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Intersection of AI and Blockchain Technology: Concerns and Prospects

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Abstract. Artificial Intelligence (AI) and blockchain are two major technologies that emphasize the break through innovations in various industries. Every technology has its own benefits in spite of its technical complexity for building advanced business applications. Combination of AI and blockchain has led to the restructuring of architectural changes to meet the present industrial demands of globalized financial markets, Internet of things, intelligent business data models and smart medical applications. Alliance of AI and blockchain technologies give rise to decentralized AI which enables machines to understand and take decisions on reliable and secured data independently by avoiding the involvement of any intermediaries in the course of action. In this paper, we review the intersection junctures, benefits and support provided by AI and blockchain. We also shed light on tools and latest technologies that has emerged as a result of intersection between these two technologies.

Keywords: Artificial intelligence · Decentralised AI · Blockchain · Machine learning · Data security · Data integrity

1 Introduction

Artificial intelligence and blockchain are the two emerging technologies by a wide margin, where AI makes a system powerful by providing cognitive functions such as learning, inferring and adapting by analyzing data samples. Blockchain technology is a decentralised, distributed ledger, which stores the data in encrypted format. AI and Blockchain have gained the recognition in today's world due to the fact that AI can automate challenging assignments and can provide data modeling for difficult circumstances than human beings. Contrarily blockchain renders stronger data privacy and security.

Blockchain and AI jointly may look implausible. However, they amalgamate together by dealing with the flaws and stabilizing the worst tendencies of each other. AI uses the datasets hoarded in blockchain and its distributed computing built on blockchain transmutations. Whereas blockchain uses AI for monetizing user-controlled data, generating AI based market place and developing autonomous organizations.

Blockchain internally uses distributed ledger that facilitates account reconciliation process using encryption techniques and message transmission protocols and maintains bulk data by utilizing distributed architecture. It always ensures data security along with

high speed data processing and quick data sharing. Hence blockchain is an outstanding technology which offers sustainability, spontaneous data exchange, compatibility, data protection and interlinking [1].

Blockchain techniques are used to endeavor a healthcare system which helps people to understand their data and to own copyrights on its usage. They also support server less connectivity and decentralized web future wherein people can have control on their data, identity and fortune [2].

Almost all the machine learning techniques using AI depend on centralized architecture wherein cluster of servers run definite model in opposition to validating datasets [3]. Because of the centralized nature of AI only the companies with good computational power, access to superior quality datasets can take substantial amount of advantage of AI prospect. Companies like Amazon, Microsoft and Google contribute more in monopolizing the power of AI, because of their computing facilities [4]. This could result in bad, insecure and highly menacing AI decisions, which can have critical repercussions in the real world. To overcome these unfavorable outcomes we need a distributed and secure way of storing, retrieving and accessing of data. The field of decentralized AI is one of the leading trends that are looking to address this challenge [5].

The application of blockchain in the healthcare industry is been of great interest and advancing areas for research and development. The patient's data is widely spread across various sources due to the regular change in healthcare providers. Easy access to the previous data is often lost by the patient, whereas the primary ownership is retained by the provider [6, 7]. Decentralized AI is utilized in the fields of healthcare sector and biomedical research to rapidly analyze biomedical samples, and enhance healthcare assistance by deploying robots in elderly care.

Decentralised AI focuses on asset management to eliminate corporate dynamics and comparative market analysis. It is also used in the banking sector to handle dynamic variety of transactions. Decentralized AI also contributes to the field of asset management to eliminate independent power and in firms for market analysis. It also applies to routing techniques to control traffic. This not only ensures avoidance of congestion but also prevents it [3].

The rest of this paper is organized as follows. Section 2 enlightens the literature survey. Section 3 highlights about the technologies available on centralized AI. Section 4 presents the technologies based on decentralised AI. Section 5 discuss about AI for blockchain. Section 6 discuss about blockchain for AI. Section 7 presents the AI and blockchain intersection benefits. Section 8 highlights the issues and problems at the intersection of AI and blockchain. Finally, Sect. 9 concludes this paper and gives some future directions.

2 Literature Review

When AI is integrated with blockchain, the resulting technology would provide users a revolutionary data model. This helps in accomplishing better data authenticity. The authors in [8] talks about ChainIntel P2P network which are bunch of active nodes that rely on distributed AI applications intended for their work such as face, voice, picture recognition and smart homes. The work in [4] focuses on ethereum and IPFS which

controls the data repository and resources by providing a better safety and confidentiality to the records. The work in [9] spotlights on partially homomorphic encryption like Pallier and Goldwasser-Micali encryption schemes that provide security to have safer transaction and that safeguard trading parties confidential aspects.

The work in [10] highlights two well-known scientists who examined the capability of blockchain to modernize and automate the IoT and energy. Their work spotlights on the AI solutions to transfer energy resource in a distributed environment using encryption technology. The work in [11] focuses on a concept called swarm robotic ecosystem based on blockchain. The concept is constructed on smart contracts which are distributed in nature, and are used to develop a structured swarm mechanism to get rid of byzantine members.

The work in [12] calls attention to distributed EHR MedRec. It motivated EHR stakeholders and medical associations to take part in POW and in response allowed them to access data. With the help of Harvard medical hospital this concept was implemented and tested. This work in [13] primarily focuses on another prototype in contrast to MedRec. The model provides formidable access to EHR system, leading to cloud storage acceptance and key transfer access for data encryption. The work in [14] underlines that a single diagnostic report of patient could be generated by using distributed AI.

The work in [15] highlights that the Dutch land registry organizations used decentralised AI model for their landed property sector. The aim was to predict the result using AI and handle the huge amount of data using blockchain. The work in [16] underscores the usage of P2P e-cash system to ensure the decentralised trading and knowledge management. The work in [17] focuses the significance of using decentralised AI for solving the internet related issues. The work in [18] highlights the experiments done in Pisa Italy for forecasting pollution levels.

The work in [19] highlights that snipAIR launched in 2019 was treated as a substitute to SIRI to safeguard user's data. SnipAIR makes sure that the personal data will remain intact within connected home rather than storing it on cloud. The work in [20] enshrines a process called longgenesis which delivers a platform for coining and allocating the data such as medical records and health data.

The work in [4] highlights the fact that machine learning internally employs AI and blockchain to automate the procedure by minimizing the manual work to improve the efficiency. Hybrid learning models is the last but not the least among the common trends highlighted here. It uses the real time data and the data source for decision making. The work in [21] talks about distributed AI and smart-contract problems.

3 Technologies Based on Centralized AI

3.1 Digital Twin

Digital twin is one of the software applications that try to connect the gaps between virtual world and physical systems. As an instance, General Electric (GE) is constructing an AI workforce that screens its locomotives, aircraft engines, gasoline turbines to forecast any upcoming failure with the assistance of GE machine's software models hosted on cloud. Their digital twins are essentially strains of software code. Nevertheless, these

optimized versions are similar to the design drawing in 3D which consists of interactive visual representations using charts, points and diagrams [22].

3.2 SenseTime

SenseTime leads the image recognition industry by developing face recognition technology that is used for fee and photo evaluation verification in bank cards. Since the aim of most of the companies today, is to extract the worth of videos and images across the Internet using AI technology, this tool has been of utmost importance.

3.3 AIONE

This facilitates software developers to construct intelligent assistants. It also referred to human interference intelligence system. AIONE toolbox has following services such as APIs, document library and building agents. The basic advantage of this tool is to convert data to common sets of rules which helps machine learning and AI structures.

3.4 Deep Learning for Java (Deeplearning4j)

Deep Learning for Java (Deeplearning4j): It is a prominent open source library used in Java virtual machine. This is basically designed to work with applications like Hadoop and Apache Spark [23]. This incorporates following services such as stacked denoising autoencoder, word2vec, deep belief net, Boltzmann machine, deep autoencoder and Doc2vec.

3.5 TensorFlow

Tensorflow is a deep learning library which helps in developing and deploying models on browsers, as well as on mobiles. It has a wide range of tools available for the development of deep learning and machine learning applications. It is also used for numerical computations and graphical representations [24].

3.6 PyTorch

PyTorch is an open source library, primarily used for various applications such as natural language processing, forecast time sequences, and cloud support and computer vision. It is developed by Facebook's AI Research lab (FAIR). Multiple pieces of deep learning software are built with the help of PyTorch [24].

3.7 Keras

Keras is an open source deep learning framework used for low level computations and acts as an interface for the Tensorflow library. It has the capability to implement arbitrary research and has various practices to reduce the cognitive load and speed up experimentation cycles [25].

4 Technologies Based on Decentralized AI

The integration of blockchain and AI is addressed as decentralised AI. Due to the centralised nature of AI there is a possibility of data alteration which threatens the originality of data. Whereas decentralised nature of blockchain offers reliable and immutable features to AI on intersection with blockchain. This attributes to development of new innovative technologies in multiple fields. The highlights of decentralised AI technologies are shown in Table 1.

Table 1. Technologies based on decentralised AI

Technology	Objective	Application	Method	Category
snipAIR [19]	Protection of user's personal data	GOOGLE Home, AMAZON Echo	Protect data within parameters of connected homes, instead of its storage on cloud	Machine Learning
KEEL [18]	To predict the traffic levels, to avoid congestion	To resolve traffic bottleneck	By C4.5 Classification technology	Machine Learning
ChainIntel [8]	Handling the security threats faced in the world of internet	Networking	By implementing AI models	Deep Learning
MedRec [12]	Assist practitioners in understanding the current evidence	In medical and research field	Extraction of data by Miners	Deep Learning
Nebula Genomics [26]	Provides a reliable and safe platform for sharing and monetizing life's data	Marketing	Bridging the gap between the companies that want data and the people who want their genome sequence analyzed	Deep Learning
Neuromation [27]	Help the developers to better train neural networks	Medical Instruments and industrial robots	By training models to empower the distributed computational power and blockchain	Deep Learning

5 AI for Blockchain

Figure 1 illustrates the key properties of AI which illuminate the facts that AI can easily integrate with other technologies, can adapt quickly, and can provide a platform to build an autonomous system for prediction, governance and resource management [27].

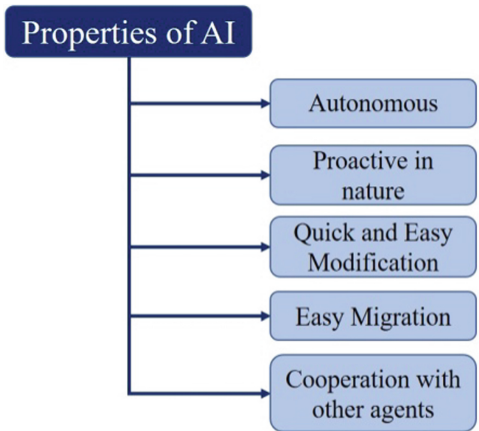


Fig. 1. Properties of AI.

The design and functionality of blockchain includes numerous parameters and trade-offs among decentralization, security, functionalities, overall performance and many such these. AI can ease these choices, optimize and automate it for better governance and higher performance. Furthermore as blockchain makes data publicly available on its platforms, AI performs a key function in offering customers privacy and confidentiality. On the flip side, blockchain ought to use AI for the purpose of legalization of the user-controlled records, or it also aims at creating self sustaining agencies.

5.1 Automatic Governance

Efficient and easy management of data can be achieved by AI. AI is proving to be exponentially important for the purpose of information governance. Subsequently blockchain maintains an inflexible ledger that holds the records of all undertakings using independent peer networks. Multiple stakeholders are a part of the Information Governance. It has become increasingly important to consider all types of information as records for efficient governance. This can be achieved by smooth functioning of these two technologies [28].

5.2 Real-Time Flagging of Fraudulent Transactions

With AI accompanying blockchain at the time of an e-contract, the data owners have the complete transparency of the proceedings and with AI monitoring the process, it can instantaneously notify and flag if there is a breach or fraud in the data inserted and processed [29].

5.3 Enhances Security

Security in blockchain consists of an application that includes mechanisms such as data encryption and cryptocontracts. For detecting threats in an application, IDS (Intrusion Detection System) and IPS (Intrusion Protection System) are extremely important. The solution that adds to the improvement of blockchain system is the creation of sturdy ciphers which enhances the device security. AI plays a great role in minimizing the weakness of blockchain's implementation in the field of cryptanalysis and delivers by creating powerful ciphers that boost blockchain defense procedure and its resilience [30].

5.4 Efficient Creation of Digital Investment Assets

According to literature survey there is no sufficient data with respect to AI to apply on economic artifacts dealt over blockchain. Increase in the data volumes going through blockchain prompts derivation of helpful observations from data [31].

The blockchain-AI convergence process covers 4 phases as shown in Fig. 2.

Phase I: Proof of concept on blockchain.

Phase II: Blockchain tokenization of assets.

Phase III: Digital investment assets on Blockchain.

Phase IV: AI as a financial representative which powers digital investment assets.

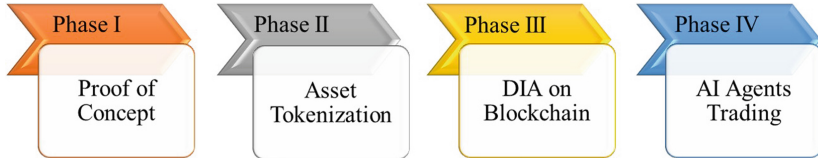


Fig. 2. Depicting AI based digital investment assets using blockchain.

5.5 Scalability

Scalability being a key feature of blockchain enabled distributed learning and many such enhancements through AI. Scalability also uses fusion of AI and blockchain technology. It has obstacles like bootstrap time, cost per transaction and latency. These characteristics have a big impact on blockchain scalability. In a blockchain technology, as each block accommodates some amount of business data, traditional mining is not successful. As some of the advanced AI algorithms show an ability to learn from different distributed data sources, it proves to be an excellent solution for blockchain.

6 Blockchain for AI

Figure 3 portrays the special characteristics of blockchain, resulting in a much secure and reliable variant of the same.

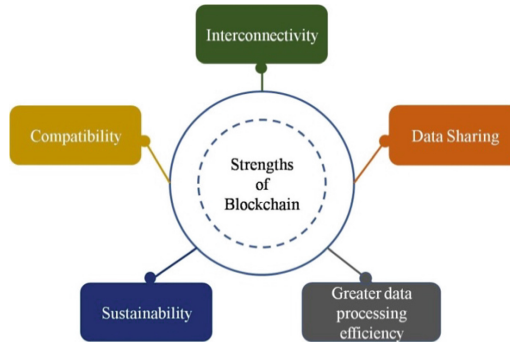


Fig. 3. Strengths of blockchain.

6.1 Transparency in AI

With Blockchain integrated, AI proceedings can be monitored in the controlled way where the experts and data scientists can have access to the data being fed and processed in AI without the fear of interference or tampering in the data [27].

6.2 Improved Trust on Robotic Decisions

Decisions taken by AI must always be simple and understandable for the stakeholders to perceive and trust it. Blockchain stores a record of the transactions in the form of distributed ledger in a point to point manner making it easier to receive and trust the conclusions derived from AI, as storing information in an encrypted manner assures tamper-proof records for the auditing process. This makes AI on a blockchain system give more clarity on the decisions taken which in turn gains the trust of users [32].

6.3 Decentralized Intelligence

For taking decisions having high stakes and involving numerous agents for performing different micro tasks with access to common data, individual cybersecurity AI agents could be combined to provide a fully structured security to the underlying networks and to troubleshoot any scheduling anomalies [33].

6.4 Keeping Data Private

Blockchain eliminates the identifying parameters or details. There are methods to infer as to which data is particularly concerned with whom. The process of training algorithms, making predictions and performing analysis of data can be achieved with the help of anonymized data rather than relying on companies like Google or Amazon to collect data [30].

6.5 Data Distribution and Security

The primary and key aspects in the growth of AI are the ability to handle big datasets and provide security to them. Currently almost all of the AI models require storage models on cloud or centralised servers. This makes the data more vulnerable to threats, as it has just one point of access to it [34]. Blockchain being decentralised in nature resolves this issue and removes the threat by distributed storage of data on numerous systems across the world. Though the data is diffused, the access to it is still easy and doesn't require much effort. This acts as entry point for variant data sets which expands the practicing and learning of AI/ML algorithms. It is challenging to secure data when it is with respect to AI in industries especially in businesses and the health care sectors [30].

7 Intersection Between Blockchain and AI

Figure 4a depicts an assemblage of selected features from both AI and blockchain which produces decentralised AI. Figure 4b summarizes how one technology compliments the other across various aspects of the integration.

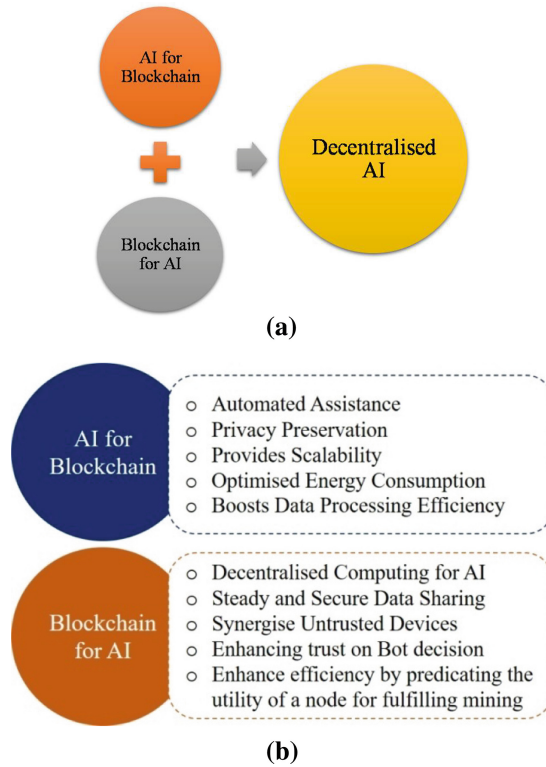


Fig. 4. (a) Decentralised AI. (b) Depicts how one technology compliments the other across various aspects of the intersection.

AI and blockchain are two different technologies. AI promotes the centralized intelligence on organized data in closed environment. Blockchain fosters decentralized applications in open data platform [3]. This results in convergence of AI and blockchain for development of breakthrough technologies.

The intersection of blockchain with AI happens at the following junctures:

- a) **Anti Hacking:** It is conceivable for hackers to introduce malicious data into an AI model in order to introduce bias for financial gain or to generate chaos. For instance, it is possible to introduce a few errant pixels into an image of a giraffe, to trick the AI into identifying it as a dog.
- b) **Privacy Protection:** Blockchain can even perform one way homomorphic encryption (HE) to protect our privacy. This way medical record can be made available to the general public to develop innovative AI solutions; for instance, in a recent study done in China, AI is now able to detect lung cancer with significantly higher accuracy than oncologists. However, privacy regulations hinder AI development in other developed countries. Blockchain can help us open the door without loss of privacy [35].
- c) **Ownership:** One of the biggest criticisms of Facebook and other media platforms is how they own our data. Blockchain is well suited to storing your data so that you get paid if you choose to share it with an institution. Taking this a step further, we have companies like SingularityNET that offers full stack AI services. A developer can make, for instance, a sales forecasting AI service and share it via this platform. However, blockchain is used in the background so that the developer always retains ownership of his algorithm and hence can be appropriately compensated.
- d) **Bias:** For controlling the bias, we utilize blockchain to document the whole process of AI modeling. This will document how each decision was taken concerning the layers in the neural network, which activation functions to apply, how would the data be collected and cleansed, and so on. Each of these decisions has a tiny but vital impact on any biases in the design.
- e) **Contracts:** One of the big use cases for blockchain is to carry out smart contracts. These are immutable programs submitted to the blockchain for execution under specific circumstances. For instance, on the passing of person X, all assets kept under his name should be transferred to person Y. But these are all hard coded steps. In the future, we can have AI use reinforcement learning to train a bot to act on our behalf to network events, rather than follow scripted rules. From there, the AI bot can evolve to protect itself from security threats and so on.

Table 2. AI and blockchain intersection benefits [4]

AI	Blockchain	Intersection Benefits
Centralized	Decentralized	Improved data security
Probabilistic	Immutable	Informed and collective decision making
Changing	Deterministic	Enhanced trust on decisions with respect to robots
Volatile	Data Integrity	Decentralised Intelligence

The above Table 2 lists the individual properties of AI and Blockchain and tries to give us a brief idea about the benefits of integrating the two technologies in different perspectives and how combining these will counter each other's loopholes and help emerge with better and stronger technologies.

8 Issues and Problems at the Intersection of AI and Blockchain

AI and Blockchain are the key resources for innovation that we are witnessing today. By acknowledging the great change in our day to day life, they are all destined to fundamentally redefine the way we live, interact and work. As it is a highly disruptive technology, they are expected to contribute hundreds of billions to the global economy. Developments in this field could work and change the need for a third-party approach that could disrupt critical industries.

8.1 Governance

A number of stages and activities are involved in the process of deployment, structuring and management of a blockchain platform. This process involves people either directly or indirectly which is basically the stakeholders and the active participants. One of the major issues faced with respect to this is the variant of blockchain to be deployed, who troubleshoots, administers and resolves disputes in the blockchain, authors of smart contracts, destination for posting of nodes in the blockchain. This issue is faced even with private consortium blockchain [3].

8.2 Tedious Consolidation of Outputs

The nodes in blockchain are heterogeneous and decentralised in nature. The storage of information is achieved by the decentralised ledger which ensures secure storage and immutability of information using techniques such as hashing and cryptographic encryption. Hence, they are politically and architecturally decentralised. This results in Blockchain being public and open sourced, which makes it tedious for AI to consolidate the outputs from various sources into a single point without which further derivations on data cannot be made at all [36].

8.3 Magnitude of Efforts

Both of these technologies are poles apart as one fosters decentralised intelligence in open data platforms whereas the other promotes centralised application in a closed data environment. The concept of integrating these two is relatively new. As a result of which enormous amount of time and investment is necessary to explore these two technologies in depth and to find similar grounds to enable integration [37].

8.4 Higher Computational Needs

Efficient and greater computational power is required for the ecosystem that uses decentralised AI. As an instance, Google search engine will require exponentially more time to ensure security and other advancements for the search, which makes it difficult to keep up with the pace of the process. When we think of Artificial Intelligence and Blockchain alone, they both show that they have a bright future. By 2025, AI market is projected to extend to nearly \$39.7 billion whereas the global blockchain market was worth of only \$3.0 billion at 2020 [38].

8.5 Security

Security is one of the key challenges with respect to integration of AI and blockchain. AI is delivered with reliable and abundant information, by the Blockchain platform which is public, isolated and securely distributed. This uses cryptography algorithms which makes it impossible for data thefts to occur. However, for AI to make better predictions on data, it might need to change the protected data which has to be decrypted in the first case. This decryption of data by AI might lead to data hacking [36].

9 Conclusion

In this paper we have highlighted the concerns and prospects at the intersection of blockchain and AI and how these two technologies faint the loopholes of each other to build a more powerful technology. Here we have clearly depicted how these two technologies promise to complement each other in the best possible way. We have also presented various tools and technologies in the field of AI and blockchain that are playing a crucial role for the rise sustainable development. The technical implications that arise at the intersection between AI and blockchain technology gives rise to decentralised AI which enables the process of decision making on reliable and secured data independently by avoiding the involvement of any intermediaries in the course of action. The detailed implications can be addressed as a future enhancement.

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