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Brain Tumor Segmentation Using MRI Images Based on Blockchain

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Abstract: Brain tumor segmentation plays a critical role in the accurate diagnosis and treatment planning of brain-related diseases. Integrating blockchain technology with medical imaging offers promising solutions for secure, privacy-preserving data sharing and collaborative research. The paper provides an in-depth analysis of recent advancements in brain tumor segmentation using MRI images. Also, it explores blockchain technology's potential to enhance these processes' reliability, security, and efficiency. The paper highlights existing approaches' challenges, advantages, and limitations and presents a comprehensive overview of blockchain-based methodologies applied to brain tumor segmentation. Furthermore, the review discusses the ethical considerations, patient consent, and regulatory implications of utilizing blockchain in medical image processing. The paper review aims to shed light on the transformative potential of blockchain technology in brain tumor segmentation and encourage future research and development in this area.

Keywords: Security, Data integrity, Blockchain, Health care, Brain tumor, Segmentation.

1. Introduction

1.1 Background

Medical imaging, namely Magnetic Resonance Imaging (MRI), is crucial in contemporary healthcare by offering significant insights into diverse diseases and situations [1]. As mentioned earlier, the diagnosis of brain tumors has considerable significance owing to its profound implications for patient prognosis and the formulation of treatment strategies [2][3]. The precise identification and delineation of brain tumors from MRI images (as shown in fig.1.) are of utmost importance to provide an accurate diagnosis, facilitate informed therapeutic decision-making, and enable effective monitoring of disease progression. Manual segmentation is lengthy and unreliable, so observers may disagree and make diagnostic errors [4][5].

The fast development of computer vision and machine learning techniques has led to encouraging results in automated brain tumour segmentation methods. The methods utilized in this study employ advanced image processing techniques and deep learning models to extract tumor areas from MRI data effectively [6]. Nevertheless, obstacles still need to be overcome to achieve model generalization, robustness across various tumor types, and the acquisition of extensive labelled datasets for training purposes.

Simultaneously, there has been significant interest in blockchain technology across other fields because of its intrinsic characteristics of decentralization, transparency, and immutability. Initially created as the foundational technology for digital currencies, blockchain has now transcended its original purpose and found utility in other sectors, including but not limited to finance, supply chain management, data security, and healthcare [7][8]. The healthcare industry has recognized the growing significance of blockchain technology in ensuring secure and privacy-preserving data management, particularly in protecting patient data privacy [9]. The use of blockchain technology in medical imaging presents a unique and innovative approach to bolstering data security, promoting the exchange of information across different institutions, and stimulating collaborative research within an environment characterized by a lack of trust [10].

The objective of this research paper is to conduct a comprehensive examination of the latest developments in the segmentation of brain tumors through MRI scans. Additionally, it seeks to investigate the potential advantages that can be derived by incorporating blockchain technology into this process [11][12]. Furthermore, the study will critically evaluate the performance, benefits, and constraints associated with current methodologies. The research aims to combine the capabilities of medical image processing and blockchain technology to facilitate a thorough analysis that contributes to advancements in precise and secure brain tumor segmentation [13]. The forthcoming sections of this study will explore the fundamental principles underlying blockchain technology, the current improvements in brain tumor segmentation, and the potential consequences of integrating blockchain into medical image processing and patient care [14].

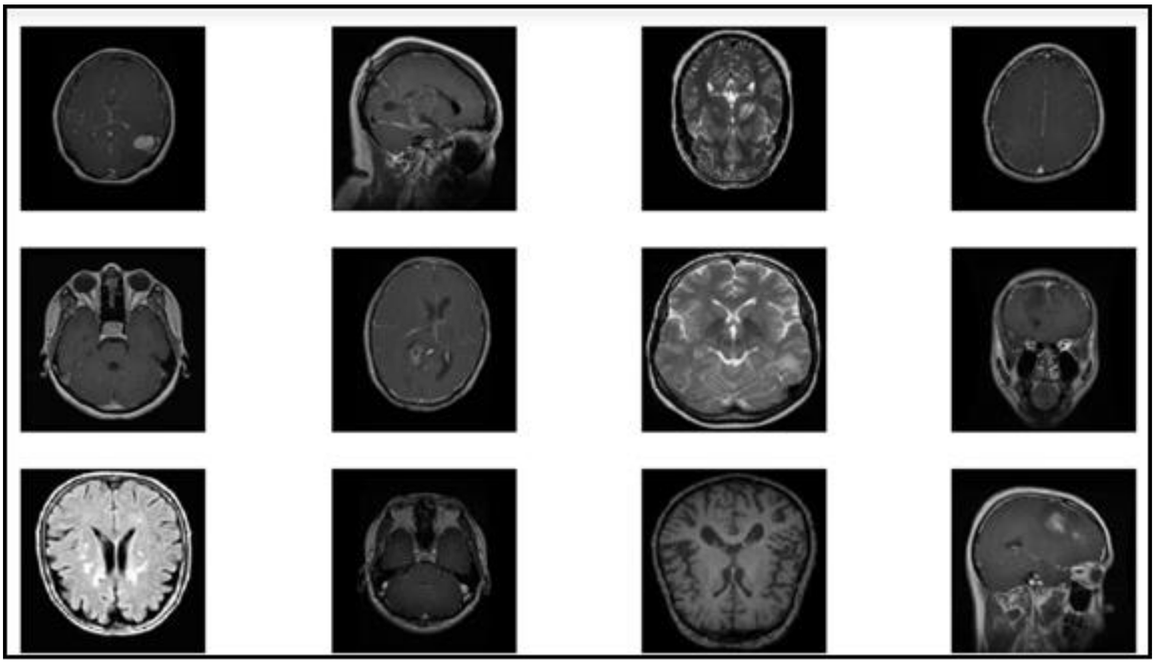

Fig1. Brain tumor Images

1.2. Motivation

The "Brain Tumor Segmentation Using MRI Images Based on Blockchain" research is motivated by various crucial reasons that necessitate progress in medical imaging and data management technology. The section explains the precise causes and convincing factors that underline the importance of the proposed research.

1. Growing Number of Brain Tumors [15]: The number of cases of brain tumors has been rising significantly, placing a heavy load on healthcare systems worldwide. Brain tumour attributes' intricate and diverse nature pose difficulties in accurately defining tumor boundaries by conventional manual techniques.
2. The Importance of Precise and Effective Segmentation [16]: The precision of brain tumor segmentation directly impacts the formulation of treatment plans, the execution of surgical operations, and the evaluation of therapeutic response. Automated segmentation algorithms provide the potential to minimize human error, enhance productivity, and deliver consistent and replicable outcomes. The enhancement of tumor identification and characterization relies heavily on the crucial advancements made in segmentation techniques.
3. Challenges in Traditional Segmentation Methods [17]: Segmentation algorithms need help with various tumor forms, unbalanced datasets, and real-world robustness. Researchers seek novel algorithms to improve efficiency and generalizability.
4. Data Privacy and Security Issues [18]: Medical imaging data, particularly brain MRI scans, include confidential and individually

identifiable information. Maintaining patient data privacy and preventing illegal access, manipulation, and data breaches are of utmost importance within the healthcare sector. Utilizing blockchain technology may address the risks associated with the centralized structure of conventional data storage systems.

5. Healthcare Blockchain Emergence [19]: The use of blockchain technology into the healthcare sector has demonstrated potential in effectively tackling issues related to data security, interoperability, and data exchange. The decentralized and irreversible characteristics of this technology provide a safe and transparent platform for the management and dissemination of medical data, including highly sensitive medical imaging.
6. Research Collaboration and Data Sharing [20]: The investigation of brain tumors necessitates the establishment of collaborative partnerships among various medical institutions, researchers, and doctors. Utilizing blockchain technology enables the secure and transparent sharing of data across several institutions, promoting collaboration and facilitating large-scale studies and improvements in research.
7. Ethical and Legal Considerations [21]: The growing dependence on artificial intelligence and machine learning algorithms in medical decision-making necessitates a heightened focus on ethical concerns about data ownership, patient permission, and algorithm openness. The characteristics of blockchain technology, such as its capacity to provide patient-centric data governance and auditability, are in accordance with ethical norms governing medical data administration.
8. Possibility for Transformative Effects [22]: The integration of cutting-edge medical image processing techniques with blockchain technology has the promise of transforming the fields of brain tumor detection, treatment planning, and patient care. Using blockchain-based solutions in medical imaging can yield several benefits, including greater data integrity, improved cooperation among stakeholders, and, ultimately, superior healthcare results.

1.3. Scope of the Review

The scope of the review specifically covers the following details:

1. Brain Tumor Segmentation Techniques: The research paper examines contemporary brain tumor segmentation methods that utilize machine learning, deep learning, and other image-processing approaches [23]. This paper will analyze the merits and drawbacks of current methodologies and their corresponding performance measures.
2. Role of MRI Imaging in Brain Tumor Diagnosis [24]: The paper aims to comprehensively analyze the importance of magnetic resonance imaging (MRI) in diagnosing brain tumors. The research paper will thoroughly examine the many types of magnetic resonance imaging (MRI) sequences often employed, the imaging procedures utilized, and the unique issues encountered in the context of brain tumor imaging.
3. Blockchain Technology in Healthcare and Medical Imaging [25]: The paper will provide an overview of the foundational aspects of blockchain technology, with a particular focus on its prominent characteristics, including decentralization, immutability, and transparency. The paper will examine the many uses of blockchain technology within the healthcare sector, emphasizing its utilization in medical image management and safeguarding data privacy.
4. Potential Benefits of Blockchain in Brain Tumor Segmentation [26]: The research paper will examine how blockchain technology might address brain tumor segmentation issues such as data security, privacy, and collaboration. It will demonstrate how blockchain may improve data integrity, cross-institutional data exchange, and decentralized segmentation algorithms.
5. Performance Evaluation Metrics: A specific section will be allocated to examining several performance assessment measures that are routinely employed to assess the precision and effectiveness of algorithms used in brain tumor segmentation. The data will provide a comprehensive evaluation of the efficacy of

blockchain-based methodologies compared to conventional techniques.

6. Ethical and Regulatory Implications: The purpose of the present analysis is to examine the ethical concerns and regulatory consequences that arise from utilising blockchain technology in medical image processing. The aspects above encompass patient permission, ownership of data, adherence to data protection standards, and openness of algorithms.
7. Case Studies and Successful Implementations: The research paper aims to offer valuable insights into real-world case studies and successful implementations of brain tumor segmentation algorithms based on blockchain technology. The analysis will identify and emphasise the accomplishments, obstacles encountered, and insights gained from these enactments.
8. Future Directions and Opportunities: The review aims to analyze prospective avenues for future research and explore chances for additional breakthroughs in combining blockchain technology with medical image processing specifically for brain tumor segmentation. The following includes:

- Integrating artificial intelligence and blockchain technologies.
- The development of scalable solutions.
- Formulating strategies to address challenges related to the use of these technologies.

2. Brain Tumor Segmentation Using MRI Images: State-of-the-Art

2.1 Importance of Brain Tumor Segmentation

Segmentation as shown in Fig.2. (brain tumors) is a critical and essential process in medical image analysis and identifying brain tumors. The task at hand encompasses systematically segmenting tumor areas from MRI scans, allowing exact characterisation, formulation of treatment plans, and monitoring the illness [27]. The following significant elements help to clarify the significance of brain tumor segmentation:

1. Early Detection and Diagnosis: The timely identification and precise diagnosis of brain tumors are crucial to initiate suitable medical therapies quickly. Segmentation plays a vital role in identifying tumor borders, enabling doctors to accurately assess tumor size, location, and extension. These factors are paramount in facilitating early diagnosis and customizing individualized treatment approaches [28].
2. Treatment Planning and Surgical Navigation [29]: Accurate characterization of tumors is of utmost importance in the treatment planning process, as it furnishes essential data for guiding surgical navigation. Accurate tumor localization is crucial for surgeons to provide safe and successful tumor excision, limiting potential harm to healthy brain tissue and enhancing overall patient outcomes.
3. Assessment of Therapeutic Response: After undergoing treatment, such as surgery, radiation therapy, or chemotherapy, the process of segmentation aids in evaluating the effectiveness of the medicine. Comparing segmented tumor areas before and after therapy can help assess treatment effectiveness and create knowledgeable judgments for additional therapeutic approaches.
4. Research and Clinical Trials: The utilization of brain tumor segmentation facilitates studies and clinical trials centered on managing and assessing brain tumors, as well as the effectiveness of therapy interventions. Precise segmentation enables the examination of therapy efficacy, the identification of biomarkers, and the advancement of novel therapeutic approaches.
5. Quantitative Analysis: Segmentation enables the application of quantitative analysis to tumor features, including volume, shape, and growth rate. The utilization of quantitative metrics facilitates the disease monitoring process, enables the tracking of tumor progression, and allows for the evaluation of treatment effectiveness over time.
6. Personalized Medicine: The field of customized medicine is enhanced by precise tumor segmentation, which enables the customization of treatment strategies based on the unique characteristics of each patient's tumor. The methodology guarantees the

optimization of medicines tailored to specific patients, augmenting treatment success rates.

7. The Improvement of AI and Machine Learning Models [30]: Using labelled segmentation data is significant in training and enhancing artificial intelligence (AI) and machine learning models. These models have the potential to aid doctors in the automation of the segmentation process, hence resulting in improved efficiency and enhanced consistency of outcomes.
8. Education and Training: Education and training in brain tumor segmentation are crucial components for the instruction of medical students, radiologists, and neurosurgeons. This technology facilitates comprehension of tumor anatomy, improves diagnostic abilities, and offers practical training in interpreting medical images [31].

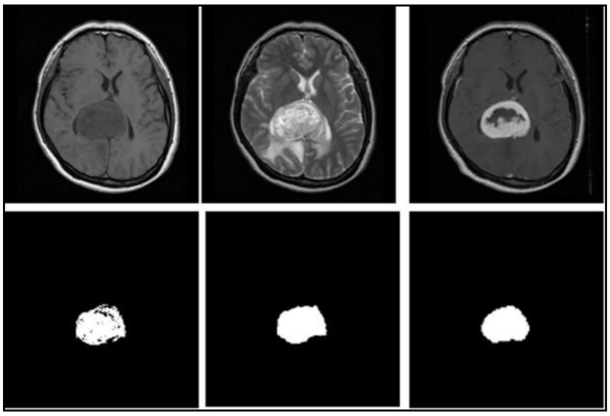

Fig. 2. Brain tumor Segmentation [32]

2.2. MRI Imaging in Brain Tumor Diagnosis

Magnetic resonance imaging, or MRI, is a simple and effective imaging technique frequently employed in detecting and assessing brain tumor in fig.3. MRI is the imaging technique for spotting abnormalities, including brain malignancies, because of its excellent spatial resolution and capacity to offer fine-grained soft tissue contrast [33]. MRI is essential for several aspects of brain tumor diagnosis, including [34][35]:

1. Tumor Detection and Localization [36]: Magnetic Resonance Imaging (MRI) enables healthcare professionals to image and effectively identify brain malignancies with precision. The tumour detection process relies on identifying anomalous tissue areas with discernible contrast features compared to healthy brain tissue. Accurate tumour localization inside the cerebral region facilitates effective treatment planning.
2. Tumor Classification: The utilization of MRI allows for the categorization of brain tumors into distinct categories by analyzing their imaging characteristics, including signal intensity, enhancing patterns, and form. These characteristics facilitate the differentiation between benign and malignant tumors and offer crucial data for making decisions regarding therapy [37].
3. Tumor grading: Tumar grading plays a crucial role in assessing the level of malignancy shown by brain tumors. MRI can aid in tumor grading by assessing many characteristics, including tumor necrosis, contrast enhancement, edema, and invasion of adjacent tissues [38].
4. Preoperative planning: Preoperative planning involves the utilization of MRI to get comprehensive data on the dimensions, positioning, and potential closeness of the tumor to vital cerebral structures, including eloquent regions and vascular pathways. Preoperative planning assists neurosurgeons in formulating preoperative strategies to enhance surgical resection and safeguard brain functionality [39].
5. Treatment Response Assessment: MRI evaluates treatment response during and following therapeutic interventions, such as radiation therapy or chemotherapy. The assessment of changes in tumor size, enhancement patterns, and the presence of edema guides the evaluation of treatment success and the development of therapeutic methods [40].
6. Monitoring the Progression of Disease: Longitudinal magnetic resonance imaging (MRI) scans hold significant value in the context of disease progression monitoring and assessment of therapy response in tumors over an extended period. Serial magnetic resonance imaging (MRI) evaluations are crucial in assessing therapy efficacy and the guidance of illness management [42].
7. Image-Guided Biopsies [43]: Magnetic resonance imaging (MRI) can facilitate image-guided biopsies, allowing for accurate

localization of areas of interest within tissue that may be deemed questionable. Image-guided biopsies facilitate the acquisition of tissue samples that are then subjected to histological investigation, hence providing further assistance in tumor categorization and grading.

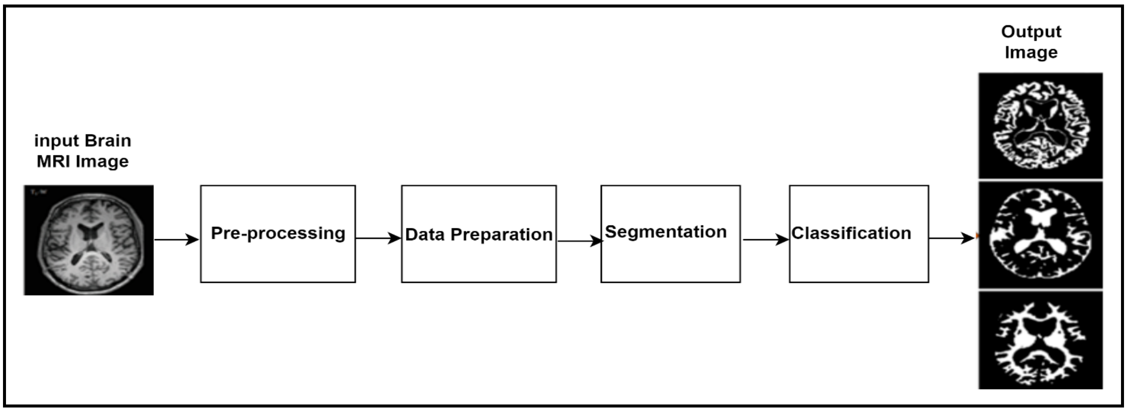

Fig.3. MRI Imaging in Brain Tumor Diagnosis [41]

8. Non-Invasive Characterization: Magnetic resonance imaging (MRI) can offer non-invasive functional imaging data, including perfusion and diffusion tensor imaging (DTI). These imaging techniques may aid in characterising tumor vascularity, cellular density, and structural connections inside the brain [44].

2.3. Challenges and Existing Approaches in Segmentation

The segmentation of brain tumors from MRI images is a challenging undertaking, primarily because of the presence of tumor heterogeneity, image artifacts, and the unique features exhibited by different tumors. Numerous methodologies have been devised to tackle these issues, employing diverse strategies and algorithms. The sections below examine the primary obstacles encountered in brain tumor segmentation and offer a comprehensive assessment of prevalent current methodologies [45].

1. Tumor Heterogeneity [46]: Brain tumors demonstrate significant heterogeneity in their structural characteristics, including form, size, texture, and intensity. Consequently, the development of a consistently applicable segmentation method poses considerable challenges. The appearance of tumor subtypes and locations within the same tumor can exhibit variability.
2. Ambiguity of Tumor boundaries: Tumor boundaries may exhibit a diffuse and indistinct nature, leading to seamless integration with surrounding healthy brain tissue. Differentiating tumor borders from typical brain structures is a significant challenge, especially in instances involving infiltrative or low-grade tumors.
3. Image Artifacts and Noise: Magnetic resonance imaging (MRI) pictures might exhibit artifacts due to patient mobility, magnetic field inhomogeneities, or defects in the imaging process. The presence of noise inside images has the potential to impact the accuracy of segmentation, leading to the occurrence of false-positive or false-negative detections [47].
4. Partial Volume Effect: The partial volume effect arises when a voxel encompasses a combination of tumor and healthy tissue, resulting in partial contributions to the overall intensity. The phenomenon mentioned above can potentially generate mistakes throughout the segmentation procedure [48].
5. Class Imbalance: Within several datasets about brain tumors, there exists a notable disparity in the number of tumor voxels and non-tumor voxels, resulting in an imbalance between the two classes. Class imbalance can introduce bias into the segmentation algorithm, leading to a disproportionate emphasis on the majority class and thus compromising the system's capacity to detect tumor locations reliably [49].
6. Scarce and Incomplete Annotations: The acquisition of precise and thorough manual annotations for training segmentation

algorithms might present difficulties due to the task's specialized knowledge and time-intensive nature [50].

The current methodologies employed in the segmentation of brain tumors as shown in fig.4. [51]:

1. Thresholding and Region Growing: To segment the tumor, a simple thresholding method sets intensity thresholds to demarcate tumor regions from healthy tissue. Region-expanding methods are utilized to enlarge the segmented areas by adhering to voxel similarity criteria [52].
2. Manual and Semi-Automated Methods of Segmentation [53]: Manual segmentation by specialists is still the gold standard, but it is lengthy process and subject to inter-observer variation. Semi-automated tools are utilized to aid specialists in enhancing manual segmentations.
3. Supervised machine learning: machine learning, which entails teaching a model the tumor's signature features using annotated MRI data [54].
4. Unsupervised clustering: Unsupervised clustering eliminates the requirement for labelled data by automatically forming groups of voxels with shared traits. K-means and Fuzzy C-means clustering are two prominent examples of clustering algorithms [55].
5. Deep Learning-Based Segmentation [56]: Deep learning, particularly CNNs, has demonstrated impressive performance in brain tumor segmentation because of its capacity to learn hierarchical characteristics from the input. The utilization of U-Net and 3D Convolutional Neural Network (CNN) architectures is prevalent in the field of 3D Magnetic Resonance Imaging (MRI) segmentation.
6. Multi-Modal Fusion: Using information from various MRI scans (T1-weighted, T2-weighted, FLAIR, etc.) has been looked into to improve segmentation accuracy and address the fact that tumors can look different [57].

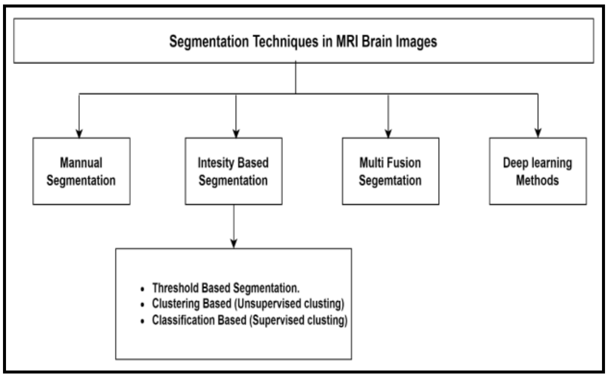

Fig.4. Segmentation Techniques in MRI Brain Image

3. Introduction to Blockchain Technology

3.1. Fundamental Principles of Blockchain Technology

Blockchain is the decentralized and distributed technology behind Bitcoin and other cryptocurrencies. Transactions and data may be recorded and verified in a way that is both secure and transparent and resistant to tampering according to its guiding principles [58][59]. Fig.5. shows the basic principles of blockchain involve the following [60]:

1. Decentralization: Blockchain is run by a distributed network of computers, or "nodes," responsible for updating and validating the distributed ledger. Any one person or organization does not control the entire system. Redundancy and fault tolerance are ensured by every node having a copy of the full blockchain [61].
2. Distributed ledger: The blockchain stores records of transactions or data in a chain of blocks that are connected by cryptographic hashes. A blockchain is a distributed ledger in which each block permanently records data, such as a list of transactions and a link to the prior block. Due to its distributed structure, the blockchain is identical across all nodes in the network [62].
3. Consensus Mechanisms [63]: Blockchain uses consensus methods to ensure that nodes in the network disagree on the ledger's current state. Before a transaction is added to the blockchain, consensus methods guarantee that all nodes agree on its legitimacy. Delegated Proof of Stake (DPoS), Proof of Work (PoW), and Proof

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of Stake are all examples of popular consensus procedures.

4. Immutability: data included in a block on the blockchain is immutable; that is, it cannot be changed or removed. This quality makes the recorded data unchangeable and secure against tampering [64].
5. Cryptographic Security [65]: Blockchain employs cryptography to encrypt data and restrict who may access it. A cryptographic hash, or string of defined length created from the data in a block, is included in each block. If the information in the block were altered in any way, the hash would change, and the network would be put on high alert.
6. Transparency and Auditability: All blockchain-recorded transactions and data are viewable by all network members, making them auditable. Due to this transparency, anybody may check the legitimacy of past transactions and trace the origin of any data. It is a great way to improve network responsibility and trust [66].
7. Smart Contracts: Computer-encoded agreements that carry out their terms. They run without human intervention if specific criteria are satisfied [67]. Since smart contracts allow for automated and trustless exchanges, they may be used to conduct business directly between two parties.
8. Permission (private) or permissionless (public) [68]: Permissioned blockchains are ideal for private applications because they limit access and participation to approved parties. On the other hand, permissionless blockchains are widely employed in the cryptocurrency industry since anybody may join and contribute to the network.

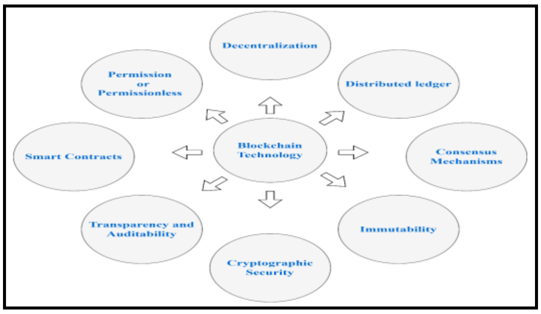

Fig.5. Fundamental Principles of Blockchain Technology

3.2 Decentralization and Immutability

3.2.1 Decentralization

Fig.6. shows decentralization is a core concept in blockchain technology, and it refers to the dispersion of power and control among a distributed network of nodes rather than a centralized one. No single organization or group can exert total dominance or control over a blockchain network. Instead, authority is delegated throughout the network to increase its robustness, transparency, and resistance to failure from isolated nodes. The consensus mechanism ensures decentralization by ensuring all participants in a distributed ledger agree on the veracity of transactions and the system's current state. Each node keeps a full copy of the blockchain, and it takes agreement from the network to make any modifications or updates. Blockchain guarantees that the information stored on the blockchain cannot be manipulated or altered by a single party without the consensus of the whole network [69][70].

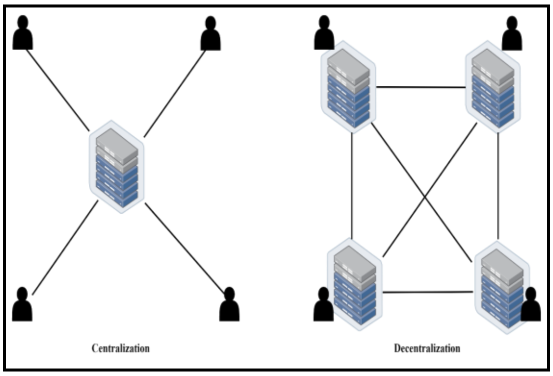

Fig.6. Centralization and Decentralization

3.2.2 Immutability

Data stored on the blockchain is immutable, another fundamental blockchain concept that guarantees its integrity and longevity. Once the information has been recorded in a block and uploaded to the blockchain, it can no longer be changed or removed as shown in fig.7. Cryptographic hash functionsFf can create data that cannot be altered. A cryptographic hash, or string of defined length derived from the data in a blockchain block, is included in each block. Similar to a fingerprint, the hash is a unique identifier of the data in the block; therefore, any modification to that data would produce a new hash. It is computationally infeasible to tamper with past data without invalidating the whole blockchain because of how blocks are linked together using the preceding block's hash. Strong security and confidence in the data stored on the blockchain are provided by its immutability. Whenever a transaction or piece of data is uploaded to the blockchain, it is practically "set in stone," guaranteeing an unchangeable record of occurrences [71][72].

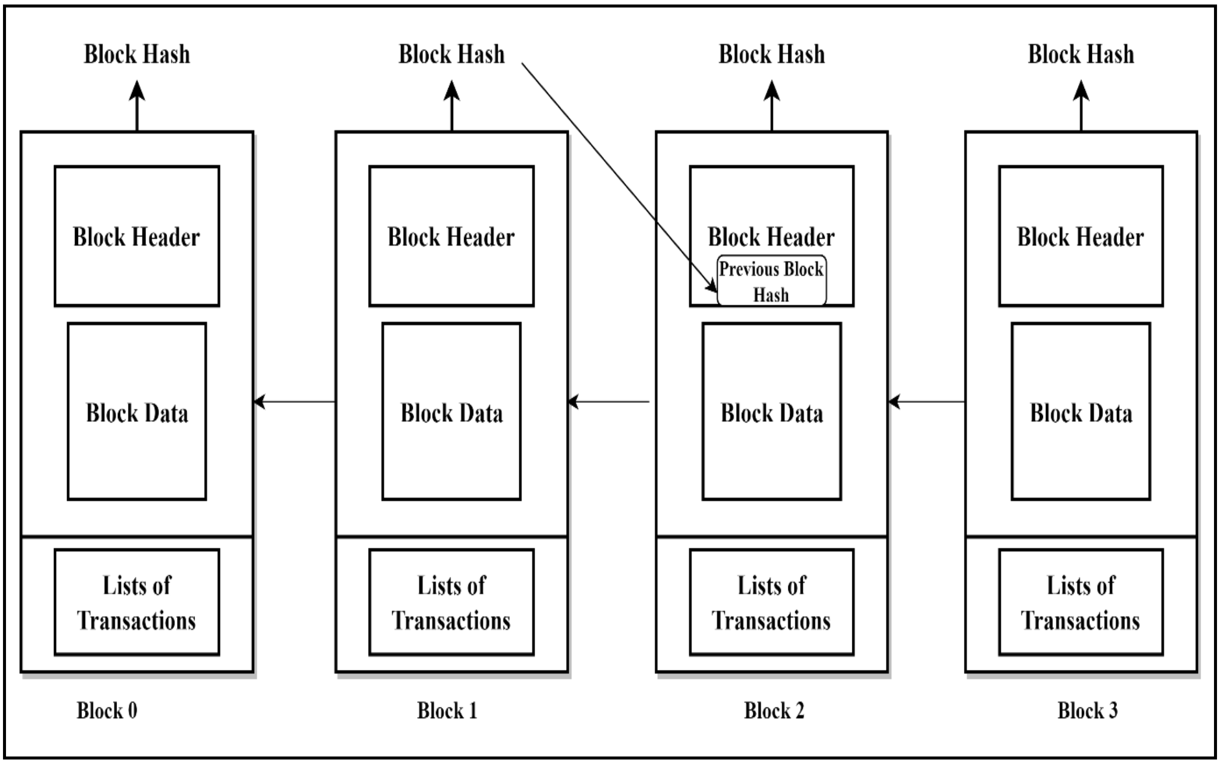

Fig.7. Immutability in Blockchain

The Role of Consensus Mechanisms as shown in fig.8.

In blockchain networks, consensus mechanisms are protocols used to reach agreement among dispersed nodes on the legitimacy of transactions and the ledger's state. Consensus is necessary to avoid duplicate spending and other harmful actions and keep the blockchain running smoothly. There are several consensus procedures, each with its unique strategy for reaching consensus [73]. The following are examples of consensus-building methods:

1. Proof-of-Work (PoW) [74]: The initial consensus mechanism for Bitcoin and many other cryptocurrencies is proof-of-work (PoW). In Proof-of-Work (PoW), nodes compete to add new blocks to the blockchain by solving complex mathematical challenges. The miner who adds the block first is the one who receives the bitcoin reward for solving the problem. While secure and resistant to assaults, Proof-of-Work (PoW) demands a lot of processing effort, making it an energy waste.
2. Proof of Stake (PoS) [75]: Token holders prepared to "stake" some of their tokens in exchange for the opportunity to produce new blocks are considered validators in the Proof of Stake (PoS) consensus. Token holders with the highest stakes will have the highest possibility of being picked as a validator to construct a block. PoS reduces energy consumption compared to PoW while ensuring privacy via stake forfeiture for harmful activity.
3. Delegated Proof of Stake (DPoS): Token holders in a DPoS [76] network cast votes for a set number of delegates who take turns generating blocks. Those who earn the most votes become delegates; verifying trades and generating new blocks is their job. DPoS attempts to speed up block creation and consensus without sacrificing decentralization.

4. Byzantine Fault Tolerance in Real-World Applications (PBFT): In private or permissioned blockchains, PBFT [77] is the consensus technique of choice. A consensus on the transaction sequence and the legality of the blocks is reached by a voting procedure involving a preset group of validators. Because of how quickly PBFT may reach an agreement, it is well-suited for use cases that need low latency and large transaction throughput.

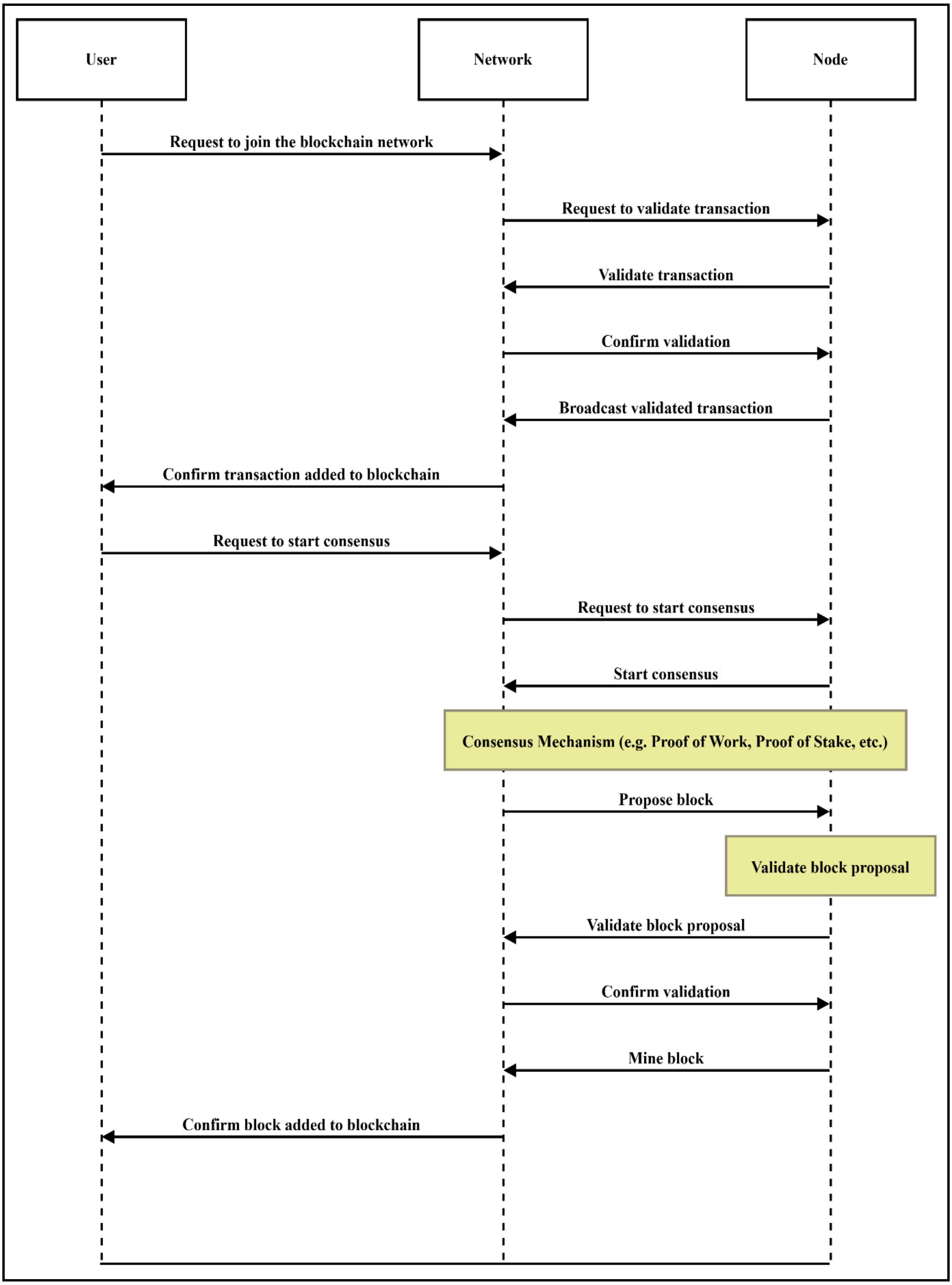

Fig. 8. The Role of Consensus Mechanisms

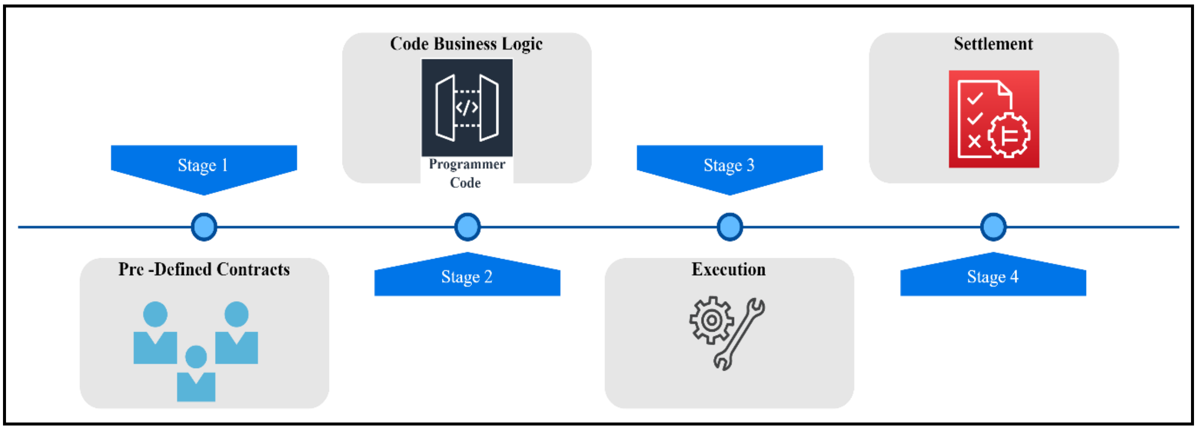

Fig.9. How smart contracts works

3.4 Smart Contracts

The terms and conditions of a smart contract are encoded into software code, making it an agreement that can carry out its commitments. Smart contracts are decentralised digital agreements recorded and executed on a distributed ledger. The details of the agreement are written directly into computer code as explained in fig.9. Autonomous execution occurs when predetermined criteria are satisfied, obviating intermediaries or human involvement requirements [78]. Smart contracts play a vital role in blockchain technology, facilitating automated and decentralised interactions without the need for trust between involved parties. The smart contract is executed automatically, and the desired outcome is obtained when specific conditions outlined in the contract are met. In the context of supply chain management, a smart contract can autonomously initiate the disbursement of funds to a supplier following verification of product delivery by a mutually agreed-upon third-party oracle [79] [80]. Smart contracts are commonly developed using high-level programming languages and are stored on the blockchain, ensuring their replication across all nodes. After being deployed, smart contracts exhibit immutability, guaranteeing the preservation of the contract's terms without the possibility of alteration or tampering [81].

Smart contracts offer numerous benefits, such as enhanced transparency, heightened security, improved efficiency, and elimination of intermediaries, thereby mitigating the potential for fraudulent activities and human mistakes in contractual arrangements [82]. The uses of blockchain technology extend beyond cryptocurrencies and encompass other domains such as supply chain management, insurance, voting systems, decentralised finance (DeFi), and other areas [83].

Table 1. Shows various Brain Tumor Segmentation Using MRI Images Based on Blockchain

S.No	Authors	Year	Technique	Benefits	Limitation
1	Artatrana Biswaprasan Dash et al. [84]	2021	Blockchain with Segmentation: Clustering Approach	It uses HCIS method for detecting and identifying human brain tumours. It improved segmentation methods to help doctors locate the problem regions more precisely.	• Not specify how to implement Blockchain. • No experimental result of implementation. • Only theortical view.

2	Farah Mohammad et al. [85]	2023	Blockchain-based Secure CNN	• The characteristics are retrieved using three advanced models and a blockchain-based security framework. • The outcomes demonstrate that the blockchain-based Secure CNN is resilient against the various threats tested, maintaining consistency and accuracy in its identification performance.	Hashing algorithm should be more secure.
3	Gauravkumar Ahire et al. [86]	2021	Machine Learning and Blockchain for tumor identification	• It facilitates the diagnosis of a brain tumour in many patients without unnecessary follow-up testing. • Diagnosing a brain tumour does not require an active internet connection. • It has the potential to reduce human resources requirements significantly.	Minor Error Potential: The issue arises during database preparation and evaluation. • Acquiring Data: The data's inconsistency may occur due to the large volume of information gathered. • Lengthy: The training and testing of the machine might take longer if there is a lot of information to process.
4	Asma Belhadi et al. [87]	2023	BIoMT-ISeg: Blockchain internet of medical things for intelligent segmentation	• Detected attacks with using the blockchain technology. • Work on different medical images: Ultrasound Nerve Segmentation, Brain Image Segmentation, Breast Ultrasound Image Dataset, COVID-19 Radiography Database. • Multiple learning algorithms are used to achieve better segmentation performance.	Only detect 76% attacked.
5	Mohanty et al. [88]	2022	CNN-LSTM model	Works on two data set: • 2D (Brain MRI) • 1D (EEG)	Use SQL Server for storing details of patient.

4. Blockchain in Medical Image Processing: Advantages and Limitations

Utilizing blockchain technology in medical image processing presents numerous benefits, particularly regarding data security, privacy, patient-centric data control, interoperability, scalability, and ethical considerations. Nevertheless, it is imperative to acknowledge specific constraints and obstacles that necessitate attention and resolution. In this analysis, we will examine and go into each facet of the subject matter at hand [89][90]. The Fig. 10. Shows how to use Blockchain in medical image processing

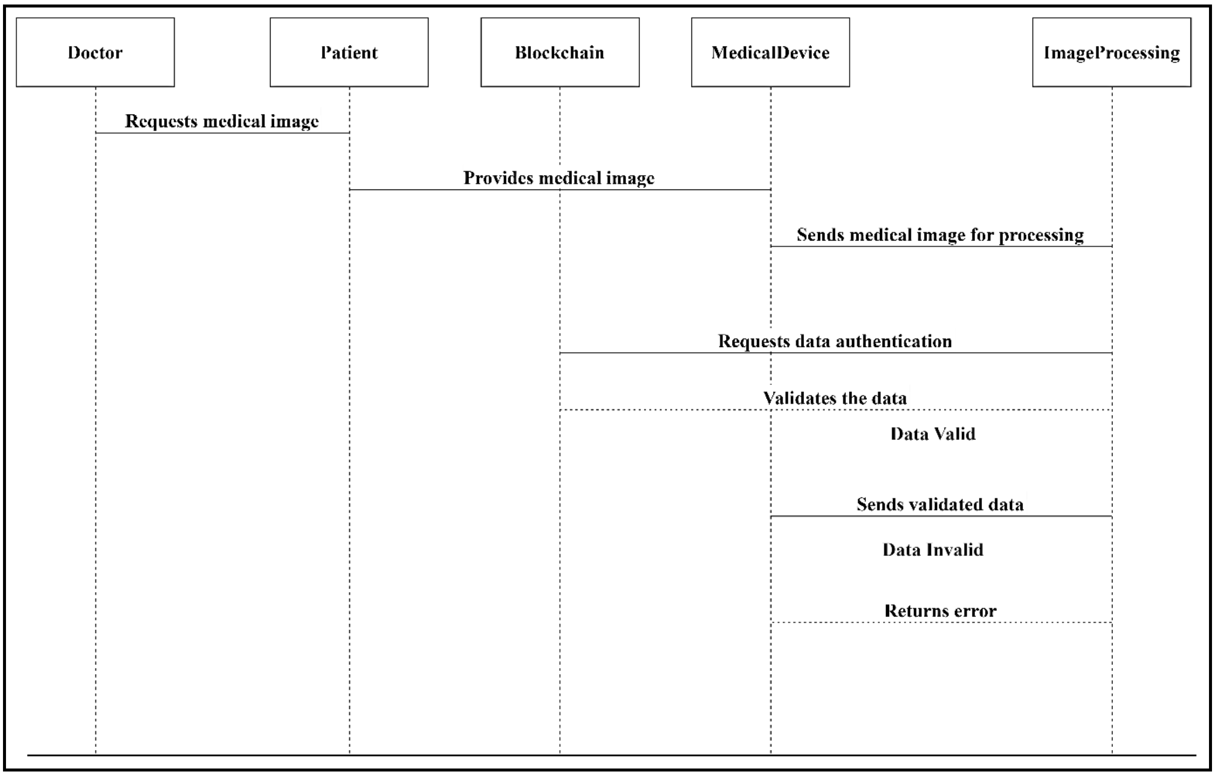

Fig. 10. Use of Blockchain in medical image processing

4.1 Data Security and Privacy [91]:

Advantages:

- Using decentralisation and cryptography ensures that medical picture data is preserved securely and immutably. Blockchain prevents data breaches and unauthorised access.
- Blockchain transactions are encrypted to improve data security, and only authorised parties can access them using cryptographic keys.
- Public and private keys enable safe data exchange and access control, enabling patients and healthcare providers to manage medical image viewing and modification.

Limitations:

- Blockchain provides strong data security, but endpoints (e.g., devices that take and upload medical images) and access points should be protected.
- Private key compromises can lead to data breaches, highlighting the need for effective critical management practices.

4.2. Patient-Centric Data Control [92]:

Advantages:

- Blockchain increases patient control over medical picture data, enabling selective sharing with healthcare practitioners and researchers while retaining anonymity.
- Patient-centric data control can boost patient participation and trust in healthcare by empowering them to govern access to sensitive medical information.

Limitations:

- Blockchain gives tools for patient-centred data control, but it might take much work to ensure patients know about these tools and can use them successfully.
- The complexity of achieving interoperability between various blockchain platforms and healthcare systems is challenging, restricting the

smooth interchange of patient data across heterogeneous platforms.

4.3. Interoperability and Data Sharing [93]:

Advantages:

- Blockchain enables safe, standardized data transmission between healthcare professionals, enabling joint diagnosis and treatment planning.
- Data-sharing deals can be made automatically through smart contracts, which makes the process more efficient and transparent.

Limitations:

- To achieve full interoperability across disparate healthcare systems and blockchain platforms, technological, legislative, and organisational problems must be addressed.
- Smooth data interchange between healthcare organisations requires standardisation of data formats and protocols.

4.4 Scalability and Performance [94]:

Advantages:

- Some improvements to blockchain technology, like sharding and side chains, are meant to make it more scalable to handle more transactions and data without slowing down.
- Integrating off-chain operations with blockchain for important data can improve speed while taking advantage of the security benefits of blockchain.

Limitations:

- While processing a large volume of medical image data and transactions, traditional blockchain networks may experience scalability issues.
- Transaction times and computational expenses may increase when dealing with extensive medical images processed on-chain.

4.5 Ethical Considerations [95] [96]:

Advantages:

- Blockchain's openness and audibility can solve ethical concerns with data ownership, provenance, and algorithm transparency.
- The utilisation of blockchain technology in medical image processing has the potential to adhere to ethical considerations regarding consent and data protection.

Limitations:

- Ethical issues go beyond technology and must consider legal, social, and cultural factors to be implemented ethically.
- Managing transparency with patient confidentiality and sensitive medical information is a tricky balance.

5. Comparative Analysis of Existing Approaches

5.1 Performance Metrics:

Measurable performance indicators are crucial for comparing various blockchain-based medical image processing methods. Commonly used comparison indicators include the following:

- Jaccard Index of Dissimilarity (IoU) and Dice Similarity Coefficient (DSC) [97]: The overlap between the ground truth (manual segmentation) and the algorithm's segmentation output is measured by these measures. The greater the value, the more precise the segmentation.
- Sensitivity and Specificity [98]: Sensitivity refers to correctly identifying actual positive pixels as tumour, while specificity refers to correctly identifying actual negative pixels as non-tumor.
- Hausdorff Distance [99]: Maximum distance between ground truth and segmentation results pixels, as measured by the Hausdorff Distance metric. A decrease in value indicates an improvement in the accuracy of the segmentation.
- Execution Time [100]: The time required by each method to process medical image data is crucial for real-time or time-sensitive applications.

5.2 Computational Efficiency:

Large datasets and images of high resolution are typical in healthcare, making computational efficiency a crucial aspect of medical image processing. The following factors should be considered in comparative analysis:

- Processing Time: The time it takes for each method to finish segmentation on a standard dataset.
- Resource Utilization: Comparisons of CPU and GPU utilization, memory consumption, and energy efficiency might help determine the needed computing resources.

- Parallelization: Better scalability may be achieved using approaches amenable to parallel processing or distributed computing.

Table 2. shows the comparative analysis of existing approaches in Brain Tumor Segmentation Using MRI Images Based on Blockchain

Reference	Proposed Method	Attack detection Using Blockchain		Overall Accuracy	DataSet Type
		YES	NO		
[85]	Secure CNN	97%	62.1%	99.75%	Brain MRI (Kaggle)
[101]	CNN	NA	NA	97.5%	Brain MRI Image
[87]	BIoMT-ISeg	76%	15%	95%	Multiple Dataset (Ultrasound Nerve Segmentation, Brain Image Segmentation, Breast Ultrasound Image Dataset, COVID-19 Radiography Database.)
[102]	J. segCNN	NA	NA	Approx 100%	BRATS 2020 and 2021 dataset.
[88]	CNN-LSTM model	NA	NA	99%	Brain MRI

- Table 2. shows the comparative analysis of existing approaches in Brain Tumor Segmentation Using MRI Images Based on Blockchain. Proposed Methods: The research works employ various methods such as "Secure CNN," "CNN," "BIoMT-ISeg," "J. segCNN," and "CNN-LSTM model" for medical image segmentation. These methods vary in complexity and innovation, which may affect their performance.
- Attack Detection Using Blockchain: Only the first research work ("Secure CNN") explicitly incorporates attack detection using blockchain technology, indicating a proactive approach to enhancing security and data integrity.
- Overall Accuracy: The reported overall accuracy of the proposed methods varies across the research works. "J. segCNN" claims an approximate accuracy of 100%, while the other methods range from 95% to 99.75%. The reported accuracy levels highlight the efficacy of the methods in segmenting medical images.
- DataSet Type: The research works utilize diverse datasets, including "Brain MRI (Kaggle)," "Brain MRI Image," "Multiple Dataset (Ultrasound Nerve Segmentation, Brain Image Segmentation, Breast Ultrasound Image Dataset, COVID-19 Radiography Database)," and "BRATS 2020 and 2021 dataset." Dataset selection can influence the generalizability and applicability of the proposed methods.

In conclusion, the comparison underscores the variations in methods, security features, accuracy levels, and dataset types among the research works. The incorporation of blockchain technology for attack detection ("Secure CNN") showcases a promising direction for enhancing data security in medical image segmentation. The diverse dataset types used in the research works demonstrate a comprehensive exploration of real-world scenarios. While accuracy levels vary, they collectively underscore the advancements made in medical image segmentation techniques. Further research could delve into optimizing accuracy, exploring additional security measures, and expanding the scope of blockchain integration for improved healthcare outcomes.

6. Conclusion

In conclusion, using blockchain technology in medical image processing can dramatically alter the healthcare system by improving the privacy and security of patient information and shifting healthcare towards the needs of individual patients. Blockchain's distributed and immutable nature protects medical image data from being altered or corrupted in transit. Using smart contracts, consent management and data sharing agreements may be carried out manually, giving patients more say over their health information. There are many benefits to implementing blockchain for medical image processing, including increased data security, streamlined data sharing and cooperation, and more active patient participation. Patients can be protected while research and clinical insights are made possible using privacy-preserving algorithms. Patients, doctors, and researchers can all have more faith in the system as a whole thanks to blockchain's auditable and verifiable data trails.

Interoperability, scalability, and regulatory compliance are just a few obstacles that must be cleared. Integrating blockchain networks with healthcare systems requires standardised data formats and protocols and cross-platform compatibility. The increasing volume of medical image data and transactions necessitates using scalability solutions such as sharding and layer 2 solutions. Collaboration, educational campaigns, and proof-of-concept projects can help overcome adoption barriers like high implementation costs and low awareness. Association between healthcare institutions, technology suppliers, and researchers is crucial to further blockchain adoption and realise its disruptive potential in medical image processing.

Prospects for improved segmentation accuracy and privacy-preserving procedures lie with hybrid systems that combine AI and blockchain. Medical image processing will benefit from ongoing research and development into blockchain technology, which will produce more effective, scalable, and secure solutions. Ultimately, the healthcare industry can increase diagnosis accuracy, adapt treatment approaches to individual patient's needs, and boost overall patient outcomes by responsibly adopting blockchain technology. Trust and confidence in the disruptive power of blockchain in healthcare can only be built if players maintain a firm commitment to ethical considerations, patient consent, and data protection as the field evolves. Blockchain can transform medical image processing and open the door for a more patient-centric, data-driven healthcare ecosystem with cautious deployment and collaboration.

7. Declarations

Conflict of interest: The authors declare that they have no conflict of interest.

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