VCAR: Vedic Compression Algorithm Over Region of Interest on Radiological Image

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***Abstract*— Performing an effective, reliable, and faster compression is one of the important processes in managing the radiological images that relates to either storage or transmission purpose. Ensuring no loss of significant clinical information during transmission along with faster computational capabilities are quite less to find in literature pertaining to medical image compression techniques. Therefore, this paper introduces a technique called as VCAR or Vedic Compression Algorithm over Region of interest that uses the potential vertical and cross over multiple characteristics of Urdhava Tiryakbhyam sutra in Vedic mathematics. VCAR takes the input image as region of interest extracted by author's prior technique and then subjects it to compression. The outcome of the study was found to be superior compared to frequently used DCT-based compression techniques with respect to computational speed, Peak Signal to Noise Ratio (PSNR), visual quality in the forms of bits per pixels over multiple standard medical image databases.**

Keywords-component; Medical Image Compression, PSNR, Region of Interest, Vedic Mathematics

I. INTRODUCTION

The healthcare industry has undergone a sea change revolution by adopting the most significant and advanced technologies, where digital imaging system has contributed massively both in diagnosis as well as prognosis of critical diseases [1]. For more than a decade, various top-notch organizations viz, GE, Philips, Siemens, etc., organization have already introduced different forms of imaging devices for identifying and studying the clinical condition more precisely. Various image capturing techniques viz., Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), X-ray, ultrasound, etc are already in usage in every healthcare facilities [2]. With the advancement of various storage devices, storage of medical reports are no more expensive with the availability of cloud-based system [3][4]. However, the problem arises process, in transmission stage only. In order to understand, it is required to take a deep look into two significant phenomenons called as Telemedicine [5] and Robotic Surgery [6]. In both of these process, it is essentially required to perform real-time analysis of the patient located in one part of the world and physician located in another part of the world. It is also said that image or video i.e. multimedia files are quite heavy files when it comes to transmission and usually it suffers from packet loss or disruption in the standards of the data being transmitted. The biggest problem in this part is a slight or even a minor error in clinical report may cost the life of the patient, which the technology cannot allow it to happen. In order to mitigate this problem, researchers, academicians, and organizations have been carrying out investigation towards an effective compression algorithm that can reduce the size of the radiological images without losing significant clinical information. But still the successes of such compression algorithms are only found in research papers or in few journals. Utility of such and reliable compression algorithm for medical images are yet to be explored. More than past two decades there has been extensive research on data compression but unfortunately the compression techniques have different impact if data is natural image or medical image. A good compression algorithm is the one that can perform reduction of size along with retention of maximum visual quality. These visual qualities of medical images are usually judged by SNR (Signal-to-Noise Ratio), MSE (Mean Square Error) or BPP (Bits-Per-Pixels). Moreover, a compression algorithm has also to prove its supportability of real-time data processing along with retention of image quality. Hence, there is a big trade-off in compression algorithm effectiveness with respect to data quality and computational capability. This means that till date it was found that if the compression performance has increased than probably the computational capability has not increased. Evolution of such problems will never support adoption of compression algorithms in real-time devices over healthcare facilities. Therefore, this paper has identified the potential charecteristics of Vedic mathematics using *Urdhava Tiryakbhyam sutra*, which has shown that it is possible to perform medical image compression with retaining maximum visual quality and ensuring faster processing speed. Majority of the medical image compression algorithms have an encoding and decoding stage which requires faster processing of pixel elements that are normally arranged in matrix format. This paper has shown how *Urdhava Tiryakbhyam sutra* is applied as multiplier to fastly process the medical image. The proposed system of VCAR considers region of interest as the input image and apply it for compression. Section II has discussed the existing literatures of medical image compression and is followed by identification of issues of existing system. In Section III. The proposed system is discussed in Section IV and is followed by implementation technique in Section V. The outcome analysis is discussed in Section VI while summary of the paper is narrated in Section VII.

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II. EXISTING STUDIES

Author's prior study [7] has already briefed about some of the existing technique of performing medical image compression. This section discusses about the existing techniques that have been introduced most recently in the area of medical image compression.

Study on image compression was carried out by Shirsat and Bairagi [8], where the authors have explicitly studied lossless type of compression on medical images. The authors have used predictive-based coding technique using a lifting scheme called as Integer Wavelet Transform. The authors have also introduced both forward and reverse lifting scheme and the outcome of the study was evaluated with respect to compression ratio on 6 different medical images. Adoption of tree based technique for carrying out compression was seen in the study of Sudha and Sudhakar [9]. The authors have used MRI and CT scan images for evaluating the compressing using enhanced version of SPIHT algorithm i.e. Set Partitional in Hierarchical Trees. The outcome of the algorithm was testified with respect to PSNR (Peak Signal-to-Noise ratio) and SSIM (Structural Similarity Index). The work done by Ponomarenko et al. [10] have focused on performing lossy image compression by considering various forms of visual parameters. Encoding plays a critical role in compression algorithms in the existing system. Study in such direction was focused by Camlica et al. [11]. The authors have presented a technique to discard an image block with significant error in encoding. The study has also considered adoption Support Vector Machines in order to perform auto-encoding scheme. Fouad and Mansour et al. [12] have introduced a scheme that uses conventional compression technique using DCT (Discrete Cosine Transform). Although the prime idea of the system was to validate the input image, but this scheme has introduced a better compression scheme which is quite simple in nature. Study towards lossless compression is also carried out by Pizzolante and Carpentieri [13] have recently introduced a lossless predictive scheme for compressing medical image with multidimensional features. Incorporation of intelligence techniques was seen in the study carried out by Moorthi [14]. The author has used Region of Interest (ROI) based approach using SPIHT scheme, which is nearby similar to the technique proposed by Sudha and Sudhakar [9]. Similar direction of implementation was also carried out by Rajkumar and Latte [15]. Various other author's viz., Sowjanya et al. [16], Sarala et al. [17], and Kunchigi et al. [18] have worked on Vedic mathematic schemes. Studies on medical compression have many literatures but majority of them are somewhat enhanced versions of each other. None of the papers published till date has actually proved how it can solve computational complexity when compression is being performed on the complex and massive medical images. The next section discusses about the significant issues identified from the existing literatures.

III. ISSUES IN EXISTING SYSTEM

The prior section has discussed about some of the existing system that are found to be used in the area of compression. Various techniques have their own advantages as well as limitations. This section will discuss about the issues that were being explored in the existing techniques of medical image compression.

- **Less focus on Image type**: It is already known that medical images are quite complex in its type, size, and format. Majority of the advanced radiological images e.g. MRI images; PET-CT scan images can occupy a space of around megabytes to gigabytes. Such forms of radiological images are quite challenging to store and thereby transmit on any networking channels. From the research viewpoint, some of the existing tools used for processing radiological images are OpenCL [19], CUDA [20], and Qt-Threaded [21]. However, usages of such tools are found to be exercised by very few researchers and journal publications.
- **Less Focus on Mathematics**: Majority of the medical compression algorithms implemented till date are found to be more or less an enhanced version of conventional compression schemes. Although the outcomes are optimistic and are found to have better size reduction, but on the other hand it is also associated with various significant flaws e.g. ensuring data (pixel) integrity, time consuming algorithm processing, memory occupation going unnoticed etc. A suitable mathematical modelling was not much found to be used that have parallel focus on algorithm processing performance along with data quality when it comes to compressing a complex and bigger dimension of radiological image.
- **Lack of optimization in ROI-based compression Schemes**: It was also seen that ROI based techniques are much in use in medical image compression. Majority of the existing ROI-based technique just applies the compression scheme on the ROI part without much focus on the algorithm performances using optimization schemes. However, when it comes to enhance the signal quality of ROI part, there are only few works that performs maximum optimization of medical image compression. Maximum optimization will mean more values of signal quality.
- **Negligent to Computational Potentials**: All the existing systems are more concentrated on carrying out compression by minimizing the size of radiological image. But at the same time, the existing system is not found to be friendly with its processing from hardware viewpoint. It has different operational capability as well as functional performance on different system configuration and doesn't provide any benchmarked compressed size that makes the validation quite impossible.

Hence, by observing all the limitations of the existing system, there is a need to propose a novel system that can address the above mentioned limitations. The next section will highlight one such technique for compressing radiological image.

IV. VCAR SCHEME

The major objective of the proposed scheme is to ensure a cost effective compression on complex radiological images. The uniqueness of the proposed concept is that the compression algorithm is going to be implemented on the sophisticated ROI extracted part of the complex radiological image. The proposed system consists of two core operations viz., i) extraction of ROI part and ii) performing compression on the ROI part. The operation of extraction of the ROI based section is implemented using our prior framework [22], while the compression of the ROI part is carried out using novel compression scheme based on Vedic mathematics. As the focus of the proposed system is mainly to achieve the cost effectiveness in terms of computational capabilities, hence, the proposed scheme applies a standard multiplier design called as *Urdhava Tiryakbhyam sutra*, which is the third Vedic sutra out of 16 standard Vedic sutras. This sutra assists in carrying out vertical and crosswise multiplication. Hence, the proposed system is coined as VCAR, which means Vedic Compression Algorithm over Region of Interest. Therefore, the major steps of action discussed in this paper are as follows:

1. *Extraction of ROI*: To take the input of the radiological image and apply the MAXSHIFT method just like implemented in our prior work [22]. Applying this process will permit performing encoding of the region of interest and then to the background area. The solution will also assist the user to extract multiple regions in order to perform compression on same input image.
2. *Blocking Operations*: VCAR also applies blocking operation for the input ROI image processed using scheme discussed in [22] for ensuring better adaptability of the compression scheme based on *Urdhava Tiryakbhyam sutra*, which requires rows and columns to carry out its multiplications. The scheme has the supportability of 8x8, 16x16, and 32x32 of the block size.
3. *Vedic Mathematics*: VCAR scheme applies *Urdhava Tiryakbhyam sutra* on the resultant image of the block that performs vertical and cross over multiplication and thereby speeds up the processing (compression) capability of the proposed scheme of VCAR.
4. *Analysis*: The outcome of the study analyzed with respect to PSNR and compression ratio for evaluating the quality of the decompressed radiological image, while it also uses processing speed of the algorithm in order to understand the algorithm effectiveness with respect to time complexity.

The proposed system equally addresses the issues of the redundancies using run-length coding process. The design of the proposed algorithm is based on a fact that addition of elements by concurrent means will lead to partial products and this capability can be further strengthened by incorporating *Urdhava Tiryakbhyam sutra* to promote parallelism. The system allows simultaneous computation of summations of the elements being generated by the partial multiplication. Hence, such forms of multiplier do not depend on processor and its frequency of clock.

V. IMPLEMENTING VCAR

The design of the VCAR is carried out using MATLAB on the radiological image database of Cornell University [23]. The implementation of the VCAR is carried out by the following steps discussed,

i) Extraction of ROI: The algorithm discussed in our prior work [22] is used where the input image is read and polygonal shape based on ROI is applied to select even unsymmetrical clinical part of the radiological image. The ROI part is then subjected to Discrete Wavelet Transformation to extract vertical, diagonal, and horizontal coefficient. Morphological operation of dilation (or erosion) is applied. The study applies a scheme that scales up the ROI portion and scales down the background portion. Entropy encoding is followed using Huffman (or Arithmetic coding). Fig.1 shows the procedure of scaling up the ROI of the image used in [22]. Hence, the system thereby maintains maximum quality of the image in 8 bit plane

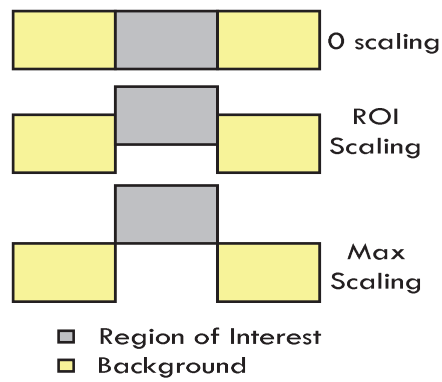

Figure 1 Scaling of ROI image [22]

ii) Blocking Operations: A closer look into the *Urdhava Tiryakbhyam sutra* operation shows that there are multiple steps of addition of elements in one row (Left), which goes to Middle row, and then to right row. Hence, in order to develop it, in MATLAB will require a dynamic buffer system that can store and process the carry over while keeping on adding two elements in *Urdhava Tiryakbhyam sutra*.

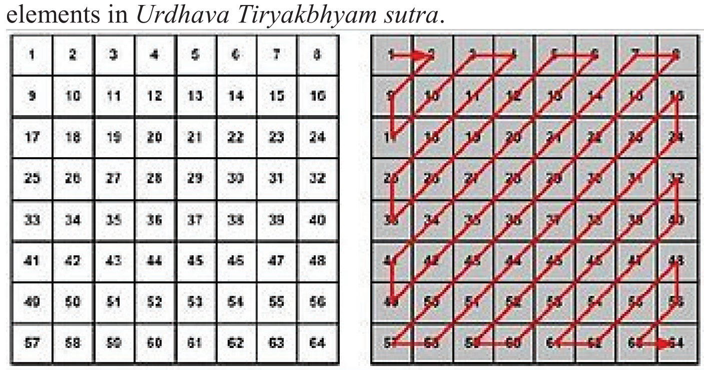

Figure 2 Blocking Operation in VCAR

Fig.2 shows that blocking operation of VCAR that can be of the size of 8x8, 16x16, or 32x32. The advantage of this procedure is that it is different from conventional row-wise operation that it is studied that majority of image processing operations are mainly row wise. Row wise operation is quite slower compared to proposed Vedic multiplication scheme (which is zig zag manner).

iii) Vedic Mathematics:
After the processed blocked of image is received, it is subjected to *Urdhava Tiryakbhyam sutra* for speeding up the processing method of compression. The blocked image is enhanced to double precision. By considering extra zero elements to the matrix that consist of the blocked image, the proposed algorithm performs compression using a Vedic multiplier as exhibited in 5^{th} line of the algorithm. The variable N represents size of blocked image *X* and transposition matrix is represented by *T*. p and q are the matrix occupied by 1-(N-1) elements and [0, (n-1)] elements respectively. The technique applies the multiplication on the squared blocks of an image with particular size R resulting in highly compressed image.

Algorithm for Vedic Compression Algorithm (VCA)

Input: Grayscale Image (I_{gray})

Output: Compressed Image using Vedic approach

Start

1. Initialize the size of the block (8x8 || 16x16 || 32x32)
2. $R \rightarrow$ Double the precision of block size.
3. $X \rightarrow$ Double the precision of I_{gray}.
4. Evaluate the size of X
5. Apply function of Vedic multiplier

$$\delta = V_{mult}\left(\sqrt{\frac{2}{N}}, \cos(p^{T}(2.(q+1)).pi / 2N)\right)$$

6. Apply compression

$$V_{comp} = \delta . X . \delta^{T}$$

7. Perform block wise Vedic Compression

$$V_{comp}(block) \xrightarrow{V_{comp}} X, [R, R]$$

End

iv) Analysis: The analysis of the proposed study is carried out using performance parameters viz., processing speed, Peak Signal-to-Noise Ratio (PSNR), Bits-Per-Pixels (BPP), and compression ratio. The system mainly uses two parameters Mean Squared Error (MSE) and PSNR to signify the signal quality or the lossless compression. The standard value for PSNR is between 30-45 dB for lossy multimedia compression. However it is only applicable for 8 bits of pixel density. In case of 16 bit of pixel density, the standard value of PSNR will range somewhat from 55 dB to 75 dB. In case of wireless networking media, the standard value is 20-25 dB. The loss of the data owing to compression over complex and bigger size of radiological images are evaluated using error between the original image and reconstructed image. The analysis of the proposed simulation is also carried out using different machines with multiple configurations, where the focus was mainly laid to RAM size and processor capabilities mainly.

VI. Result Analysis

The outcome of the study was evaluated on multiple radiological images from frequently used medical databases. Multiple forms of images with multiple modalities were testified for the VACR technique. This section will present some of the significant outcomes of the VCAR.

i. VACR Computational Capability: The prime anticipation of the proposed system is basically to accomplish a superior processing speed. Therefore, the outcome of the proposed VCAR is compared with the conventional DCT based compression scheme which is widely used compression algorithm in medical image processing. Table 1 and Table 2 highlights the processing speed as well as % of compression of the proposed VCAR algorithm and DCT based techniques. In order to the get the outcome exhibited in table 1 and 2, all the respective images from the dataset are subjected to similar computing and simulation environment of 32 bit PC, 4 GB RAM, and core i3 processor of Windows 7.

Table 1Numerical Outcome of Processing Speed

Database	Speed(s)	
	VCAR	DCT
Cornell University Database [23]	0.62	0.87
National Biomedical Imaging Archive [24]	0.57	0.82
Chest x-ray Atlas[25]	0.58	0.91
MIDAS database[26]	0.71	0.83
UCL Machine Learning[27]	0.65	0.95
Digital Database for Screening Mammogram (DDSM)[28]	0.60	0.88
Digital Retinal Images for vessel Extraction (DRIVE)[29]	0.51	0.79
SCR database: Segmentation in Chest Radiographs[30]	0.49	0.84

Table 2 Numerical Outcome of Compression Analysis

Database	% of Compression	
	VCAR	DCT
Cornell University Database [23]	47%	21%
National Biomedical Imaging Archive [24]	35%	17%
Chest x-ray Atlas[25]	37%	15%
MIDAS database[26]	51%	18%
UCL Machine Learning[27]	49%	21%
DDSM [28]	56%	27%
DRIVE [29]	61%	35%
SCR database: Segmentation in Chest Radiographs[30]	49%	22%

ii) VACR Blocking Outcomes: VCAR applies a specific form of blocking on the image encoded with MAXHIFT technique [22]. However, interestingly there is no correlation between the numbers of the blocks on the performance parameters. Table 3 highlights the outcome of compressed size, compression ratio, MSE, and PSNR. The outcome clearly blocking size of 8x8 is more than enough to have least MSE value and more compression size. Although, VCAR is capable of altering into multiple forms of block sizes, but we comment that may be it is not required. The requirement of block sizes differs from dataset to dataset. The outcome of this table is accomplished by averaging from all the 8 different database used in study.

Table 3 Numerical Outcomes of Impact of Blocking Size

	Block Size		
Factors	**8x8**	**16x16**	**32x32**
CS	159608	151197	100444
CR	3.2848	3.4676	5.2197
MSE	2.3839	19.9899	18.2825
PSNR	44.358	35.1227	35.5105

iii) VCAR Visual Quality Outcomes: Although the proposed VCAR mainly intends to prioritize compression, but it equally emphasized on the signal quality that is evaluated with respect to PSNR and BPP. Table 4 shows the outcomes of PSNR and BPP.

Table 4 Result of SNR and BPP

Image Inputs	PSNR	BPP
Cornell University Database [21]	42.33	0.44
National Biomedical Imaging Archive	44.65	0.43
Chest x-ray Atlas	45.86	0.41
MIDAS database	51.32	0.32
UCL Machine Learning	39.74	0.65
Digital Database for Screening Mammogram (DDSM)	43.88	0.41
Digital Retinal Images for vessel Extraction (DRIVE)	47.83	0.56
SCR database: Segmentation in Chest Radiographs	44.33	0.47

From the numerical outcome being accomplished from Table 1, Table 2, Table 3, and Table 4, it can be said that the proposed system offers high speed computing as well as processing of the medical image compression. The computing performance in the lower and higher configuration machines are found with only lesser variance as compared to the exhibited outcomes of the study. VCAR also enhances the visual quality of the decompressed image by ensuring the PSNR within the standard range. The outcome eventually shows that proposed VCAR technique can outperform any existing DCT-based compression technique with retention of superior quality of signal.

VII. CONCLUSION

This paper has presented a simple and yet robust compression technique that is mainly meant for compressing the radiological images. This paper has discussed about the existing literatures towards compression of medical images and has outlined the issues associated with existing compression techniques. Therefore, with an agenda of enhancing the compression performance with respect to computational speed and maximum visual quality retention, the proposed system applies Vedic mathematics by implementing *Urdhava Tiryakbhyam sutra* that deals with vertical and crossover multiplications. The compression algorithm is applied over the region of interest using a system that scales up to 8 bit plane for region of interest area and scales down the background. This phenomenon considerable saves the memory of the system by concentrating its complete focus on the region of interest itself. It was also seen that majority of the existing compression algorithms are more or less enhancement to conventional DCT based techniques in medical image compression. Therefore, the outcome of the proposed system is compared with conventional scheme of DCT. The outcomes shows that proposed VCAR scheme outperforms conventional DCT-based compression scheme with respect to computational speed, % of compression achieved, PSNR, BPP, etc. Our future work will be in the direction of further optimizing the algorithm scheme. The proposed system has used only one Vedic sutra; hence, its efficiency could have been tested with other Vedic Sutras too. However, it is not done owing to reasons e.g. the present sutra is basically assisting the processing control while performing compression using multiplier scheme, whereas other forms of Vedic sutra doesn't support such cross-over multiplication scheme. Till now, no other researchers too have experimented with other Vedic sutra apart from Urdhava Tiryakbhyam. Hence, in order to enhance the computation speed of the enhanced compression technique using Vedic mathematics by further application of optimization schemes.

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