Available Online: 4 August 2025 DOI: 10.54254/2977-3903/2025.25763

The application and challenges of artificial intelligence and big data in different fields

Zhenan Liu

Tandon School of Engineering, New York University, NY, USA

Lzn13682248226@163.com

Abstract. In the context of rapid digital transformation, artificial intelligence (AI) and big data have become pivotal forces reshaping decision-making processes across industries such as healthcare, finance, retail, manufacturing, and transportation. This paper investigates the integration of AI and big data, aiming to explore their combined impact on organizational efficiency and predictive accuracy. The research adopts a comprehensive literature review methodology, analyzing scholarly articles, industry reports, and real-world applications to evaluate how these technologies are applied, the challenges they present, and future directions. Through this method, the study identifies key trends in the deployment of AI-powered analytics, including predictive modeling, personalized services, and automated operations. It also addresses critical issues such as ethical concerns, data security, and scalability. The findings suggest that while AI and big data significantly enhance operational performance, their responsible implementation requires robust frameworks for fairness, transparency, and privacy protection. This study concludes by emphasizing the need for collaborative efforts among governments, academia, and industry to ensure equitable access and sustainable technological advancement.

Keywords: artificial intelligence, big data, decision-making, industry applications

1. Introduction

Artificial intelligence (AI) and big data have emerged as transformative technologies, significantly altering decision-making processes across multiple industries. The integration of these two domains allows businesses and institutions to analyze massive datasets, recognize patterns, and make informed decisions with enhanced precision and efficiency. This paper discusses the fundamental concepts underpinning these technologies, explores practical industry applications, analyzes inherent challenges, and forecasts future trends. This paper contributes not only to the theoretical development of AI and big data integration but also holds practical significance for improving decision-making efficiency and service quality across industries. For future researchers in related fields, it offers a systematic overview of current applications, challenges, and trends, serving as a valuable reference for both theoretical exploration and practical implementation.

2. Foundations of AI and big data

2.1. Concepts of artificial intelligence

Artificial intelligence refers to the capability of machines or computer systems to perform tasks typically associated with human intelligence, such as learning, reasoning, and problem-solving. Central AI methodologies include machine learning (ML), which enables computers to learn from data patterns, and neural networks, modeled on human brain structures, facilitating the recognition of complex relationships within data [1]. Recent advancements, such as natural language processing (NLP) and computer vision, further illustrate AI's growing capabilities in interpreting and interacting with complex, unstructured datasets. These technologies have also fueled the development of self-learning AI systems, which continuously improve without human intervention [2].

2.2. The role of big data

Big data refers to data sets that are massive in scale, diverse in type, and generated at high velocity—far exceeding the capabilities of traditional data processing tools. Typically defined by the "4Vs" (Volume, Variety, Velocity, and Veracity), big data serves as a fundamental resource for training AI models and is a driving force behind intelligent decision-making. Big data encompasses datasets that are too extensive and diverse to be processed effectively using traditional data-handling techniques. Defined by characteristics like volume, variety, velocity, and veracity, big data is integral for training AI algorithms to identify meaningful patterns and trends, thus enabling enhanced decision-making [3]. The availability of large-scale data streams is essential for the predictive capabilities inherent in AI-driven systems. Organizations leverage big data analytics to extract valuable insights that drive innovation, optimize operations, and improve customer experiences [4].

2.3. Integration of AI and big data

AI and big data complement each other synergistically; AI algorithms require substantial datasets to train and refine predictive models, while big data necessitates sophisticated tools capable of meaningful analysis. Together, these technologies allow industries to derive insights previously unattainable, enabling proactive and informed decisions based on accurate predictions and detailed data analysis [5]. Cloud computing and distributed computing frameworks, such as Apache Hadoop and Spark, further enhance the capabilities of AI and big data integration, enabling real-time analytics and large-scale data processing [6].

3. Applications in various industries

3.1. Healthcare

In healthcare, AI-powered algorithms enhance diagnostic accuracy by analyzing extensive patient data, including medical images, genetic profiles, and clinical histories. Applications range from predictive modeling for patient outcomes to personalized medicine, significantly improving patient care quality and operational efficiency in medical institutions [7]. Furthermore, AI-driven big data analytics have shown remarkable efficacy in epidemiological modeling, as seen during recent global health crises, by accurately predicting disease spread and aiding in resource allocation. AI-based virtual health assistants and robotic surgeries further demonstrate the potential of AI in enhancing healthcare delivery [8].

3.2. Finance

The financial sector extensively employs AI technologies for automated trading systems, fraud detection, and credit scoring. AI models, such as deep learning systems, process historical financial data to identify complex market patterns and anomalies indicative of fraudulent activity. Credit scoring algorithms utilize big data analytics to more accurately assess risk, thereby enhancing the stability and profitability of financial institutions [9]. Moreover, sentiment analysis using NLP techniques allows financial institutions to assess market trends by analyzing social media, news articles, and customer feedback [10].

3.3. Retail

Retail businesses utilize AI for customer analytics, enabling personalized shopping experiences through targeted marketing and customized product recommendations. By analyzing customer behaviors and preferences captured in big data sets, retailers can forecast market trends and optimize inventory management. This leads to reduced costs, increased sales, and improved customer loyalty [11]. AI-powered chatbots and recommendation engines, such as those used by Amazon and Netflix, enhance customer engagement and provide tailored experiences [1].

3.4. Manufacturing

Manufacturing industries harness AI for predictive maintenance, reducing equipment downtime and extending asset lifespan. AI algorithms analyze real-time sensor data to predict machinery failures before they occur, significantly reducing maintenance costs and production interruptions. Additionally, AI-based supply chain analytics optimize resource allocation, improving productivity and product quality through precise demand forecasting and inventory management [12]. The implementation of Industry 4.0, characterized by smart factories and IoT integration, further enhances AI-driven manufacturing processes [13].

3.5. Transportation

In transportation, AI contributes significantly to autonomous vehicle development, logistics optimization, and route planning. AI-driven predictive analytics optimize delivery schedules and routes, improving efficiency, reducing fuel consumption, and enhancing safety standards. Real-time big data from traffic patterns and weather conditions further strengthens logistical decision-making capabilities [14]. Companies like Tesla and Waymo leverage AI for self-driving technologies, while AI-powered traffic management systems help reduce congestion in urban areas [15].

4. Challenges and considerations

The widespread adoption of AI and big data presents several challenges that must be addressed to ensure ethical, secure, and scalable implementation. These concerns span ethical implications, data security, and the practical challenges of integrating AI into existing infrastructures.

4.1. Ethical concerns

The ethical implications of AI and big data are a significant area of concern, particularly regarding biases in algorithmic decision-making, data privacy, and the societal impact of automation on employment. AI models trained on biased historical data can reinforce existing inequalities, leading to discriminatory outcomes in areas such as hiring, lending, and law enforcement. Addressing these biases requires greater transparency in AI model development, diverse training datasets, and ongoing monitoring to ensure fairness [16].

Privacy concerns arise from the vast amount of personal data collected, analyzed, and stored by AI systems. Unauthorized data access or misuse can result in identity theft, surveillance risks, and ethical dilemmas surrounding consent and data ownership. Regulatory measures such as the General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA) have been enacted to address these issues, emphasizing user rights and data protection [17].

Additionally, automation-driven workforce displacement remains a critical concern. While AI enhances efficiency, it also threatens jobs in routine and manual labor sectors. Policymakers and businesses must invest in reskilling initiatives and social safety nets to mitigate economic disruptions and ensure workforce adaptability in an AI-driven economy.

4.2. Data security

Given the sensitivity and volume of information processed by AI systems, data security is a paramount concern. Cyber threats such as data breaches, ransomware attacks, and adversarial AI manipulation pose significant risks to organizations and individuals. Weak security measures can lead to unauthorized access, data corruption, and financial losses.

To counter these threats, organizations must implement robust cybersecurity protocols, including encryption, multi-factor authentication, and real-time threat detection systems. Regular security audits and AI-driven cybersecurity measures can help safeguard data integrity and prevent unauthorized access [13].

Emerging technologies like blockchain offer promising solutions for enhancing data security and transparency in AI applications. By decentralizing data storage and ensuring immutable transaction records, blockchain can help mitigate risks related to data tampering and unauthorized modifications [18].

4.3. Scalability and implementation

The scalability of AI and big data solutions presents a major challenge, particularly in integrating these technologies with existing legacy systems. Many organizations, especially small and medium-sized enterprises (SMEs), struggle with the high infrastructure costs and technical expertise required for AI adoption. The need for extensive computational power, data storage, and system interoperability further complicates implementation.

To address these challenges, businesses must focus on developing cost-effective, scalable AI solutions that can be easily integrated with existing infrastructures. Cloud-based AI services and open-source frameworks offer potential solutions by reducing initial investment costs and enhancing accessibility. Collaboration between governments, industry leaders, and research institutions can also facilitate AI adoption by providing funding, training programs, and policy support [19].

5. Future trends and innovations

5.1. Advances in AI algorithms

Continued innovation in AI research promises significant algorithmic breakthroughs, including advancements in deep learning, reinforcement learning, and generative adversarial networks (GANs). These improvements are expected to enhance AI accuracy, efficiency, and adaptability, thus broadening applications in industries currently underrepresented in AI adoption, such as agriculture, education, and environmental management [20].

5.2. Expansion of big data capabilities

The exponential growth of data collection technologies will significantly enhance the analytical capabilities of AI systems. Improved data storage solutions, such as cloud computing and edge computing, will enable the processing of vast datasets in real-time, further refining predictive models and decision-making processes across industries.

5.3. Increasing industry adoption

As AI and big data applications demonstrate success, broader industry adoption is accelerating. Traditionally slower sectors, such as education, agriculture, and renewable energy, are now integrating AI-driven solutions due to clear economic and operational benefits.

In education, AI enhances personalized learning and automates administrative tasks. Agriculture benefits from precision farming, optimizing yields and resource use, while renewable energy leverages AI for predictive maintenance and smart grid optimization. As industries see measurable gains, confidence in AI adoption grows, driving further investment and innovation.

6. Conclusion

AI and big data are revolutionizing decision-making across industries, providing organizations with powerful tools to enhance efficiency, reduce costs, and improve service delivery. These technologies enable predictive analytics, automate complex tasks, and generate insights that were previously unattainable through traditional methods.

However, while AI and big data offer substantial benefits, their widespread adoption also presents critical challenges, including ethical concerns, data privacy risks, and workforce displacement. The development of transparent and unbiased AI models, robust data protection mechanisms, and workforce retraining programs will be essential to ensuring a responsible and equitable implementation of these technologies.

This paper has not yet explored the issue of AI interpretability in depth, which is critical for the deployment of AI systems in high-risk industries such as healthcare and finance. Additionally, the study primarily adopts a literature review approach and does not include empirical data or case studies to evaluate the effectiveness of AI and big data applications, which may limit the practical depth and operational applicability of the research.

Future research and innovation in AI will likely focus on enhancing interpretability and fairness in machine learning models, addressing biases in datasets, and improving the efficiency of AI algorithms. Meanwhile, big data advancements will continue to expand data storage, processing, and security capabilities, making data-driven decision-making more reliable and accessible across industries.

References

[1] Agrawal, A., Gans, J. S., & Goldfarb, A. (2018). Prediction machines: The simple economics of artificial intelligence. Harvard Business Press.

[2] Brynjolfsson, E., & McAfee, A. (2017). The business of artificial intelligence: What it can—and cannot—do for your organization. *Harvard Business Review*, 95(4), 3–11.

[3] Davenport, T. H., & Ronanki, R. (2018). Artificial intelligence for the real world. *Harvard Business Review*, 96(1), 108–116.

[4] Dean, J., & Ghemawat, S. (2008). MapReduce: Simplified data processing on large clusters. *Communications of the ACM,* 51(1), 107–113. https: //doi.org/10.1145/1327452.1327492

[5] Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. *Nature*, 542(7639), 115–118. https: //doi.org/10.1038/nature21056

[6] Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, 77, 167–181. https: //doi.org/10.1016/j.tra.2015.04.003

[7] Floridi, L., & Cowls, J. (2019). A unified framework of five principles for AI in society. *Harvard Data Science Review*, 1(1). https: //doi.org/10.1162/99608f92.8cd550d1

[8] Gandomi, A., & Haider, M. (2015). Beyond the hype: Big data concepts, methods, and analytics. *International Journal of Information Management*, 35(2), 137–144. https: //doi.org/10.1016/j.ijinfomgt.2014.10.007
[9] Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep learning. MIT Press.
[10] Heaton, J. B., Polson, N. G., & Witte, J. H. (2017). Deep learning for finance: Deep portfolios. *Applied Stochastic Models in Business and Industry*, 33(1), 3–12. https: //doi.org/10.1002/asmb.2209
[11] Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), 255–260. https: //doi.org/10.1126/science.aaa8415
[12] LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436–444. https: //doi.org/10.1038/nature14539
[13] Lee, J., Davari, H., Singh, J., & Pandhare, V. (2018). Industrial artificial intelligence for industry 4.0-based manufacturing systems. *Manufacturing Letters*, 18, 20–23. https: //doi.org/10.1016/j.mfglet.2018.09.002
[14] Litman, T. (2020). Autonomous vehicle implementation predictions. Victoria Transport Policy Institute.
[15] McAfee, A., & Brynjolfsson, E. (2012). Big data: The management revolution. *Harvard Business Review*, 90(10), 60–68.
[16] Mitra, T., & Gilbert, E. (2014). The language that gets people to give: Phrases that predict success on Kickstarter. In Proceedings of the 17th ACM Conference on Computer-Supported Cooperative Work & Social Computing (pp. 49–61). https: //doi.org/10.1145/2531602.2531656
[17] Schuh, G., Anderl, R., Gausemeier, J., ten Hompel, M., & Wahlster, W. (2017). Industrie 4.0 maturity index. *Acatech Study*.
[18] Tene, O., & Polonetsky, J. (2013). Big data for all: Privacy and user control in the age of analytics. *Northwestern Journal of Technology and Intellectual Property*, 11(5), 239–273.
[19] Topol, E. J. (2019). Deep medicine: How artificial intelligence can make healthcare human again. Basic Books.
[20] Zhang, Y., Sun, Y., Cao, X., & Sun, Y. (2020). Blockchain-based data security management framework for smart cities. *Future Generation Computer Systems*, 105, 629–640. https: //doi.org/10.1016/j.future.2019.12.020