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A novel blockchain and fractional DCT based image storage and retrieval framework

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Abstract

Securing medical images are a challenging task for researchers as they are prone to cyber- attacks. A potential solution to this problem can be blockchain, which provide secure and unchangeable storage. Fractional Discrete Cosine Transform (frDCT) has the capability to minimizes the amount of data necessary for expressing an image in a secure way. This paper presents a novel framework for compressing as well as securely storing and retrieving medical images by extraction of feature maps from medical images by frDCT, followed by encoding and storing the feature map on decentralized cloud and linking them on blockchain using fractional angle α. The proposed framework provides numerous benefits such as improved data sharing and collaboration, enhanced security, compression as well as efficient retrieval and processing of medical image data which in turn decreases the computational energy requirement providing sustainability. The performance of proposed framework has been evaluated by employing image quality metric such as MSE, PSNR, SSIM and multi-SSIM by comparing it with correct and incorrect α values on six different values of frDCT parameter α.

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

Keywords: *Distributed storage, Fractional DCT, Fractional angle's, Feature extraction.*

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1. Introduction

Images are capable of storing large amount of data and are useful transmitting large amount of information across different geographical locations using different cloud services. These data sharing increases chances of cyber-attacks on digital images making it a challenging task for researchers. Maintaining security, sensitivity, and privacy on monitoring patient data online increases the challenges due to involvement of patient sensitive data [1]. There is a strong need of a robust system cable of securing and transmitting digital images across the network. Blockchain can serve as a potential solution to this problem. Combining blockchain application with areas of medical research may provide newer potential in the biomedical field research [2]. However, the storage and transmission of large digital images can be challenging due to their size and complexity.

One approach to addressing this challenge is to use compression techniques to reduce the size of digital images. Among the various compression techniques available, the Discrete Cosine Transform (DCT) has been widely used due to its excellent compression performance and low computational complexity [3]. However, the DCT suffers from block artifacts and loss of high-frequency information which degrades the image quality after compression [4]. Fractional DCT (FrDCT) uses fractional values for the frequency coefficients, which allows for more accurate representation of the image's high-frequency components which increases the quality of compressed image.

1.1 *Blockchain*

Blockchain technology is built on a combination of existing technologies that work together to create a secure and decentralized system for storing and verifying transactions. The important elements that make up blockchain include distributed ledgers, cryptography, consensus algorithms, peer-to-peer networks and smart contracts [5]. 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 [6]. The Blockchain has decentralized information base that contains detailed order of blocks for maintaining transactions list with each and every block having three block fragments called information, hash block, and hash of previous block.

1.2 *frDCT*

The frDCT is a generalization form of DCT, with DCT only allowing for integer values for frequency indexing, the frDCT allows for fractional values as well. This means that the frDCT can accurately represent signal components at any frequency, making it more efficient for compression. The mathematical expression for the frDCT involves the input signal, the transformed signal, number of points in input signal, and frequency indices that can take fractional values between -0.5 and 0.5 [7]. Compared to the DCT, the frDCT has advantages such as better energy compaction, higher accuracy in representing signal components at any frequency, and faster computational speed using the Fast Fourier Transform algorithm.

When $\alpha = 1$, FrDCT behave as DCT while at $\alpha=0$ no change in data.

By using angle α, FrDCT generates generalization, providing more flexibility than DCT.

$$A_\alpha = Ve^{\alpha E}V \tag{1}$$

where A_α is FrDCT kernel

Eigen-vectors and eigen-values are used for calculating FrDCT kernel matrix. Matrix C is used as eigen- vector of DCT kernel matrix [8].

If u_n is eigen-vector of DCT kernel matrix then V matrix is

$$C = [a_1, b_1, \ldots\ldots\ldots\ldots, a_{N/2}, b_{N/2}] \tag{2}$$

with a_N denoting real and b_N being imaginary part of eigen vector

$$E = \text{diag}[E_1 \ldots\ldots\ldots E_{N/2}] \tag{3}$$

The simplification of Eq. 3 will be.

$$E = \begin{bmatrix} 0 & \psi n \\ -\psi n & 0 \end{bmatrix} \tag{4}$$

The frDCT is useful in reducing amount of data needed to be stored on cloud by converting the image data into a smaller set of coefficients. α coefficients are used to identify and access the specific blocks of transformed image data stored on the cloud [9]. The blockchain is used to securely store the unique ID of the stored image, ensuring that the stored data cannot be tampered with or lost.

The presented work is organized as: the next Section discusses the working of our presented framework with discussing algorithm and methodology of working of frDCT in establishing the image compression based on frDCT and image storage and retrieval methodology is presented, followed by integration of the presented methodology with blockchain and distributed cloud. Section 3 provide the performance and security

analysis on standard image quality metrices. Next, we perform the experimental analysis on MATLAB software indicating the importance of knowing correct and incorrect α values during storage and retrieval based on presented image quality metrices. Finally, we conclude in Section 5 along with stating it's future application followed by bibliography in the end.

2. Methodology

2.1 *frDCT Implementation*

The methodology involves multiple steps including image acquisition, image compression, image storage and retrieval process. A methodology for the same is explained by algorithm below and a detailed flowchart explaining the same is shown in Figure 1.

Algorithm for storage and Retrieval using frDCT and Blockchain

Storage:
Input:
- Retinal image obtained from ALL-IDB1 dataset [10].
- frDCT parameters α.

Step 1: Convert input images into M × M size, non-overlapping tiles of size m x m (τ)
Step 2: Apply 2-Dimensional DCT on each and every tile
Step 3: Perform zigzag scan on tile τ to convert into a vector s.
Step 4: Select first n coefficient of the vectors
Step 5: Rearrange these coefficients in a 2-D form using un-zigzag scan
Step 6: Apply 2-D FRDCT with α giving secure output *LFD_FRDCT*
Step 7: Store the *LFD_FRDCT* on cloud as cloud secured data.
Retrieval:
- LFD_FCTDCT from cloud
- α and n from blockchain.

Step 1: Apply 2D inverse FrDCT on LFD_FCTDCT with same value of α.
Step 2: Scan the output matrix of step 1 in zigzag order to obtain a vector ω.
Step 3: Create a vector of size $1 \times N \times N$ by padding the remaining coefficient to be
zero at tailing end.
Step 4: Apply inverse DCT2 to get the processed tile τ'
Step 5: Combine all the tile to obtain the retrieved image

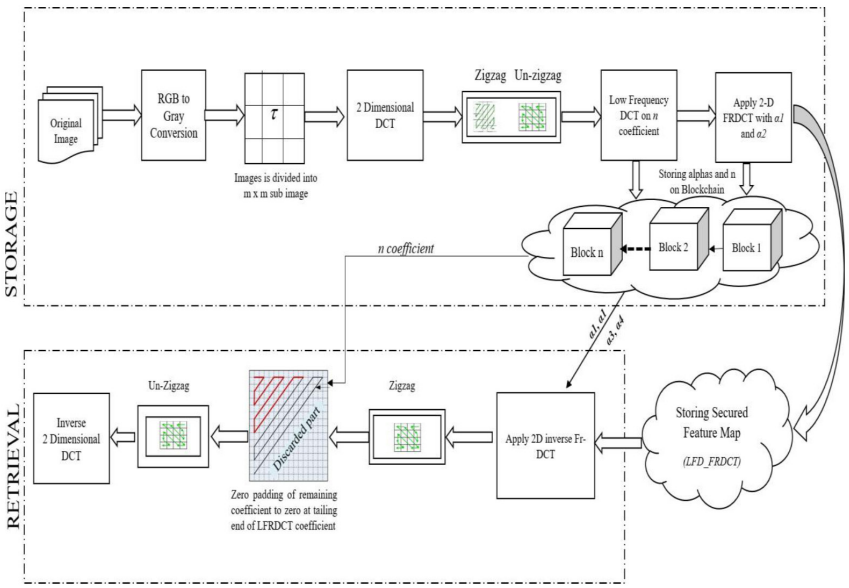


Figure 1

Proposed Framework

3. Performance and Security Analysis

For evaluating the performance of our proposed architecture, we have used quantitative parameters for comparing the proposed methods with standard image quality metrices. The performance evaluation is done on MATLAB software (R2023a) on intel i5 2.9 GHz processor system. Our algorithm is tested on MSE, PSNR, SSIM and MSSIM [11]-[13] on our originally secured and retrieved images based on different values of α.

Table 1 shows superior performance of our architecture when same α values are used in storage and retrieval stage. Our architecture provided nearly same output on different α values, indicating successful storage and retrieval of images for any values of α provided with same value of α's for both storage and retrieval.

Table 2 show the decrease in image quality when user provide different α values at retrieval stage. Even a slight difference in α values between storage and retrieval stage greatly distort image. The image distortion can be shown by drastic decrease in MSE, PSNR, SSIM and MSSIM quality metrices values.

Table 1

Performance evaluation on correct α at input and inverse stage

Stored α value	Retrieved α value	MSE	PSNR(in db)	SSIM	Multi-SSIM
0.4	0.4	0.92	48.54	0.993	0.997
0.7	0.7	0.93	48.54	0.993	0.997
1.2	1.2	0.93	48.54	0.993	0.997
1.5	1.5	0.93	48.54	0.993	0.997
2.3	2.3	0.93	48.54	0.993	0.997
2.8	2.8	0.93	48.54	0.993	0.997

Table 2

Performance evaluation on different α's at input and inverse stage.

Stored α value	Retrieved α value	MSE	PSNR (in dB)	SSIM	Multi-SSIM
0.4	0.2	5694.64	10.31	0.19	0.36
0.7	0.3	3831.31	21.62	0.50	0.72
1.2	1.0	5205.21	17.14	0.20	0.32
1.5	1.2	7115.40	15.66	0.20	0.33
1.8	1.3	7692.15	13.38	0.18	0.33
2.3	2.5	6537.97	12.98	0.19	0.74

4. Experimental Analysis

This Section highlights the experimental analysis of the image storage. We have used retinal image for storage on blockchain.

4.1 *Image storage with α values*

For evaluating the performance of our proposed framework, MATLAB software (R2023b) on intel i7 2.9 GHz processor system is used. Figure 2(a) shows the stored and retrieved image with using same α's values at storage and retrieval stage. Figure 2(b) shows the stored and retrieved image with different α's values at storage and retrieval stage indicating the great loss to image quality at retrieval stage due to difference in α values.

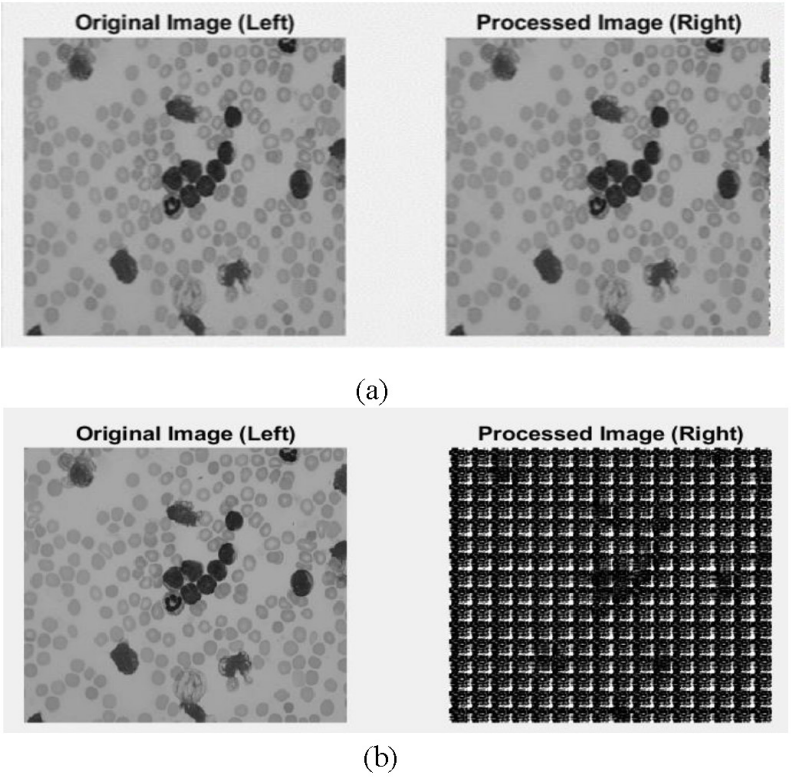


Figure 2

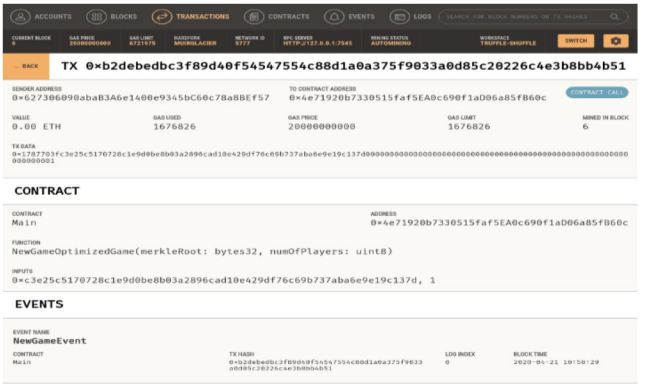
Original and processed image

(A). α=1.2 at both storage and retrieval

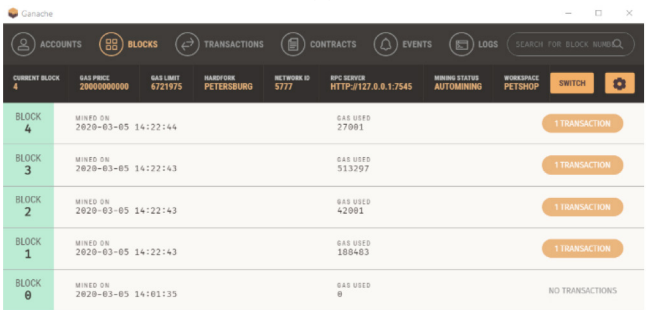
(B) α= 1.2 at storage and α= 1.0 at retrieval

4.2 *Blockchain Storage*

Ganache software [14] is capable of providing real-time simulation of smart contract executions based on Ethereum platform. Here, we have used Ganache for simulating the storage of fractional parameter (α) and n number of coefficient on blockchain. Ganache provides 10 blocks free for mining simulation, we have used only 1 for storing the fractional angles values and 1 block for storing the number of coefficients taken. Figure 3 shows storage of our alpha's values and number of coefficients on Ganache software.



(a)



(b)

Figure 3

Implementation on Ganache Framework.
(a) Ganache user interface layout
(b) Transaction execution status

5. Discussion and Conclusion

The research paper provides a novel approach for securing retinal images based on FrDCT feature maps on the cloud and linking them to the blockchain in highly secure manner providing a storage and retrieval mechanism with help of cloud and blockchain storage. The paper is able to provide a compression as well as secured storage and retrieval technique for storing images on blockchain. The paper utilizes α coefficients values to be known during storage and retrieval stage. This enhances the security aspects as only authorized user retrieving the image has access to correct alpha values. Any variation in alpha values deteriorate the image on large

extend. Moreover, the user should also know the correct number of coefficients being used for retrieving the image. The presented method reduces the retinal image storage requirements while ensuring the security and accessibility of the stored data. The experimental analysis on few image quality matrices such as MSE, PSNR and SSIMs showed that images are successfully retrieved when same α are used during storage and retrieval stage. This framework can be implemented in securing other types of images along with integrating it with deep learning techniques to make it capable of real-time decision making in near future.

References

[1] 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).

[2] Ottakath, Najmath, Abdulla Al-Ali, Somaya Al-Maadeed, Omar Elharrouss, and Amr Mohamed. "Enhanced computer vision applications with blockchain: A review of applications and opportunities." *Journal of King Saud University-Computer and Information Sciences* 35, no. 10, 101801, (2023).

[3] N. Ahmed, T. Natarajan, and K. R. Rao, "Discrete Cosine Transform," *IEEE Transactions on Computers*, vol. C–23, no. 1, pp. 90–93, (1974).

[4] Abramova V, Lukin V, Abramov S, Kryvenko S, Lech P, Okarma K. A Fast and Accurate Prediction of Distortions in DCT-Based Lossy Image Compression. *Electronics*, 12(11):2347, (2023).

[5] A. K. Yadav and V. P. Vishwakarma, Adoptation of Blockchain of Things(BCOT): Oppurtunities & Challenges, in IEEE International Conference on Blockchain and Distributed Systems Security, ICBDS 2022, Institute of Electrical and Electronics Engineers Inc., (2022).

[6] Nakamoto S. Bitcoin: A Peer-to-Peer Electronic Cash System, (2008). Available from: https://bitcoin.org/bitcoin.pdf

[7] G. Cariolaro, T. Erseghe, and P. Kraniauskas, The fractional discrete cosine transform, *IEEE Transactions on Signal Processing*, vol. 50, no. 4, pp. 902–911, (2002).

[8] A Goel and VP Vishwakarma, "Fractional DCT and DWT Hybridization Based Efficient Feature Extraction for Gender Classification," *Pattern Recognition Letters*, vol. 95, pp. 8- 13, (2017).

[9] G. Sundaram, B. Panna, R. K. Jha, and S. Kumar, Image encryption based on fractional discrete cosine transform and DWT with interplane arrangements in dost domain, *IET Image Process*, vol. 17, no. 4, pp. 1195– 1207, (2023).

[10] R.D. Labati, V. Piuri, F Scotti. ALL-IDB: the acute lymphoblastic leukemia image database for image processing, in Proc. of the 2011 IEEE Int. Conf. on Image Processing (ICIP 2011), Brussels, Belgium, pp. 2045-2048, ISBN: 9781-4577-1302-6, (2011).

[11] N. Mahendiran and C. Deepa, A Comprehensive Analysis on Image Encryption and Compression Techniques with the Assessment of Performance Evaluation Metrics, *SN Comput Sci*, vol. 2, no. 1, p. 29, (2021).

[12] R. G. Deshpande, L. L. Ragha, and S. K. Sharma, Video Quality Assessment through PSNR Estimation for Different Compression Standards, *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 11, no. 3, p. 918, (2018).

[13] R Dosselmann and XD Yang, "A Comprehensive Assessment of the Structural Similarity Index," *Signal, Image and Video Processing*, vol. 5, no. 1, pp. 81-91, (2011).

[14] ConsenSys AG, "Ganache Documentation". https://trufflesuite.com/ganache/.