Data Analytics and Artificial Intelligence
Vol: 2(5), 2022
REST Publisher; ISBN: 978-81-948459-4-2
Website: http://restpublisher.com/book-series/data-analytics-and-artificial-intelligence/

Blockchain for Deep Learning

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Abstract. Deep learning has grown immensely in recent years due to its capacity to make sensible conclusions. The great majority of today's deep learning systems, which are constructed on centralised servers, lack appropriate operational transparency, traceability, reliability, security, and trustworthy data provenance features. If deep learning models are trained on centralized data, the single point of failure problem may also arise. In this essay, we investigate the benefits of fusing blockchain technology with deep learning. We examine the body of research on deep learning and blockchain integration. By creating a theme taxonomy based on seven criteria—blockchain type, deep learning models, deep learning-specific consensus protocols, application area, services, data kinds, and deployment goals—we classify and organise the literature. We outline the advantages and disadvantages of the most advanced blockchain-based deep learning frameworks to give meaningful conversations. Additionally, based on four criteria—blockchain type, consensus protocol, deep learning method, and dataset—we compare the current blockchain-based deep learning frameworks. Finally, we outline significant research issues that must be resolved in order to create highly reliable deep learning systems. Keywords: Deep Learning, Blockchain, Smart Manufacturing, Scalability, Security, Privacy, machine learning, Federated learning, Transparency

1. Introduction

Deep learning's promise has been seen in practically all industrial areas. For instance, in the healthcare industry, doctors employ deep learning models to accurately diagnose the patient's ailment based on their symptoms. Deep learning models have been used to predict the disease spread rate in a specific location during the recent pandemic brought on by the spread of coronavirus illness (COVID-19), and to aid the authorities in managing the pandemic using the anticipated results [1-3]. Additionally, cutting-edge deep learning methods have helped doctors diagnose COVID-19 patients using the dataset of CT and X-ray pictures [4, 5]. In addition to healthcare applications, security personnel at airports have used deep learning to find and validate prohibited items.Data integrity, security, and secrecy can all be handled well by blockchain, a decentralised system [2, 10, 11, 11]. The combination of blockchain and deep learning can provide a number of advantages, including efficient data processing and automated decision-making.A smart city is an infrastructure for the quick development of next generation sensing devices and a growing industry based on sensors networks, telecommunications, and other factors. Smart management, smart control, and smart communications are necessary for the development of the smart city and are employed in a variety of recent sophisticated applications, including smart manufacturing, smart automobiles, smart farming, and others.

The following are the paper's main contributions:

- Based on seven key factors, we develop a taxonomy to organise and classify the available research on blockchain-based deep learning systems.
- We outline the advantages and disadvantages of the most advanced blockchain-based deep learning frameworks.
- We contrast the deep learning frameworks for blockchains based on key factors.
- We explore a number of research issues that may have an impact on the effectiveness, precision, and predictability of current deep learning frameworks based on blockchain technology.

2. Background

In this section, the main characteristics of deep learning and blockchain are briefly discussed, along with the advantages of combining them in terms of data security, automated decision-making, and improved robustness.

3. Blockchain technology

The manner the blockchain saves data makes it very impossible for hackers to alter, corrupt, or destroy data. It is by design a decentralised system that stores and processes data and transactions using a P2P architecture. There are many nodes in it, and they all work together to validate and store the transactions as blocks

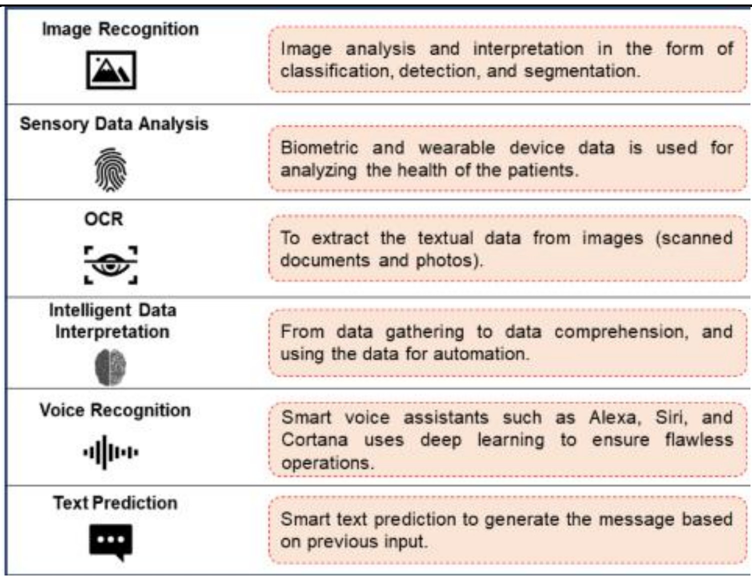

FIGURE 1. Block chain technology

A set of transactions are stored in each block of the chain, and it is assured that the blocks that already exist are correctly linked to the newly formed blocks to build the chain of blocks.The newly added block is disseminated to all participating nodes after being added to the local chain by a miner to guarantee data consistency [28, 29]. The blockchain transactions are verified and approved by the miner nodes thanks to the decentralised consensus mechanism. For instance, several blockchain platforms implement the Proof-of-work and Proof-of-Stake consensus protocols, which can protect the blockchain against any internal or external data hacking assault. Another key component of blockchain technology is smart contracts, which function like an electronic programme and only execute when certain conditions are satisfied [3, 17, 30]. The goal of smart contracts is to lower business risk and expense.

4. Federalized learning and deep learning

AI and machine learning are both included in deep learning. Existing deep learning techniques teach a model to represent the most fundamental type of data in latent space. Pictures, text, and speech signals are examples of data. The connection between deep learning, AI, and machine learning is depicted in Figure 4. Deep learning enables hardware to carry out several tasks with accuracy comparable to or sometimes even superior to that of humans. Image classification [37], object identification [38], self-driving cars [39], disease prediction [40], and voice control [41] are well-known applications of deep learning techniques that serve as examples of its extensive use in several domains. Lots of labelled data are used to train the deep learning models.

5. Blockchain-basedDeep learning

Blockchain technology can help Deep learning models be reused and trustily shared, which is a crucial necessity. Similar to this, the major drivers driving the integration of blockchain with deep learning are auditability, data verification, and attestation of results, provenance, and traceability of ownership, usage, and guarantee of fairness [24]. In order to learn the features and produce an output with probability vectors in place, deep learning models are fed a huge amount of data from a variety of samples. Even while deep learning models excel at making predictions from raw data, many real-world scenarios still depend on the quality of the input. The blockchain is a massive database that all network nodes may access and store data in.

6. Blockchain type

Based on the blockchain platforms used by the current deep learning frameworks for blockchain, this parameter divides the existing studies into three groups. The time-specific modalities of the blockchain help to improve many of the servicesand applications that the deep learning algorithms enable because they have time-related restrictions. Modern deep learning frameworks can categorise blockchain platforms into public, private, and consortium/federated categories based on their design, characteristics, and policies. These categories are explained below.

Public blockchain: The public blockchain platform leveraged by the existing blockchain-assisted deep learning frameworks allows permission less or unrestricted access to the distributed ledger by the users or machine learning devices. Users access the ledger copy that is distributed among all nodes within the public blockchain network and performs transactions. Public blockchain platforms maintain transaction anonymity because of decentralized data storage and processing. Furthermore, public blockchain platforms are secure against several types of attacks; therefore, they assist the deep learning models in coming up with the correct and trustworthy results [28, 30, 57].

Private Blockchain: The blockchain-assisted deep learning frameworks use private blockchains that are controlled and managed by a single organisation. Private platforms are permitted where the controlling entity has the necessary power [58]. Since the central authority is aware of the validators' and nodes' identities, the private network requires significantly less difficult mathematical operations to verify the transactions. Consequently, the private platform executes transactions more quickly than the public platform.

7. Deep learning models

The gathered data is processed by a deep learning model, which creates patterns that may be applied to various use cases to aid in decision-making. The deep learning models used for decision-making in many application domains are divided into five main types based on the configuration of neural network layers. An overview of deep learning models that have produced patterns and made judgments using data from blockchains is provided below**.**

Consortium/federated blockchain: Convolution Neural Network (CNN), also referred to as ConvNet, analyses an image to recognise the items, give the objects weights, and categorise them in accordance with the context. Additionally, it makes object instances in the processed image detectable [60]. CNN has been used by the deep learning frameworks built on blockchain to classify photos, identify objects, and segment instances in a variety of use scenarios. Because CNN uses flexible filters to identify the qualities of the image, blockchain-based studies benefit from the algorithm's minimal pre-processing time requirement.

Recurrent neural network: When given input of visual data, a CNN model performs better. However, Recurrent Neural Network (RNN) generates patterns using sequential or time-series data [61]. For blockchain-based solutions, voice or speech recognition, speech-to-text conversion, voice search, and natural language processing are some of the well-known RNN uses (NLP). Additionally, in CNN models, the input data are independent of one another, whereas in RNN models, the previous inputs are linked and affect the result.

Generative adversarial networks (GAN): The generative model is able to produce original data and learns patterns in an unsupervised manner. More specifically, it is a type of deep learning modelling that makes use of convolutional neural networks. The GAN model is built with a generator network and a discriminator network. The discriminator learns to distinguish between true and bogus data, whereas the generator creates fresh samples.

Deep reinforcement learning (DRL): DRL allows expert systems to more accurately analyse the data since it is inspired by ideas of human behaviour that are based on behavioural ecology. DRL models make up the environment in which intelligent agents act in order to learn. Agents are also implicitly rewarded or punished based on their actions. Reinforced learning-based models are those that reward actions that result in the intended outcome [65].

Geometric deep learning: It is a deep learning variation that concentrates on creating neural networks with non-Euclidean data as their foundation [66]. A particular type of non-Euclidean data is a graph. Using graph-based data allows data modelling to be completed with less time and effort. Instead of data in the conventional form to generic neural networks, the graphs are input to the geometric deep learning models.

8. Application areas

This parameter identifies the primary application domains that the most advanced blockchain-assisted machine learning frameworks concentrate on to guarantee data integrity. Health care, IoVs, traffic control, and safety and protection are the key areas.

9. Services

This parameter emphasises the core functionality of blockchain-based deep learning systems aimed towards numerous application domains, including healthcare, vehicular communication, and IoT. Anomaly detection, traffic violation prediction, privacy preservation, cellular traffic management, andforking prevention are just a few of the goals that current techniques attempt to achieve.

Privacy preservation: Data about an entity cannot be altered or read by unauthorised individuals thanks to privacy protection. The anonymity of the data used in deep learning models may be preserved via blockchain technology [78].Proxy re-encryption and extremely complex data encryption techniques can offer privacy protection.

Violation prediction: Traffic infractions come in numerous forms, such as speeding, drunk driving, lane switching illegally, and failing to stop at a red light. The combination of deep learning and blockchain is essential for forecasting the violations committed by drivers. For instance, the deep learning-based classifier can forecast traffic events using highly secure blockchain data [79]. Such information can be immutably recorded on the blockchain and used by the department of highways to develop the network of roads, insurance firms to evaluate damage, and law enforcement organisations to enact laws.

Anomaly detection: The discovery of data that deviates from typical behaviour is the focus of anomaly detection. The encoder-decoder network in deep learning can understand the typical behaviour of a real-world event based on blockchain-based data and transactions [80]. Based on the examination of the data, it can recognise an anomaly right away. Additionally, the model is able to identify these.

Data types: The characteristics of this parameter specify the kinds of data that the deep learning models supported by cutting-edge blockchain technology can accept and analyse. Blockchain-based deep learning models often accept text and visual data as input.

10. Blockchain-based deep learning

Modern blockchain-based deep learning solutions for various application domains are covered in detail in this section. It contrasts current deep learning frameworks built on blockchain based on parameters chosen from the literature.

Review of blockchain-based deep learning Frameworks: This section provides an overview of current deep learning frameworks built on block chains with a focus on healthcare, automotive networks, cellular traffic management, and blockchain security and defence against hostile attacks. Data evaluation Deep learning models' resource-friendly architecture and patient-centric data handling have become crucial components, notably in pharmacogenomics research. A decentralised approach that feeds pharmacogenomics data to deep learning models to forecast ovarian cancer has been proposed in the work reported in [85].

Comparison of existing frameworks: This section contrasts current deep learning frameworks for blockchains based on a number of factors. The solution category, blockchain type, consensus strategy, deep learning techniques, data set used by the deep learning model, study strengths, and study constraints are the primary parameters that are taken into account for the analysis. Table 2 contrasts the research projects outlined above in several categories where blockchain and deep learning are involved.

11. Conclusion

We have studied cutting-edge blockchain-based deep learning frameworks in this article. We discussed in detail the advantages brought about by the integration of deep learning and blockchain, as well as their key features. The successful integration of deep learning with blockchain can improve the QoS in several applications, primarily related to healthcare, blockchain security, data traffic management, and vehicular communication in urban areas. It can also facilitate existing systems in terms of data security and privacy and improve data security and privacy. Based on seven criteria, including the type of blockchain, deep learning models, deep learning-specific consensus protocols, services, application domains, deployment goals, and data types, we developed a taxonomy to group the reported literature into different categories.

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