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Securing CXR Images in Healthcare System using Smart Contracts and Medchain

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***Abstract* - In recent days, the digital sharing of medical images is highly complex in terms of data security. Modern technology depends on third-party arbitrators for storing and accessing the images. This cross-site image interface allows a patient to access medical reports for a period of time. To eliminate third-party access, we use blockchain technology for the centralized infrastructure. This technology provides a persuading solution for accessing and storing images in the trustworthy domain. The medical image is stored using a distributed file system called "IPFS" (Inter-Planetary File System). The smart contract is responsible for access level control in the distributed environment. IPFS provides a decentralized repository that can be accessible extensively. IPFS generates a CID (Content Identifier) that can be stored in the smart contract and blockchain network. In the prediction module, the images (such as chest x-ray) are uploaded in IPFS has been trained using a Deep learning algorithm such as VGG (Visual geometry group) for prediction. After training, the VGG predicts using a chest X-ray image where the result obtained is patient affected by covid or normal. The outcome of the project is to maintain the electronic medical records (EMR) digitally in the blockchain network.**

Keywords: Blockchain, Smart Contract, IPFS, CID, EMR, VGG.

I. INTRODUCTION

Data security is an approach for securing data from illegal access and data corruption throughout its lifespan. Data Security requires to place specified authority, quality plans, and approach to protecting data from the obstacles such as illegal access, unexpected loss, demolition. The organization applies and generates data that is secured according to government regulations which contains the orders for how the data should be stored. The HIPAA secrecy regulation designates a federal measure to safeguard personalized medical documents and each individual health information is referred as "Protected Health Information" (PHI).
The data breach that occurred around 3.92 million, cost worth. The medical data of patient are shared with the third party for their benefits, which causes data breaches. The data breaches can be overcome by maintaining the medical images and data in the blockchain and smart contracts. The blockchain provides a higher level of security to the data stored and accessed inside a block with a key called HASH key. This key validates each user and then allows them to access their medical data. Each transaction occurs in digital ledger cost some minimum gas value through metamask wallet. The transaction has been effectively maintained in the public blockchain grid in the form of EMR (Electronic Medical Report). The access level security of the users is provided by the agreement written in the Smart Contracts (SC). These SC protects the application accessibility from the unauthorized users.
IPFS is a peer-to-peer (p2p) storage network. When storing any file or image in IPFS it generates a Content Identifier (CID) which is a hash value of the encrypted data.
Deep learning is an AI process i.e., it mimics like functioning of the human brain in processing data and creating patterns that are used in decision-making. It is used for processing the chest x-ray image where the images are trained using the VGG-16 algorithm for prediction.

II. RELATED WORK

Vishal Patel has proposed a framework for secured and decentralized allocation of medical picture information through blockchain consensus [1]. This paper focuses on an Image-Sharing Network (ISN) that acts as a centralized authority for sharing images using a third party, PHR maintains patient data using the token-generated hash value. The advantage is that image sharing via blockchain is allowing patient-controlled picture communication does not require the necessity of a central Clearinghouse. The disadvantage is the Image-Sharing Network (ISN) has only limited access to the unauthorized network, and authorized PHR vendors.

Bhabendu Kumar Mohanta, Soumyashree S Panda, Debasish Jena has proposed An Overview of Smart Contract and Use cases in Blockchain Technology [2]. The smart contract is used for automating the transaction without the mediator involved. The main advantage is the Communication using smart contracts, which secure against any malicious attack and also, eradicate the mediator transaction and automatize the system. The disadvantage of the system is in the digital rights industry, the ratio of charge and patent are the problems that occur.

Yi Ding, Fuyuan Tan, Zhen Qin, Mingsheng Cao, Kim-Kwang Raymond Choo, and Zhiguang Qin has proposed DeepKeyGen: A Deep Learning-based Stream Cipher Generator for Medical Image Encryption and Decryption [3]. This paper focuses on the encryption and decryption of medical images using the XOR algorithm and private keys. The advantage is the DeepKeyGen is a generator to yield the private key, it is used for encrypting and decrypting medical images. The disadvantage is exclusively the medical pictures are assumed to charge for providing security.

Rachna Jain, Meenu Gupta, Soham Taneja, and D. Jude Hemanth have proposed Deep learning-based detection and analysis of COVID-19 on chest X-ray images [4]. This paper focuses on predicting covid using chest x-ray and deep learning model (Xception V3 model). The data sets are been collected, trained, and validated to check the number of infections using computer vision and the output is classified as normal, pneumonia, and covid patients. The advantage is Chest X-ray can be taken at a lower cost compared with a CT scan. The xception model had predicted the chest X-ray images with a higher accuracy rate. The disadvantage is medical data are time-consuming and expensive.

Khandaker Foysal Haque and Ahmed Abdel Gawad have proposed A Deep Learning Approach to Detect COVID-19 Patients from Chest X-ray Images [5]. In this paper, data sets are trained and validated using the CNN model. The trained model is been evaluated using metrics parameters. The output of the classification is normal or covid patient. The advantage is CNN has a higher accuracy of earlier and rapid detection of COVID-19 hence decreasing testing duration and cost. ResNet50 achieves a higher accuracy rate compared with the Xception model. The disadvantage is chest x-ray should be taken every day for the covid patient for better analysis.

The existing system uses the Deepkeygen algorithm to recommend generators to produce the private key for encoding and decoding the medical image. In Deepkeygen, the GAN is assumed has the knowledge grid that yield the private key. The estimation of Deepkeygen uses three data sets. In training, the generator transmits the initial image from the source domain to the transformation domain and the output is obtained as the private key. The discriminator is used to differentiate between the keys generated by the generator. In encryption, the plain image (pi) is encrypted using generated private key and XOR algorithm. In decryption, the ciphered image (ci) is decrypted using the private key and XOR algorithm. The analysis and outcome of project to obtain a higher-level security by producing private key.

III. PROPOSED SYSTEM

A blockchain security model for promoting Confidentiality, Integrity, validation, and authorization is developed. The access level protection and availability of CXR images only for the permitted and validated individuals using the smart contract and framework (Truffle framework) are provided. Medical images of the lung such as x-ray are uploaded by lab technicians/Patients in the IPFS. The chest x-ray (CXR) images are stored in IPFS. CXR images are uploaded to the application from the dataset. Images cannot be directly stored in the smart contract, so the IPFS plugin is used for storing the medical image in the blockchain network. In the prediction module, the dataset from Kaggle (CXR) is used for the training dataset. The medical images have been trained using Deep learning algorithms (VGG-16), where the image augmentation is performed. In the feature extraction of the CXR image, it undergoes VGG-16 layers of image pooling in which the max number of pixels is taken. The output of the prediction, such that the patient has been affected by covid or not the details are stored in the blockchain and smart contract. The digital medical record of each patient is maintained has the EMR in the blockchain.

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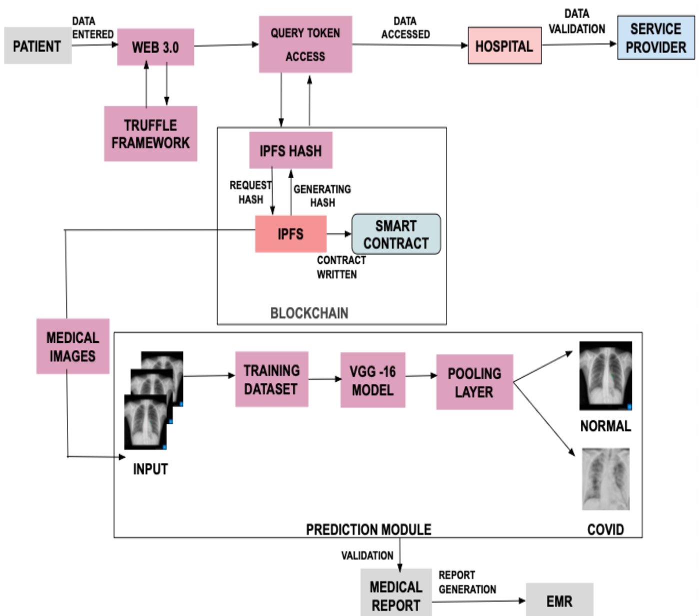

Fig 1.1 Architecture of Proposed System

In the Fig.1.1, initially, datasets of the Chest x-ray image (CXR) are collected from Kaggle. The CXR images are uploaded by the patient/ lab technician using a web application. The images are first uploaded into the IPFS protocol and it generates a CID hash value, this value is stored in the blockchain.

The dataset is trained using the VGG-16 model for achieving a higher accuracy rate. The images will have feature extraction from which the max value is taken from the image called the Pooling matrix and data augmentation is also performed. The prediction is obtained after series of image level training and output is obtained from FC layer. The prediction result is maintained using SC and blockchain.

1V MODULE DESCRIPTION

1. Image Repository and Key Generation Using IPFS

In this module, the medical image of CXR is obtained from an open-source repository named kaggle. The image dataset is firstly uploaded into the IPFS repository. The Lab technicians and patients have uploaded the CXR image of each patient after the X-ray. The report of the patient can be directly uploaded by using patient credentials. The changes in the X-ray reports can be transformed by Lab technicians as well. IPFS is a distributed file storage system that maintains huge data with a higher level of security and tracks the data. When an image is uploaded by the patient, he accesses a web application to log in and verify the process using Ethereum and metamask transactions. The lab technicians / patient uploads CXR image into IPFS repository. This transaction generates a hash value and runs on a ropston test network using metamask wallet, which cost some minimum gas value interms of ether for validating each transaction that occur in blockchain.

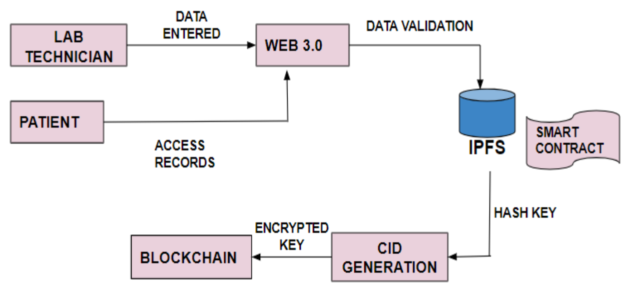

Fig 1.2 Image Repository and Key Generation Using IPFS

This Fig1.2, the generated hash value is stored inside the blockchain and smart contracts for providing security and privacy for medical images. The hash value is also known as Content Identifier (CID). This id can be used to access the images stored in the IPFS node.

2. Data Collection and Pre-processing of Images

In this module, the medical image stored in the IPFS file system is utilized for training and classification for prediction. The scaling of x-ray images are pre-processed by size (length, breadth, and height), resolution, etc. The images are taken from an open-source repository where they may be variations in terms of size and resolution. Image augmentation is a technique used for resizing and variation of an existing image for training the model efficiently. The data normalization is a process of ensuring each input image has a similar data distribution.

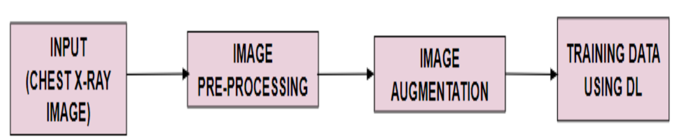

Fig 1.3 Data Collection and Pre-processing of Images

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Paper: 3

This Fig1.3, the images are augmented for a fixed size which will be easier to pre-process and train the model. Further, the images are trained using a deep learning algorithm called the VGG-16 model consists of a total of 16 layers Value geometry graph. VGG model is efficiently used for object detection and classification of images. It provides higher accuracy of object identification and training.

3. Training Chest X-Ray Image Using the VGG-16 Model

In this module, the trained datasets are also followed for feature extraction where each pixel of CXR are been calculated. The max pixels images are captured for extracting matrix value. These images endure a VGG 16-layers of training. VGG model comprises (Thirteen convolutional layers, five max-pooling layers, and three fully-connected layers). The convolutional and fully connected layers are determined by each parameter. The feature extraction is a process of training a bulk image and also leads to dimensionality reduction of the input image. The dimensionality reduction of the image increases the learning speed and generalization of the image. In the input layer, feature extraction is performed for analyzing the differences in the image of CXR. The value of the image in terms of pixels is stored in the form of the matrix for machine-readable format. The input layer to the max-pooling layer is considered to have the feature extraction layer in the convolution network. The captured object is been converted into the NumPy matrix value of pixel data.

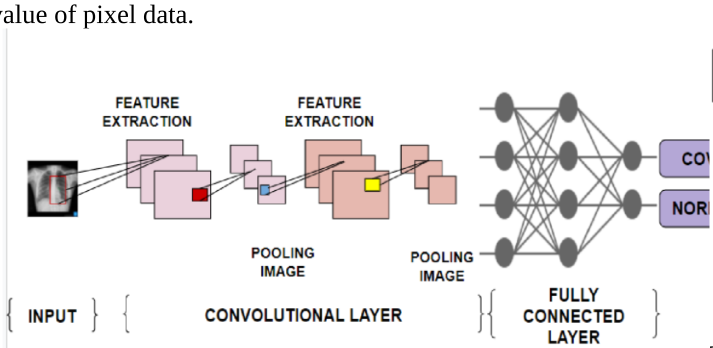

Fig 1.4 Training CXR Image Using the VGG-16 Model

Pooling is the technique of downsizing the measurements of the attribute maps. Max pooling takes the highest value of the segment from the area surrounded by the convolutional filter. In the pooling layer, the extracted features of the image are down sampled.

(sh - k + 1) / l x (w - k+ 1)/l x c

Whereas,

sh - height of segment
w - width of segment
c – no of channels in the segment
k – the size of filter
l – length of the stride

The RELU (Rectified linear unit) function fails to trigger all the neurons at the same time.

f(z)= max(0,z)

where it returns o for any negative input value of the image and for positive value z it returns the value again.

The Fully Connected (FC) layer in the CNN is responsible for the classification of the classes after the pre-trained and feature extraction of the VGG 16 model. An FC layer is responsible for the interaction of each neuron of one layer with another layer. This layer after undergoing MLP training, testing, and validation of input data classifies the CXR whether the patient is infected by covid or not.

4. Prediction Storage and Report Generation

In this module, the predicted output using the VGG-16 model for CXR image classification is uploaded into the blockchain using IPFS. This IPFS stores the image and returns an authentication token in a URL. This URL can be secured using blockchain and the images of the CXR value will be available only for authorized users with the authentication token generated by the IPFS plugin.

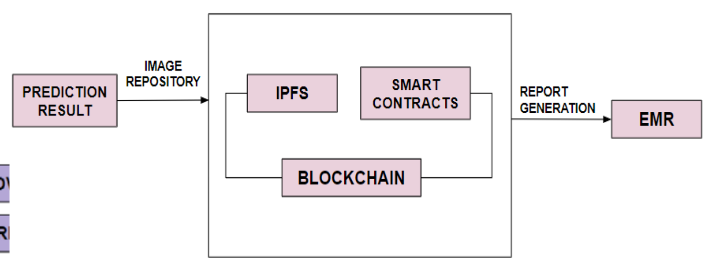

Fig 1.5 Prediction Storage and Report Generation

The smart contracts provide access-level security to the authorized users, whereas others cannot view the storage in the blockchain for access. The blockchain maintains the patient's data in the form of EMR (Electronic Medical Record). These EMR are stored in the form of blocks and then hashed using the SHA-256 algorithm.

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Paper: 3

V PERFORMANCE ANALYSIS

In the existing system, CXR images are trained using InceptionV3 and Xception models. The training and testing of CXR images is done using the models. The inception model is efficient compared to the xception model, since it requires additional parameters for training, so minimizing the parameters will have higher accuracy in training CXR images. The collected data is totally 6432 CXR images., 5467 images is used for training and 965 images are used for testing.

The training CXR using xception net there is a loss of around 0.6 and runs 100 epochs for improving the accuracy during training. In the testing phase, loss occurs around 1.0 and runs batch size of 32. This xception model provides 0.95 accuracy level in training and testing using CXR image. The training CXR using inception v3 net there is a loss of around 0.3 and runs 100 epochs for improving the accuracy during training. In the testing phase, the loss occurs around 1.0 and runs batch size of 32. This inception model provides 0.96 accuracy level in training and testing using CXR image.

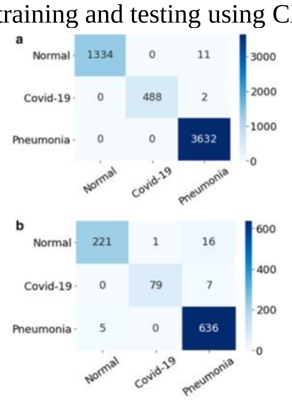

Fig 1.6 Confusion Matrix of CXR using Xception Net and Inception V3 model

The matrix A is trained using xception model where 6432 CXR image and validating (TP, FP, FN and TN) cases using prediction. The normal patients identified were 1334, covid-19 patient around 488 and pneumonia patient around 3632. The matrix B is trained using inception model where 800 CXR image and validating (TP, FP, FN and TN) cases using prediction. The normal patients identified where 221, covid-19 patient around 79 and pneumonia patient around 366.

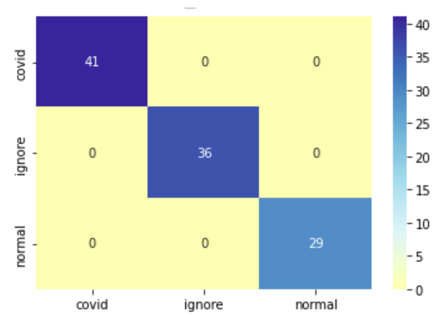

Fig 1.7 Confusion matrix

This Fig.1.7, shows that the proposed system has obtained a 3*3 matrix during training using VGG-16 model where 430 CXR image and validating (TP, FP, FN and TN) cases using prediction. The normal patients identified where 29, covid-19 patient around 41 and ignore (different image other than CXR) dataset around 36.

	precision	recall	f1-score	support
covid	1.00	1.00	1.00	41
ignore	1.00	1.00	1.00	36
normal	1.00	1.00	1.00	29
accuracy			1.00	106
macro avg	1.00	1.00	1.00	106
weighted avg	1.00	1.00	1.00	106

Fig 1.8 Prediction Accuracy of Image pre-processing

This Fig 1.8, the precision and accuracy rate are high, while training CXR image, where 75% CXR utilized for training along with 25% utilized for testing. The parameters induced from the collab after training where the accuracy rate is high along with the weights used for predicting accuracy of images

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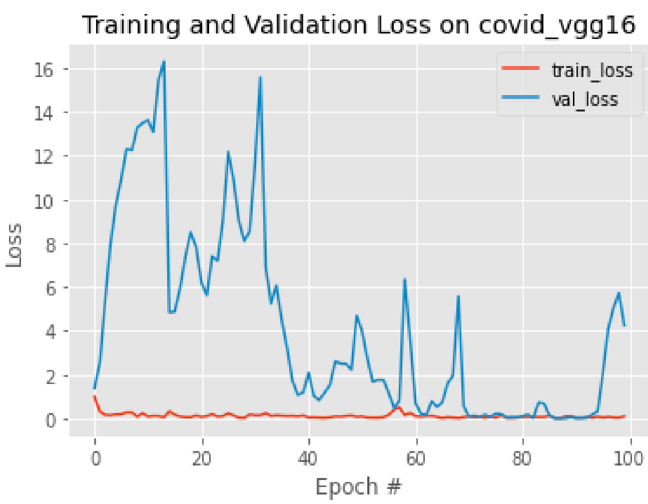

Fig 1.9 Training and Validation loss on the CXR using VGG-16

This Fig.1.9, the training of CXR image loss rate around 0.1 and validation loss rate around 16.5 it is calculated for the batch size of 32 images for 100 epochs. Compared to existing system, the training and validation loss during training is less.

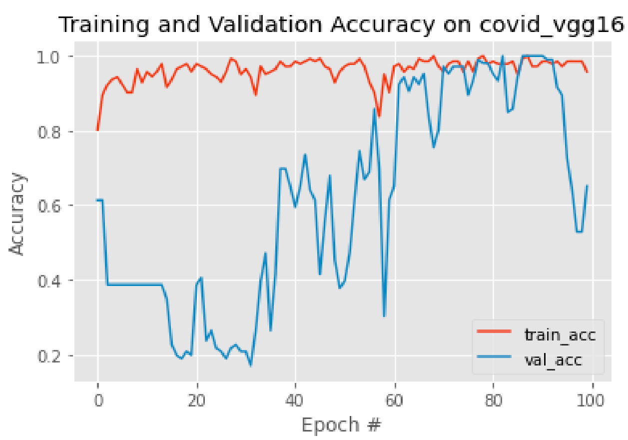

Fig 2.0 Training and Validation Accuracy on the CXR using VGG-16

The Fig.2.0, during training the validation accuracy obtained is around 0.6 for 100 epochs while training for batch size of 32 images. The training accuracy obtained around 0.98 percent. Compared to existing system, the training and validation accuracy during training is high.

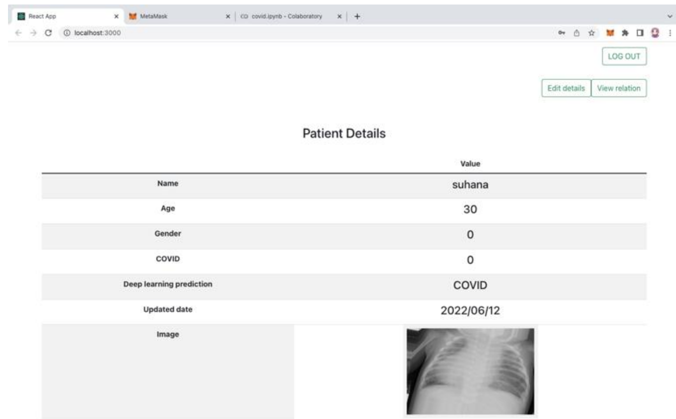

Fig 2.1 Patient Data

This Fig.2.1 represents the patient data followed by the parameters like name, age, gender, covid details, deep learning prediction, date modified and CXR image

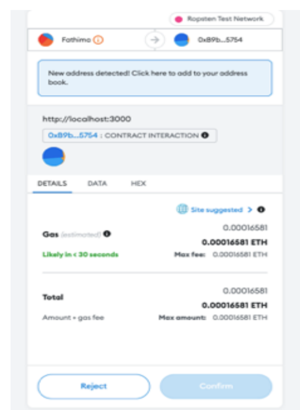

Fig 2.2 Metamask Transaction for Blockchain Validation

This Fig.2.2 represents the Ethereum transaction for the modification of records in EMR using the Smart contract. The transaction cost 0.00016581 in ropston test network.

The Fig.2.3 represents the updated X-ray image of the deep learning prediction. It also maintains relation data in order to help, the patient in an emergency situation to view the medical report.

Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 7-Issue 1, January 2024
Paper: 3

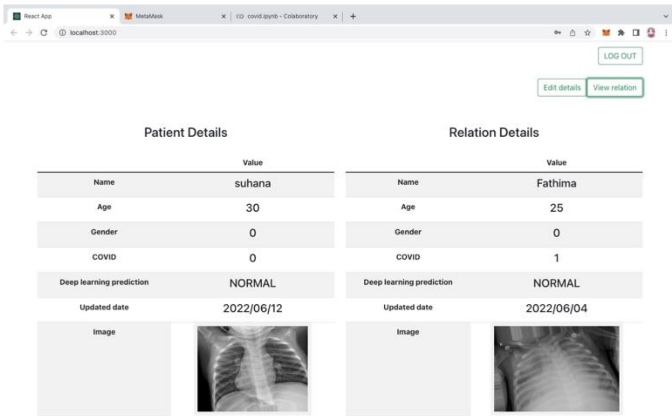

Fig 2.3 Patient Relation Details

CONCLUSION

Medical data requires security and privacy when it is perpetuated by the hospital. According to HIPAA rules, the hospital should protect patient data in a secure manner. In current days, the loss of personal medical records is been identified. The medical data can be stored using blockchain and smart contract technology where the hacker cannot steal any information. This blockchain technology provides an efficient distributed file storage where any modification to EMR needs an authentication key. In this project chest x-ray (CXR) images are stored in the blockchain and smart contract using the IPFS plugin. The CXR images are stored in IPFS, and using those CXR images we can predict whether they are affected by Covid or healthy patients using the Deep learning VGG 16 model. The outcome of the prediction is maintained in the blockchain. The patient record can be maintained has the EMR.

FUTURE WORK

The future work focuses on improving the prediction accuracy while training the CXR image.

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Volume 7-Issue 1, January 2024
Paper: 3

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