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Resolving Covid-19 with Blockchain and AI: a Systematic Review

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ABSTRACT

In the early months of 2020, a fast-spreading outbreak was brought about by the new virus SARS-CoV-2. The uncontrolled spread, which led to a pandemic, illustrated the healthcare system's slow response time to public health emergencies at that time. Blockchain technology was anticipated to be crucial in the effort to contain the COVID-19 pandemic. In that review, many potential blockchain applications were discovered; however, the majority of them were still in their infancy, and it couldn't yet be predicted how they could contribute to the fight against COVID-19 through the use of platforms, access kinds, and consensus algorithms. Modern innovations such as blockchain and artificial intelligence (AI) were shown to be promising in limiting the spread of a virus. Blockchain could specifically aid in the battle against pandemics by supporting early epidemic identification, assuring the ordering of clinical information, and maintaining a trustworthy medical chain during disease tracing. AI also offered smart forms of diagnosing coronavirus therapies and supported the development of pharmaceuticals. Blockchain and AI software for epidemic and pandemic containment were analyzed in that research. First, a new conceptual strategy was proposed to tackle COVID-19 through an architecture that fused AI with blockchain. State-of-the-art research on the benefits of blockchain and AI in COVID-19 containment was then reviewed. Recent initiatives and use cases developed to tackle the coronavirus pandemic were also presented. A case study using federated intelligence for COVID-19 identification was also provided. Finally, attention was drawn to problems and prospective directions for further investigation into future coronavirus-like wide-ranging scenarios.

1. Introduction

The coronavirus (COVID-19) outbreak represented a serious threat to the entire world (Zhou et al., 2020). The World Health Organization (WHO) was compelled to declare the epidemic a pandemic within a month of its rapid spread because of its extraordinary severity. Numerous industries, including distribution networks, commerce, insurance, agriculture, transportation, and tourism, were significantly disrupted as a result of the virus's proliferation, which forced governments and business owners to suspend activities on a global scale (Monrat et al., 2019). The Organization for Development and Cooperation (OECD) predicted that the coronavirus pandemic would result in the slowest global economic growth since 2009 (Kadadha et al., 2020). As seen in Fig. 1, governments across the world adapted specific forms of lockdowns, curfews, and encouraged social confinement and work from home (WFH) as the prevalence of the illness rose. Every effort was made to ensure victims received assistance while also halting the global spread of the deadly coronavirus. Technology-enabled solutions played a crucial role in resolving the global health crisis as governments strived to address these issues. The applications of cutting-edge technologies, such as blockchain and artificial intelligence (AI), held the potential to provide solutions to the COVID-19 pandemic. Blockchain could aid in early outbreak detection, accelerate drug distribution, and provide consensus on the ordering of COVID-19 records, facilitating the response to the pandemic. Additionally, AI, both supervised and unsupervised (ML), offered smart ways to track epidemics in real-time, including flare-ups, anticipate pandemic patterns, perceive COVID-19 treatment side effects, and assist in drug development (Chesbrough et al., 2020).

Blockchain offers promising security options against a pandemic such as coronavirus. As a matter of fact, systems that exchange clinical information can utilize the blockchain to construct an immutable record of exchanges. Blockchain exchanges cannot bring about the change or adjustment

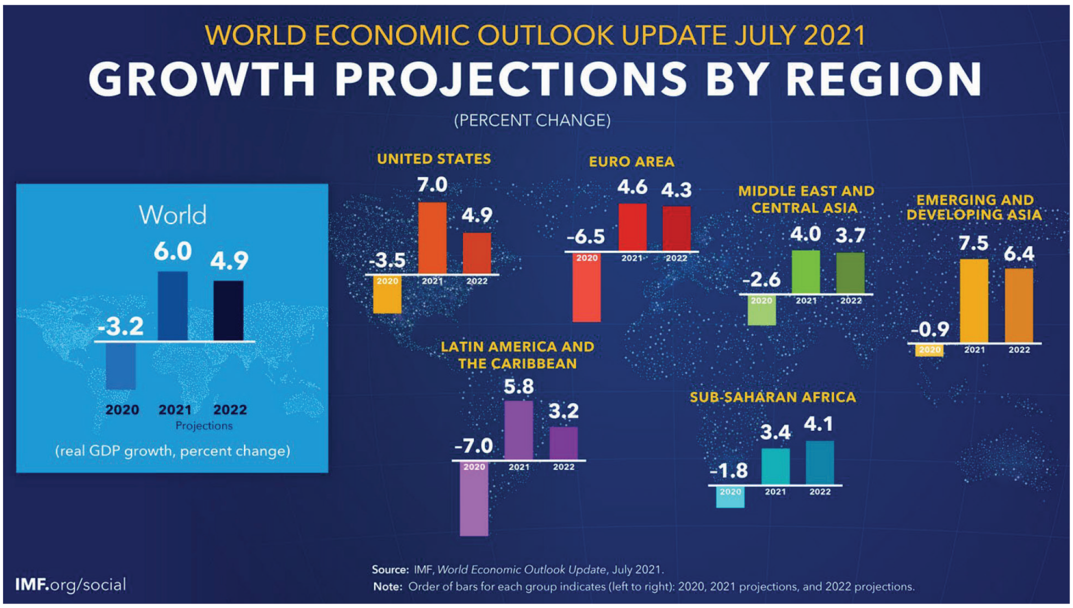

Figure 1. The impact of COVID-19 on global economic growth

of coronavirus information. Moreover, once transactions have been recorded on the blockchain, they may not be altered or removed. For all servers used to store health data, including cloud servers, the coronavirus information assortment and reflecting on the blockchain would also be represented freely by the blockchain (Khurshid et al., 2020). All the more significantly, the utilization of blockchain innovation and brilliant agreements eliminates the requirement for centralized servers to guarantee fairness among transaction participants, including patients, medical clinics, and state-run administrations, as well as to truly control data access and use. With the coronavirus information management system, which depends on blockchain technology, each entity is afforded equivalent administration power over all areas of medical services. Because of its decentralized design, blockchain specifically could keep working effectively regardless of whether at least one gathering fail (Fusco et al., 2020). Two of the most particular attributes of blockchain that are missing from other conventional security methods are the detectability and decentralization it offers. Furthermore, blockchain can offer reliable support for dependable coronavirus investigation. Obtaining coronavirus information is perhaps the main component in the illness examination process. The correctness of the information procured during information gathering determines the precision of coronavirus investigation. Kalla et al. (2020) Among the potentially devastating results of utilizing defective information or problematic data set sources is an unacceptable finding of coronavirus. Furthermore, some sources containing coronavirus information were obtained from institutions, the public at large, or the media during an epidemiological crisis without proper supervision, which meant changes to the coronavirus information could be made. These issues would undoubtedly influence the validity of the coronavirus logical cycle by lowering the accuracy of the data that was gathered (Huumo et al., 2016). This makes blockchain an ideal technology as its security characteristics guarantee the precision of the stored information. The blockchain also offers agreement techniques. The coronavirus data and information should be conveyed from information sources to beneficiaries (such as medical clinics or diagnostic labs) in the right arrangement to achieve good information gathering. With these blockchain capabilities, accurate information collection for a suitable understanding of coronavirus would be supported. By combining crowdsourcing and crowdsensing advances, blockchain's motivating factors can be extremely useful in creating coronavirus prevention techniques. The time-consuming, outdated Covid diagnostic method is another weakness, which frequently requires several hours to complete the infection testing. Consequently, it is necessary to foster methods for speeding up Covid location while maintaining high precision. Besides, handling massive amounts of complex Covid data with human-dependent clinical technologies is very troublesome. The efficiency of AI algorithms can also be greatly enhanced by effectively networking and fusing data, which is the lifeblood of AI. Increasing the effectiveness of dispersed data in many entities with potential conflicts of interest can be accomplished by enabling data sharing among many service providers. AI is positioned to become one of the most potent technologies and tools for enhancing cybersecurity, as it can check massive amounts of data more quickly to save time, identify and mitigate threats. AI can also provide more accurate prediction and decision support on security rules that a PDC should implement, given enough data and a blockchain-based smart contract for secure data sharing.

1.1. Principle Finding for Blockchain and Artificial Intelligence to Determine coronavirus

Cheng et al. (2020) have explored various dimensions of addressing Covid outbreaks through the integration of blockchain and AI technologies. Notably, in the context of combating other viral pandemics, like Ebola, blockchain has been effectively utilized for real-time vaccination management, continuous contact tracing, and pattern analysis of disease spread. Their research also emphasizes the role of blockchain's cryptographic capabilities in preventing the insecure transfer of patient or provider data. This innovative blockchain technology can streamline the standard procedures for launching drug trials, as well as document and track all funding activities and donations in a secure and permanent manner during the battle against Covid outbreaks. Artificial intelligence has played a significant role in fighting diseases such as coronavirus. Jang et al. (2017) employed predictive data-driven learning techniques, utilizing Bayesian algorithms (ML), for the development of effective treatments against the Influenza virus. These practical examples illustrate the versatility of artificial intelligence in predicting viral spread and in the development of treatments for communicable diseases, thus contributing to the prevention of infectious outbreaks. The diverse applications of artificial intelligence have proven instrumental in curbing the Covid outbreak.

Furthermore, artificial intelligence can be harnessed for disease prediction and detection. The prediction of virus spread can be simplified by considering factors such as weather conditions, healthcare accessibility, and transmission modes. In this context, artificial intelligence can assist in identifying the characteristics of the virus and in detecting Covid in outbreaks of mild illnesses. Notable Covid symptoms include renal failure, severe acute respiratory syndrome, and pneumonia. The severity of Covid is influenced by factors such as immunity and an individual's genetic makeup, and current conventional treatments are insufficient to address all symptoms comprehensively. Artificial intelligence-based technologies, like genomic sequencing and neural networks, can significantly aid in managing these severe symptoms. For example, in assessing the prognosis of coronavirus pneumonia, a combination of chest and CT scans, alongside other methods, was utilized. RT-PCR, a prominent Covid-related test for acute respiratory diseases, was employed. In particular, logistic regression models were used to analyze the relationship between clinical data, including CT measurements, and patient outcomes (ICU admission and mortality versus no ICU admission or mortality). Subsequently, the use of the area under the receiver operating characteristic curve facilitated the calculation of adverse effects, thus contributing to clinical decision-making for optimal patient treatment. Additionally, artificial intelligence may expedite the discovery of new Covid strains by establishing connections between a novel Covid and closely related viruses, such as SARS.

1.2. Search Strategy

Numerous recent research initiatives have been initiated to explore potential applications of cryptocurrencies and artificial intelligence in combating the coronavirus pandemic. The primary focus of this study, centers on examining the Bitcoin protocol's ability to address the trust issue during the coronavirus pandemic. The authors provide a comprehensive analysis of the advantages and disadvantages of implementing blockchain technology within the healthcare system, including discussions on its potential for handling coronavirus-related issues, such as contact tracing, disaster relief, health data exchange, e-government, supply chain management, online education, and outbreak management research is also ongoing on how artificial intelligence can contribute to coronavirus pandemic management. This work emphasizes the use of technology and various forms of intelligence to mitigate the pandemic's impacts. Additionally, it offers a concise introduction to the development of pandemic intelligence and provides a succinct explanation of deep learning's roles in coronavirus business intelligence. The implications of AI in the fight against coronavirus, encompassing disease detection and diagnosis, virology and pathophysiology, therapeutic and vaccine research, and pandemic and spread prediction, are thoroughly covered in this comprehensive work.

- In contrast to prior survey endeavors, this research provides an exhaustive assessment of both blockchain and artificial intelligence for combatting the coronavirus.
- The principal objective of this article is to impart a comprehensive understanding and propose a plan for addressing the healthcare challenges brought about by the Covid outbreak through the use of cryptocurrency and artificial intelligence.
- This study conducts a thorough review and examination of solutions and use cases for blockchain and artificial intelligence technologies cantered around the Covid (coronavirus) outbreak, drawing from the latest findings and a rapidly growing body of research.
- A case study involving the application of integrated artificial intelligence for coronavirus detection demonstrates the method's benefits and limitations.

The overarching goal of this review article is to offer a comprehensive overview of the research on the application of blockchain technology and artificial intelligence in the context of COVID-19 epidemiology. This includes systematic mapping as the chosen research methodology. Before delving into the rationale for employing blockchain and AI to address COVID-19, it is imperative to acknowledge the limitations of current healthcare systems. The second step involves locating all relevant scientific literature pertaining to the investigation's subject matter. Papers addressing the elements of blockchain technology and AI technology relevant to combatting the COVID-19 epidemic have been categorized to support efforts to combat the pandemic. In order to filter and select the most pertinent technical literature, we employed search methods focused on blockchain, machine learning, and deep learning. Our searches were conducted in scientific databases, with a focus on peer-reviewed, high-quality papers presented at conferences, workshops, symposiums, and other research-related events, as well as those published in books and journals. We utilized scientific databases such as IEEE Xplore, Digital Library, Springer Link, and Science Direct to retrieve relevant papers. The fourth and final step involves title-based screening of each linked paper, during which subpar content, unavailable texts, and non-English-language papers were excluded while selecting the most relevant publications.

2. Background

This research study explores promising research avenues at the intersection of blockchain and artificial intelligence (AI) for managing the COVID-19 pandemic, offering a comprehensive guide for researchers.

2.1. Corona Pandemic

The COVID-19 pandemic originated in December 2019 in Wuhan, a city with a population of 11 million and the capital of China's Hubei Province. The new coronavirus is believed to have originated in bats, supported by various pieces of evidence, although the exact intermediate species remains uncertain. COVID-19 primarily affects the respiratory system, leading to symptoms ranging from mild, such as a runny nose or cough, to severe cases that impede breathing. Common symptoms include fever, cough, and fatigue. While the majority experience mild symptoms, older individuals and those with preexisting conditions are more vulnerable. The World Health Organization reported 959,116 fatalities and 30,949,804 confirmed cases of COVID-19 worldwide. The pandemic has rapidly spread, particularly in the US, Southeast Asia, and Europe, significantly disrupting daily life and economic growth. Cities have been under lockdown, people's movements restricted, and businesses forced to pause operations, with lasting repercussions on the global economy (Ashby et al., 2020). This viral outbreak has emerged as one of the most significant threats to financial markets and the global economy.

2.2. Blockchain and AI Technologies

The foundational technology of Bitcoin is commonly referred to as blockchain. Decentralization is a fundamental aspect of blockchain, wherein data is distributed across a network of nodes rather than residing in a single location. This decentralized structure imparts exceptional robustness and security by eliminating single points of failure. The transparency of blockchain is crucial for its overall operation, and consensus mechanisms facilitate this transparency. Consensus involves a set of rules that ensure agreement among all participants regarding the current state of the distributed blockchain ledger. Blockchains can be categorized as either public (permissionless) or private (permissioned) based on the chosen classification (Kadadha et al., 2020). Public blockchains allow anyone to conduct transactions, interact with other users, and participate in the consensus process. Bitcoin and Ethereum represent notable applications of public blockchains Conversely, private blockchains are restricted to a specific community within a large organization, where participants must adhere to an authorization process. Every blockchain comprises three fundamental building blocks: the block, consensus algorithms, and distributed ledger (database). Figure 2 illustrates the operation of a blockchain. Any type of record, including scientific data, can be executed and stored on the blockchain. A blockchain is formed by linking numerous blocks, each consisting of multiple transactions. An interconnected chain is created by including a header section on each block containing the hash of the preceding block. The primary advantage of blockchain lies in its ability to maintain the chronological order of data, including COVID-19-related information. These data points are securely stored in chronological order on the blockchain.

Blockchain's proof of work (PoW) and the underlying consensus mechanism ensure the network's security and transparency, without the involvement of intermediaries. The distributed ledger is resistant to tampering because each record possesses a unique cryptographic signature independent of a specific date. In terms of consensus algorithms, the most widely used method for validating blocks across the blockchain should not be controlled by any single entity, allowing all users with equal rights to govern each block, thereby preventing security issues such as double-spending attacks. This is achieved through consensus building. From a blockchain perspective, the consensus process directly provides assurance regarding the settlement of every data dimension within the blockchain among the involved entities

The primary objective of mining is to serve as the leading node in the verification of a block. This process involves pitting nodes with the highest computational power against each other. Successful miners are rewarded with a positive number of coins for their efforts. Over time, as blockchain technology has evolved, various new consensus algorithms have been introduced, including Proof of Stake (PoS). Innovative technology, such as smart contracts, has gained significance across multiple domains, including healthcare (Fetzer et al., 2021). Smart contracts are programmable utilities within the blockchain ecosystem. Nick Szabo coined the term "smart contract" to describe it as a "digital transaction protocol that executes the terms of a contract." The core objectives of smart contract design include fulfilling common contractual requirements (such as payment terms, liens, confidentiality, or enforcement), reducing exceptions, both malicious and unintentional, and diminishing the need for trusted intermediaries. Each conditional script is associated with a distinct blockchain address, and an official transaction is initiated when it enters a smart contract. Because smart contracts operate

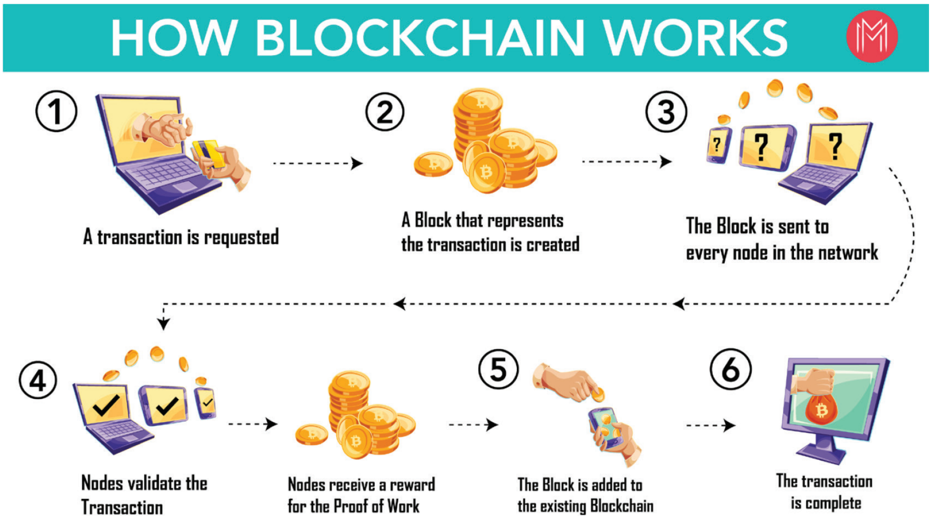

Figure 2. Blockchain framework

independently of external states, they offer a high level of transparency to the blockchain community. The outcomes of smart contract execution by community nodes are transparently recorded on the blockchain.

Blockchain technology has the capability to interact with the Internet of Things (IoT) in the context of healthcare (Wang et al., 2018). IoT devices, like sensors and gateways, can collect real-time sensory data from patients and securely transmit it to a blockchain for sharing and archiving. Blockchain technology enables decentralized communication between IoT users and devices, eliminating the need for central authorities to facilitate communication among healthcare professionals, including doctors, nurses, and patients. In cases of erratic IoT activity, such as sensor data collection, community members (comprising blockchain nodes) can monitor and approve transactional events and manage community operations. This approach could update the public ledger accessible to all network users, even though the role of central authorities is currently diminished (Saleh et al., 2019). Blockchain has demonstrated promise in securing medical records, simplifying record management, and directly storing scientific data. It has also proven effective in biomedical applications, making it a viable solution to address healthcare challenges stemming from the COVID-19 pandemic. Modern COVID-19 data analysis, prediction, and drug/vaccine discovery have benefited significantly from the application of artificial intelligence (AI) techniques. Recent research primarily underscores the use of two core AI methods: machine learning (ML) and deep learning (DL). ML forms part of AI and focuses on understanding the structure of data and incorporating it into models that individuals can communicate and use (Rangone et al., 2021). The goal of ML is to allow computers to produce values within a given range based on statistical evaluation methods rather than relying on records as training inputs. ML can establish patterns from data to automate decision-making using inputs from facts alone. For instance, several early studies employed temperature-monitoring-based techniques, such as facial and body temperature recognition with smart caps, to identify individuals with abnormal temperatures and those who may be symptomatic. An American AI company utilizes intelligent graphs powered by ML to monitor disease activity across China, enabling the development of an alert system that informs users if an infected individual has visited their vicinity. This response simplifies the identification of infected individuals and provides them with access to medical resources. AI-driven solutions have been effectively applied in innovative COVID-19 containment methods.

In deep learning, increasing the number of layers in neural networks enhances their capacity to model numerous neurons in the brain's network, which spans various layers. A fundamental deep neural network consists of three layers: an input layer for gathering data samples, a hidden layer for processing, and an output layer for forecasting outcomes. The depth of the hidden layers in this context signifies the depth of feature learning. Supervised or unsupervised learning techniques are used to produce the desired outcome, adjusting the weights between perceptron based on labeled or unlabeled statistical patterns. DL, a prominent field within AI, finds application in speech recognition, computer vision, image processing, and object detection for healthcare purposes, with COVID-19 infection prediction and the development of related drugs and vaccines as particular areas of focus. Several AI research teams have harnessed DL-powered solutions to predict COVID-19 infections and distribute the necessary treatments and vaccines. The public literature encompasses a wide array of AI-based techniques for COVID-19 detection, analysis, and prediction. Due to the pandemic, it has become more challenging to collect adequate data for the use of AI algorithms, and concerns about user privacy have grown due to data centers sharing public information for COVID-19 data analysis. In this context, federated learning (FL) has emerged as a promising AI strategy to develop cost-effective COVID-19 scientific applications with advanced security safeguards. Federated learning is a distributed AI approach that enables the training of powerful AI models by aggregating local updates from various hospitals and research facilities without necessitating direct access to local information. As it mitigates the risk of personal data exposure, the gamble of personal data leakage during this pandemic is likely reduced. The quality and accuracy of COVID-19 data instruction would also be notably enhanced, as FL trains AI models using a vast array of data and computational resources from numerous COVID-19 data sources. Centralized AI systems, which have limited data and computational power, cannot achieve this. To effectively control the COVID-19 epidemic, it is essential to monitor virus transmission and assess the likelihood of an outbreak. AI can leverage vast data sets on relevant subjects, including case occurrences, deaths, demographics, and environmental factors, to predict future COVID-19 occurrences and outbreak scale. Moreover, it facilitates the development of assessment techniques used to predict potential outbreaks, which is highly beneficial for governments seeking to formulate the most effective COVID-19 countermeasures. To establish the structure of COVID-19 and develop potential remedies to keep individuals healthy, it is imperative to model COVID-19 infections. The task of constructing a data-learning and evaluation mechanism to accurately predict the real COVID-19 infection pattern would be exceedingly challenging without the aid of machines. AI-driven algorithms on computers that mimic AI technology have the capability to assess how an individual's constituent proteins will fold or deform based on their genome, drawing from data. This information is then utilized to ascertain the shape of receptors, thereby facilitating the development of effective COVID-19 drugs. Effective COVID-19 drug discovery may become more straightforward due to this development.

3. Relevant Work

- We provide a comprehensive high-level blueprint of blockchain AI-based systems for COVID-19, emphasizing their framework-level components, participants, and roles.

- These systems encompass secure privacy data tracking, digital health passports, and digital contact tracing.
- We engage in insightful discussions on recent ongoing research initiatives to illustrate the practical implementation of blockchain technology across various domains in delivering healthcare services aimed at curbing the spread of COVID-19.
- We delve into a detailed exploration of several key open research challenges that currently hinder the progress of blockchain and AI technologies in their fight against the COVID-19 pandemic to gain a complete understanding of their potential.

3.1. Blockchain and AI technology mitigate COVID Challenges

In this document, we discuss Figure 3, which leverages artificial intelligence and blockchain technology to combat the challenges posed by COVID-19. The structure consists of four interconnected layers Bansal et al (2020) In the initial phase, raw data is generated by amalgamating information from various sources, including clinical laboratories, hospitals, social media platforms, and other resources. Over time, this data accumulates into extensive datasets. In the context of COVID, this data encompasses historical infection patterns, a list of outbreak locations, and COVID datasets containing time-series metrics, radiology images, X-ray results, and virus genome sequences. These sources may include the CDC, major healthcare organizations, clinical labs, the general public, and the media. For instance, China recently established a substantial database that compiles daily updates of confirmed cases over time based on public health commission reports (Hussain et al., 2020). The medical community has made a database of chest X-ray and CT images accessible on the public GitHub platform for research purposes. Researchers and authorities can use these representative data sources to monitor, assess, and predict the COVID outbreak. However, when employing blockchain technology for tracking and analyzing the COVID outbreak, the security of data from these sources must be ensured. Blockchain technology offers practical solutions for COVID-related services such as outbreak tracking, secure daily operations, scientific supply chain management, and donation tracking. Through logical approaches and artificial intelligence, the collective data from the blockchain network is examined (Agbo et al., 2019).

Artificial intelligence (AI)-based methodologies are employed to analyze the encoded data within the blockchain network. The five primary facets through which AI can contribute to the battle against the COVID-19 pandemic encompass COVID-19 detection, analysis of COVID-19 data, advancement in vaccines and drug development, and forecasting future COVID-19-like outbreaks. The ensuing elucidation delineates these applications. Various innovations in blockchain-AI frameworks are poised for potential realization due to their architectural configurations. For instance, by harnessing blockchain technology, secure channels of communication can be established between healthcare institutions and coronavirus research centers. COVID-19 data can subsequently be transmitted to the cloud, housing AI capabilities for data processing and statistical analysis. The processed data can then be re-routed through the blockchain to enable COVID-19 analysis by healthcare professionals. Figure 4 elucidates a representative use case for the proposed architecture. Aggregated hospital records can be uploaded to the blockchain of a data center. The da ta center can employ artificial intelligence tools, such as a neural network, for the analysis of COVID-19 records. Various techniques, including regression and classification, may be employed. Furthermore, a decentralized ledger underpinned by blockchain technology is employed to ensure a secure exchange of analyzed results among hospitals, stakeholders, and the data center. It is noteworthy that COVID-19 applications may leverage both private and public blockchain networks. Several mechanisms for enhancing security concerning private blockchains are

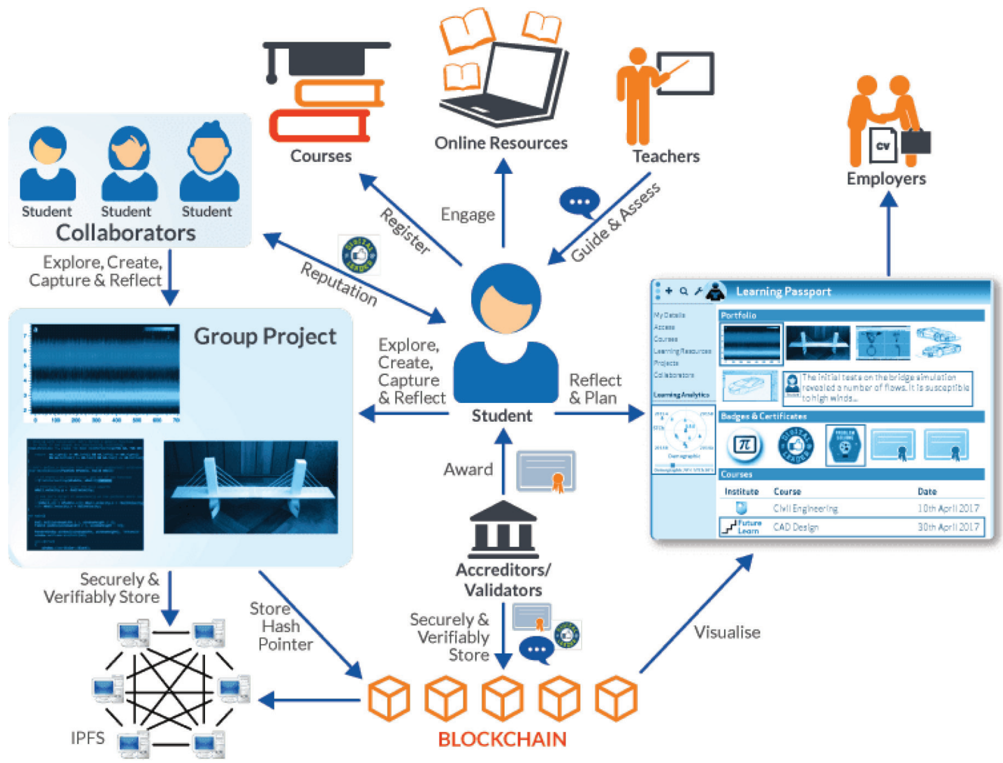

Figure 3. Artificial intelligence and blockchain to battle the Covid

available. For instance, blockchain entities can formally validate their responsibilities in data exchange within a private blockchain network designed for hospital communications among patients and staff. In the context of the blockchain community, where transactions and data exchange events can be verifiable in a transparent and open manner, smart contracts may be selectively deployed to provide robust authentication.

4. Discussion

This section delves into the integration of blockchain and artificial intelligence (AI) in the battle against the coronavirus. Numerous key stakeholders, including governmental bodies, healthcare practitioners, and medical institutions, are collaboratively engaged within a shared blockchain ecosystem. In this context, governments may necessitate blockchain technology for epidemic tracking, while medical professionals seek precise data to support machine learning (ML) and deep learning (DL) models in COVID-19 prediction and diagnosis. Furthermore, healthcare organizations can employ blockchain for expedited disbursement of patient donations or medical assistance. The amalgamation of blockchain technology exhibits substantial potential for bolstering strategies to combat the COVID-19 pandemic effectively.

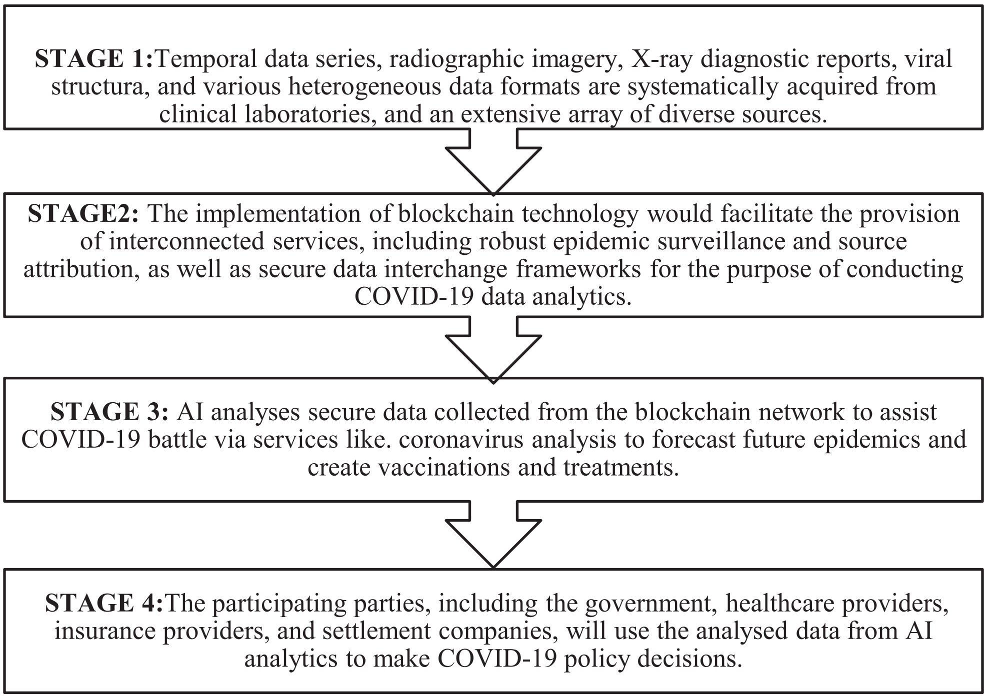

Figure 4. The working flowchart of our proposed blockchain-AI architecture for fighting COVID-19

4.1. Access Type and Outbreaks

Approximately half of the referenced studies are in the proposal phase. The limited acceptance of blockchain technology and the dearth of expertise in developing blockchain systems, particularly within the healthcare sector, may contribute to this status. Health applications, for instance, confront the choice between public blockchains, offering widespread usage and robust security assurances but potentially exposing privacy concerns, and private blockchains, affording controlled access but demanding more extensive configuration and management efforts. The majority of research predominantly adopts public blockchains, such as Ethereum and Bitcoin, which can be attributed to the accessibility of requisite skills, ease of adoption, and a certain level of security guarantee. In contrast, a prior scoping analysis of blockchain applications in healthcare, health sciences, and health education, conducted prior to the COVID-19 outbreak, revealed that hybrid blockchains were the most commonly employed type (38%) among the 39 studies considered, followed by public blockchains (10%). Blockchain technology can play a pivotal role in tracing and mitigating the coronavirus outbreak. Practically, blockchain can facilitate the tracking and provision of data visualization tools for monitoring fatal coronavirus cases. A blockchain, functioning as a distributed ledger database, can capture updates in nearly real-time and securely anchor them in immutable blocks linked to one another. This technology holds the potential to assist the multitude of coronavirus patients by unalterably documenting characteristic signs and symptoms of infection. This is particularly crucial since many patients may intentionally exaggerate their symptoms, potentially leading to flawed patient quarantine efforts. Governments and healthcare institutions can leverage blockchain to provide real-time data concerning affected regions and secure zones for implementing preventive measures, incorporating demographic data, geographical location, and the latest coronavirus statistics within containment areas.

The proliferation of misinformation through social media and the internet during the ongoing coronavirus pandemic is a substantial concern. Presently, public awareness has reached unprecedented levels (Saleh et al., 2020). Instances such as Turkey and North Korea initially reporting no diagnosed cases, contrary to WHO statistics, and skepticism surrounding the authenticity of case numbers reported by Iran due to the lower count of infected cases and deaths have arisen. Social media platforms, such as Facebook and Twitter, serve as essential channels for disseminating information about the coronavirus outbreak, but they also facilitate the spread of erroneous information related to COVID-19. The dissemination of false information further compounds the challenge of distinguishing reliable information sources. This prevalence of misinformation fuels various forms of online vigilantism, scapegoating, along with the proliferation of baseless and exaggerated claims. To mitigate public anxiety and streamline coronavirus management, collaborative efforts among governments, IT enterprises, and public health authorities are required to formulate methods for verifying and validating pandemic-related information and news. The establishment of a blockchain-based repository for COVID-19 data records can be established through consensus among decentralized entities such as healthcare providers, hospitals, and governmental agencies with the goal of enhancing data governance.

4.2. Medical Supplies and Transaction cost

Dai et al. (2020) Blockchain applications have demonstrated substantial success in trading and commodity supply chains. In the midst of the ongoing pandemic, the healthcare sector is grappling with the challenge of maintaining a consistent supply of essential food and medications. Blockchain technology can offer invaluable support to supply chain operations by enabling precise tracking of the flow of goods from their origin to their destination. Recently, a blockchain-based network designed to allow users to monitor the medical supply chain's supply and demand was established through collaboration between China's Economy and Information Technology Department, Zhejiang Provincial Health Commission, and Alipay (Colombi et al., 2020). This network involves the recording and monitoring of safety equipment such as masks, gloves, and other items used in the fight against the coronavirus outbreak. The business asserts that blockchain can ensure a high level of traceability within the medical supply chain by securely linking blocks and transactions, thereby facilitating rapid data transmission through blockchain decentralization. The ability of authorities to respond promptly and establish an efficient supply chain is crucial during an outbreak, and blockchain technology offers solutions to supply chain challenges, potentially saving a significant amount of money and lives (Ting et al., 2020). Another area of focus is the potential of blockchain in contribution tracing applications. During the coronavirus crisis, one of the vital actions to support affected individuals and ensure they have access to treatment and a reasonable standard of living is through monetary donations. A critical concern revolves around mapping donation activities to ensure that donated goods and funds reach their intended recipients (Alzubi et al., 2021). Blockchain facilitates the tracking of donations by issuing signatures and certificates for each update pertaining to donations, including details such as the time, location, donation amounts, and lists of intended beneficiaries. An illustrative case involves using blockchain to track the distribution of essential items like food and protective gear such as N95 masks in affected regions. All parties involved, including donors, healthcare professionals, and nonprofit organizations, can utilize blockchain to monitor the progress of donations, with any changes made to the donation network being communicated to all relevant parties. For example, the Italian Red Cross has started accepting Bitcoin donations to procure critically needed medical supplies for affected areas (Albulescu et al., 2020).

4.3. Consensus Mechanism

The consensus algorithm employed significantly influences the functionality of a blockchain system. The majority of public blockchain implementations rely on the Proof of Work methodology, which requires nodes in the blockchain network to solve complex mathematical puzzles to validate transaction blocks. This method consumes substantial computational resources and can drain the batteries of devices with limited capabilities. To enhance performance, including reducing latency, energy consumption, and increasing throughput and scalability, several COVID-19 applications are experimenting with various consensus algorithms. This innovation aims to make blockchains more suitable for critical, time-sensitive applications that operate on resource-constrained hardware. The use of diverse consensus mechanisms, whether on private, hybrid, or some public blockchains, contributes to improving performance (Ray et al., 2021).

5. How AI Can Enhance Blockchain: Privacy & Security

Pham et al. (2020) The convergence of artificial intelligence (AI) and blockchain technology has the potential to create an exceptionally secure and tightly sealed framework, offering robust capabilities and possibilities (Shi et al., 2021). This innovation presents numerous advantages, a few of which include:

- Enhanced corporate data models
- Globalized authentication systems Innovative auditing and compliance mechanisms
- More intelligent financial systems
- Open governance structures Smart retail solutions
- Intelligent predictive analytics.

6. Challenges

The integration of blockchain and AI constitutes a complex endeavor with several as yet unresolved issues. In this section, we delineate key challenges that are commonly associated with the concept of security and privacy, briefly summarized as follows:

6.1. Smart Contracts Security

Smart contracts play a pivotal role in verifying COVID-19 vaccination certificates, issuing immunity passports, and executing agreements between various entities. Additionally, they facilitate the tracking of digital assets such as vaccines and personal protective equipment (PPE). While smart contracts offer multiple benefits, including ease of modification and cost-effectiveness, certain challenges arise due to the inherent design of blockchain technology when employing smart contracts in COVID-19 management.

6.2. Information Quality and Quantity

AI applications heavily rely on the quality of the data they receive. The quality of data plays a crucial role in ensuring the proper functioning of AI applications (Jiang et al., 2020). Biased data will result in biased application outputs. Furthermore, the quantity of data is equally vital, as a significant volume of data is required for an AI application to operate effectively.

6.3. Data Sharing

Data providers construct databases and authorize access to specific database elements. Providers can share data from multiple databases, provided they all belong to the same account. Subsequently, one or more accounts, including the provider's own, can be linked for data sharing (Nguyen et al., 2019). Notably, no physical data duplication or transfer occurs across accounts when utilizing Secure Data Sharing. Instead, Snowflake's unique service layer and metadata store are employed for all sharing. This is a critical concept because it implies that shared data does not necessitate storage space within a consumer's account, thus avoiding contributing to the consumer's monthly data storage expenses. Consumers are billed solely for the computational resources utilized when querying the shared data.

7. Limitation

This review primarily focused on the blockchain technologies referenced in existing literature. Consequently, several blockchain technologies that have been developed but lack comprehensive documentation in the literature were excluded from this review. These technologies encompass Hash log (a platform for monitoring COVID-19 development), VeChain (a platform for tracking COVID-19 vaccination progress), Hyperchain (a platform for tracking donations), and Civitas (a mobile app for social isolation). The review was constrained to English-language studies due to practical limitations, potentially resulting in the omission of studies published in other languages. While some aspects of blockchain technologies for COVID-19, such as the consensus process and platform, have been documented in a few studies, other factors like anticipated delays and transaction costs have not been thoroughly discussed. Consequently, certain characteristics of COVID-19 blockchain technology may not have been adequately addressed. Most studies included in this review are preprints that have not undergone peer review and may therefore contain inaccuracies. Thus, the accuracy of our conclusions may be influenced by the authenticity of the data presented in these studies.

8. Application

Artificial intelligence (AI) can aid in mitigating the spread of COVID-19 by predicting the extent of the outbreak based on changes in people's mobile phone usage patterns (Sarker, 2019). AI algorithms can detect alterations in phone usage patterns, such as increased call activity during early morning hours by sick individuals, reduced call activity by individuals who succumbed to coronavirus infection, or the appearance of new phones in nearby cities as individuals relocated from lockdown areas. Additionally, the lockdown and home confinement measures have affected people's sleep habits, resulting in later bedtimes and extended sleep durations (Garg et al., 2020). These AI applications can analyze various actions to depict mobile users' behavior, utilizing historical phone usage data to model and forecast specific user activities. Deep learning (DL) techniques, focusing on deep data analysis and high-performance model prediction, can precisely assess mobile app usage, including abnormal calling patterns and inactive phone services. These AI applications can play a significant role in understanding and estimating the scale of the coronavirus outbreak.

8.1. Contract Management

Employing blockchain technology in contract management offers a means to validate contract data, which can prove beneficial for various industries, including technology and construction sectors (Novikov et al., 2018). Utilizing blockchain for contract management enables businesses to enhance supply chain efficiency while evaluating vendors for better deals and reduced lead times.

8.2. Insurances

The insurance sector, a new application area for blockchain, could significantly benefit from blockchain technology. Smart contracts enable the automation of some insurance products, potentially reducing inaccuracies, inefficiencies, and fraud detection while ensuring client legitimacy and adherence to policies.

8.3. Programming Languages

Blockchain applications are developed using common programming languages such as C++, Python, JavaScript, Go, or Java. Solidity, a statically-typed programming language, has been designed specifically for creating smart contracts, particularly on Ethereum. Solidity is becoming a standard language for smart contract development as more blockchain platforms adopt it. Its ECMAScript-like syntax simplifies the learning curve for web developers (Shen et al., 2019).

8.4. Data storage

Data is a critical and indispensable resource for organizations. Blockchain technology offers efficient data utilization and secure data storage, serving as a decentralized and immutable ledger that various businesses can use for digital asset management. Decentralized data, as found in blockchain, cannot be altered by any single entity, promoting global data sharing and security (Dorri et al., 2019).

9. Recommendation

Blockchain technology holds the potential to address issues related to data integrity, transparency, security, fraud reduction, trust, and privacy, as indicated by a comprehensive review of the literature. A wide range of industries, including finance, accounting, e-government, business process management, insurance, entertainment, trading platforms, healthcare, the internet of things, law firms, and more, stand to benefit from blockchain technology. Implementing blockchain technology, however, can be costly for organizations, especially those with outdated systems. It is vital for organizations to understand blockchain technology thoroughly, including its advantages, opportunities, and challenges. As a result, blockchain technology can complement and enhance existing systems, and it may even lead to the development of entirely new systems in the future.

10. Conclusion

In this study, we conducted a cutting-edge analysis of the potential applications of blockchain and AI technologies in combating the COVID-19 pandemic. We introduced a conceptual architecture that combines blockchain and AI to address critical aspects of the pandemic, including outbreak tracking, user privacy protection, secure daily operations, medical supply chain management, and donation record-keeping. We also highlighted the potential of AI to address various COVID-19 challenges. Case studies and prominent initiatives involving blockchain and AI in the fight against COVID-19 were presented. Several challenges and future directions were identified. We believe that this timely survey will provide valuable insights into ongoing research on the use of blockchain and AI technologies in the fight against COVID-19, inspiring researchers and stakeholders to continue their efforts in utilizing these cutting-edge technologies to address future pandemics. To ensure the credibility and traceability of content, smart contracts hash interplanetary file system (IPFS) to store digital content and its associated metadata. These proposed solutions aim to enhance the reliability and integrity of blockchain systems in combating COVID-19. The survey provides a comprehensive overview of recent research into the application of AI and blockchain technology to the COVID-19 pandemic, addressing various aspects of the crisis.

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