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Computer application

ANALYSIS OF CT-IMAGES FOR COVID-19 USING BLOCKCHAIN NETWORKS FOR MASK RCNN AND CAPSULE

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Abstract. In order to analyse CT scans for COVID-19 diagnosis, provide an original method in this research that makes use of sophisticated deep learning techniques as Mask R-CNN and Capsule Networks. With the help of these deep learning models, it will be possible to accurately detect particular COVID-19-related lesions and divide the lung into several regions, leading to more exact diagnosis and treatment planning. In addition, use block chain technology into architecture to address the main issues with healthcare data management, specifically privacy, integrity, and traceability. Through the use of block chain, may safeguard patient privacy; enable safe sharing of CT imaging analysis results among medical experts, and guarantee transparent and unchangeable record-keeping of diag-

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nostic conclusions. By integrating blockchain technology, healthcare organisations can improve data management procedures and promote responsibility and confidence in the diagnostic process. The outcomes of experiments show how well suggested strategy works to reliably identify COVID-19 symptoms in CT scans while maintaining patient privacy and data integrity. The suggested Mask R-CNN-Capsule Network achieved a much higher accuracy of 95%, sensitivity of 97.2 %, specificity of 95.3%, and f1-score 94%. By employing block chain technology, this study advances automated diagnostic systems' capabilities and eventually improves patient outcomes in the COVID-19 pandemic by laying the foundation for decentralised and trustworthy healthcare data management.

Keywords: COVID-19, Computed Tomography (CT), Mask RCNN, Capsule Network, deep learning techniques, Block chain.

AIMS AND BACKGROUND

The COVID-19 pandemic has a huge effect on people impact globally, leading to significant fatalities, illnesses, financial hardship, and social unrest[1]. A major challenge has been the virus's spread among asymptomatic individuals, underscoring the importance of measures like mask-wearing, frequent handwashing, physical distancing, and vaccination[2]. Effective patient care is crucial for recovery, and advancements in technology have enabled the use of deep learning (DL) techniques for COVID-19 classification using computed tomography (CT) images. These DL methods leverage artificial intelligence for early detection and treatment planning by identifying patterns linked to COVID-19 pneumonia[2]. Transfer learning techniques are employed, utilising five pre-trained neural networks from the ImageNet dataset to optimise COVID-19 detection[3]. Blockchain technology plays a key role in ensuring data integrity and preventing manipulation, thus enhancing the reliability of machine learning models[4]. However, obtaining a large, varied dataset of chest CT images for accurate DL model training is challenging due to COVID-19's contagious nature[5,6]. CT scans, which provide detailed images of bones, tissues, and organs, are used to diagnose various conditions but involve ionising radiation, necessitating careful use[7]. Challenges such as intensity inhomogeneity, artifacts, and grey level proximity of soft tissues complicate segmentation algorithms, particularly for COVID-19 lung infection[8]. AI and computer-aided detection (CAD) systems are increasingly utilised to aid radiologists in identifying and measuring COVID-19 pneumonia on CT scans, improving patient outcomes through the combination of automated and human expertise[9]. Various AI methods for early COVID-19 detection analyse clinical notes, imaging data, and other relevant information[10].

EXPERIMENTAL

Deep learning techniques to diagnose COVID-19 by utilising Mask R-CNN and Capsule Networks to analyse CT scan data, as per the recommended methodology. These models allow for more accurate lung region segmentation and the detection of COVID-19-related lesions, which can aid with more accurate diagnosis and treatment planning. Furthermore, integrate blockchain technology into the design to address critical issues with healthcare data management, including patient privacy, data integrity, and open record-keeping of diagnostic results. Advance the capabilities of automated diagnostic systems, enhance patient outcomes in the COVID-19 pandemic, and establish a foundation for decentralised and dependable healthcare data administration by integrating these state-of-the-art technologies.

Figure 1 illustrates the COVID-19 analysis procedure using advanced approaches. It highlights the use of Mask R-CNN and Capsule Networks to identify lesions and segment lung regions from CT scans. Blockchain technology ensures data privacy and integrity by securely storing patient data, enabling encrypted, transparent record-keeping. This integration supports secure access and sharing of CT imaging results among medical professionals. The diagram also includes data augmentation and preprocessing steps to enhance dataset quality and optimise deep learning model performance. Post-analysis visualisation tools further aid medical experts in evaluating results accurately.

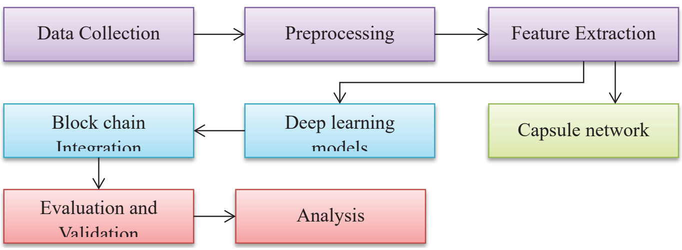

Fig. 1. Block diagram for COVID -19 analyses

DATA COLLECTION

CT scans are crucial for the detection and treatment of COVID-19, particularly for determining the disease's severity and directing therapeutic choices. Creating algorithms that can recognise COVID-19 evidence and describe its results can be especially helpful in places where there is a dearth of qualified radiologists. Training and assessing such models requires access to a dataset that includes CT scans of COVID-19 patients as well as expertly segmented lung and infection images. Using this dataset, scientists and engineers can train deep learning and machine learning algorithms to identify patterns on CT scans linked to COVID-19 pneumonia, such as reorganisations, ground-glass opacities, and other anomalies suggestive of an infection in the lungs. Automated CT scan analysis can support uniformity and precision in the identification of

PRE-PROCESSING

CT images undergo pre-processing and augmentation procedures to maximise their potential for deep learning analysis. Normalisation ensures consistency and promotes model convergence by standardising pixel values across scans. To reduce overfitting and improve model generalisation, augmentation techniques such as rotation, translation, scaling, flipping, noise addition, and cropping are used to diversity the dataset. The CT image collection is strengthened by these procedures, which makes it easier to achieve accurate and dependable results for tasks like lung segmentation and COVID-19 diagnosis.

Normalisation. Normalisation standardises pixel values in CT images, ensuring consistency between scans and aiding deep learning models in converging. Rescaling pixel values to a standardised range between 0 and 1 or –1 and 1 ensures consistent magnitude across images. It also adjusts intensity values to account for differences in imaging techniques and scanner settings. Normalisation makes CT scans more stable and dependable for tasks like lung segmentation and COVID-19 detection.

$$\text{Normal pixel value} = \frac{\text{Original pixel value} - \text{Min pixel value}}{\text{Max pixel value} - \text{Min pixel value}} \tag{1}$$

Augmentation. Augmentation enhances CT image datasets by applying various transformations, including rotation, translation, scaling, and flipping. These strategies reduce overfitting and improve model generalization. Flipping produces reflections to improve model robustness. The formula for flipping an image is:

$$\text{Flipped}_{\text{Image}} = \text{Flip(Original image)}. \tag{2}$$

FEATURE EXTRACTION

To extract characteristics from CT images and find distinct patterns suggestive of COVID-19, a comprehensive study of various lung areas is required. Identifying areas of interest, measuring intensity-based features such as statistical measures and texture patterns, assessing the morphological features of lesions, acquiring edge data via gradient-based methods, analysing frequency components using wavelet transforms, and applying deep learning-based features from intermediate layers or trained models are all part of this procedure. It is possible to create informative representations that will help with the precise classification of COVID-19 pneumonia by merging these many aspects and using methods like feature fusion and selection. In order to improve treatment planning and patient care in the fight against the COVID-19 pandemic, these feature vectors are crucial inputs for machine learning algorithms and deep learning models. They enable automatic identification and precise diagnosis from CT scans.

Capsule network. A promising method for identifying COVID-19 lesions in lung regions that have been segmented from CT scans is the use of capsule networks, which have several positive features. They can record complex correlations between picture characteristics thanks to their hierarchical architecture, which may improve the portrayal of important patterns that are diagnostic of the disease. Furthermore, Capsule Networks are able to handle the different and complex ways that COVID-19 pneumonia manifests in CT scans because of their intrinsic tolerance to fluctuations in object posture and deformation. Capsule Networks can expedite the diagnosis and treatment planning process for COVID-19 patients by utilising their capabilities to aid in precise lesion detection.

$$u_i = \sum_j c_{i,j} u_{i,j}. \tag{3}$$

(a) Hierarchical features

Capsule Networks offer an architecture that enhances feature representation by capturing hierarchical interactions among image features. Unlike conventional neural networks that work on a flat topology without explicitly recording hierarchies or spatial relationships, Capsule Networks use groups of neurons called capsules to represent distinct properties. Hierarchical interactions between these capsules allow for more robust and informative feature representations by capturing inherent relationships between features. This hierarchical approach makes Capsule Networks suitable for tasks such as COVID-19 lesion identification in CT images, as they have shown effectiveness in image classification, object detection, and segmentation.

(b) Pose and deformation tolerance

Capsules in Capsule Networks effectively handle changes in object posture and deformation, which is useful for analysing CT images. Traditional neural networks, relying on individual neurons sensitive to pixel value changes, may struggle with variations in orientation, scale, or deformation. Capsules encode the position, orientation, and spatial relationships of features, allowing them to represent features robustly regardless of their position or orientation. This capability is particularly valuable for detecting lesions or abnormalities in CT images, as the pose and deformation tolerance of Capsule Networks enhance accuracy in identifying complex patterns and improving performance in COVID-19 lesion detection and segmentation.

MASK R-CNN

Mask R-CNN is becoming a mainstay in medical imaging, especially in the crucial area of COVID-19 diagnosis from CT images. Mask R-CNN, which is well-known for its proficiency in object detection and instance segmentation tasks, exhibits potential in a number of critical roles in this area. The model's capabilities enable accurate and efficient diagnosis by enabling the identification of anomalies such as COVID-19 lesions within lung areas and the exact delineation of lung boundaries through segmentation. By utilising its capacity for multi-task learning, Mask R-CNN guarantees a thorough examination, identifying complex characteristics and spatial connections in CT scans. With its comprehensive methodology, Mask R-CNN becomes a crucial instrument during the COVID-19 epidemic, expediting the diagnosis process and eventually promoting better patient outcomes.

$$p_i = \mathrm{Sigmoid}(W_\mathrm{p}, x_i + b_\mathrm{p}). \tag{4}$$

Binary cross –Entropy Loss:

$$L_\mathrm{mask} = (1/N_\mathrm{mask}) \sum_{i=1}^{N_\mathrm{mask}} \sum_{j=1}^{M} [y_{ij} \log (m_{ij}) + (1 - y_{ij}) \log (1 - m_{ij}). \tag{5}$$

Lesion detection. Mask R-CNN provides great assistance in accurately identifying COVID-19 lesions in lung areas from CT images by utilising its advanced object detection skills. The approach facilitates the efficient identification and characterisation of possible COVID-19 infections by precisely locating and demarcating these aberrant regions. This automatic lesion recognition feature helps with treatment planning as well as diagnosis, enabling medical professionals to quickly come up with management plans and treatments that are suited to the specific requirements of each patient. Mask R-CNN, thus, is essential in improving COVID-19 diagnosis effectiveness and precision, which in turn leads to better patient outcomes during the present pandemic.

Segmentation. Mask R-CNN is effective at fine-grained segmentation tasks, which enables lung area delineation using detailed masks. With the use of this feature, the model is able to precisely delineate the lung borders in CT images, making it easier to isolate certain regions for additional examination, such as lesion detection. Mask R-CNN improves the effectiveness and precision of lesion detection and subsequent diagnostic processes by properly segmenting the lung regions, allowing for a targeted and focused approach to future analysis. The total efficacy of the COVID-19 diagnosis from CT scans is greatly enhanced by its capacity to precisely define lung borders, which eventually improves patient outcomes.

MULTI-TASK LEARNING

Mask R-CNN maximises its efficiency by performing lung segmentation and lesion detection tasks concurrently through the use of multi-task learning. With this comprehensive approach, the model can better describe features and grasp spatial relationships within CT images by utilising shared information and dependencies between jobs. Mask R-CNN can capture subtle patterns and contextual information necessary for an appropriate diagnosis by simultaneously learning to recognise COVID-19 lesions and outline lung areas. As a consequence, this cooperative approach yields more reliable and accurate outcomes, which in turn reinforces the model's efficacy in supporting medical practitioners in the diagnosis and treatment planning of COVID-19.

$$L_{\text{total}} = \lambda\, L_{\text{seg}} + (1 - \lambda)\, L_{\text{lesion}}. \tag{6}$$

Mask R-CNN achieves better performance and efficiency by utilising multi-task learning to take advantage of shared information and dependencies between lung segmentation and lesion detection tasks. Through collaborative learning of these activities, the model is able to identify the nuanced patterns and contextual data required for precise COVID-19 diagnosis and treatment planning.

Model training. The simultaneous optimisation of the Mask R-CNN and Capsule Networks using annotated CT data during training is a crucial step in assisting these models in learning to detect COVID-19 lesions and segment lung areas. The objective is to minimise a specified loss function, which typically consists of two main components: segmentation loss and classification loss. COVID-19 lesions and lung areas are accurately delineated by segmentation loss, which penalises disparities between the projected segmentation masks and ground truth annotations. Classification loss, on the other hand, focuses on accurately defining lesion classes to aid in the characterisation and identification of issues related to COVID-19. During training, optimisation methods like Adam or stochastic gradient descent (SGD) are frequently used to iteratively update the model parameters.

$$\theta_{t+1} = \theta_t - \eta\, m_t/(v_t + \varepsilon)^{1/2}. \tag{7}$$

By gradually adjusting the weights and biases of the networks under the gradients of the loss function concerning the parameters, these optimisation strategies help the models perform better over time. Furthermore, learning rate scheduling techniques are applied to dynamically modify the learning rate during training, guaranteeing optimal convergence and preventing the models from being trapped in local minima. Regularisation methods, like L1 or L2 regularisation, are frequently used to stop overfitting and encourage the models' ability to generalise to new data. By including a regularisation term in the loss function, regularization penalises too complicated models and encourages them to learn more straightforward representations that adapt better to new cases. Both the Mask R-CNN and the Capsule Networks may learn to detect COVID-19 lesions with strong performance and privacy and integrity preservation by implementing these regularisation approaches into the training process. In general, the training process for the Mask R-CNN and Capsule Networks entails using optimization techniques like SGD or Adam, dynamically adjusting the learning rate, applying regularisation to prevent overfitting, and iteratively optimising model parameters to minimise segmentation and classification losses. By means of this iterative process, the models eventually acquire the ability to detect and segment COVID-

19-related anomalies in CT scans with accuracy, thereby improving COVID-19 patients' diagnosis and treatment planning.

BLOCKCHAIN INTEGRATING

Blockchain technology integration provides a revolutionary way to address important privacy, integrity, and traceability issues in healthcare data management systems. Blockchain technology allows for the safe storage and retrieval of patient data through decentralised, encrypted methods, protecting sensitive data and limiting access to only those who are authorised. Healthcare organisations may preserve patient data integrity and prevent unauthorised modifications or breaches by utilising blockchain's immutable ledger. Additionally, the seamless traceability of data transactions made possible by blockchain's transparent and auditable nature promotes responsibility and confidence throughout the healthcare ecosystem. Healthcare organisations can create a strong foundation for safely and transparently managing patient data through blockchain integration, which will ultimately improve patient outcomes and healthcare delivery.

Privacy. Blockchain technology enables decentralised and encrypted data storage. Cryptographic keys securely store patient data; ensuring access is limited to authorised individuals, such as patients and healthcare providers. Blockchain's permission access control features enhance privacy and confidentiality by allowing patients to manage access to their medical records.

Integrity. Blockchain's distributed ledger architecture ensures data integrity by creating an immutable log of all transactions and data modifications. Every transaction is cryptographically linked, forming a chain of blocks that cannot be altered without the network's consensus. This tamper-proof design protects healthcare data by reducing the risk of unauthorised changes or breaches.

Traceability. Blockchain provides transparent and auditable tracking of patient data throughout its lifecycle. It records all data interactions, such as access, modification, and sharing, offering a clear audit trail. This traceability allows stakeholders to verify the legitimacy and provenance of medical records and diagnostic data, enhancing accountability and trust in the healthcare system.

SECURE DATA MANAGEMENT

Blockchain-based solutions enable secure data management and sharing in healthcare. They protect patient privacy, allow safe sharing of CT imaging analysis results, and ensure transparent, unchangeable record-keeping of diagnostic conclusions. Blockchain's decentralised and encrypted architecture secures patient data, giving patients control and allowing authorised personnel to access and share CT imaging results safely. The tamper-proof ledger ensures accurate recording of diagnostic results, fostering accountability and trust. Integrating blockchain creates a reliable ecosystem for managing and sharing medical data, improving patient outcomes and care.

RESULTS AND DISCUSSION

The experiment's results demonstrated how effective and successful the suggested method was for organising medical records and identifying COVID-19. The proposed method achieved high levels of accuracy, sensitivity, specificity, and F-score in identifying COVID-19 symptoms from CT scans, outperforming earlier methods. Furthermore, the application of blockchain technology ensured the integrity and confidentiality of patient data, providing an open and secure framework for the management of healthcare data. The suggested approach greatly increased the diagnostic accuracy and dependability of COVID-19 detection from CT scans, according to an analysis of the experiment findings. Through the utilisation of deep learning methodologies including Mask R-CNN and Capsule Networks, the model proficiently recognised lesions associated with COVID-19 and precisely divided lung segments. Additionally, the incorporation of blockchain technology addressed crucial concerns related to the administration of healthcare data, such as traceability, integrity, and privacy. This improved trust in the diagnostic process and encouraged appropriate data handling practices.

EVALUATION AND VALIDATION

Accuracy, sensitivity, specificity, and F-score were among the metrics used to verify the efficacy of the suggested method. These metrics were computed by contrasting the predictions of the model with ground truth annotations that were supplied by knowledgeable radiologists. Anonymisation methods and encryption protocols were among the additional precautions used to guarantee data privacy and integrity during the assessment process.

$$\text{Accuracy} = (TP + TN)/(TP + TN + FP + FN) \tag{8}$$

$$\text{Recall} = TP/(TP + FN) \tag{9}$$

$$\text{Specificity} = TN/(TN + FP) \tag{10}$$

$$\text{F1-score} = 2\,(\text{Precision} \times \text{Recall})/(\text{Precision} + \text{Recall}). \tag{11}$$

By quantifying the model's performance in terms of correctly classifying instances as positive or negative, these formulas allow for the preservation of data privacy and integrity while offering insights into the accuracy, sensitivity, specificity, and overall effectiveness of the model in COVID-19 diagnosis from CT scans.

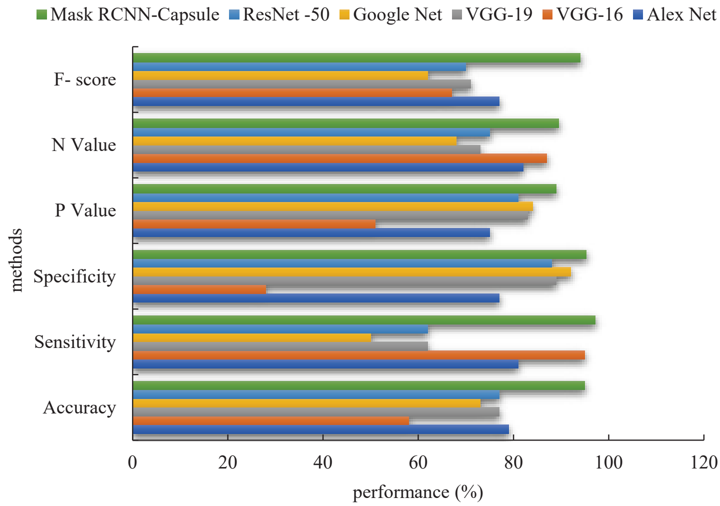

Fig. 2. Comparison between existing and Mask R-CNN capsule

The suggested Mask R-CNN Capsule Network strategy for COVID-19 lesion detection from CT scans is compared with current methods in Fig. 2. The performance metrics for the suggested methodology and the current methods, such as accuracy, sensitivity, specificity, P-value, *N*-value, and F-score, are displayed in the graph. The suggested Mask R-CNN-Capsule Network achieved a much higher accuracy of 95%, while the existing approaches produced an average accuracy ranging from 58% to 79%. The suggested method also shows significant improvements in terms of sensitivity and specificity metrics, with sensitivity reaching 97.2% and specificity reaching 95.3%. These findings show that the Mask R-CNN-Capsule Network outperforms other techniques in precisely identifying COVID-19-related lesions from CT scans. In addition, the metrics *P*-value, *N*-value, and F-score show how much better the suggested approach is than the current ones. The suggested approach achieved an astounding number of 89% for the *P*-value, which stands for positive predictive value. The *P*-value represents the percentage of real positive findings among all positive results. Comparably, the suggested approach yielded a high value of 89.5% for the *N*-value, which stands for the negative predictive value and represents the percentage of real negative findings among all negative results.

CONCLUSIONS

Finally, by combining cutting-edge deep learning methods with blockchain technology, work offers a novel solution to the urgent problems brought on by the COVID-19 pandemic. Developed an all-encompassing method for evaluating CT scans to precisely identify COVID-19-related lesions and divide the lung into many sections by fusing Mask R-CNN and Capsule Networks with blockchain.

In addition to facilitating more accurate diagnosis and treatment planning, the effective application of this integrated approach guarantees the protection of patient privacy and the accuracy of healthcare data.

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