

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/381043810>

Transformative Impact of Artificial Intelligence on IoT Applications: A Systematic Review of Advancements, Challenges, and Future Trends

Article · May 2024

DOI: 10.5281/zenodo.11397763

CITATIONS

2

READS

143

4 authors, including:



Amanullah Totakhail

Sayed Jamaluddin Afghani University

1 PUBLICATION 2 CITATIONS

SEE PROFILE



Hamayoon Ghafory

Kabul Education University

10 PUBLICATIONS 98 CITATIONS

SEE PROFILE



Musawer Hakimi

Samangan University

66 PUBLICATIONS 393 CITATIONS

SEE PROFILE



Research Article

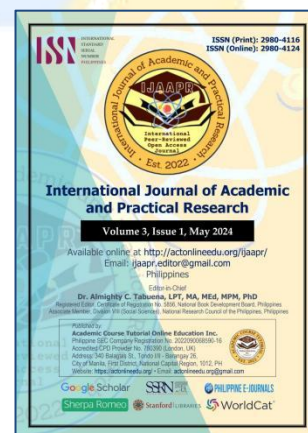
Transformative Impact of Artificial Intelligence on IoT Applications: A Systematic Review of Advancements, Challenges, and Future Trends

Zakirullah Ezam¹, Amanullah Totakhail¹,
Hamayoon Ghafory² , and Musawer Hakimi³ 

¹Sayed Jamaluddin Afghani University, Kunar, Afghanistan

²Kabul Education University, Kabul, Afghanistan

³Samangan University, Samangan, Afghanistan



Article Information

Article ID Number

202404092

Article History

Received	30	Apr	2024
Reviewed	08	May	2024
Revised	15	May	2024
Accepted	22	May	2024
Published	30	May	2024

Gunning Fog Index: 18.83

Corresponding Author

Musawer Hakimi
musawer@adc.edu.in

Quick Response Code



Copyright © 2024 by the Author/s

Abstract

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) has significantly transformed various industries, presenting both challenges and opportunities. This study conducts a comprehensive literature analysis to examine the impact of AI on enhancing IoT applications. It addresses important questions including the advancements, difficulties, opportunities, and future trends related to AI in this context. A systematic approach, following the guidelines of PRISMA, was employed to identify, select, and examine relevant academic articles published between 2016 and 2024. By carefully collecting and combining data from selected research, comprehensive insights into the current status of AI-integrated IoT applications were gained. The aim of this study is to provide a comprehensive understanding of how AI is revolutionizing IoT applications. It explores significant advancements, challenges, opportunities, and future directions. Through the utilization of a methodical approach, relevant data were collected and combined to facilitate a comprehensive examination of AI-driven advancements in different sectors. The results reveal a situation full of potential for transformation, showcasing advancements in AI in areas such as manufacturing, healthcare, home automation, urban planning, and cybersecurity. These developments emphasize the vital role of AI in enhancing operational efficiency, improving healthcare delivery, setting higher standards for residential life, and fostering sustainable urban expansion. However, it is important to address concerns around data privacy and security, the interoperability of different systems, limitations in scalability, and the lack of skilled workers in order to fully take advantage of the prospects provided by AI-powered IoT applications. Overall, the combination of AI and IoT holds significant potential for driving technological advancement and fostering interconnected and sustainable solutions in several domains. By addressing obstacles and leveraging advantages, organizations can harness the vast potential of AI-integrated IoT applications, propelling the era of digital advancement and societal development.

Keywords

artificial intelligence, challenges, innovations, internet of things, opportunities

DOI  10.5281/zenodo.11397763

URL: <https://actonlineedu.org/ijaapr-v3i1-202404092>

INTRODUCTION

Background of the Study

The combination of Artificial Intelligence (AI) and the Internet of Things (IoT) has attracted considerable interest from researchers and practitioners in recent years. This integration has had a profound impact on different parts of human life and industries (Al-Turjman, 2019; Singla, 2020; Al-Turjman et al., 2021). The combination of AI and IoT has resulted in the creation of smart devices that can make decisions on their own, transforming various fields including healthcare, manufacturing, transportation, and smart cities (Sepasgozar et al., 2020; Marikyan et al., 2019; Jan et al., 2023). Through the utilization of AI algorithms, IoT devices have the ability to analyze intricate data in real-time, enhance processes, and independently adjust to dynamic situations (Wu et al., 2020; Stojkoska & Trivodaliev, 2017).

The integration of artificial intelligence (AI) and Internet of Things (IoT) has led to a wide range of creative applications in many industries. These examples include predictive maintenance in manufacturing and remote patient monitoring in healthcare (Hassan et al., 2018; Lin et al., 2019). Nevertheless, the process of integrating these systems also brings up several obstacles, such as concerns over the privacy and security of data, as well as difficulties in achieving interoperability (Lv et al., 2021; Zhang et al., 2021). However, researchers persist in investigating innovative AI-powered solutions to tackle these obstacles and unleash the complete potential of AI in boosting IoT applications (Qinxia et al., 2021).

An extensive analysis of the current body of literature on AI-enabled IoT applications uncovers a wide range of research covering several areas like cybersecurity, smart home technologies, and predictive analytics (Sepasgozar et al., 2019; Chen et al., 2020; Abdullahi et al., 2022). Scientists have examined the consequences of artificial intelligence (AI) in improving the security of the Internet of Things (IoT), facilitating predictive analytics, and optimizing the allocation of resources in intelligent cities (Serrano et al., 2018; Zhou et al., 2016; Hansen & Bøgh, 2021). Furthermore, research has examined the impact of artificial intelligence (AI) on enhancing the productivity and efficacy of Internet of Things (IoT) devices, thus facilitating the development of smarter and self-governing systems (Dwivedi et al., 2021; Liao et al., 2020). Moreover, the integration of AI with IoT has resulted in the creation of novel solutions for applications that prioritize human needs, such as personalized healthcare, smart agriculture, and environmental monitoring (Chen et al., 2020; Abdullahi et al., 2022). These innovations have significant potential to address urgent societal concerns and enhance the quality of life for many populations (Al-Turjman, 2019; Singla, 2020).

This systematic review seeks to thoroughly analyze the current literature, methodology, and future research directions in order to address the increasing significance of AI-enabled IoT applications. This review aims to analyze and consolidate important findings from various studies and highlight areas where current research is lacking. Its purpose is to provide valuable insights to researchers, practitioners, and policymakers regarding the significant impact of AI on improving IoT applications. Additionally, it aims to offer guidance for future research endeavors in this rapidly growing field.

Literature Review

The combination of Artificial Intelligence (AI) and the Internet of Things (IoT) has brought about a new period of technical advancement, transforming several industries by integrating intelligent systems and interconnected gadgets in a smooth manner. This systematic review rigorously analyzes the profound influence of artificial intelligence (AI) on improving Internet of Things (IoT) applications in several fields. It draws valuable insights from influential publications in the field. In his work, Al-Turjman (2019) offers a comprehensive explanation of the integration of Artificial Intelligence (AI) in the Internet of Things (IoT), clarifying the essential concepts and principles that form the basis of this mutually beneficial connection. In Singla's (2020) study, the author investigates the use of artificial intelligence (AI) in the Internet of Things (IoT) in healthcare. The study demonstrates how AI-powered analytics and predictive modeling significantly transform patient care and remote monitoring, ultimately resulting in tailored treatment approaches. Al-Turjman et al. (2021) extensively explore the notion of "Intelligence of Things," highlighting the crucial role of AI in promoting innovation and facilitating important applications in different sectors.

The incorporation of artificial intelligence (AI) into the Internet of Things (IoT) has had a substantial influence on intelligent environments, improved user interactions, and optimized the management of resources. Sepasgozar et al. (2020) provide a comprehensive analysis of AI and IoT applications in smart homes, emphasizing the user-focused approach enabled by AI-powered systems. In a similar vein, Sepasgozar et al. (2019) put forth a framework for forecasting the level of approval that citizens will have towards smart city technology, emphasizing the significance of artificial intelligence in creating solutions that are easy for users to navigate. Marikyan et al. (2019) offer a viewpoint that focuses on the needs and preferences of users when it comes to smart home technology. They highlight the significance of artificial intelligence in customizing and automating various household chores. The influence of AI goes beyond residential and urban areas to industrial environments, where it facilitates automation, predictive maintenance, and process optimization. Jan et al. (2023) and Fazil et al. (2023) provide a comprehensive analysis of the use of artificial intelligence (AI) in Industry 4.0. They emphasize the significant changes it brings to manufacturing processes and supply chain management. Asghari et al. (2019) presents a comprehensive analysis of IoT implementations in many industries, demonstrating how AI significantly improves operational efficiency and fosters innovation.

The interconnectivity of IoT systems gives rise to substantial security risks, requiring the implementation of strong cybersecurity solutions. In this study, Abdullahi et al. (2022) do a comprehensive analysis of artificial intelligence (AI) techniques for identifying cybersecurity attacks in the Internet of Things (IoT). This findings highlight the capability of AI in enhancing security protocols and reducing potential risks. Wu et al. (2020) increase the existing knowledge by conducting a survey on the study related to the improvement of security in Internet of Things (IoT) through the use of artificial intelligence (AI). They investigate several AI algorithms that may be used for detecting threats and assessing risks.



Although AI has the ability to bring about significant changes in IoT, there are still ongoing concerns related to data privacy, security risks, and interoperability. In their 2017 publication, Stojkoska and Trivodaliev examine the obstacles and remedies associated with smart houses constructed using the Internet of Things (IoT) framework. They highlight the importance of implementing strong security measures and established protocols. Liao et al. (2020) emphasize the significance of doing security analysis on IoT devices, emphasizing the crucial function of AI in identifying and reducing vulnerabilities. In the future, researchers are investigating the possibility of using artificial intelligence (AI) to develop highly advanced Internet of Things (IoT) applications. Hassan et al. (2018) and Hasas et al. (2024) offer an advanced patient monitoring model that utilizes artificial intelligence and cloud computing to uncover valuable information in the healthcare field. This model opens up possibilities for tailored and proactive healthcare treatments. Lin et al. (2019) demonstrates the utilization of artificial intelligence on Internet of Things (IoT) devices, which facilitates the development of distributed intelligence and edge computing.

To summarize, this systematic analysis highlights the significant impact of AI on improving IoT applications in several fields. Artificial intelligence enhances Internet of Things (IoT) systems by providing them with the ability to analyze data, make decisions, automate processes, and ensure security. This integration has resulted in notable progress in several fields such as healthcare, smart homes, cities, industries, and more. As research progresses in understanding the possibilities of this mutually beneficial relationship, we may anticipate the emergence of increasingly more advanced and intelligent Internet of Things (IoT) applications. This will propel the era of digital transformation and contribute to societal growth.

Theoretical and Conceptual framework

This study's theoretical and conceptual framework explores the symbiotic link between artificial intelligence (AI) and the internet of things (IoT), as well as the transformational potential that these two technologies offer across numerous fields. It is based on this junction. The framework highlights the fundamental role of AI in enhancing IoT applications, enabling predictive maintenance, healthcare monitoring, smart home technologies, and urban planning solutions. It draws on seminal publications such as Al-Turjman (2019), Singla (2020), and Sepasgozar et al. (2020). Furthermore, research by Abdullahi et al. (2022) and Asghari et al. (2019) shapes the conceptual understanding of AI-enabled IoT ecosystems by shedding light on the difficulties relating to data security and interoperability. By outlining the potential for improving security and predictive analytics in IoT contexts through AI interventions, Lv et al. (2021) and Wu et al. (2020) add to the framework. Furthermore, studies conducted in 2019 by Lin et al. and Marikyan et al. provide insights into how AI-driven automation and user-centric design are conceptualized in IoT architecture. As noted by Qinxia et al. (2021) and Hasas et al. (2024), the framework is further enhanced by the investigation of new developments, such as explainable AI (Ribeiro et al., 2016), edge computing (Li et al., 2021), and energy-efficient algorithms (Yang et al., 2020). Through the synthesis of these fundamental and innovative findings, this study offers a thorough theoretical framework for examining the complex dynamics of AI-enabled Internet of Things applications, opening up new avenues for future investigation and invention in this quickly developing field.

Statement of the Problem

The incorporation of Artificial Intelligence (AI) into Internet of Things (IoT) applications brings numerous potential and problems across multiple industries. As AI-driven technologies become more prevalent in numerous industries, it is critical to fully understand their influence on IoT systems. The purpose of this study is to conduct a comprehensive literature review to look into the advances, challenges, and future trends in AI-enabled IoT applications. By examining the intersection of AI and IoT, the study hopes to provide useful insights into maximizing the benefits and overcoming the challenges of integrating these transformative technologies, thereby contributing to the advancement of digital innovation and societal progress. Throughout the study, we will seek answers to the following questions:

1. What is the leading AI-driven advancements in different industries in the context of IoT applications?
2. What are the difficulties and advantages that emerge from the integration of AI into IoT systems, and how can these be resolved?
3. What are the expected future trends and research directions in the field of AI-enabled IoT applications?

METHODS

The study titled "The Role of Artificial Intelligence in Enhancing IoT Applications: A Systematic Review" followed the principles of systematic literature review (SLR) with great attention to detail. As outlined by Asghari et al. (2019), systematic literature review (SLR) is a rigorous and transparent method that guarantees the dependability and credibility of the review results. It follows a systematic, complete, and replicable process. Using content analysis, a hybrid technique that combines text analysis, following the methodology proposed by Zheng et al. (2018), with a focus on assessing validity in accordance with the study objective. The choice of utilizing SLR as the methodological framework for this study was motivated by the aim of investigating literature pertaining to the potential advantages and obstacles presented by the incorporation of artificial intelligence in IoT applications. This undertaking encompassed crucial stages, including the development of research inquiries, carrying out a comprehensive examination of existing literature, implementing predetermined criteria for inclusion, exclusion, and quality, and executing a methodology for analysis, as emphasized by Asghari et al. (2019). This methodological approach facilitated the retrieval of relevant ideas from the chosen publications, with specific attention given to the keywords employed in the search procedure. Following the systematic strategy advocated by Sepasgozar et al. (2020), we acquired and examined all pertinent literature within the study's scope. The review process was undertaken with great attention to detail, following the methodology advocated by Lv (2021). This methodology emphasizes the need of sticking to a systematic approach to guarantee the review conclusions are rigorous and complete.

Figure 1 depicts the step-by-step procedure used in this systematic literature review, incorporating knowledge from many authors. The technique included rigorous procedures to find, select, and analyze literature, ensuring the strength and credibility of the review results.

Figure 1
Step-by-Step Procedure for Conducting a Systematic Literature Review (SLR)



The diagram illustrates the systematic methodology employed in conducting a Systematic Literature Review (SLR). The process commences by establishing the Scope and Objective in order to elucidate the specific area of research. The process of identifying a database include choosing specific databases to search for material that is relevant to the topic. Accurate definition of search terms is essential for the purpose of filtering and retrieving certain research. Inclusion and exclusion criteria are set to ascertain the suitability of articles for eligibility. Article extraction from a database refers to the systematic retrieval of selected articles. Data Synthesis is the stage in which the retrieved data is carefully examined and merged together to provide the conclusions of the review. This systematic procedure guarantees a thorough and impartial gathering of study data.

Table 1
Search Strategies in Databases for AI and IoT Literature

Database Searched	Search Terms	Boolean Operators Used	Search Strategy
HINDAWI	"Artificial Intelligence" AND "Internet of Things"	AND	Specific search terms combined using AND operator
RESEARCH GATE	AI AND IoT	AND	Keywords AI and IoT combined using AND operator
IEEE	"AI" OR "Artificial Intelligence" AND "IoT" OR "Internet of Things"	OR, AND	AI-related terms OR IoT-related terms combined using OR operator, then both sets combined using AND operator
ACM DIGITAL LIBRARY	"Artificial Intelligence" OR "AI" AND "Internet of Things" OR "IoT"	OR, AND	AI-related terms OR IoT-related terms combined using OR operator, then both sets combined using AND operator
SPRINGER	"AI" AND "IoT"	AND	Keywords AI and IoT combined using AND operator

The table above, labeled as Table 1, provides an overview of the search tactics used in different databases to collect literature on Artificial Intelligence (AI) and the Internet of Things (IoT). The text demonstrates a persistent utilization of Boolean operators such as "AND" and "OR" to enhance the precision of search outcomes. For example, the HINDAWI and RESEARCH GATE databases employ the logical operator "AND" to ensure that articles include both AI and IoT. Unlike IEEE and ACM DIGITAL LIBRARY, which utilize a mix of "OR" and "AND" operators, the search is broadened to encompass any AI-related phrases in conjunction with IoT. SPRINGER's technique is direct, employing the use of "AND" to directly connect AI and IoT.

Table 2
Parameters for Article Inclusion and Exclusion

Inclusion Criteria	Exclusion Criteria
Articles directly address the role of AI in enhancing IoT applications.	Lack of relevance to the role of AI in enhancing IoT applications.
Articles published between 2017 and 2024, aligning with contemporary research.	Articles published before 2017 or after 2024.
Articles focus on AI-driven innovations, challenges, opportunities, or future trends within IoT applications.	Articles focusing on AI-driven innovations, challenges, opportunities, or future trends within IoT applications.
Only peer-reviewed articles are considered, ensuring the reliability and credibility of the research.	Non-peer-reviewed articles, such as blog posts or opinion pieces.
Article written in English Language	Articles not written in English.

The above table 2 delineates the **Inclusion and Exclusion Criteria** for selecting scholarly articles. Inclusion involves articles relevant to the research topic, published between **2017 and 2024**, focusing on **AI-driven innovations** within IoT applications, and must be **peer-reviewed** and in **English**. Exclusion criteria filter out articles that lack relevance to AI's role in IoT, are outside the specified publication years, are not peer-reviewed, or are not in English. This ensures a focused and high-quality dataset for analysis, reflecting the most pertinent and credible research in the field.

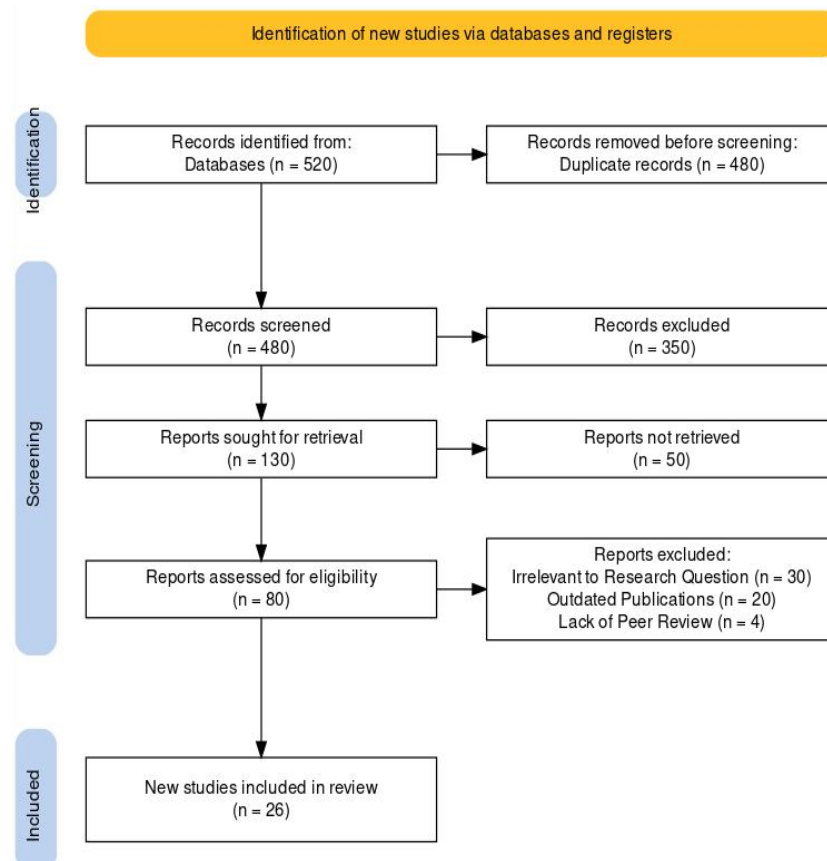
Data Extraction

The process of data extraction entailed a methodical approach to locating, gathering, and analyzing pertinent information from the chosen articles. Every article that met the requirements for inclusion was carefully examined to extract important data points pertaining to the function of artificial intelligence in improving Internet of Things (IoT) applications. This involved gathering information on AI-driven advancements, difficulties, prospects, and forthcoming patterns in many fields such as healthcare, manufacturing, smart cities, and cybersecurity. The data extraction process also included information regarding the methodology used, findings presented, and implications discussed in each piece. By conducting a methodical process of extracting data, we were able to obtain extensive information to inform the systematic review. This approach ensured a thorough study of the available literature and yielded significant insights for researchers, practitioners, and policymakers in the field of AI-enabled IoT applications.

Data Synthesis

Data synthesis encompassed the methodical amalgamation and examination of the acquired data to deduce significant insights and conclusions regarding the impact of artificial intelligence (AI) on augmenting Internet of Things (IoT) applications. The approach involved organizing and categorizing the collected information according to theme areas such as AI-driven advancements, difficulties, prospects, and upcoming trends in IoT sectors like healthcare, manufacturing, smart cities, and cybersecurity. By doing a comparative analysis of the synthesized data, we were able to identify patterns, trends, and correlations among different variables. This research provided a thorough picture of the existing landscape and emerging directions in AI-enabled IoT applications. In addition, the process of combining and analyzing data allowed for the discovery of areas where study is lacking, opportunities for further investigation, and suggestions for future studies to enhance understanding and progress in this rapidly developing subject. Data synthesis played a vital role in the systematic review, allowing for the creation of valuable insights that can be used to make informed decisions, develop policies, and improve technology in AI-driven IoT ecosystems.

Figure 2
PRISMA flow diagrams



PRISMA 2020-compliant flow diagrams provide a standardized method for conducting systematic reviews, improving clarity and reproducibility. They visually outline the review stages, from identifying studies to their inclusion. Adhering to PRISMA guidelines ensures robust methodology and clear reporting. Following article assessment against set criteria, 23 articles were deemed suitable for inclusion in this study.

RESULTS AND DISCUSSION

Results

The results portion of our study presents a detailed analysis of the findings from our systematic review. We highlight the significant advancements in artificial intelligence (AI) technology that have been used to Internet of Things (IoT) applications in many industries. In addition, we examine the difficulties, possibilities, and upcoming developments that are influencing the field of AI-powered IoT systems, providing valuable information on how to maximize their ability to bring about significant changes.

What is the prominent AI-driven innovations in various industries within IoT applications?

Table 3

Prominent AI-Driven Innovations in Various Industries within IoT Applications

AI Application	Industry	Citation
Predictive Maintenance	Manufacturing	(Jan et al., 2023)
Healthcare Monitoring	Healthcare	(Singla, 2020)
Smart Home Technology	Home Automation	(Stojkoska & Trivodaliev, 2017)
Smart City Solutions	Urban Planning	(Sepasgozar et al., 2019)
IoT Security	Cybersecurity	(Wu et al., 2020)

Examining the AI-powered advancements in IoT applications across different sectors uncovers a promising landscape with immense potential for transformation and noteworthy consequences. The implementation of predictive maintenance systems in manufacturing, as emphasized by Jan et al. (2023), demonstrates the industry's move towards proactive asset management, with the goal of reducing interruptions and maximizing operational efficiency. In Singla's (2020) study, the focus is on the significant impact of technology in transforming patient care through AI-enabled healthcare monitoring. This includes the ability to remotely monitor patients and provide individualized health interventions. In their study, Stojkoska and Trivodaliev (2017) provide insight into the growing market of smart home technology. They demonstrate how artificial intelligence-based automation improves the quality of domestic living by increasing energy efficiency and ease.

In addition, Sepasgozar et al. (2019) demonstrate the incorporation of artificial intelligence (AI) and Internet of Things (IoT) in urban planning. This integration enables smart city solutions to enhance the allocation of resources, management of infrastructure, and provision of services to citizens. As a result, it promotes the development of sustainable and resilient urban settings. Nevertheless, the swift expansion of Internet of Things (IoT) devices also gives rise to apprehensions regarding cybersecurity, as demonstrated by Wu et al. (2020). This underscores the urgent requirement for security solutions based on artificial intelligence (AI) to protect interconnected systems from potential risks.

What challenges and opportunities arise from integrating AI into IoT systems, and how can these be addressed?

Table 4

Challenges and Opportunities of Integrating AI into IoT Systems

Challenges	Opportunities
Data Privacy and Security Concerns (Abdullahi et al., 2022)	Enhanced Predictive Analytics (Lv et al., 2021)
Interoperability Issues (Lin et al., 2019)	Improved Decision-Making (Zhou et al., 2016)
Scalability and Performance (Asghari et al., 2019)	Automation of Routine Tasks (Hassan et al., 2018)
Ethical and Regulatory Compliance	Personalized User Experiences (Zhou et al., 2016)
Skill Gap and Workforce Training	Cost Reduction through Efficiency

The incorporation of artificial intelligence (AI) into Internet of Things (IoT) systems poses several difficulties and possibilities that have a substantial influence on the effectiveness and efficiency of these interconnected networks. An important obstacle is the apprehension regarding the confidentiality and protection of data. Given the widespread use of IoT devices that gather large quantities of sensitive data, it is crucial to implement strong cybersecurity measures in order to prevent unwanted access and safeguard user privacy (Abdullahi et al., 2022). Moreover, the compatibility of different Internet of Things (IoT) devices and platforms presents a notable obstacle, since distinct systems may encounter difficulties in exchanging information and data smoothly (Lin et al., 2019). The lack of interoperability poses a significant challenge to the scalability and efficiency of IoT networks, impeding their capacity to provide value across a wide range of use cases and applications (Asghari et al., 2019). Although there are difficulties, the integration of AI into IoT systems presents a multitude of possibilities for innovation and progress. Organizations can use enhanced predictive analytics capabilities to extract valuable insights from IoT data, which can then be used to make proactive decisions and develop strategic plans (Lv et al., 2021). Furthermore, the implementation of AI-driven algorithms to automate repetitive tasks improves operational efficiency and productivity by minimizing the need for manual intervention (Hassan et al., 2018). AI technologies offer the potential for personalized user experiences by allowing services and suggestions to be tailored to individual interests and behaviors (Zhou et al., 2016).

In order to tackle the difficulties and take advantage of the possibilities offered by AI-enabled IoT devices, enterprises need to implement a comprehensive strategy. It is crucial to have strong cybersecurity protocols, such as encryption and access controls, in order to protect sensitive data and reduce security vulnerabilities (Abdullahi et al., 2022). Moreover, the act of investing in interoperable technologies and standards enables the smooth integration and communication across Internet of Things (IoT) devices and platforms, which in turn promotes the potential to scale and interoperate (Lin et al., 2019). AI development and deployment should be guided by ethical concerns to enable responsible and accountable utilization of AI technology. This will help establish confidence among users and stakeholders (Dwivedi et al., 2021). Furthermore, continuous workforce training and development programs are crucial in providing workers with the requisite skills to effectively utilize AI and optimize its potential in IoT applications (Chen et al., 2020). By confronting these obstacles and embracing the possibilities presented by AI-enabled IoT devices, organizations can unlock novel levels of ingenuity, effectiveness, and value generation in the digital era.

What future trends and research directions can be anticipated in the realm of AI-enabled IoT applications?

Table 5
Future Trends and Research Directions in AI-enabled IoT Applications

Trends and Research Directions	Description	Citation
Edge Computing	Utilizing edge computing to process data closer to the source, reducing latency and bandwidth usage in AI-enabled IoT applications.	(Li et al., 2021)
Privacy and Security	Addressing concerns regarding data privacy and security in AI-enabled IoT systems through enhanced encryption, authentication, and access control mechanisms.	(Al-Fuqaha et al., 2015)
Interoperability	Developing standardized protocols and frameworks to ensure interoperability among diverse IoT devices and AI systems for seamless integration and communication.	(Khan et al., 2020)
Explainable AI	Advancing research on explainable AI techniques to enhance transparency and trustworthiness in AI-driven decision-making processes within IoT applications.	(Ribeiro et al., 2016)
Energy Efficiency	Exploring energy-efficient AI algorithms and hardware designs to optimize power consumption and prolong the battery life of IoT devices, contributing to sustainability efforts.	(Yang et al., 2020)

The future of AI-enabled IoT applications presents auspicious trends and research directions that are positioned to disrupt diverse industries. Edge computing is becoming increasingly important as a significant trend. It enables the processing of data in real-time at the network's edge, resulting in reduced latency and improved scalability (Li et al., 2021). Ensuring privacy and security are still the most important concerns, prompting researchers to focus on developing strong encryption and authentication methods to protect sensitive data in the Internet of Things (IoT) (Al-Fuqaha et al., 2015). Ensuring smooth communication among diverse IoT devices and AI systems requires established protocols and frameworks, which is a crucial aspect known as interoperability (Khan et al., 2020). Furthermore, there is an increasing need for AI systems that can provide explanations for their decisions. This requires the development of transparent AI models that can clarify the decision-making process, hence promoting trust and responsibility (Ribeiro et al., 2016). The importance of energy efficiency has led to research on AI algorithms and hardware solutions that aim to decrease power consumption and improve sustainability in IoT ecosystems (Yang et al., 2020). By focusing on these emerging patterns and areas of study, AI-powered Internet of Things (IoT) applications may fully unleash their capabilities and fuel groundbreaking advancements in several fields.

Discussion

The integration of Artificial Intelligence (AI) with the Internet of Things (IoT) is a significant and revolutionary change in technology. It is transforming several sectors and fields by using intelligent systems and interconnected gadgets. The literature study presented here highlights the significant influence of AI on improving IoT applications in various industries, based on important studies in the field. The incorporation of artificial intelligence (AI) into the Internet of Things (IoT) has sparked notable advancements in various sectors. These include predictive maintenance in manufacturing, healthcare monitoring, smart home technology, smart city solutions, and improvements in cybersecurity. According to Jan et al. (2023), predictive maintenance technologies have allowed for proactive asset management in manufacturing, reducing disruptions and maximizing operational efficiency. Singla (2020) has demonstrated that AI-driven analytics and predictive modeling have transformed patient care in healthcare by enabling remote monitoring and individualized treatment techniques. Stojkoska and Trivodaliev (2017) have explored how smart home technologies have improved the quality of residential living by using artificial intelligence to automate tasks, resulting in increased energy efficiency and convenience.

In addition, the combination of artificial intelligence (AI) and Internet of Things (IoT) has resulted in the creation of intelligent urban solutions that enhance the allocation of resources, management of infrastructure, and provision of services to citizens. This is demonstrated by the work of Sepasgozar et al. (2019). Nevertheless, the exponential growth of Internet of Things (IoT) devices has also sparked worries about cybersecurity. This highlights the urgent requirement for security solutions based on artificial intelligence (AI) to protect interconnected systems from possible threats, as exemplified by Wu et al. (2020). The incorporation of artificial intelligence (AI) into Internet of Things (IoT) systems presents various prospects for innovation and progress. However, it also brings about notable obstacles, such as concerns regarding data privacy and security, difficulties in achieving interoperability, limitations in scalability and performance, adherence to ethical and regulatory standards, and gaps in workforce expertise. To tackle these issues and take advantage of the benefits presented by AI-enabled IoT systems, a comprehensive strategy is needed. This strategy should include strong cybersecurity measures, compatible technology, ethical AI development processes, and continuous workforce training and development programs.

Future trends and research directions in AI-enabled IoT applications encompass edge computing, privacy and security advancements, interoperability standards, explainable AI methodologies, and energy-efficient algorithms and hardware designs. By focusing on these emerging patterns and areas of study, AI-powered Internet of Things (IoT) applications can fully realize their capabilities and stimulate progress in several fields, leading to a more intelligent, interconnected, and environmentally friendly future.

CONCLUSION AND RECOMMENDATIONS

Conclusion and Implications

The integration of Artificial Intelligence (AI) with the Internet of Things (IoT) represents a substantial advancement in technology, with far-reaching implications across various industries. An extensive literature analysis was undertaken to evaluate the impact of AI in enhancing IoT applications, utilizing important scholarly contributions. The literature highlights several AI-driven developments in IoT, such as predictive maintenance in manufacturing, healthcare monitoring systems, smart home technologies, intelligent urban planning, and cybersecurity enhancements. These achievements illustrate the power of AI to improve operational efficiency, boost the quality of health care, elevate living standards, and promote urban sustainability.

On the other hand, incorporating AI into IoT systems brings about difficulties such as safeguarding data privacy, addressing security risks, managing interoperability complications, dealing with scalability problems, grappling with ethical questions, and facing shortages of skilled workers. To overcome these issues, it is imperative to collaborate and build robust cybersecurity policies, promote technology interoperability, enforce ethical AI practices, and offer extensive workforce training. Upcoming studies and patterns in AI-integrated IoT indicate promising advancements such as edge computing, enhanced privacy protections, establishment of interoperability standards, transparent AI methodology, and energy-efficient algorithms and hardware. By embracing these directions, the full potential of AI in IoT may be realized, leading to the acceleration of digital transformation and societal progress.

To summarize, the combination of AI and IoT holds the potential to completely transform technology, creating more intelligent, networked, and environmentally-friendly solutions in several industries. Collaboration between researchers, industry professionals, and politicians is essential in order to utilize the revolutionary potential of AI-enhanced IoT technology. This collaboration will help address societal challenges and create a more inclusive and prosperous future for all.

Recommendations

According to the results of this study, there are numerous suggestions that can be made to improve the integration of Artificial Intelligence (AI) with the Internet of Things (IoT). First and foremost, stakeholders should give priority to investing in strong cybersecurity measures in order to protect data privacy and reduce security threats. In addition, it is important to focus on developing standards that allow different systems to work together effectively and openly sharing the methods used in artificial intelligence. Moreover, it is imperative to establish ongoing workforce training initiatives to tackle any deficiencies in skills and guarantee the efficient deployment of AI in IoT applications. Ultimately, it is crucial for continuous research and development efforts to prioritize the advancement of energy-efficient algorithms and hardware designs in order to foster sustainability within IoT networks.

IMPLICATIONS

The findings of this study have important consequences for different individuals or groups involved. Researchers gain valuable insights into the present condition and future prospects of AI-enabled IoT applications, which help them in guiding their future investigations. Industry professionals can utilize the discoveries to create cutting-edge solutions and strategies, improving operational efficiency and competitiveness. Policymakers can utilize the ideas to develop regulatory frameworks that encourage responsible deployment of AI and protect data privacy. Furthermore, the research emphasizes the significance of interdisciplinary cooperation and ongoing education in effectively managing the intricacies of AI-integrated IoT ecosystems. In conclusion, the consequences highlight the significant capacity of AI to revolutionize sectors and enhance the overall standard of living.

REFERENCES

- Abdullahi, M., Baashar, Y., Alhussian, H., Alwadain, A., Aziz, N., Capretz, L. F., & Abdulkadir, S. J. (2022). Detecting cybersecurity attacks in Internet of Things using artificial intelligence methods: A systematic literature review. *Electronics*, 11(2), 198. <https://doi.org/10.1016/j.rser.2021.111530>
- Al-Turjman, F. (Ed.). (2019). *Artificial intelligence in IoT* (1st ed.). Springer. <https://doi.org/10.1007/978-3-030-04110-6>
- Al-Turjman, F., Nayyar, A., Devi, A., & Shukla, P. K. (Eds.). (2021). *Intelligence of things: AI-IoT based critical applications and innovations*. Springer. <https://doi.org/10.1007/978-3-030-82800-4>
- Asghari, P., Rahmani, A. M., & Javadi, H. H. S. (2019). Internet of Things applications: A systematic review. *Computer Networks*, 148, 241-261. <https://doi.org/10.1016/j.comnet.2018.12.008>
- Chen, H., Khan, S., Kou, B., Nazir, S., Liu, W., & Hussain, A. (2020). A smart machine learning model for the detection of brain hemorrhage diagnosis based Internet of Things in smart cities. *Complexity*, 2020, 1-10. <https://doi.org/10.1155/2020/3047869>
- Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., & Williams, M. D. (2021). *Artificial intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy*.

- International Journal of Information Management, 57, 101994. <https://doi.org/10.1016/j.ijinfomgt.2019.08.002>
- Fazil, A. W., Hakimi, M., Akbari, R., Quchi, M. M., & Khaliqyar, K. Q. (2023). Comparative analysis of machine learning models for data classification: An in-depth exploration. *Journal of Computer Science and Technology Studies*, 5(4), 160-168. <https://doi.org/10.32996/jcsts.2023.5.4.16>
- Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and open synthesis. *Campbell Systematic Reviews*, 18, e1230. <https://doi.org/10.1002/cl2.1230>
- Hansen, E. B., & Bøgh, S. (2021). Artificial intelligence and Internet of Things in small and medium-sized enterprises: A survey. *Journal of Manufacturing Systems*, 58, 362-372. <https://doi.org/10.1016/j.jmsy.2020.08.009>
- Hassan, M. K., El Desouky, A. I., Elghamrawy, S. M., & Sarhan, A. M. (2018). Intelligent hybrid remote patient-monitoring model with cloud-based framework for knowledge discovery. *Computers & Electrical Engineering*, 70, 1034-1048. <https://doi.org/10.1016/j.compeleceng.2018.02.032>
- Hasas, A., Hakimi, M., Shahidzay, A. K., & Fazil, A. W. (2024). AI for social good: Leveraging artificial intelligence for community development. *Journal of Community Service and Society Empowerment*, 2(02), 196-210. <https://doi.org/10.59653/jcsse.v2i02.592>
- Hasas, A., Zarinkhail, M. S., Hakimi, M., & Quchi, M. M. (2024). Strengthening digital security: Dynamic attack detection with LSTM, KNN, and random forest. *Journal of Computer Science and Technology Studies*, 6(1), 49-57. <https://doi.org/10.32996/jcsts.2024.6.1.6>
- Jan, Z., Ahamed, F., Mayer, W., Patel, N., Grossmann, G., Stumptner, M., & Kuusk, A. (2023). Artificial intelligence for industry 4.0: Systematic review of applications, challenges, and opportunities. *Expert Systems with Applications*, 216, 119456. <https://doi.org/10.1016/j.eswa.2022.119456>
- Liao, B., Ali, Y., Nazir, S., He, L., & Khan, H. U. (2020). Security analysis of IoT devices by using mobile computing: A systematic literature review. *IEEE Access*, 8, 120331-120350. <https://doi.org/10.1109/ACCESS.2020.3006358>
- Lin, Y.-W., Lin, Y.-B., & Liu, C.-Y. (2019). Altalk: A tutorial to implement AI as IoT devices. *IET Networks*, 8(3), 195-202. <https://doi.org/10.1049/iet-net.2018.5182>
- Lv, Z., Qiao, L., Singh, A. K., & Wang, Q. (2021). AI-empowered IoT security for smart cities. *ACM Transactions on Internet Technology*, 21(4), 1-21. <https://doi.org/10.1145/3406115>
- Marikyan, D., Papagiannidis, S., & Alamanos, E. (2019). A systematic review of the smart home literature: A user perspective. *Technological Forecasting and Social Change*, 138, 139-154. <https://doi.org/10.1016/j.techfore.2018.08.015>
- Qinxia, H., Nazir, S., Li, M., Ullah, H., Lianlian, W., & Ahmad, S. (2021). AI-enabled sensing and decision-making for IoT systems. *Complexity*, 2021, 1-9. <https://doi.org/10.1155/2021/6616279>
- Sepasgozar, S., Karimi, R., Farahzadi, L., Moezzi, F., Shirowzhan, S., Ebrahimzadeh, S. M., & Aye, L. (2020). A systematic content review of artificial intelligence and the internet of things applications in smart home. *Applied Sciences*, 10(9), 3074. <https://doi.org/10.3390/app10093074>
- Sepasgozar, S. M., Hawken, S., Sargolzaei, S., & Foroozanfa, M. (2019). Implementing citizen centric technology in developing smart cities: A model for predicting the acceptance of urban technologies. *Technological Forecasting and Social Change*, 142, 105-116. <https://doi.org/10.1016/j.techfore.2018.09.012>
- Serrano, M., Dang, H. N., & Nguyen, H. M. Q. (2018, October). Recent advances on artificial intelligence and Internet of Things convergence for human-centric applications: Internet of Things science. In *Proceedings of the 8th International Conference on the Internet of Things* (pp. 1-5). <https://doi.org/10.1145/3277593.3277638>
- Singla, S. (2020). AI and IoT in healthcare. In P. Raj, J. Chatterjee, A. Kumar, & B. Balamurugan (Eds.), *Internet of things use cases for the healthcare industry* (pp. 1-13). Springer. https://doi.org/10.1007/978-3-030-37526-3_1
- Stojkoska, B. L. R., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, 140, 1454-1464. <https://doi.org/10.1016/j.jclepro.2016.10.006>
- Wu, H., Han, H., Wang, X., & Sun, S. (2020). Research on artificial intelligence enhancing Internet of Things security: A survey. *IEEE Access*, 8, 153826-153848. <https://doi.org/10.1109/ACCESS.2020.3018170>
- Zhang, T., Zhao, Y., Jia, W., & Chen, M. Y. (2021). Collaborative algorithms that combine AI with IoT towards monitoring and control system. *Future Generation Computer Systems*, 125, 677-686. <https://doi.org/10.1016/j.future.2021.07.008>
- Zhou, Z., Tsang, K. F., Zhao, Z., & Wu, H. (2016). Data intelligence on the Internet of Things. *Personal and Ubiquitous Computing*, 20, 277-281. <https://doi.org/10.1007/s00779-016-0912-1>

Author(s)' Statements on Ethics and Conflict of Interest

Ethics Statement	The author/s hereby declare that research/publication ethics and citing principles have been considered in all the stages of the study. The author/s take full responsibility for the content of the paper in case of dispute.
Originality and Plagiarism Assessment	The manuscript has a similarity assessment of less than 20% in accordance with the publication ethics in terms of originality and plagiarism and the plagiarism policy of the journal.
Statement of Interest	The author/s have no conflict of interest to declare.
Funding	None
Acknowledgements	The researchers extend their heartfelt gratitude to all mentors, participants, and funding agencies for their invaluable contributions to this study on AI-enabled IoT applications. Thank you for your support and guidance.

Suggested Citation

American Psychological Association (APA)	Exzam, Z., Totakhail, A., Ghafory, H., & Hakimi, M. (2024). Transformative Impact of Artificial Intelligence on IoT Applications: A Systematic Review of Advancements, Challenges, and Future Trends. <i>International Journal of Academic and Practical Research</i> , 3(1), 155-164.
---	--



Author Biographies

Zakirullah Ezam, Sayed Jamaluddin Afghani University, Kunar, Afghanistan. Email: zakir.azam@sjau.edu.af

Amanullah Totakhail, Sayed Jamaluddin Afghani University, Kunar, Afghanistan. Email: amanullah-tutakhail@sjau.edu.af

Hamayoon Ghafory, Kabul Education University, Kabul, Afghanistan. Email: hamayoon.ghafory@gmail.com

Musawer Hakimi, Samangan University, Samangan, Afghanistan. Email: musawer@adc.edu.in

Copyright © 2024 by the Author/s

