Available online at www.qu.edu.iq/journalcm
JOURNAL OF AL-QADISIYAH FOR COMPUTER SCIENCE AND MATHEMATICS
ISSN:2521-3504(online) ISSN:2074-0204(print)

A Hybrid Approaches for Medical Image Compression: Survey

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ARTICLE INFO

Article history:
Received: 15 /04/2023
Rrevised form: 27 /05/2023
Accepted : 01 /06/2023
Available online: 30 /06/2023

Keywords: Compression Ratio, Wavelet Transform, image Compression

ABSTRACT

Data compression is necessary for the storing, transfer, and manipulation of digital data in today's rapidly changing world due to the widespread use of medical technology and the vast data creation by various medical modalities. Many scientists and engineers have proposed new compression processes, methods, and algorithms in recent years. There is a discussion of the current state of these compression strategies, including their recent advances in the form of hybrid techniques, performance requirements, legal challenges, and the potential to advance medical technology.

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https://doi.org/10.29304/jqcm.2023.15.2.1237

1. INTRODUCTION

Before the advent of digital technology, most medical imaging tests were performed on radiological films; today, however, all tests are performed digitally, increasing the volume of digital medical data over the past several decades [1]. According to the most recent data from the Office of the National Coordinator (ONC) for Health IT, over 84% of hospitals have embraced electronic health record (EHR) systems. Information including patient demographics, clinical notes, x-ray images, diagnoses, findings, and prescriptions relevant to the care of the patient are all digitally stored in EHR systems [2]. Digital data created by medical imaging modalities is increasing quickly, necessitating effective storage and transmission methods. These modalities include computed tomography (CT), magnetic resonance imaging (MRI), electrocardiography (ECG), X-rays, ultrasound (US), and mammograms, among others. For quick interaction, and finding context-dependent images, Methods of compression can analyze a huge collection of images or Metrics of Volume [3].

2. Compression System Model

The compressor and the decompressor make up the two halves of the compression system model. Both the compressor and the decompressor have many stages: the first has to preprocess and encode, while the latter has decoding and postprocessing (Figure 1). Preprocessing, which occurs before encoding, involves performing a variety of application-specific actions on the image in order to get it ready for encoding. Some of the compression process's

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unwanted artifacts can be removed by postprocessing, which is done after the file has been decoded. Many useful compression algorithms are hybrids of several separate compression methods [4].

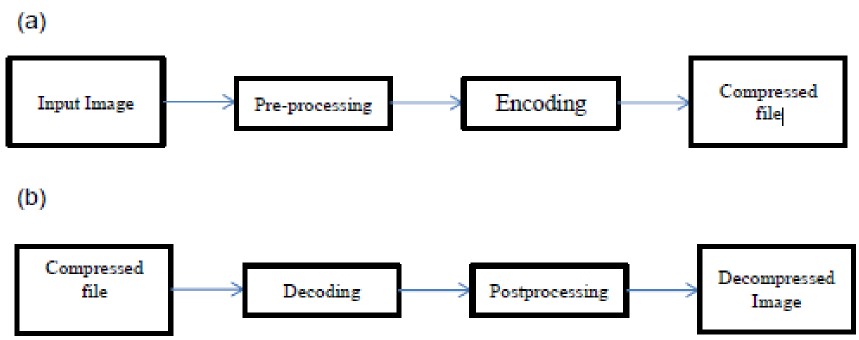

Fig. 1. compression system model.
(a) Compression. (b) Decompression.

3. Quality Measures

The ratio of the original (uncompressed file) and the compressed file is referred to as the compression ratio. Here is an equation for calculating the compression ratio:

$$Compression\ Ratio = \frac{uncompressed\ file\ size\ (byte)}{compressed\ file\ size\ (byte)} \qquad (1)$$

-The mean square error (MSE), in many cases can be symbolized by the σ_q^2, which is determined according to the following equation (2),(3):

$$MSE = \sigma_q^2 = \frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}(f(x,y) - g(x,y))^2 \qquad (2)$$

where f and g are M*N size images. MSE is often called quantization error variance σ_q^2. This metric is helpful since it provides an approximate amount of the energy lost during the Lossy compression of the original image f.

- In many applications, the signal-to-noise ratio (SNR) is expressed in terms of MSE, and is defined as:

$$SNR = 10\log_{10}\frac{\sigma^2}{\sigma_q^2} = 10\log_{10}\left[\frac{\frac{1}{M*N}\sum_{y=1}^{N}\sum_{x=1}^{M}(f(x,y))^2}{\frac{1}{M*N}\sum_{Y=1}^{N}\sum_{X=1}^{M}(f(x,y)-g(x,y))^2}\right] \qquad (3)$$

where σ^2 is the variance of the original image, and σ_q^2 is the *MSE*. The signal-to-noise ratio (SNR), expressed in decibels (dB), is an excellent indicator of the quality of the reproduced signal.

- A more subjective qualitative evaluation of quality is PSNR (Peak Signal-to-Noise Ratio). It is employed when error magnitude is more concerned with the peak value of the image than the average squared value of the image. To calculate the PSNR between two 8-bit-per-pixel pictures, we use the following formula:

$$PSNR = 10\log_{10}\left[\frac{255^2}{MSE}\right](db) \qquad (4)$$

4. Image Compression Techniques

Compression methods that successfully overcome the constraints of bandwidth and storage space have proven to have high performance. The study authors present a number of compression methods for medical compression, they split into three major types: lossless, Lossy, and hybrid. Medical image compression often employs lossless compression mechanisms since the information being compressed is highly sensitive and no data loss may be tolerated [5]. Hybrid compression methods use two or more methods to produce a high level of compression. The result of lossless compression is an image that is visually indistinguishable from the original, while the result of Lossy compression is a decrease in image quality [3].

Image Compression Techniques

4.1 Lossless compression Techniques

By using this method, we can compress images while keeping all of the original data intact. After being compressed, the original image and the syntactical image are identical thanks to this method [4]. As a result, the image data are restored without any corruption, and among these logarithms:

- Run Length Code (RLE)

- Huffman coding.

- Lempel-zev-Wet (LZW).

- Arithmetic coding.

4.2 Lossy Compression Techniques

This type of compression always results in some loss of information that can neither be recovered nor recreated with the same quality as the original image. That implies there is minimal blurring to the image [4]. The less noise in the system, the better these algorithms perform:

4.2.1 Wavelet

One of the most fundamental encoding methods, wavelet transformation is frequently employed in the spatial and frequency domains. Wavelet transformation is employed in the spatial domain to decompose an image into its approximation and detail sub-signals, respectively [6].

4.2.2 Discrete Wavelet Transform DWT

In this signal type, the image is broken down into groups of blocks through the use of low-pass filters and high-pass filters, with the main function recognized by equation (5), and the resulting equation obtained via calibration function as shown below:

$$\phi(x) = \sum(-1)^b c_{b+1}\psi(2x+b) \qquad (5)$$

As shown in the following diagram, a filter splits the incoming signal into two bands, one containing information about sharp edges in the image and the other containing data about the smoothing of those edges [7].

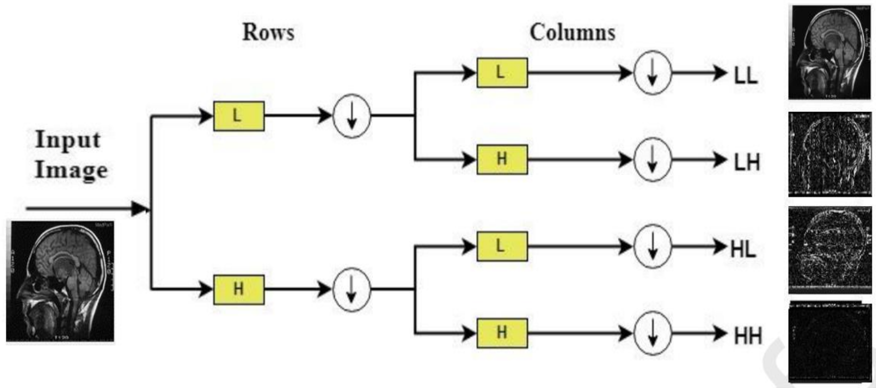

Fig. 2. the process of wavelet.

The wavelet decomposition of an image is based on splitting it into four sub-images after conducting convolution on each row and column of the image as shown in Figure (2). The LL sub-band is created by first combining image rows and columns with a low-pass filter (LPF), and then combining those two together. Until every row and column of the image has been convolved, this process is repeated. This area is regarded as the crucial sub-band since it has the initial image's closest approximation. The low-pass filter (LPF) and high-pass filter (HPF) convolution process produce the sub-image known as the LH. Similar to how the HPF and LPF for the rows and columns are combined to form the HL. After executing a convolution on an HPF and convolution for rows and columns, the HH is finally produced [8].

5. Literature Reviews

In signal processing, wavelet transformations and vector quantization are two active research areas. Compression using methods such as DWT and VQ is not new; several researchers have already done it in various ways. For example,

M. Mozammel et al [9]. proposed compression technique based on DWT. at first, decomposes an image into coefficients called sub-bands and then the resulting coefficients are compared with a threshold. Coefficients under the threshold are set to zero, and the coefficients above the threshold value are encoded with a lossless compression technique. used A set of test images (BMP format). The program has been implemented using Visual C++. finds that a threshold value of $\delta = 30$ is a good choice for compression ratios.

Patel TS [10]. Proposed a hybrid approach combining DWT and VQ That research involved transforming an image, preprocessing the resulting coefficients, and then vector quantizing the image. They used a DWT transformation to break down the original image into four distinct bands. Finally, this difference matrix was applied to vector quantization. When compared to the same method without the preprocessing stage, the result revealed a greater compression ratio; nonetheless, the margin of error was still too large. The research also has the problem that the resultant data is twice as big as the quantized data since the mean of each block must be transferred along with the codebook to the decoder.

Mohammed and Hussein [11]. presented a hybrid transform strategy including the Discrete Wavelet Transform (DWT) and the Discrete Cosine Transform (DCT) for compressing medical images. Initially, the image was in RGB format, but after some processing, it was changed to YCbCr and a forward DWT was applied. Next, they used 2D forward DCT to transfer to the frequency domain by partitioning each HL and LH sub band into 8×8 blocks. A brightness quantization matrix was then applied to the obtained DCT coefficients. The suggested technique was then used on 256x256 and 512x512 MRI brain and lung images. However, blocking artifacts are visible in the reconstructed image, which is a fundamental weakness of utilizing a DCT. The diagnostic value of the medical image is drastically diminished as a result.

Janet et al [12]. have also proposed using the contourlet transform an extension of the wavelet in conjunction with Huffman coding to achieve lossless compression of medical images. Their technique takes a grayscale image as input. The input medical image is transformed using a 2-dimensional contourlet transform and then divided into 8 sub-bands, each representing a different frequency range. The percentage of compression is then determined after applying global thresholding and Huffman encoding to the lower frequency sub-bands. However, the discovery would have been much more impressive if Huffman encoding hadn't been preceded by vector quantization, which led to a less bit-representative representation of the compressed image.

Paul Nii Tackie Ammah, Ebenezer Owusu [13]. In their technique, Filtering the images during preprocessing is done to get rid of speckles and salt and pepper noises in ultrasonic imaging. Next, DWT is used to filter the images. As a result of applying a threshold to the produced coefficients, any coefficients that are too small are replaced with zeros. The output then undergoes vector quantization. After that, the quantized coefficients are Huffman encoded.

H. B. Kekre, Prachi Natu and Tanuja Sarode [14]. First, select an N×N image database that contains color images. Second, apply the DKT-DCT hybrid wavelet transform on the images, keeping just the 3.125% low-frequency coefficients and discarding the rest of the high-frequency ones. Third, make 16-bit and 32-bit codebooks using the VQ method on the transformed images. Compression ratios are improved 6 times and 4.8 times, respectively. Thus, maximum compression ratios of 192 and 153.6 are achieved. Fourth, use the codebook's indexes to reconstruct images.

Ranjeet Kumar, Utpreksh Patbhaje, A. Kumar [15]. In this paper, truncated SVD is used as a means of image reduction. The suggested technique may represent images with a low-rank matrix, and it includes two stages: SVD based image compression and SVT based image quality retrieval. When doing image compression, image quality is paramount. Therefore, a technique of retrieving images with preserved visual quality according to the human vision system (HVS) is also proposed.

Al-Fayadh, Ali, et al [16]. The study's author developed a method for compressing images that combined a hybrid discrete cosine transform (DCT) with classified vector quantization (CVQ). High-quality medical compressed images are produced by a simple yet effective classifier-based gradient technique in the spatial domain, and the orientation of blocks is detected without the use of a threshold. Singular value decomposition was used to generate the codebooks for classification. achieved a high bit rate and high PSNR.

Mohammed Fadhil Radad, et al [17]. proposed a method that combines DWT (the wavelet transform) and vector quantization (VQ). The proposed method for compressing medical images aims to do so in a way that maintains the image's diagnostic information while still allowing for a high compression ratio. Initially, an edge is maintained while reducing splash, salt, or particle noise in medical images. This is done without losing your competitive advantage. Further compression was achieved by employing the discrete wavelet transform (DWT), a lossless compression method for the wavelet coefficients in the lowest frequency sub-band. For the high-frequency sub-bands, however, the most efficient method of generating coefficients was thresholding. The result was then vector-quantized using the BPNN method, which stands for back propagation neural network. To improve compression performance, the suggested approach strikes a nice balance between compression ratio and image quality.

Mofreh et al. [18]. proposed LPC and DWT with Huffman, a novel approach to image compression with the goal of increasing compression ratios. This method combines elements of the LPC and the DWT with Huffman. It can be shown that the disclosed method offers a better compression rate than both the Huffman and DWT methods.

Parikh et al. [19]. proposed the compression of medical images using high-efficiency video coding (HEVC). This work compares the experimental results computed using JPEG 2000 to those computed using A Comparison of Three Medical Methods (CT, MRI, and CR). In contrast to JPEG 2000, the compression performance of the provided approach is seen to be 54% better.

Somasundaram, et al [20]. proposed the hybrid method of multi-WT with deflate encoders. The primary goal of the method is to decrease the bandwidth required for transmission by compressing the medical data. As can be shown, the proposed method outperforms more traditional compression methods in terms of compression ratio.

Perumal, B., and M. Pallikonda Rajasekaran [21]. introduced a hybrid method called DWT-BPNN. to reduce the size of medical images. In order to evaluate the efficacy of the method described, the author conducts a comparative study of the discrete wavelet transform coding, and the hybrid DWT with back propagation neural network. Based on the compression ratio and PSNR, the suggested hybrid approach is clearly better than the state-of-the-art methods.

Karthikeyan and Thirumoorthi [22]. suggested the fast Fourier transform, which is a hybrid method for compressing images. The author of this study also examines three alternative compression strategies, including the Karhunen-Loeve Transform, the Walsh-Hadamard Transform, and the Fast Fourier Transform, and draws comparisons between them and the suggested method. When compared to the author-described methodologies, the proposed approach is seen to produce superior and more efficient outcomes across the board.

Thomas, et al [23]. proposed a hybrid Lossy/lossless method for compressing medical images for telemedicine use. It has been found that the proposed hybrid strategy makes efficient use of arithmetic entropy coding to accomplish a higher compression ratio with less information loss.

Rani [24]. suggested A new hybrid approach for medical image compression Specifically, Haar Wavelet Transform and PSO are used in the method described. Results show that the proposed method improves the CR and PSNR.

Ali al-Fayad et al [25]. proposed a hybrid method using classified vector quantization (CVQ), Discrete Sine Transform (DST), and singular value decomposition (SVD). Make use of a classifier-based gradient approach that works well in the spatial domain, in which each block of the input image is classified using a single threshold and assigned to one of a finite number of classes. High-quality images are obtained by determining the block's orientation with no cutoff using only three AC coefficients of the DST coefficients. We compared the suggested method to the industry standard VQ-based, CVQ based, and JPEG-2000 image compression techniques. Extensive simulations have demonstrated that the suggested strategy enhances edge quality and increases PSNR over reference methods.

Ayoobkhan et al. [26]. introduced a new lossy compression technique for medical images called PE-VQ. In this method, evolutionary algorithms and artificial bee colonies are utilized to create a codebook that achieves the best outcomes, while prediction error and VQ are employed to compress images efficiently. The proposed method has been seen to outperform the competing algorithms in terms of PSNR attained for a given compression ratio.

Rufai, Awwal Mohammed, et al [27]. presented new methods for medical image compression. SVD Singular value decomposition with Huffman coding is cited as part of the method used in the study. The simulation results show that the presented method outperforms Huffman coding and JPEG 2000 in terms of both quantitative and qualitative metrics.

References	Technique type	Method Used	dataset	Merits
[9]	Hybrid	DWT with threshold	JPEG, and GIF	High Compression Rate
[10]	Hybrid	DWT with VQ	JPEG	High Compression Rate
[11]	Hybrid	DWT with DCT	MRI	High Compression Rate
[12]	Lossless	contourlet transform with Huffman	MRI, CT, and US	High Compression Rate
[13]	Hybrid	DWT with VQ	MRI, CT, and US	higher CR and PSNR
[14]	Hybrid	DKT-DCT with VQ	color image	High Compression Rate
[15]	Hybrid	SVD-SVT	different image	Higher SSIM
[16]	Hybrid	DCT with CVQ	MRI, and CT	achieved a high bit rate and high PSNR
[17]	Hybrid	DWT with VQ	DICOM image	Achieves Higher CR, and PSNR
[18]	Hybrid	LPC and DWT with Huffman	MRI, and CT	Higher CR
[19]	Hybrid	High efficiency Video coding	CT, MRI, and CR	Higher CR
[20]	Hybrid	DWT with Hybrid algorithm	DICOM image	Higher CR
[21]	Hybrid	DWT with BPNN	DICOM image	higher CR and PSNR
[22]	Hybrid	Sparse-Fast-Fourier Transform	CT	high CR, SC, and PSNR

[23]	Hybrid	FDC with arithmetic coding	DICOM image	Best CR
[24]	Hybrid	Haar Wavelet Transform with PSO	DICOM image	Higher CR and PSNR
[25]	Hybrid	DST with SVD-VQ	Barbara, Peppers, and Lena	Higher CR, and PSNR
[26]	Lossy	PE with VQ	X-ray	Higher CR, and PSNR
[27]	Lossy	SVD with Huffman	MRI	Best PSNR

Table1. Literature Reviews

6. Research challenges

Numerous compression methods, both new and old, are examined in this book, all with the goal of reducing the size of medical images. There are still several questions to be answered, despite the fact that these methods can yield substantial benefits.

A higher compression rate can be achieved by using certain compression techniques, but they are also significantly more sophisticated and have efficiency and optimization problems. Some of the methods are significantly more productive, but they take up a lot of time, which is a problem. Some compression methods are specific to MRI and CT and cannot be used with any other medical imaging modalities; this study illustrates this point. The use of lossy compression yields the best results, although there is room for improvement in the methods used to eliminate background noise. Since the physician must manually complete the AutoShaping in the region of interest, it stands to reason that mistake could occur.

7. Conclusion

Several methods for compressing medical photographs are presented in this study, and it is shown how they might be utilized to circumvent common storage and bandwidth constraints. After looking at the research, we can say that the compression ratio is crucial to the success of the compression method. Generally speaking, the greater the compression ratio, the more effective the method. In this context, ensuring that no essential data is lost is of paramount importance.

Here are a few additional standout features of this manuscript:

- Many different compression methods have been proposed for use with medical images, all with the goal of making the compressed images smaller and more manageable.

- Researchers typically use PSNR, CR, and MSE to measure the efficacy of their methods.

- There is a growing body of research that shows that hybrid techniques, which combine the best features of Lossy and lossless compression methods, are the preferred method for medical image compression.

References

[1] F. Liu, M. Hernandez-Cabronero, V. Sanchez, M. W. Marcellin, and A. Bilgin, "The current role of image compression standards in medical imaging," *Information (Switzerland)*, vol. 8, no. 4. MDPI AG, Oct. 19, 2017. doi: 10.3390/info8040131.

[2] B. Shickel, P. J. Tighe, A. Bihorac, and P. Rashidi, "Deep EHR: a survey of recent advances in deep learning techniques for electronic health record (EHR) analysis," *IEEE J Biomed Health Inform*, vol. 22, no. 5, pp. 1589–1604, 2017.

[3] S. Bhavani and K. Thanushkodi, "A survey on coding algorithms in medical image compression," *International Journal on Computer Science and Engineering*, vol. 2, no. 5, pp. 1429–1434, 2010.

[4] S. E. Umbaugh, *Digital image processing and analysis: human and computer vision applications with CVIPtools*. CRC press, 2010.

[5] M. Abo-Zahhad, R. R. Gharieb, S. M. Ahmed, and M. K. Abd-Ellah, "Huffman image compression incorporating DPCM and DWT," *Journal of Signal and Information Processing*, vol. 6, no. 02, p. 123, 2015.

[6] I. Daubechies, "The wavelet transform, time-frequency localization and signal analysis," *IEEE Trans Inf Theory*, vol. 36, no. 5, pp. 961–1005, 1990.

[7] C. Valens, "A really friendly guide to wavelets," 1999.

[8] R. Starosolski, "Hybrid adaptive lossless image compression based on discrete wavelet transform," *Entropy*, vol. 22, no. 7, p. 751, 2020.

[9] M. M. H. Chowdhury and A. Khatun, "Image compression using discrete wavelet transform," *International Journal of Computer Science Issues (IJCSI)*, vol. 9, no. 4, p. 327, 2012.

[10] T. S. Patel, R. Modi, and K. J. Patel, "Image compression using DWT and vector quantization," *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 1, no. 3, p. 653, 2013.

[11] A. A. Mohammed and J. A. Hussein, "Efficient hybrid transform scheme for medical image compression," *Int J Comput Appl*, vol. 27, no. 7, pp. 975–8887, 2011.

[12] J. Janet, D. Mohandass, and S. Meenalosini, "Lossless compression techniques for medical images in telemedicine," *Advances in Telemedicine Technologies, Enabling Factors, Scenario*, pp. 111–130, 2011.

[13] P. N. T. Ammah and E. Owusu, "Robust medical image compression based on wavelet transform and vector quantization," *Inform Med Unlocked*, vol. 15, p. 100183, 2019.

[14] H. B. Kekre, P. Natu, and T. Sarode, "Color image compression using vector quantization and hybrid wavelet transform," *Procedia Comput Sci*, vol. 89, pp. 778–784, 2016.

[15] R. Kumar, U. Patbhaje, and A. Kumar, "An efficient technique for image compression and quality retrieval using matrix completion," *Journal of King Saud University-Computer and Information Sciences*, vol. 34, no. 4, pp. 1231–1239, 2022.

[16] A. Al-Fayadh, A. J. Hussain, P. Lisboa, D. Al-Jumeily, and M. Al-Jumaily, "A hybrid image compression method and its application to medical images," in *2009 Second International Conference on Developments in eSystems Engineering*, 2009, pp. 107–112.

[17] M. F. Radad, A. Obeid, and A. Al-Fayadh, "A Hybrid Discrete Wavelet Transform with Vector Quantization for Efficient Medical Image Compression", doi: 10.14704/nq.2022.20.8.NQ44909.

[18] A. Mofreh, T. M. Barakat, and A. M. Refaat, "A new lossless medical image compression technique using hybrid prediction model," *Signal Processing: An International Journal (SPIJ)*, vol. 10, no. 3, p. 20, 2016.

[19] S. S. Parikh, D. Ruiz, H. Kalva, G. Fernández-Escribano, and V. Adzic, "High bit-depth medical image compression with hevc," *IEEE J Biomed Health Inform*, vol. 22, no. 2, pp. 552–560, 2017.

[20] T. Somassoundaram and N. P. Subramaniam, "High performance angiogram sequence compression using 2D bi-orthogonal multiwavelet and hybrid SPIHT-DEFLATE algorithm," *Indian J Sci Technol*, vol. 8, no. 14, p. 1, 2015.

[21] B. Perumal and M. P. Rajasekaran, "A hybrid discrete wavelet transform with neural network back propagation approach for efficient medical image compression," in *2016 International Conference on Emerging Trends in Engineering, Technology and Science (ICETETS)*, 2016, pp. 1–5.

[22] T. Karthikeyan and C. Thirumoorthi, "A hybrid medical image compression techniques for lung cancer," *Indian J Sci Technol*, vol. 9, no. 39, 2016.

[23] D. S. Thomas, M. Moorthi, and R. Muthalagu, "Medical image compression based on automated ROI selection for telemedicine application," *Int. J. Eng. Comput. Sci*, vol. 3, pp. 3638–3642, 2014.

[24] M. M. S. Rani and P. Chitra, “A hybrid medical image coding method based on haar wavelet transform and particle swarm optimization technique,” *International Journal of Pure and Applied Mathematics*, vol. 118, no. 8, pp. 3056–3067, 2018.

[25] A. Al-Fayadh and H. Majid, “Singular value decomposition based classified vector quantization image compression method using discrete sine transform,” *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 21, pp. 12883–12891, 2016.

[26] M. U. A. Ayoobkhan, E. Chikkannan, and K. Ramakrishnan, “Lossy image compression based on prediction error and vector quantisation,” *EURASIP J Image Video Process*, vol. 2017, no. 1, pp. 1–13, 2017.

[27] A. M. Rufai, G. Anbarjafari, and H. Demirel, “Lossy medical image compression using Huffman coding and singular value decomposition,” in *2013 21st Signal processing and communications applications conference (SIU)*, 2013, pp. 1–4.