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The Evolution of Artificial Intelligence and Its Interaction with Blockchain[1]

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ABSTRACT

The evolving technology, which has become popular recently along with the digitalized world, has brought about many integrations with the evolution of artificial intelligence. The resurgence of blockchain technology, which has resurfaced with cryptocurrencies, is one of these integrations that stands out. It is likely to observe acceleration, practicality, and, more importantly, secure progress in business processes as a result of the combination of the infrastructure used by artificial intelligence and the infrastructure of blockchain technology. Decision-makers in the economy are expected to involve artificial intelligence in the decisions they have made or will make with this technological integration. Blockchain technology is crucial not only for companies but also for all decision-makers in the economy in terms of providing decision-makers with a more secure progress and allowing high data-based artificial intelligence to create blocks that securely store this data in today's age. The study will provide insights into this integration and possible scenarios. It is believed that the combination of artificial intelligence with blockchain technology will pave the way for new business models, bring about new opportunities, and create more transparent and reliable business environments.

Keywords: Artificial Intelligence, Blockchain, Technology.

1. Introduction

In recent years, developments in information and communication technologies, along with globalization, worldwide have significantly reduced transaction costs, thereby facilitating increased cross-border trade and investment in goods and services (Harmancı and Umutlu, 2025:18). Alongside the globalized world,

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technology interactions in the fourth industrial revolution are increasing. With the increase in value-added in technology, artificial intelligence has become the focus of the world's agenda. The growing frenzy of artificial intelligence is evident in almost every aspect of our lives. Initially focused on our phones responding to verbal commands, artificial intelligence has quickly progressed beyond just responding to being able to perform tasks and make adjustments to the tasks performed. The extent to which artificial intelligence can further advance in our lives is a matter of great curiosity.

Digitalization has brought about another phenomenon in our lives, which is Blockchain technology. Also known as the block chain, it was rediscovered with Satoshi Nakamoto's paper on Bitcoin in 2008, although it had emerged long before. Nakamoto's paper extensively discussed not only Bitcoin, which was proposed as a solution to the problems created by central authorities in money transfers but also the underlying technology of blockchain (Yildirim, 2019). The foundations of Blockchain technology date back to 1991 when Stuart Haber and W. Scott Stornetta conceived a system aimed at preventing the alteration of date information in documents. This concept represents a significant step in the field of information technology to ensure the security and integrity of documents. The work of Stuart Haber and W. Scott Stornetta later inspired Satoshi Nakamoto's introduction of the blockchain-based system for Bitcoin in 2008. As a result, blockchain technology has become a fundamental structure that enables the secure and immutable recording of digital assets (Kara, 2020).

The technological advancements from the First Industrial Revolution, which began with the invention of steam engines in the 18th century, to the present day have led to the use of smart machines in many fields, from production to the service sector. The fourth industrial revolution, known as Industry 4.0 can be evaluated in terms of changing economic organization. Industry 4.0 incorporates more culture, taste, and habits into production than ever before, but it distances people from the production system (Karaarslan and Erdal Avcı, 2025:2). With Industry 4.0, major investments are being made in automation and robotics to develop technological innovations. In recent years, the rapid development of information and communication technologies and their integration into supply chains have led to the emergence of the fourth industrial revolution, Industry 4.0 (Öztürk, 2025:60). With Industry 4.0, concepts such as "artificial intelligence," "machine learning," "the internet of things," "blockchain technology," "virtual reality," and "digital manufacturing" have emerged. With the Fourth Industrial Revolution (Industry 4.0), concepts such as "artificial intelligence," "machine learning," "the internet of things," "blockchain technology," "virtual reality," and "digital manufacturing" have emerged. Innovations in artificial intelligence technologies are now being integrated into society, replacing professions such as accountants, legal assistants, soldiers, drivers, and nurses with artificial intelligence technologies. There is no doubt that developments in the field of artificial intelligence will lead to the establishment of a new global economic balance and deeply transform humanity through the economic benefits it brings (Arndts & Kappner, 2019).

The aim of this study is to explore the potential developments that may arise from the integration of two prominent technologies of our time, artificial intelligence and blockchain, driven by increasing technological advancements. In this context, the study evaluates artificial intelligence and blockchain

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technologies and examines the innovations that may result from their integration, as well as the possible outcomes of these innovations.

Blockchain technology stands out as an evolving and growing technology. The development of blockchain technology has particularly accelerated with the integration of artificial intelligence into our lives. This study explains artificial intelligence and blockchain technology, and discusses the advancements in technology and finance resulting from the synergy of these two elements in light of recent developments.

2. ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is defined as a system of computers or computer-assisted machines capable of performing tasks such as problem-solving, perception, generalization, and learning from past experiences, with human-like or superhuman qualities. Artificial intelligence consists of technologies such as artificial neural networks, machine learning, fuzzy logic, genetic algorithms, and expert systems. It is a system that operates based on algorithms and is fed by large datasets (Demirdogmez, 2022). In other words, it is an attempt to examine the ways in which computers can perform various cognitive tasks that humans are currently better at (Shapiro, 1987) and to build an intelligent structure (Ginsberg, 1993). Studies on artificial intelligence generally aim to create systems that exhibit characteristics associated with intelligence in human behavior (such as understanding language, learning, making judgments, solving problems, etc.) and to develop similar artificial commands (Barr & Feigenbaum, 1981).

The various applications of artificial intelligence technology are rapidly expanding in today's world. Numerous examples, such as advanced driverless vehicles, online search engines, facial recognition systems on social media platforms, retailers offering personalized online shopping experiences to consumers, and logistics and cargo companies determining the most optimal routes, demonstrate how artificial intelligence has become integrated into our lives. Additionally, governments can forecast pandemics in advance, marketers can provide real-time personalized content to their customers, and virtual assistants can interact with consumers in natural language. Artificial intelligence has achieved significant successes in areas such as speech recognition and understanding, image processing, and natural language processing.

The universal definitions of artificial intelligence generally fall into two categories: artificial intelligence systems that think or behave like humans, and artificial intelligence systems that think or behave rationally. These systems are divided into narrow (or weak) artificial intelligence and general (or strong) artificial intelligence in the literature.

Narrow or weak artificial intelligence systems are structures that can autonomously perform a specific task with human-like capabilities. They are only suitable for the tasks they are designed for and therefore have a very limited or narrow range of capabilities. For example, they may include limited goals such as performing natural language processing functions like translation systems or navigating in a foreign physical environment. The majority of existing artificial intelligence systems today are closer to this

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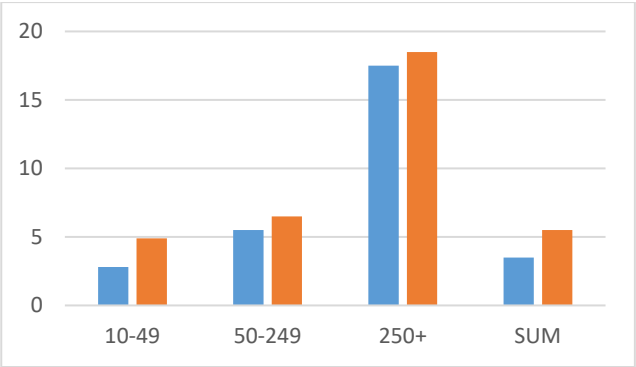
narrow and limited type.

On the other hand, general or strong artificial intelligence systems are structures that can efficiently perform any intellectual task. In advanced stages, it is believed that they will evolve into intelligent systems with true consciousness, capable of thinking like humans and independently setting new goals. Robots portrayed in popular culture are often examples of these general artificial intelligence systems. However, such a system is not yet available at present.

According to the data from the Turkish Statistical Institute (TUIK), the percentage of enterprises in Turkey that reported using any artificial intelligence technology increased from 3.5% in 2022 to 5.5% in 2023. When examining the percentage of enterprises using AI by employee size, it was found that 4.9% of enterprises with 10-49 employees, 6.5% of enterprises with 50-249 employees, and 18.5% of enterprises with 250 or more employees used AI. These percentages were 2.8%, 5.5%, and 17.5% respectively in 2022 (TUIK, 2022).



Graph 1 The percentage of enterprises using artificial intelligence by employee size in 2022 and 2023 (TUIK, 2022).

When examining the reasons why enterprises do not use any artificial intelligence technologies, the most significant reason was high costs, reported by 60.7% of respondents. This was followed by a lack of relevant expertise within the enterprise at 53.8% and incompatibility with existing equipment, software, or systems at 49.6%.

According to McKinsey's 2021 Global Survey on AI, 56% of respondents reported AI adoption in at least one function. The leading countries in AI adoption include the United States, China, and several European nations such as Germany and the United Kingdom (McKinsey & Company, 2021).

AI is widely used in predictive maintenance, quality control, and production optimization. According to a Capgemini report, 29% of major manufacturing companies have implemented AI in their operations. AI applications in healthcare include diagnostic systems, personalized treatment plans, and drug discovery. MarketsandMarkets projects the AI in healthcare market to reach $45.2 billion by 2026 (Capgemini, 2021). AI is utilized for demand forecasting, personalized marketing, and inventory management. A KPMG study shows that 28% of retail companies are using AI technologies. AI is prominent in fraud detection, algorithmic trading, and customer service automation. According to

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Business Insider Intelligence, 80% of banks are aware of the benefits AI can bring to their industry (KPMG, 2021).

Governments are using AI for various purposes, including public safety, traffic management, and citizen services. The OECD reports that 34% of public sector organizations have implemented AI in some form. AI is a critical component in developing smart cities for improving urban infrastructure and services. The global smart cities market is expected to grow to $820.7 billion by 2025, with AI playing a pivotal role (OECD, 2021).

With the advancement of technology, two separate areas that have entered our lives have started to progress in a way that supports each other's development. These two important technologies are on their way to creating significant interaction by addressing each other's shortcomings (Demirdogmez, 2022).

The interaction of these two emerging technologies has also become a significant point of interest on a global scale. In their study, Marwala and Xing (2018) emphasized the role of artificial intelligence in blockchain 2.0 goals and stated that it could support blockchain through various combinations (Marwala & Xing, 2018).

Tagde and colleagues (2021), in their study, highlight that a reliable blockchain system for e-health systems could be made possible with artificial intelligence. It is believed that this would especially provide significant ease in the areas of personal data privacy, data collection, and processing (Tagde, ed., 2021).

Ekramifard and colleagues (2020), in their research, emphasize that increases can be observed in areas such as distributed management, security, efficiency, prediction, and decision-making (Ekramifard, ed., 2020).

3. BLOCKCHAIN

The concept of globalization is one that has an impact across all areas, primarily in economics and information technology. In an economy that aims to statistically boost economic data, marketing practices inevitably become the driving force of the economy (Elgün and Karabıyık, 2024:2). In a globalized environment, competition has become both challenging and essential for businesses. Competitors can quickly access products and services that can be commercially successful anywhere in the world, regardless of borders, via the internet. This facilitates and accelerates competitors' actions. Today, with the influence of developing technology, the meaning of time and space has changed, resulting in an even greater importance of competition (Diken and Seles, 2024:49).

The blockchain technology, as mentioned above, was rediscovered with the 2008 Bitcoin paper, but its foundation dates back much earlier. Additionally, the term "blockchain" is not used in the paper. Instead, the paper uses peer-to-peer cash references to describe blockchain technology. The blockchain system stores transactions in blocks and adds these blocks together to form a chain. Blocks are created and recorded in the system according to specific rules. When a new block is created, it is generated by taking the summary of the previous block and adding it to the chain. This process ensures that all blocks are connected, and each block continues the chain with the summary of the previous block. When a transaction occurs, it is broadcasted over the network and verified using encryption algorithms to create

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a block. Each node in the system confirms and records this transaction between two parties. Thus, the block is verified, and the information becomes immutable or undeletable indefinitely. Each new block added to the chain makes it impossible to alter the system (Ammous, 2016).

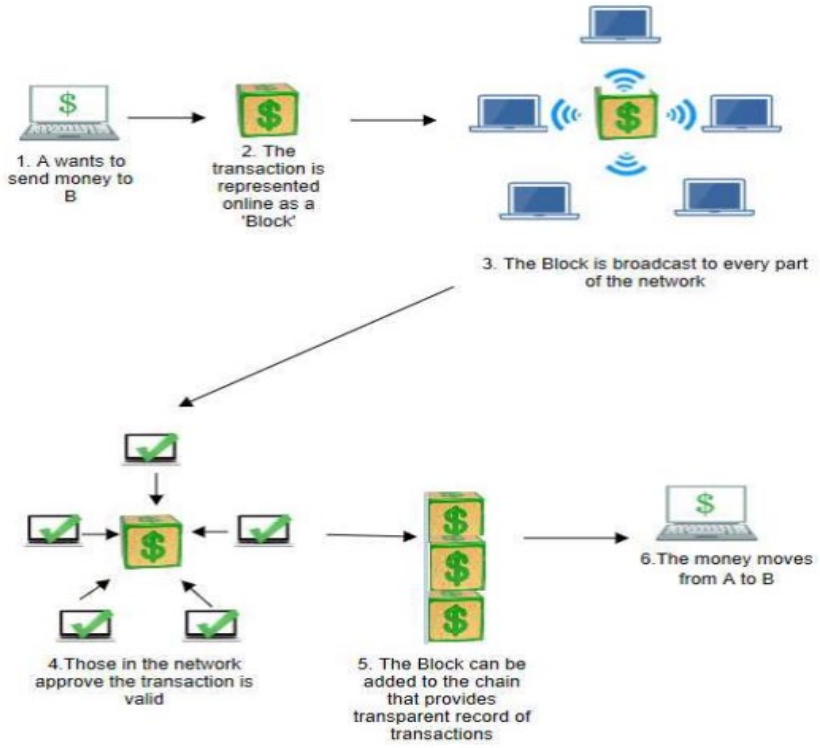

Figure 1 How to Blockchain Work (Sarmah, 2018).

The working principle of blockchain operates through "blocks." In a sample transaction, as shown in Figure 1, it is illustrated with a money transfer process. Each transaction is defined as a block. The block is broadcast to every part of the network. After the transactions in the network are approved, the blocks are added to a chain and the transaction is completed.

Blockchain has emerged as one of the forefront technologies in the new wave of digitalization known as Web 3.0. Cryptocurrencies, which are closely associated with blockchain but are distinct concepts, are the most prominent examples. Intermediaries are required to establish trust in human relationships. For instance, in a wire transfer or electronic funds transfer (EFT) transaction, banks are needed to facilitate the transfer of an existing asset to another person. Devices such as mobile phones, computers, or tablets are used to connect to the internet. These devices connect to a broad network called the "web," enabling various transactions to be conducted. This web network consists of a group of machines interconnected privately across different parts of the world.

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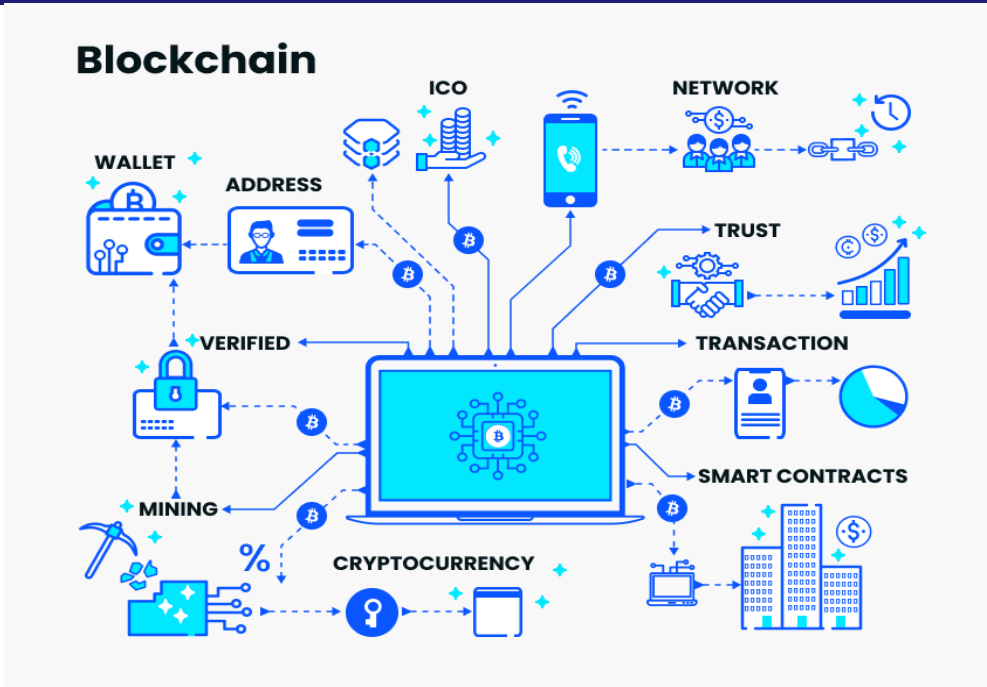

Figure 2 Operation of Blockchain

Blockchain and crypto technology enable secure data exchange among all devices connected to the internet. For example, when a money transfer occurs, these devices share the transaction and result information encryptedly. Blockchain provides a "consensus mechanism" that notifies these devices with a message like "transaction approved." This mechanism establishes automatic trust among devices and shifts the trust provided by a central authority to a decentralized structure. Cryptocurrencies are the initial products of this decentralized system and were born as a means of exchange usable in commerce. Problems such as the energy loss and high transfer fees caused by unnecessary bureaucracy, which can make traditional money transfers via the SWIFT system take days, can be solved through Blockchain-based encrypted networks. Money transfers made with Blockchain technology can be completed within minutes, regardless of the location globally, thus saving time and costs (Demirdogmez, 2022).

Every piece of information recorded and verified in the system is subsequently archived and authenticated in a similar manner with incoming data. Modifying a previous piece of information would require altering all information from that date to the present. This makes making changes nearly impossible (Sert, 2019). The "Merkle tree data structure" is used underneath Blockchain technology to ensure that no changes are made during data exchange and to verify the accuracy of the data. Therefore, data recorded on the blockchain is immutable and cannot be deleted (Ozdamar, 2022).

As seen in Graph 2, the use of blockchain is very common among banking and capital market companies. The main factors driving this are reducing costs, increasing transparency, and building trust. Research in this field suggests that by 2020, the use of blockchain will intensify significantly in areas such as banking, insurance, and government.

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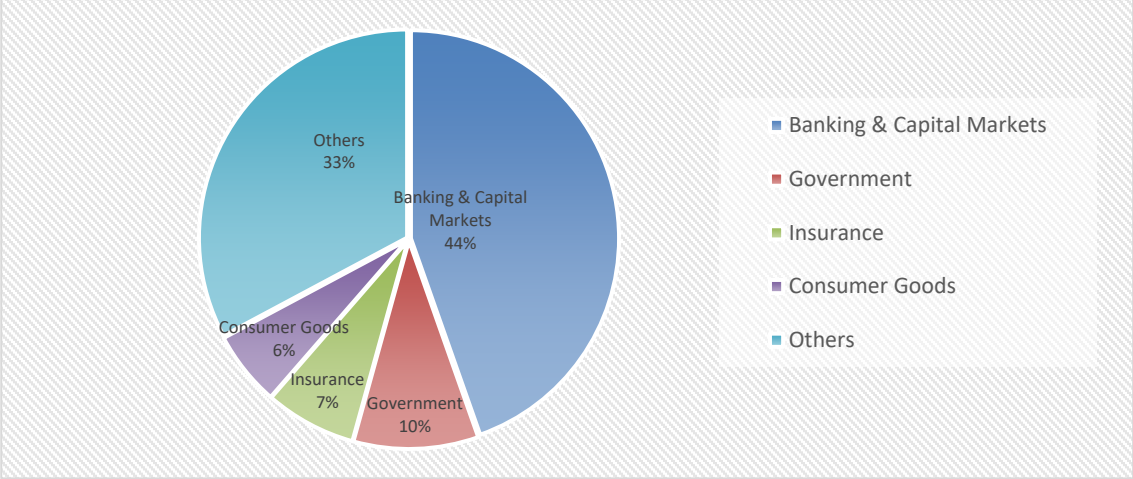

Graph 2 Sectors Using Blockchain (Sarmah, 2018).

4. ARTIFICIAL INTELLIGENCE AND BLOCKCHAIN

The integration of two popular technological subfields such as artificial intelligence and blockchain, as mentioned above, is likely to have a significant impact on key areas such as finance, economics, security systems, as well as transformations and developments in areas such as logistics and supply chains for companies. This technological advancement has also accelerated the emergence of new ideas and opportunities (Akyilmaz, 2021).

Artificial Intelligence (AI) is known for working with large volumes of data, while Blockchain technology stands out as an ideal solution for storing such data in a secure platform. AI techniques using Blockchain can contribute to the coordination, decision-making, and voting processes of numerous autonomous agents, providing decentralized learning opportunities that ensure secure sharing of information and decision outcomes. The combination of AI and Blockchain can address the existing shortcomings of both technologies, creating a more effective system overall.

AI algorithms rely on data for learning, inference, and final decision-making processes. Blockchain, on the other hand, takes on the function of cryptographically signing, verifying, and storing data in a consensus-agreed manner by all mining nodes, functioning as a distributed ledger with high integrity and flexibility, ensuring immutability. The integration of Artificial Intelligence and Blockchain creates a secure, immutable, and decentralized structure for sensitive information that AI-focused systems need to collect, store, and utilize. This combination brings significant improvements in data and information security across various domains such as medical, personal, banking and finance, trade, and legal data. Particularly, secure storage and processing of data through these technologies contribute to reliable decision-making and data integrity preservation. The consolidation of AI and Blockchain offers important advantages in data security and privacy, potentially leading to the development of safer and more effective systems in the future (Salah, ed., 2019).

The integration of AI and blockchain technologies can significantly contribute to the creation of new

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business models and marketplaces. When the transparency and reliability features of blockchain combine with the data processing and analysis capabilities of AI, more efficient and secure digital marketplaces can be built. These marketplaces have the potential to enhance consumer satisfaction and loyalty by offering more personalized services to users. Blockchain technology enables transparent tracking of transactions and secure execution in a trustworthy environment. This enhances the accuracy and reliability of the data collected and analyzed by AI. As a result, analyses and decisions made by AI are based on a more robust foundation. For example, the immutability of data stored on the blockchain mitigates the risk of data manipulation by AI algorithms. This ensures the secure and transparent operation of marketplaces and business models. Furthermore, AI's data processing and analysis capabilities enable deeper insights into users. These insights allow for the provision of more personalized services tailored to users' needs and preferences. For instance, a digital marketplace can analyze users' past shopping habits and preferences to provide them with personalized recommendations, thus improving the user experience (Kruszewska, 2021).

In conclusion, the integration of AI and blockchain technologies can contribute to enhancing the reliability and efficiency of digital marketplaces, leading to the emergence of new business models and the more efficient operation of existing marketplaces. This integration also supports sustainability of marketplaces by increasing user satisfaction and loyalty.

Blockchain and artificial intelligence technologies have the potential to lead to significant advancements in various fields. According to experts, these technologies can greatly improve supply chains, optimize energy management processes, and enhance the effectiveness of Internet of Things (IoT) sensors.

Blockchain enhances supply chains by providing transparency and traceability, making processes more reliable. With an immutable ledger that records every step, the movements of products from their source to end-users can be securely tracked. On the other hand, AI optimizes supply chain management with big data analytics and predictive models. This combination increases efficiency and reduces costs in various areas, from inventory management to logistics optimization (Daugherty, 2018).

In the energy sector, blockchain enables the secure recording and distribution of energy production and consumption data. This plays a critical role, especially in the integration of renewable energy sources. AI algorithms analyze energy consumption patterns, aiding in making smarter decisions regarding energy supply and demand balance. This leads to increased energy efficiency and optimized energy costs. Internet of Things (IoT) can utilize blockchain technology to ensure data security among devices, ensuring secure and holistic inter-device communication. AI, on the other hand, analyzes data from IoT sensors, enabling devices to operate in a smarter and more autonomous manner. For example, a smart home system can learn user habits to optimize energy consumption and enhance security (Eles, 2022).

As a result, the integration of blockchain and artificial intelligence technologies can provide revolutionary improvements in areas such as supply chains, energy management, and the Internet of Things (IoT), particularly in the analysis of large data volumes and decision-making processes. The combination of these technologies enables the development of more secure, efficient, and intelligent systems, which can enhance the performance and sustainability of various industries.

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5. CONCLUSION

With the advent of Industry 4.0, artificial intelligence technologies have significantly increased their impact, especially in the industrial sector and other areas of life. Processes once controlled by humans and supported by robots are now evolving into structures where robots with cognitive abilities play significant roles (Lucci & Kopec, 2016). This transformation is fundamentally altering the nature of the workforce. White-collar workers are beginning to be replaced by robots equipped with artificial intelligence, often referred to as "metal collars." This shift is leading to the evolution of traditional work patterns, reducing costs, increasing economic efficiency, and decreasing human errors (Goertzel & Pennachin, 1998).

The use of artificial intelligence alongside Blockchain technology can make future application deployments more secure. When combined with artificial intelligence, Blockchain provides an ideal platform for storing personal data. Artificial intelligence, when working on Blockchain, can enhance machine learning capabilities and create new financial opportunities. Smart contracts offered by Blockchain technology, when combined with machine learning algorithms, can yield much more reliable results. Additionally, artificial intelligence can achieve high levels of efficiency by improving mining algorithms to minimize energy consumption.

In the near future, the combination of these two major phenomena will bring along many innovations. However, artificial intelligence and blockchain, which are still relatively new and continue to evolve, also present various research challenges. In particular, studies to be conducted in areas such as measurability and consensus protocols will be crucial for further development.

The integration of artificial intelligence and blockchain technologies can lead to significant transformations not only in the technology and finance sectors but across all industries. This integration has the potential to deeply impact not just the technology and finance sectors but all industries. It can make business processes more efficient and secure, paving the way for not only technological but also economic and societal transformations. The integration of artificial intelligence and blockchain enhances data security, transparency, and traceability, thereby encouraging the emergence of new business models. This situation could further strengthen inter-industry collaboration and innovation in the future.

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