various applications; furthermore, it addresses the following research questions:

- RQ1: What are the current challenges in extracting value from IoT big data sets?
- RQ2: How do existing methodologies address these challenges?
- RQ3: What are the potential impacts of successfully extracting value from IoT big data on decision-making and operational efficiency?

* Corresponding author: Oluwaseyi Olakunle Mokuolu

2. Literature Review

IoT and big data have attracted significant scholarly interest, with numerous studies examining the opportunities and challenges of this integration. IoT, characterized by interconnected devices and sensors, generates an enormous volume of data that requires sophisticated processing techniques [6, 8, 9].

According to Adeusi et al. [8], Marengo [10], and Santhanagopalan et al. [11], IoT-enabled systems create opportunities for intelligent decision-making through real-time data analytics; however, the authors also note the challenges of handling the volume and heterogeneity of IoT data, which require scalable and flexible architectures. Nonetheless, the emergence of edge computing has been a critical development in addressing these challenges. Edge computing enables data processing closer to the data source, reducing latency and improving real-time decision-making capabilities [12, 13]. Furthermore, integrating edge computing with cloud technologies enhances the scalability of IoT systems, allowing for the efficient processing of large data sets [14, 15].

Various researchers, including Anees et al. [14], Gkonis et al. [16], George et al. [17], and Kuchuk and Malokhvii [18] highlight the benefits of combining edge and cloud computing to manage IoT data, emphasizing the need for optimized data processing frameworks. In big data analytics, machine learning (ML) has emerged as a powerful tool for extracting value from IoT data. Specifically, ML algorithms can analyze large data sets to identify patterns, predict outcomes, and optimize processes [19, 20]. Furthermore, integrating ML with IoT systems presents challenges related to data quality, processing time, and resource management [21, 22]. The review of existing literature reveals a growing consensus on the importance of developing robust data architectures that can accommodate the complexities of IoT-generated data.

3. Methodology

This study employs an exploratory qualitative methodology, just Knox [23], to investigate the current practices and challenges in extracting value from IoT big data sets. For relevance, a systematic literature review was conducted to gather insights from peer-reviewed academic sources published between 2022 and 2024. The selection criteria for the literature review included scholarly peer-reviewed articles relevant to IoT, big data, edge computing, and machine learning. Subsequently, the articles were screened and categorized based on their contributions to understanding IoT data processing frameworks, value extraction methodologies, and impact analysis.

In addition to the literature review, case studies of existing IoT systems were analyzed to identify practical applications of the methodologies discussed in the literature. Specifically, these case studies focused on sectors such as healthcare, smart cities, and industrial automation, where IoT data plays a crucial role in decision-making. Furthermore, the data collected from these case studies were analyzed using thematic coding to identify common challenges and best practices in value extraction from IoT data sets.

4. Results

The findings from the literature review and case studies reveal several key challenges and opportunities in extracting value from IoT big data sets:

- Data Heterogeneity: Diverse devices and sensors often generate IoT data, resulting in various data formats and structures; consequently, this heterogeneity complicates data integration and processing, requiring advanced data normalization and transformation techniques [2, 24, 25].
- Scalability Issues: The volume of IoT data continues to grow exponentially, necessitating scalable data architectures; hence, edge computing has emerged as a promising solution, enabling data processing at the network's edge and reducing the burden on central servers [4, 18, 26].
- Latency and Real-Time Processing: Many IoT applications, such as autonomous vehicles and healthcare monitoring, require real-time data processing; however, integrating edge computing with cloud-based solutions can help address latency issues, ensuring timely decision-making [15, 27, 28].
- Machine Learning Integration: ML algorithms have shown promise in extracting valuable insights from IoT data; however, the effectiveness of these algorithms depends on the quality of the data and the efficiency of the data processing framework [29, 30].
- Impact on Decision-Making: Successfully extracting value from IoT big data can significantly improve decision-making processes across various sectors [31, 32]. For instance, in smart cities, IoT data can reduce energy consumption, optimize traffic management, and enhance public safety.

5. Discussion

The findings of this study highlight the importance of developing robust and scalable data architectures to manage the complexities of IoT big data. Moreover, integrating edge computing with cloud technologies offers a promising solution to data heterogeneity and latency challenges [14, 26, 16]. Furthermore, processing data closer to the source, i.e., edge computing, reduces the need for data transmission to central servers, thereby improving real-time decision-making capabilities [12, 27]. Given the importances of machine learning in extracting value from IoT data, ML algorithms analyze vast amounts of data, identify trends, predict outcomes, and optimize operations [19, 33]. However, as noted by the researchers, integrating ML with IoT systems requires careful consideration of data quality and processing efficiency.

This study suggests that future research should develop hybrid models combining edge computing, cloud technologies, and ML algorithms to maximize the value extracted from IoT big data. Considering the impact of successfully extracting value from IoT data extends beyond individual applications [34, 35]. For instance, in smart cities, IoT data can improve public services, optimize resource allocation, and enhance residents' overall quality of life [36, 37]. Similarly, IoT data can enable personalized medicine in healthcare, promote patient outcomes, and reduce healthcare costs [20]; however, realizing these benefits requires addressing the challenges identified in this study, particularly those related to data heterogeneity and scalability, as highlighted by researchers.

Research Limitations

Given the reliance on existing literature and case studies, this study may not fully capture the rapidly evolving nature of IoT technologies. Additionally, the qualitative approach used in this study limits the generalizability of the findings; hence, future research should consider quantitative methods, such as large-scale surveys or experiments, to validate the insights gained from this study

6. Conclusion

In conclusion, extracting value from IoT big data sets presents significant challenges and opportunities; nevertheless, integrating edge computing, cloud technologies and machine learning offers a promising approach to addressing these challenges, thereby enabling more efficient data processing and real-time decision-making. However, the heterogeneity and complexity of IoT data require ongoing research to develop robust data architectures that can address the growing volume and variety of data. Regardless, this study contributes to understanding IoT big data analytics and provides a foundation for future research.

Future Research

As earlier suggested, future research should focus on developing hybrid data processing models that combine the strengths of edge computing, cloud technologies, and machine learning. Additionally, there is a need for more research on the ethical and privacy implications of IoT data collection and analysis, particularly as these technologies become more integrated into everyday life. Finally, future studies should explore the potential of blockchain technology to enhance the transparency and security of IoT data transactions.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest to be disclosed.

References

[1] Chaudhary, A. (2022). Internet of things (IOT): Research challenges and future applications. International Journal of Emerging Trends in Science and Technology. http://igmpublication.com/ijetst.in/index.php/ijetst/article/view/1559

[2] Wójcicki, K., Biegańska, M., Paliwoda, B., & Górna, J. (2022). Internet of things in industry: Research profiling, application, challenges and opportunities—a review. Energies, 15(5), 1806. https://doi.org/10.3390/en15051806

[3] Shafiq, M., Gu, Z., Cheikhrouhou, O., Alhakami, W., & Hamam, H. (2022). The Rise of "Internet of Things": Review and Open Research Issues Related to Detection and Prevention of IoT-Based Security Attacks. Wireless Communications and Mobile Computing, 2022(1), 8669348. https://doi.org/10.1155/2022/8669348

[4] Alsharif, M. H., Kelechi, A. H., Jahid, A., Kannadasan, R., Singla, M. K., Gupta, J., & Geem, Z. W. (2024). A comprehensive survey of energy-efficient computing to enable sustainable massive IoT networks. Alexandria Engineering Journal, 91, 12-29. https://doi.org/10.1016/j.aej.2024.01.067

[5] Rejeb, A., Rejeb, K., Appolloni, A., Jagtap, S., Iranmanesh, M., Alghamdi, S., & Kayikci, Y. (2024). Unleashing the power of internet of things and blockchain: A comprehensive analysis and future directions. Internet of Things and Cyber-Physical Systems, 4, 1-18. https://doi.org/10.1016/j.iotcps.2023.06.003

[6] Kumar, S. S., & Agarwal, S. (2024). Rule based complex event processing for IoT applications: Review, classification and challenges. Expert Systems, e13597. https://doi.org/10.1111/exsy.13597

[7] Rehman, Z., Tariq, N., Moqurrab, S. A., Yoo, J., & Srivastava, G. (2024). Machine learning and internet of things applications in enterprise architectures: Solutions, challenges, and open issues. Expert Systems, 41(1), e13467. https://doi.org/10.1111/exsy.13467

[8] Adeusi, K. B., Adegbola, A. E., Amajuoyi, P., Adegbola, M. D., & Benjamin, L. B. (2024). The potential of IoT to transform supply chain management through enhanced connectivity and real-time data. World Journal of Advanced Engineering Technology and Sciences, 12(1), 145-151. https://doi.org/10.30574/wjaets.2024.12.1.0202

[9] Alwahedi, F., Aldhaheri, A., Ferrag, M. A., Battah, A., & Tihanyi, N. (2024). Machine learning techniques for IoT security: Current research and future vision with generative AI and large language models. Internet of Things and Cyber-Physical Systems. https://doi.org/10.1016/j.iotcps.2023.12.003

[10] Marengo, A. (2024). Navigating the nexus of AI and IoT: A comprehensive review of data analytics and privacy paradigms. Internet of Things, 101318. https://doi.org/10.1016/j.iot.2024.101318

[11] Santhanagopalan, S., Ramachandran, M., & Rajan, A. P. (2024). AI-Enabled Data Processing for Real-World Applications of IoT: A Review-Based Approach. Semantic Web Technologies and Applications in Artificial Intelligence of Things, 356-370. https://doi.org/10.4018/979-8-3693-1487-6.ch017

[12] Modupe, O. T., Otitoola, A. A., Oladapo, O. J., Abiona, O. O., Oyeniran, O. C., Adewusi, A. O., & Obijuru, A. (2024). Reviewing the transformational impact of edge computing on real-time data processing and analytics. Computer Science & IT Research Journal, 5(3), 693-702. https://doi.org/10.51594/csitrj.v5i3.929

[13] Quy, N. M., Ngoc, L. A., Ban, N. T., Hau, N. V., & Quy, V. K. (2023). Edge computing for real-time Internet of Things applications: Future internet revolution. Wireless Personal Communications, 132(2), 1423-1452. https://doi.org/10.1007/s11277-023-10669-w

[14] Anees, T., Habib, Q., Al-Shamayleh, A. S., Khalil, W., Obaidat, M. A., & Akhunzada, A (2023). The integration of WoT and edge computing: Issues and challenges. Sustainability, 15(7), 5983. https://doi.org/10.3390/su15075983

[15] Bourechak, A., Zedadra, O., Kouahla, M. N., Guerrieri, A., Seridi, H., & Fortino, G. (2023). At the confluence of artificial intelligence and edge computing in iot-based applications: A review and new perspectives. Sensors, 23(3), 1639. https://doi.org/10.3390/s23031639

[16] Gkonis, P., Giannopoulos, A., Trakadas, P., Masip-Bruin, X., & D'Andria, F. (2023). A survey on IoT-edge-cloud continuum systems: status, challenges, use cases, and open issues. Future Internet, 15(12), 383. https://doi.org/10.3390/fi15120383

[17] George, A. S., George, A. H., & Baskar, T. (2023). Edge Computing and the Future of Cloud Computing: A Survey of Industry Perspectives and Predictions. Partners Universal International Research Journal, 2(2), 19-44. https://doi.org/10.5281/zenodo.8020101

[18] Kuchuk, H., & Malokhvii, E. (2024). INTEGRATION OF IOT WITH CLOUD, FOG, AND EDGE COMPUTING: A REVIEW. Advanced Information Systems, 8(2), 65-78. https://doi.org/10.20998/2522-9052.2024.2.08

[19] Strielkowski, W., Vlasov, A., Selivanov, K., Muraviev, K., & Shakhnov, V. (2023). Prospects and challenges of the machine learning and data-driven methods for the predictive analysis of power systems: A review. Energies, 16(10), 4025. https://doi.org/10.3390/en16104025

[20] Adeghe, E. P., Okolo, C. A., & Ojeyinka, O. T. (2024). A review of the use of machine learning in predictive analytics for patient health outcomes in pharmacy practice. OARJ of Life Sciences, 7(01), 052-058. https://doi.org/10.53022/oarjls.2024.7.1.0026

[21] Tran, M. Q., Doan, H. P., Vu, V. Q., & Vu, L. T. (2023). Machine learning and IoT-based approach for tool condition monitoring: A review and future prospects. Measurement, 207, 112351. https://doi.org/10.1016/j.measurement.2022.112351

[22] Mazhar, T., Irfan, H. M., Haq, I., Ullah, I., Ashraf, M., Shloul, T. A., & Elkamchouchi, D. H. (2023). Analysis of challenges and solutions of IoT in smart grids using AI and machine learning techniques: A review. Electronics, 12(1), 242. https://doi.org/10.3390/electronics12010242

[23] Knox, M. (2023). Design-related impacts on end-of-life experience: a brief report of findings from an exploratory qualitative study. American Journal of Hospice and Palliative Medicine®, 40(7), 753-760. https://doi.org/10.1177/10499091221129203

[24] Lakshmanna, K., Kaluri, R., Gundluru, N., Alzamil, Z. S., Rajput, D. S., Khan, A. A., & Alhussen, A. (2022). A review on deep learning techniques for IoT data. Electronics, 11(10), 1604. https://doi.org/10.3390/electronics11101604

[25] Domínguez-Bolaño, T., Campos, O., Barral, V., Escudero, C. J., & García-Naya, J. A. (2022). An overview of IoT architectures, technologies, and existing open-source projects. Internet of Things, 20, 100626. https://doi.org/10.1016/j.iot.2022.100626

[26] Chinnici, M., & De Vito, S. (2022). IoT meets opportunities and challenges: edge computing in deep urban environment. Dependable IoT for Human and Industry, 241-272. https://doi.org/10.1201/9781003337843

[27] Kong, L., Tan, J., Huang, J., Chen, G., Wang, S., Jin, X., ... & Das, S. K. (2022). Edge computing-driven internet of things: A survey. ACM Computing Surveys, 55(8), 1-41. https://doi.org/10.1145/3555308

[28] Walia, G. K., Kumar, M., & Gill, S. S. (2023). AI-empowered fog/edge resource management for IoT applications: A comprehensive review, research challenges and future perspectives. IEEE Communications Surveys & Tutorials. https://doi.org/10.1109/COMST.2023.3338015

[29] Aminizadeh, S., Heidari, A., Toumaj, S., Darbandi, M., Navimipour, N. J., Rezaei, M., & Unal, M. (2023). The applications of machine learning techniques in medical data processing based on distributed computing and the Internet of Things. Computer methods and programs in biomedicine, 107745. https://doi.org/10.1016/j.cmpb.2023.107745

[30] Sarker, I. H., Khan, A. I., Abushark, Y. B., & Alsolami, F. (2023). Internet of things (iot) security intelligence: a comprehensive overview, machine learning solutions and research directions. Mobile Networks and Applications, 28(1), 296-312. https://doi.org/10.1007/s11036-022-01937-3

[31] Li, C., Chen, Y., & Shang, Y. (2022). A review of industrial big data for decision making in intelligent manufacturing. Engineering Science and Technology, an International Journal, 29, 101021. https://doi.org/10.1016/j.jestch.2021.06.001

[32] Sarker, S., Arefin, M. S., Kowsher, M., Bhuiyan, T., Dhar, P. K., & Kwon, O. J. (2022). A comprehensive review on Big Data for industries: challenges and opportunities. IEEE Access, 11, 744-769. https://doi.org/10.1109/ACCESS.2022.3232526

[33] Bzai, J., Alam, F., Dhafer, A., Bojović, M., Altowaijri, S. M., Niazi, I. K., & Mehmood, R. (2022). Machine learning-enabled internet of things (iot): Data, applications, and industry perspective. Electronics, 11(17), 2676. https://doi.org/10.3390/electronics11172676

[34] Sunhare, P., Chowdhary, R. R., & Chattopadhyay, M. K. (2022). Internet of things and data mining: An application oriented survey. Journal of King Saud University-Computer and Information Sciences, 34(6), 3569-3590. https://doi.org/10.1016/j.jksuci.2020.07.002

[35] Allioui, H., & Mourdi, Y. (2023). Exploring the full potentials of IoT for better financial growth and stability: A comprehensive survey. Sensors, 23(19), 8015. https://doi.org/10.3390/s23198015

[36] Alahi, M. E. E., Sukkuea, A., Tina, F. W., Nag, A., Kurdthongmee, W., Suwannarat, K., & Mukhopadhyay, S. C. (2023). Integration of IoT-enabled technologies and artificial intelligence (AI) for smart city scenario: recent advancements and future trends. Sensors, 23(11), 5206. https://doi.org/10.3390/s23115206

[37] Gracias, J. S., Parnell, G. S., Specking, E., Pohl, E. A., & Buchanan, R. (2023). Smart cities—a structured literature review. Smart Cities, 6(4), 1719-1743. https://doi.org/10.3390/smartcities6040080