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High Performance Angiogram Sequence Compression using 2D Bi-orthogonal Multiwavelet and Hybrid SPIHT-DEFLATE Algorithm

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Abstract

Digital Imaging and Communication (DICOM) files play a major role in diagnosis. Storage of DICOM files and transmission is a big challenge faced by researchers. Reducing the size of DICOM files will help us to reduce the cost of storage and transmission. This paper presents the high performance compression of Angiogram files using 2D-multiwavelet transform and SPIHT encoder. First, the angiogram DICOM file is converted into frames to apply 2D multiwavelet transform and then the resulting coefficients are encoded using the SPIHT encoder. Motion estimation and compensation cannot be performed on medical videos since it may distract the original diagnostic information. The compression algorithm is tested with coronary Angiogram video taken from GRUSELAMBIX-Standard DICOM file available in Osiris. The Qualitative analysis is done on the proposed algorithm to prove its efficiency. The proposed algorithm provides better PSNR and the Average User scale values shows that the medical diagnostic information is preserved through our proposed algorithm. The better compression ratio of the proposed algorithm will highly reduce the storage space and reduce the cost of transmission.

Keywords: Angiogram Compression, Deflate Algorithm, Multi-Wavelet Transforms, SPIHT

1. Introduction

Digital Imaging and Communication (DICOM) and medical diagnostic information is one of the most important fields for the recent years. The storage of DICOM videos for numerous patients is a big challenge as the cost of storage is much higher due to larger size of the video. This also leads to more transmission costs on DICOM videos for telemedicine. The goal of this paper is to try to reduce the storage space needed for the DICOM video files in order to facilitate more information on less storage space. Compression may easily help us to achieve this goal, but the diagnostic information present in the DICOM files needs to be preserved. A hybrid three stage algorithm with multi wavelet – SPIHT and deflate have been proposed to achieve this goal.

A novel hybrid three stage compression algorithm and also dive in for the quality assessment of the proposed algorithm in the context of medical diagnostic information have been proposed in this paper. In order to study the quality of experience and quality of service provided to the user, the objective and subjective quality assessment is performed. This trend the importance of subjective quality assessment while designing an algorithm for medical diagnostic information as the highly performed objective quality may sometimes find difficult to provide diagnostic information. The objective assessment may not concentrate on the visual

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quality of the information which may lead to the loss of medical diagnostic information. So, while working with the medical diagnostic information, it is necessary to concentrate on the subjective quality of the data to ensure that the diagnostic information is preserved.

Before implementing, an existing standard on the medical data needs a special attention as its data manipulation characteristics which may distract the diagnosis. The motion detection and estimation on the existing data standards may result in false diagnosis[1]. Medical data always needs an extra attention to preserve the original diagnostic information available on the source file.

In the recent years, many compression techniques for medical diagnostic information such as MRI, CT, and EEG have been proposed. In [2] proposed a compression algorithm using discrete wavelet transform and hybrid SPIHT deflate algorithm for the medical images which reduced the storage size by more than 50% with less computation time. In [3] proposed a compression technique for ECG signal which uses the multi-wavelet transform and hybrid SPIHT deflate algorithm provided better compression ratio and PSNR. In [4] proposed a lossy compression technique for cardiac angiogram images using full frame DCT which preserve the fine details of the image. In [5] proposed a compression technique based on DWT for angiogram files which uses motion compensation prediction to remove the inter frame correlations. They claim that the technique using DWT to the coronary angiogram video files provide high quality and high compression. In [6] suggested a wavelet based compression technique for angiogram video files in which the diagnostically significant areas are allocated with more number of bits. Then, the co-efficient of the wavelet are encoded using 3D- SPIHT technique. In [7] developed a low computational cost algorithm based on H.264/AVC standard. Here in the above algorithm, the coding stage is modified by integrating a classification process which labels each fixed size region in the image as relevant or irrelevant and encode it accordingly. In [8] studied the quality assessment for medical videos compressed using HEVC using latest objective and subjective quality measurement techniques.

2. Proposed Algorithm

Similar to the video file, the original angiogram DICOM file will contain numerous frames. These DICOM files are separated into frames and then the noise in each frame is removed using the filters in the pre-processing routine. The pre-processed, filtered DICOM frame is decomposed using the multiwavelet transform. Then, the co-efficient are encoded using the hybrid SPIHT- deflate algorithm. The usage of the hybrid SPIHT – deflate algorithm on encoding, the co-efficient has the advantage of both encoding and compression. The compressed individual DICOM frames are again combined to obtain the similar DICOM file. The compressed file using the proposed algorithm is greatly reduced in storage size leading to minimal transmission bandwidth and also takes minimal storage space. The proposed algorithm is better explained using the below flow diagram (Figure 1).

For better understanding of the proposed algorithm, an overview of multiwavelet transform, hybrid SPIHT-deflate algorithm is provided below.

2.1 Multi-wavelet Transform

Multi-wavelet has been originated from the generalization of scalar vectors[9,10]. Multi scaling and multiple wavelet

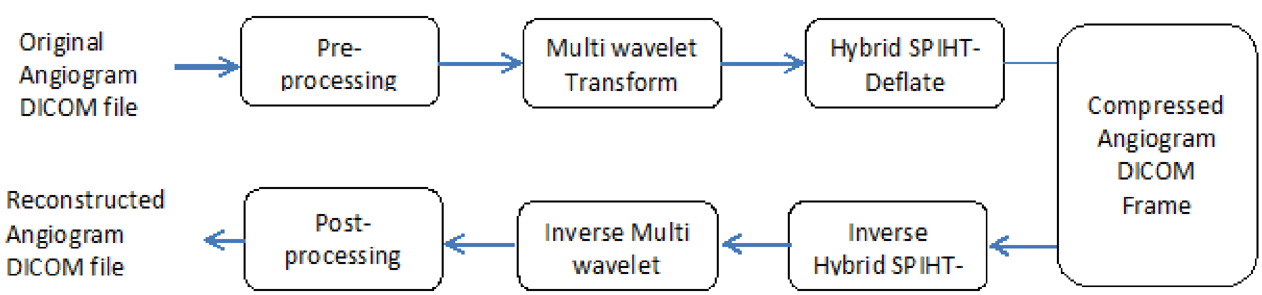

Figure 1. Flow diagram of the proposed algorithm.

functions are used in multiwavelet transform. Multi-wavelet provides better performance in terms of linear phase symmetry (preserving boundaries), orthogonality of filters, vanishing moments (higher order of approximation)[9]. The multiwavelet transform is provided in the literature[9–11], so the brief overview is provided here.

Multi-wavelets are mainly Orthogonal and Bi-orthogonal in nature. Using the prefilter, the incoming scalars are converted into vectors. The multiwavelet transform is computed by multi filters with multiple low pass and high pass filters. The low pass filter is denoted by L and high pass filter is denoted by H. The low pass filter uses the low pass filter co-efficient (Lk) and down sampled by 2 to get hk co-efficient. The multiscaling function and associated multiwavelet function are denoted using (1) and (2). These two scale equations can be realized as a matrix filter bank as shown in Figure 2 operating on *r* input data streams and then filtering them into 2*r* output data streams. Each can be down sampled by the factor two.

$$\phi(t) = \sum Lk(2t - k) \quad (1)$$

$$W(t) = \sum Hk(2t - k) \quad (2)$$

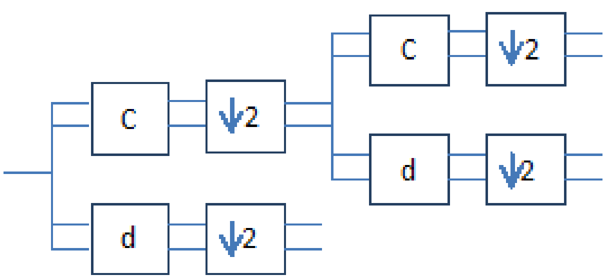

Figure 2. A Multifilter bank with low pass filter iterated one.

L_1L_1	L_1L_2	L_1H_1	L_1H_2
L_2L_1	L_2L_2	L_2H_1	L_2H_2
H_1L_1	H_1L_2	H_1H_1	H_1H_2
H_2L_1	H_2L_2	H_2H_1	H_2H_2

Figure 3. Sub-band after one level of multiwavelet decomposition.

2.2 Hybrid SPIHT-deflate Algorithm

The most efficient algorithm in the area of image compression is the Set Partitioning In Hierarchical Trees (SPIHT)[12,13]. It uses a sub-band coder which produces a pyramid structure where an input DICOM frame is decomposed sequentially by applying power complementary low pass and high pass filters and then decimating the resulting frame. These filters are one dimensional filters that are applied in cascade (row then column) to an image whereby creating the sixteen-way decomposition such as in Figure 3. This procedure is repeated until the top of the pyramid is reached.

The most significant bit is firstly ordered and encoded and lastly processed to maintain the fine digital information of the reconstructed image. Sequence of sorting and refinement passes are applied to the decreasing magnitude thresholds.

In the sorting pass, the co-efficient are checked for its significance using a threshold. If the co-efficient is greater than or equal to the current magnitude threshold then the co-efficient is said to be the significant bit. If else then the co-efficient is said to be insignificant. The significant bit's co-efficient are immediately outputted. For the positive signed co-efficient significant bit, the output of 1 is obtained from the SPIHT coder, but it is passed as 0 to the output bit stream. The co-efficient of the insignificant nodes of the SPIHT coder are scanned in a particular order. After the completion of the scan in the sorting pass, the refinement pass is conducted. In the refinement pass, the co-efficient of the insignificant bits are normalized with a certain threshold. The three sets LSP (List of Significant Pixels), LIP (List of Insignificant Pixels), LIS (List of Insignificant Sets) will be used in positioning of ordering nodes. For each decomposition level, the above order of the SPIHT will be performed by reducing the quantization threshold by half the value until it reaches 0. The hybrid SPIHT deflate algorithm is well document in [1]. The output bit stream of the SPIHT encoding process will consist of a large number of seriate 0 situations. The deflate algorithm is performed to reduce the redundancy bits present in the bit stream obtained from the SPIHT encoder.

3. Quality Metrics

In this paper, both objective quality and subjective quality is assessed to our proposed algorithm. The preservation of the diagnostic information on the medical data may not be concentrated on the objective quality measure which leads to assess the subjective quality through the opinion Score.

3.1 Objective Quality Metrics

The objective quality metrics used in the paper is explained below. The objective quality is broadly classified into two measures such as statistical measure and human visual system measure.

3.1.1 Statistical Measure

Based on the pixel information the statistical measure can be obtained. Mean Square Error (MSE) is the cumulative squared error between the ratio of compressed image and the original image given using (3). Peak Signal to Noise Ratio (PSNR) is the peak of the measured error given using (4).

$$\text{MSE} = \frac{\sum_i \sum_j \left(r_{ij} - x_{ij}\right)^2}{M \text{ x } N} \quad (3)$$

$$\text{PSNR} = 10\log_{10}\left(\frac{255^{\,2}}{MSE}\right) \quad (4)$$

Where *r* refers to original image, *n* gives the corrupted image, *x* denotes the restored image, M x N is the size of processed image.

3.1.2 Human Visual System Measure

To measure the difference between the original image and the distorted image in terms of structural information, luminance and contrast based on the human eye perception, the structural Similarity Index Model (SSIM) is developed. SSIM is given using (5).

$$SSIM(x,y) = \frac{\left(2\mu_x\mu_y + C_1\right)\left(2\sigma_{x,y} + C_2\right)}{\left(\mu_x^2 + \mu_y^2 + C_1\right)\left(\sigma_x^2 + \sigma_y^2 + C_2\right)} \quad (5)$$

Where μ_x is the average of x given by

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} xi,$$

μ_y is the average of y given by

$$\mu_y = \frac{1}{N}\sum_{i=1}^{N} yi,$$

Standard Deviation of x given by

$$\sigma x = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(xi - \mu x\right)^2}$$

Standard Deviation of y given by

$$\sigma y = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(yi - \mu y\right)^2}$$

C1= $(K_1L)^2$, C2= $(K_2L)^2$ two variables to stabilize the division with weak denominator; L the dynamic range of the pixel-values (for an 8 bit image it takes from 0 to 255), K_1=0.01 and K_2=0.03 by default.

3.2 Subjective Quality Metrics

Subjective Quality is used to know the amount of diagnostic information preserved in the medical data on the resultant output of the proposed algorithm. Subjective quality assessment is carried out by obtaining the Mean Opinion Score (MOS) from the experts on the resultant output of the proposed algorithm. MOS is obtained using a five point scale with 1 as the least with no diagnostic information and 5 is the best with entire diagnostic information.

4. Simulation Results and Discussion

The efficiency of the algorithm is tested by performing few experiments. A GUI was developed in the MATLAB 7.14.0.739. We used GRUSELAMBIX-Standard DICOM image available in Osirix[14] for testing the performance of the proposed algorithm. This paper concentrated on the Bi-Orthogonal wavelet families for this experiment due to the truth that the Bi-Orthogonal wavelets have more degree of freedom in constructing the symmetric wavelet functions than the orthogonal wavelets. Bi-orthogonal wavelet contains two scaling functions for generating different multi resolution analysis.

Experiment 1: This experiment was concluded by testing the proposed algorithm without any pre-processing filters on GRUSELAMBIX, in order to evaluate the performance on clinical diagnosis information of the reconstructed signal. Figure 4 shows the compression performance of the proposed algorithm. The reconstructed signal had preserved the clinical diagnosis information of the original signal.

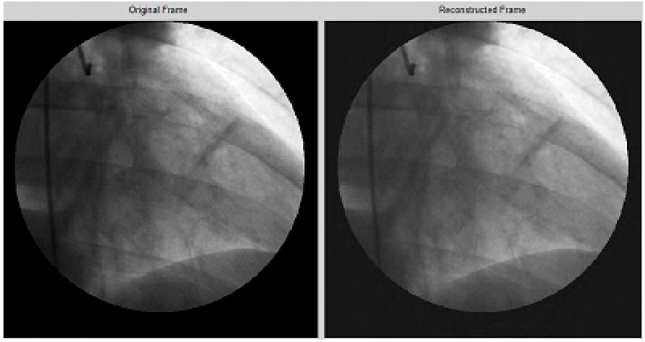

Figure 4. A Original Frame and Reconstructed frame after performing the proposed algorithm for Subjective Evaluation.

Table 1. Subjective evaluation on proposed algorithm output for dicom images of gruselambix

S.No	DICOM Image	Average User Scale
1	IM-0001-0001	4.21
2	IM-0001-0002	4.12
3	IM-0001-0003	4.23
4	IM-0001-0004	4.25
5	IM-0001-0005	3.95
6	IM-0001-0006	4.03
7	IM-0001-0007	4.08
8	IM-0001-0008	4.37
9	IM-0001-0009	4.34
10	IM-0001-0010	4.36

Table 1 reveals that the Medical Diagnostic Information is preserved as the MOS score is above 4. Figure 5 shows the Average User Scale of proposed algorithm for various DICOM images of GRUSELAMBIX.

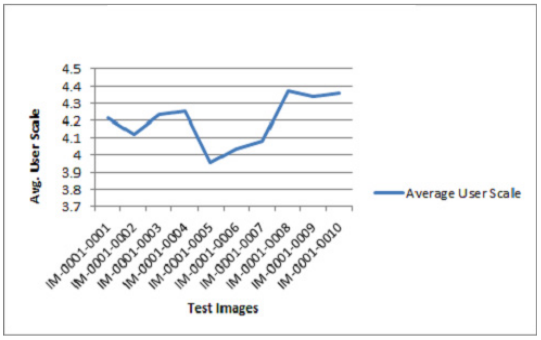

Figure 5. Subjective Evaluation of the proposed algorithm for various DICOM images plotted using Average User Scale.

Experiment 2: The proposed algorithm is tested with Coronary Angiogram GRUSELAMBIX available in Osirix[14]. Objective assessment is carried out to prove the efficiency of algorithm.

Table 2. Comparison of performance evaluation of various multiwavelet families applied to the proposed algorithm for dicom images of gruselambix

S. No	Wavelet	DICOM Image	PSNR	MSE	Universal Image Quality Index	SSIM	CR
1	Bih52S	IM-0001-0001	42.14	3.97	0.56095	0.95997	23.1494
2	Bih54n	IM-0001-0001	43.04	3.23	0.57175	0.96357	23.1494
3	Bighm2	IM-0001-0001	37.13	12.58	0.46908	0.89824	23.1494
4	Bih52S	IM-0001-0002	41.66	4.44	0.54372	0.95544	22.5016
5	Bih54n	IM-0001-0002	42.71	3.48	0.54718	0.96124	22.5016
6	Bighm2	IM-0001-0002	36.79	13.61	0.45160	0.87754	22.5016
7	Bih52S	IM-0001-0003	44.24	2.45	0.51553	0.97437	15.7501
8	Bih54n	IM-0001-0003	45.05	2.03	0.53113	0.97541	15.7501
9	Bighm2	IM-0001-0003	38.41	9.39	0.44870	0.90676	15.7501
10	Bih52S	IM-0001-0004	41.23	4.90	0.54589	0.95128	22.7694
11	Bih54n	IM-0001-0004	42.36	3.77	0.55010	0.95987	22.7694
12	Bighm2	IM-0001-0004	36.90	13.27	0.45841	0.88665	22.7694
13	Bih52S	IM-0001-0005	37.60	11.30	0.57388	0.93331	21.9680
14	Bih54n	IM-0001-0005	42.03	4.07	0.57939	0.95765	21.9680
15	Bighm2	IM-0001-0005	36.05	16.16	0.47446	0.87255	21.9680

Table 2 shows that the Bih54n provides better performance Evaluation and outperforms the Multiwavelet family.

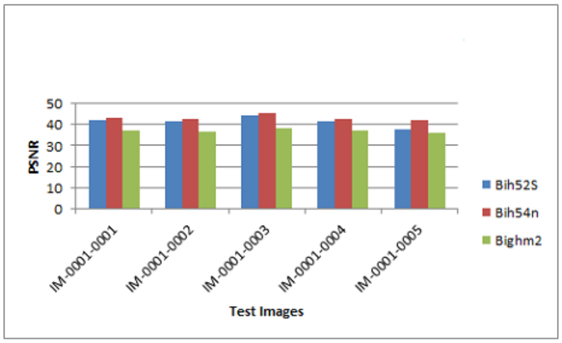

Figure 6. Comparison of PSNR of proposed algorithm with various Multiwavelet families.

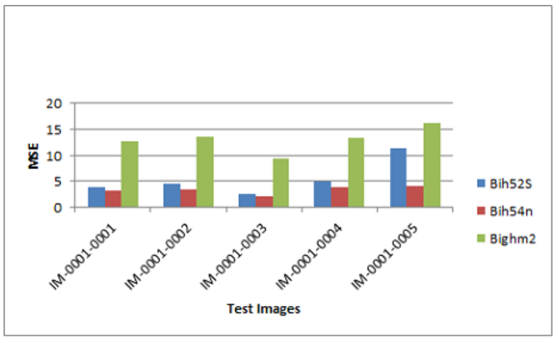

Figure 7. Comparison of MSE of proposed algorithm with various Multiwavelet families.

Figure 6 and Figure 7, shows the comparison of performance of proposed algorithm with various multiwavelet families. Bih54n provides better results in terms of PSNR, MSE.

5. Conclusion

In this paper, a simple and efficient compression technique for coronary angiogram using multiwavelet transform and hybrid SPIHT-deflate has been presented. The proposed algorithm with Bih54n, multi-wavelet type outperforms the other existing algorithm by providing better compression ratio and better performance in terms of PSNR, MSE, UIQI and SSIM through which the goal of the paper is reached.

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