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# Eigen-Chain : A unique retinopathy detecting medical image retrieval blockchain

Abhay Kumar Yadav *
Virendra P. Vishwakarma †
*Department of Computer Science & Engineering*
*Guru Gobind Singh Indraprastha University*
*University School of Information and Communication Technology*
*Dwarka, Sector 16 C*
*Delhi 110078*
*India*

**Abstract**

Securing medical images is an essential requirement in healthcare industry. Managing medical image for storing patient sensitive information has remained a challenging task for researchers across the globe. Different technologies are struggling to provide a solution to the problem. Blockchain can possibly solve the security aspect problem of medical images. However, images sizes possess a difficulty in safely storing them on blockchain due to associated costs. It also creates scalability problem in blockchain. The proposed Eigen-Chain is a novel framework for creating a secure Hard Exudates detecting mechanism and storing images on blockchain using Principal Component Analysis (PCA) eigen vectors. These eigen vector can significantly reduce the images size which reduces the energy required for storage making it a sustainable model. Eigen-chain can retrieve image from blockchain efficiently. The experimental result on benchmark databases proved the superiority of proposed approach. Moreover, the Eigen-chain has been made capable of detecting exudates in the stored images making it useful in medical sector.

***Subject Classification:*** *68U10, 94A08, 65F55.*

***Keywords:*** *Medical images, Eigen vectors, Blockchain, Diabetic retinopathy, Exudates.*

## 1. Introduction

Modern healthcare industry is a complex interconnection of different industrial enterprises, hospitals, research institutions, insurance

* *E-mail:* **abhaybbdnitm01@gmail.com (Corresponding Author)**
† *E-mail:* **vpv@ipu.ac.in**

companies, legal partners, and other governmental regulatory systems. Maintaining secrecy, privacy and scalability of patient private data is highly essential. Telemedicine and e-health services are eminent area of healthcare sectors which need data to be transferred to medical professionals for diagnosis and patient treatments remotely by telecommunication technologies. Maintaining security, sensitivity, and privacy on monitoring patient data online is a challenging task due to of patient sensitive data [1]. Another challenge of interoperability between different components that are needed to be eliminated for secure data exchange. Different type of researches has been conducted in recent times and different contemporary solutions have been presented to the healthcare industry using technologies like AI and ML [2], computer vision, deep learning, IoT and many more with purpose of enhancing the efficiency and robustness in healthcare infrastructure.

### 1.1 *Blockchain*

The origins of blockchain technology can be said to be created in 1990s when two data structure researchers S. Haber and W.S Stornetta presented an early model of merkle tree resembling series of cryptographical block created for time-stamping of digital documents [3]. The 2008 Satoshi Nakamoto paper introduced bitcoin creating it's first practical implementation in crypto-currencies. It gained popularity after 2008 when Bitcoin was created using this technology. The Blockchain has decentralized information base that contains detailed order of blocks for maintaining transactions list with each and every block [4]. The data is secured by using a linked list based on hash functions and not on pointer. Hash function generates hash values which can be used for encryption of input data. Each block is connected with previous blocks by a digitally verified signature causing difficulty in changing record, making blockchain immutable.

### 1.2 *Diabetic Retinopathy (DR)*

DR is a retinal disease which is created as an after-effect of long duration diabetes. It damages retinal membrane which responsible for the light-sensitive portion at back of human eye. They are potentially damaged with the increase of blood sugar level in the blood vessels. Different type of lesion can occur due to DR such as hard exudates(EXs), cotton wool spots(CWS), Microaneurysms (MAs), Hemorrhages etc. Exudates (EXs) are amongst the most commonly occurring lesions. There are minor yellowish patches of exudates leaking from retinal blood vessels [5]. Exudates are detected by pupil dilation method but it may affect patient's vision. MAs are easiest and earliest noticeable indicator of retinal damage. They are visible as small red bulges looking similar as blood on the retinal image. CWS or Soft Exudates appear as feathery patches with whitish color along with fuzzy borders.

### 1.3 *PCA Lossy Compression*

PCA is a popular feature reduction and feature selection method. PCA was initially used for human face recognition of human faces by Turk and Pentland [6]. It was initially used for preprocessing step for classification and segmentation. PCA is a method for measuring how variables are related with each other using covariance matrix [7]. PCA implementation in image compression involve organizing the data in m×n form for matrix A with m being number of measurement types and n being number of samples. Subtracting the mean from each m would generate A′,

$$A' = A - \langle A \rangle \tag{1}$$

Furthermore, calculation of the eigen vectors of the covariance.

$$Cx' = (1/n)\, A'A'^T \tag{2}$$

Eigen vectors are being associated with $\lambda_i$ orthogonal values and are denoted by $w_i$. Hence, eigen values with $w_i$ association can be modified as:

$$Rxx = \sum \lambda i\, w_i\, w_i^{\ T} \tag{3}$$

Orthogonal vectors contributions can be measured by Eigen values. Generally, K<N Hence PCA transformation matrix is rewritten as $W = [w1, w2,\ldots..wk]^T$. Finally, a reconstruction vector, here denoted as â is derived as

$$\hat{a} = W^T y \tag{4}$$

In this paper, a unique eigen vector-based image retrieval technique on blockchain is proposed. The paper also presents recently done researches on existing blockchain applications in healthcare sector. The paper is structured as: Section 2 highlight already developed blockchain based applications in creating image based blockchain. The section also describes already done works done in analyzing diabetic retinopathy. Section 3 describes the detailed methodology of working of Eigen-Chain. Section 4 gives the output result in exudates detection. Section 5 concludes with blockchain technology future implication in medical image and healthcare.

## 2. Background

Using blockchain has been proven useful in enhancing security in areas of healthcare sector, however limited work has been done in using blockchain for storing digital images. Some research works has been done on implementing blockchain for storing digital images but limited contribution has been done in using blockchain for detecting HEs in retinal images. This section discusses blockchain implementation in healthcare management Image Based Blockchain. Normally, blockchains store text-based data but some efforts of linking different data structures have been done. Table 1 shows works of different researchers that had implemented different types of approaches for storing images on blockchain.

**Table 1**

**Image Based Blockchain**

| Papers | Methodology | Outcome |
|---|---|---|
| Bernstein.et al. [8] | Embedding base64-encoded image on content into HTML and inserting it as input to blockchain. | Created an image based blockchain |
| Koptyra et al.[9] | Proposed a technique for joining digital image for forming a linear structure by hashing with embedded data. | Created an efficient image based blockchain |
| Bassam et al.[10] | Deep Learning methodology with blockchain. The model consists of data collection method, securing transaction values, encryption by hash value, and data classification process. | Obtained sensitivity 96.72%, specificity 97.91%, and accuracy of 98.97% from images. |
| Li et al.[11] | Five different algorithms: the blocking algorithm: the public key, private key, update, signature and verification Algorithm. | Secure transmission and storage solution using blockchain |
| Jabarulla et al.[12] | Ethereum blockchain and Inter- Planetary File System (IPFS). | proof-of-concept design for (PCIM) system |
| Sultana et. al.[13] | A model for merging blockchain and images for securing transferring and storage of medical images. | They achieved a system for combating medical health data vulnerabilities |
| Khan et. al.[14] | Cryptographically generated pixel values obtained from image were stored on blockchain. | Created permissioned, private blockchain for securing images |

*Contd...*

| | | |
|---|---|---|
| Zhang et al.[15] | Analyzing ONC requirements for blockchain, followed by creating FHIR-Chain and employing a distributed application for data authentication. | Created a secure blockchain network for medical data authentication |
| Guo et al. [16] | In order to share information with untrusted parties, patients use a blockchain-based secure encryption Scheme. | Created a secure, immutable, and accurate data management |

## 3. Methodology

A detailed methodology on detailed working of Eigen-Chain is shown in Figure 1. (see Figure 1).

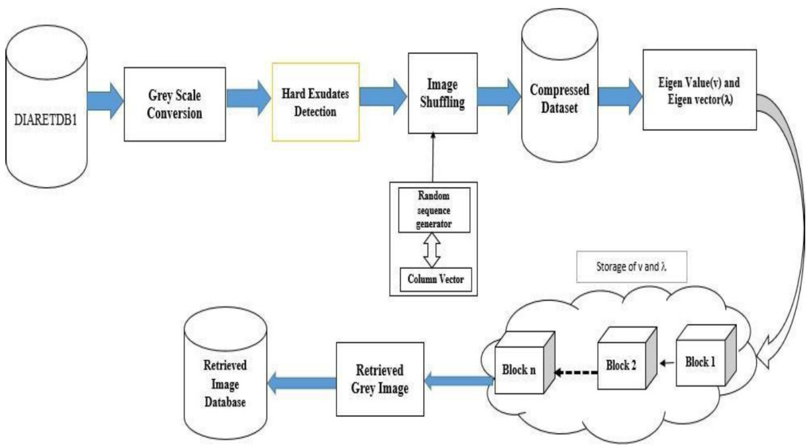



**Figure 1**

**Proposed Methodology**

## Algorithm

1. Preprocessing:
   - Load DIARETDB1 [17] dataset and convert the images into a greyscale images.
2. Hard Exudates Detection
   - Perform a top hat transformation on greyscale converted image.
   - Perform a bottom hat transformation on the obtained output.
   - Apply a thresholding technique to the top hat and bottom hat transformed images further converted into binary images.

- Compare the pixel values in the binary images with a threshold value.
- Perform erosion and dilation morphological operations for noise removal
- Generate a final result image where the detected hard exudates are highlighted.

3. Feature Extraction:
    - Apply PCA to the DIARETDB1 dataset to extract the eigen vectors.
    - Calculate the covariance matrix.
    - Compute the eigen values $\lambda$ and eigenvectors of the covariance matrix.
    - Sort $\lambda$ in descending order and select the top-k eigen vectors that capture the most significant variation in the dataset.
4. Image Encoding:
    - Project each image in the dataset onto the selected eigen vectors to obtain the corresponding feature vector representation.
    - Encode the feature vectors into a suitable format for storage and transmission, such as converting them to hexadecimal strings.
5. Blockchain Integration:
    - Connect to the blockchain network or use a blockchain platform to store the encoded image representations.
    - Create a transaction or smart contract that includes the encoded image representations as data to be stored on the blockchain.
    - Generate a unique identifier o r hash for each image to serve as its blockchain address or reference.
    - Store the encoded image representations on the blockchain, associating them with their respective identifiers.
6. Retrieval and Decoding:
    - Retrieve the encoded image representation associated with the blockchain identifier.
    - Reverse the encoding process by projecting the feature vector back onto the selected eigenvectors.
    - Reconstruct the image using the inverse transformation of the PCA algorithm.

## 4. Results

Over 130 images obtained from DIARETDB0 database [17] have been examined on MATLAB software with intel i7, 2.9 GHz processor. The images were firstly subjected to morphological operations for Hard

Exudates detection. After exudates detection, images are further subjected to Eigen-chain for securely transmitting the detected exudates images. The images are encrypted with Simple Hashing Algorithm and are propagated after converting it with eigen vector decomposition using eigen value($\lambda$) and eigen vector($v$) analysis. The eigen vectors have been used for retrieving the output images.

### 4.1 *Exudates Detection*

On evaluating our Eigen-Chain on retinal images obtained from DIARETDB0 database, we have used accuracy, sensitivity, and specificity as the performance measure. The following Table 2 shows the output results of the proposed exudates detected in the term of accuracy, sensitivity, and specificity. This result would be considered efficient in determining the Hard Exudates in the retinal images.

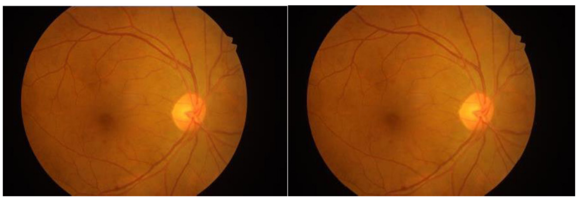
**Table 2**

**Performance parameter and analysis for Hard Exudates Detection**

| Authors | Techniques | Performance Metrics | | |
|---|---|---|---|---|
| | | Accuracy | Sensitivity | Specificity |
| Emil Saeed et al.[18] | Scale Invariant Feature Transform (SIFT) | 97.38% | 96.9% | 96.1% |
| Ruba et al.[19] | Gabor and GLCM Features | 75.2% | 100% | 75.7% |
| Wisaeng et al. [20] | Exudates Detection Using Morphology Mean Shift Algorithm | 98.35% | 98.40% | 98.13% |
| Sopharak et. al. [21] | Optimally adjusted morphological Operator for easy exudates detection | 79% | 73% | 87% |
| S. Long et. al. [22] | Dynamic Threshold and SVM Classification | 97.7% | 97.50% | 97.84% |
| Kavitha et al. [23] | Histogram based thresholding Approach | 89% | 92.87% | - |
| Sariera et al. [24] | Multilayered Perceptron Neural network (MLP) | 93% | 86.9% | 94.8% |
| Proposed | PCA with Top hat transformation and thresholding | 96.5% | 97.3% | 96.9% |

### 4.2 *Retrieved Image*

The proposed Eigen-Chain has been implemented by PCA eigen values and eigen vectors for image compression. They have used images coefficient for storing the image addresses. Further, 256 bits Simple Hashing Algorithms is used for encryption and output of SHA along with eigen vector being stored in block. This process is repeated again with 130 retinal images making a blockchain with 130 blocks. At last, retrieval of images was done for obtaining back into original form. Eigen-Chain was able to retrieve nearly 98.60% images correctly by correlation coefficient measurement (see Figure 2).



(a) Stored Image (b) Retrieved Image

**Figure 2**

**Retrieved Image using Eigen-Chain**

## 5. Conclusions

This paper presents a novel blockchain based image storage and retrieval methodology along with capability of detecting hard exudates in retinal fundus images obtained from DIARETDB0 database. The proposed Eigen-Chain for detecting exudates uses eigen vectors obtained from PCA for storing data values and are embedded with hash values further stored on blockchain solving problem arising in storing retinal images on blockchains. Since storing images directly on blockchain will leads to increase in storage and time cost. Eigen-Chain uses PCA compression property for compressing images using eigen vectors of fixed block. Only the block with eigen coefficient is stored on blockchain decreasing the block size of blockchain. The images being stored on Interplanetary File System (IPFS) distributed database.

## References

[1] E. Onyekwere, F. N. Ogwueleka, and M. E. Irhebhude, "Adoption and sustainability of bitcoin and the blockchain technology in Nigeria,"

*International Journal of Information Technology*, vol. 15, no. 5, pp. 2793–2804, (2023).

[2] K. S. C, U. Divakarala, K. Chandrasekaran, and K. H. K. Reddy, "A hierarchical blockchain architecture for secure data sharing for vehicular networks," *International Journal of Information Technology*, vol. 15, no. 3, pp. 1689–1697, (2023).

[3] Muhammed Miah, Shah Jahan Miah & Santosh Venkatraman Blockchain: At a glance idea for information science researchers, *Journal of Information and Optimization Sciences*, 42:7, 1589-1624, (2021).

[4] S. Quamara and A. K. Singh, "SChain: towards the quest for redesigning supply-chain by augmenting Blockchain for end-to-end management," *International Journal of Information Technology*, vol. 14, no. 5, pp. 2343–2354, (2022).

[5] S. B. Verma and A. K. Yadav, "Detection of Hard Exudates in Retinopathy Images," *ADCAIJ: Advances in Distributed Computing and Artificial Intelligence Journal*, vol. 8, no. 4, pp. 41–48, (2019).

[6] Approaches to Principal Component Analysis in the Presence of Missing Values," 978-951-22-9481-7, vol. 11, (2010).

[7] Alexander, and Tapani Raiko," Practical Approaches to Principal Component Analysis in the Presence of Missing Values", Journal of Machine Learning Research 11, (2010).

[8] D.J Bernstein, T Lange, eBACS: ECRYPT Benchmarking of Cryptographic Systems. (2019). Available online: https://bench.cr.yp.to/results-hash.html

[9] K. Koptyra and M. R. Ogiela, "Imagechain—Application of Blockchain Technology for Images," *Sensors*, vol. 21, no. 1, p. 82, (2020).

[10] B. A. Y. Alqaralleh, T. Vaiyapuri, V. S. Parvathy, D. Gupta, A. Khanna, and K. Shankar, "Blockchain- assisted secure image transmission and diagnosis model on Internet of Medical Things Environment," *Pers Ubiquitous Comput*, (2021).

[11] Y. Li, Y. Tu, J. Lu, and Y. Wang, "A Security Transmission and Storage Solution about Sensing Image for Blockchain in the Internet of Things," *Sensors*, vol. 20, no. 3, p. 916, (2020).

[12] M. Y. Jabarulla and H.-N. Lee, "Blockchain-Based Distributed Patient-Centric Image Management System," *Applied Sciences*, vol. 11, no. 1, p. 196, (2020).

[13] M. Sultana, A. Hossain, F. Laila, K. A. Taher, and M. N. Islam, "Towards developing a secure medical image sharing system based on zero trust principles and blockchain technology," *BMC Med Inform Decis Mak*, vol. 20, no. 1, p. 256, (2020).

[14] P. W. Khan and Y. Byun, "A Blockchain-Based Secure Image Encryption Scheme for the Industrial Internet of Things," *Entropy*, vol. 22, no. 2, p. 175, (2020).

[15] P. Zhang, J. White, D. C. Schmidt, G. Lenz, and S. T. Rosenbloom, "FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data," *Comput Struct Biotechnol J*, vol. 16, pp. 267–278, (2018).

[16] R. Guo, H. Shi, Q. Zhao, and D. Zheng, "Secure Attribute-Based Signature Scheme With Multiple Authorities for Blockchain in Electronic Health Records Systems," *IEEE Access*, vol. 6, pp. 11676–11686, (2018).

[17] T. Kauppi et al., "The DIARETDB1 Diabetic Retinopathy Database and Evaluation Protocol," in British Machine Vision Conference, (2007).

[18] E. Saeed, M. Szymkowski, K. Saeed, and Z. Mariak, "An Approach to Automatic Hard Exudate Detection in Retina Color Images by a Telemedicine System Based on the d-Eye Sensor and Image Processing Algorithms," *Sensors*, vol. 19, no. 3, p. 695, (2019).

[19] T. Ruba and K. Ramalakshmi, "Identification and segmentation of exudates using SVM classifier," in 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), IEEE, pp. 1–6, (2015).

[20] K. Wisaeng and W. Sa-Ngiamvibool, "Exudates Detection Using Morphology Mean Shift Algorithm in Retinal Images," *IEEE Access*, vol. 7, pp. 11946–11958, (2019).

[21] A. Sopharak, B. Uyyanonvara, S. Barman, and T. H. Williamson, "Automatic detection of diabetic retinopathy exudates from non-dilated retinal images using mathematical morphology methods," *Computerized Medical Imaging and Graphics*, vol. 32, no. 8, pp. 720–727, (2008).

[22] S. Long, X. Huang, Z. Chen, S. Pardhan, and D. Zheng, "Automatic Detection of Hard Exudates in Color Retinal Images Using Dynamic Threshold and SVM Classification: Algorithm Development and Evaluation," *Biomed Res Int*, vol. 2019, pp. 1–13, (2019).

[23] K. Akyol, B. Şen, and Ş. Bayır, "Automatic Detection of Optic Disc in Retinal Image by Using Keypoint Detection, Texture Analysis, and Visual Dictionary Techniques," *Comput Math Methods Med*, vol. 2016, pp. 1–10, (2016).

[24] T. M. Al Sariera, L. Rangarajan, and R. Amarnath, "Detection and classification of hard exudates in retinal images," *Journal of Intelligent & Fuzzy Systems*, vol. 38, no. 2, pp. 1943–1949, (2020).