Selective Compression of Medical Images using Multiple Regions of Interest

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Abstract: Efficient compression techniques are essential for archiving and transmission of medical images. In this paper, a selective compression technique that utilizes multiple regions of interest has been described. A medical image is classified into three regions: Primary Region of Interest (PROI), Secondary Region of Interest (SROI) and Background. The region containing diagnostic data is identified as PROI and encoded using lossless compression. The region with significant information is classified as SROI and is encoded with near lossless compression. The remaining area is classified as background region and it is encoded with very high compression ratio. We have employed the selective compression technique for medical images using JPEG-XR. The technique is compared with wavelet based compression technique (JPEG-2000). A number of medical images were compressed using both techniques with multiple regions of interest. The performance of both techniques is evaluated by means of using various image quality metrics like PSNR, SSIM and MSE. The results shows that JPEG-XR performs slightly better than wavelet based compression technique.
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1. Introduction

A huge amount of medical image data is generated by medical centers and hospitals. Efficient compression techniques are required to conveniently archive and transmit this enormous data. Telemedicine is the technique used to provide healthcare facilities to remote areas where medical professionals are not available. Telemedicine relies on efficient compression techniques for data transmission. Emerging image processing technologies can result in growth of telemedicine by improving the data compression capabilities [1].

Medical imaging devices generate enormous amount of medical image data that requires substantial resources for storage and transmission. An effective compression technique is essential for efficient handling of this data. However, unlike other images, medical images contain diagnostic data that cannot be compromised by utilizing lossy compression methods. Medical and legal restrictions do not allow any loss of significant diagnostic data. Therefore, lossless methods are generally used for medical images compression but these methods only offer modest compression ratios. The compression ratio achieved is not sufficient to deal with huge amount of data. Lossy methods, on the other hand, provide much better compression ratios but some image data is lost that cannot be recovered. This loss of image data is not acceptable due to medico legal restrictions [2]. Selective Image Compression (SeLIC) technique adopts a hybrid approach by utilizing a combination of both lossy and lossless techniques. In this method, areas of image that contain significant diagnostic information are classified as regions of interest (ROI) and areas with non significant regions are classified as background (BG). The ROIs are compressed using lossless methods or low compression whereas BG is compressed using high compression [3-4].

JPEG XR is a new still image compression technique approved by the JPEG committee and adopted as a standard by ITU-T. Continuous tone digital images are the main target applications of this standard [5-6]. The JPEG-XR standard performs at par with JPEG-2000 while requiring significantly low computational and storage resources. Therefore, devices with low computational and memory resources are key target areas for the standard [5]. The working of JPEG-XR is described in following few lines. The first step is to perform colour conversion of the input image. The standard converts the image into YUV colour format. The compression is easier to perform since U and V components can be down sampled without any loss of perceptible image quality. The basic unit of data in JPEG-XR is 4x4 pixel blocks. A 4x4 set of non overlapping blocks is called a macro block [7]. The algorithm utilizes two level hierarchal transform with two concatenated operators. First is the forward core transform and second is the overlap transform. The coefficients are scaled by quantization after application of transform. Only integer operations are employed during the quantization process in JPEG-XR. Adaptive prediction is employed and neighboring blocks which have maximum similarity are used for the prediction of the current macro-block. Adaptive variable length coding tables are used for the entropy coding. The encoded bit-stream can be either archived or transmitted through a channel. Same steps are applied in reverse order in the decoder. The JPEG-XR decoder supports useful features like ROI decoding, sequential decoding, spatial and quality scalability [8-10].

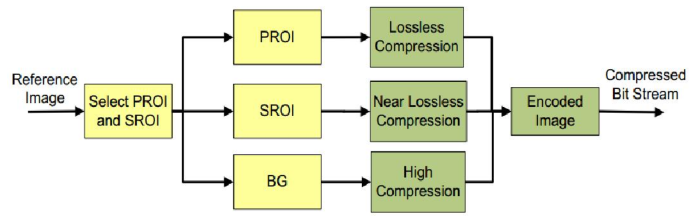
The JPEG-XR image compression standard supports ROI coding. The research proposes an optimized selective compression technique in which multiple regions of interest have been selected. These regions are compressed using different compression ratios depending upon the existence of diagnostic data. JPEG-XR standard has been used for selective compression of medical images. The same medical images are encoded by JPEG-2000 using selective compression for comparative analysis. The aim of the proposed research is to achieve adequate compression ratio while maintaining the requisite diagnostic information. The organization of the paper is as follows. Section II describes implementation of selective compression technique using multiple ROIs, Section III explains the simulation results and we conclude the paper in section IV.

2. Implementation of Selective Compression using Multiple ROIs

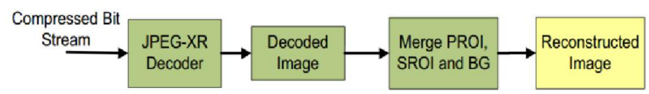
The implemented selective compression algorithm utilizes multiple regions of interest. The region with most significant diagnostic data is called Primary region of interest (PROI). The region containing data that can help in diagnosis or identification of PROI is called Secondary Region of Interest (SROI). This region is important but some loss of data may be allowed to achieve more compression. The remaining region, classified as the background (BG), contains redundant data that either can be compressed with very high compression rate or can be truncated. The block diagram of proposed implementation is shown in Fig 1.

The first step in selective compression of medical images is to select ROIs in an input image. The implementation code allows the user to identify PROI and SROI regions in the image. The remaining image data is classified as background. This method allows a medical professional to select ROIs without the using complex mathematical operations and all the calculations are performed in the background.

The data from these three regions are stored separately in different bit streams. These bit streams are compressed using different encoders. The PROI is always compressed by lossless method so that no data is lost. The SROI is compressed by a suitable compression ratio depending on the significance of contents. Very high compression ratio is used while encoding background to reduce the size of encoded image. The encoded regions are than available for archiving or transmission through channel. The block diagram of selective compression encoder is shown in Fig 1 (a). When the image data is to be retrieved the compressed data is decoded. The bit streams of decoded image regions are merged to reconstruct the image. The block diagram of selective compression decoder is shown in Fig 1(b).



(a) Selective Compression Algorithm Encoder



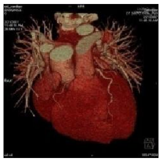
(b) Selective Compression Algorithm Decoder

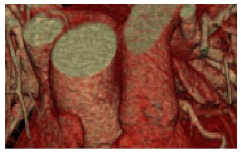
Figure 1. Selective Compression Implementation using JPEG-XR

The use of selective compression resulted in high compression ratio without any loss of significant diagnostic data. The technique outperforms lossless compression techniques in terms of compression ratio achieved while preserving the diagnostic data. The technique performs better than lossy compression because no diagnostic data is lost and significant compression is achieved.

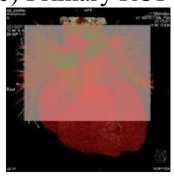
3. Simulation Results

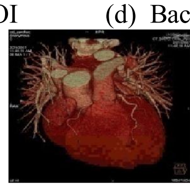
A set of medical images containing different types of medical images like MRI, X-ray etc was selected. Each image was encoded using selective image compression. The images were encoded by JPEG-XR and JPEG-2000 standards. The compression ratios were selected to ensure that bpp in an encoded image was same for comparative analysis. The encoded images were decoded and image metrics were calculated for the reconstructed images by comparing with the original image. A sample medical image, cardiac, is shown in Fig 2 with the PROI, SROI, Background regions clearly identified. Reconstructed images with JPEG-XR and JPEG-2000 are also shown. The Peak Signal to Noise ratio (PSNR), Mean Square Error (MSE) and Structural Similarity (SSIM) Index image metrics were calculated for analysis. The results obtained after application of JPEG-2000 and JPEG-XR on different images are depicted in Table 1. The results show that JPEG-XR performs slightly better or at par for these images in terms of PSNR, MSE and SSIM. Fig 3 displays the obtained results in graphs for better visualization.


(a) Original Image


(b) Primary ROI


(c) Secondary ROI


(d) Background


(e) Encoded Image with Wavelet Transform

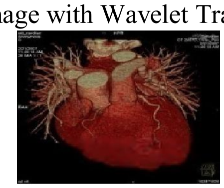
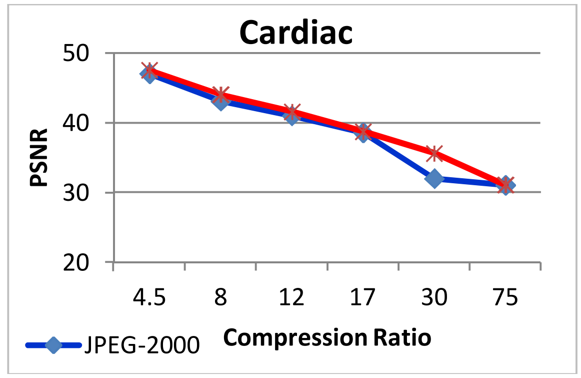

(f) Encoded Image with JPEG-XR

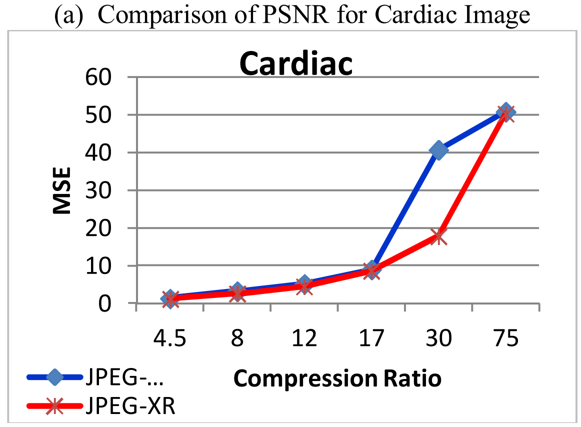
Figure 2. Cardiac Image encoded with different standards

Table 1. Simulation Results

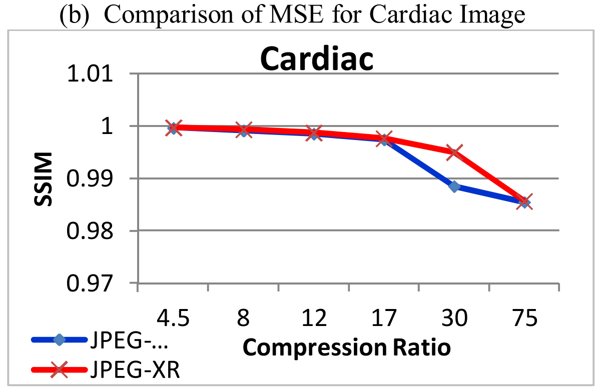
Image	Comp Ratio	PSNR JPEG 2000	PSNR JPEG XR	MSE JPEG 2000	MSE JPEG XR	SSIM JPEG 2000	SSIM JPEG XR
Cardiac	4.5	47.04	47.52	1.28	1.15	0.9996	0.9997
	8	43.13	44.06	3.16	2.55	0.9991	0.9993
	12	41.01	41.60	5.15	4.50	0.9985	0.9987
	17	38.59	38.78	8.99	8.61	0.9974	0.9976
Rabbit	3	59.74	59.28	0.07	0.07	1	1
	5	46.82	50.68	1.35	0.56	0.9998	0.9999
	8	40.56	41.24	5.71	4.89	0.9991	0.9992
	12	35.46	35.67	18.49	17.65	0.9969	0.997
	18	32.20	32.31	39.20	38.20	0.9934	0.9935
Fracture	7	41.27	41.59	4.85	4.50	0.9979	0.9981
	8	41.03	41.46	5.13	4.64	0.9978	0.998
	13	40.15	40.84	6.28	5.35	0.9973	0.9977
	18	39.43	40.18	7.42	6.24	0.9968	0.9973
MRI Chest	5	42.03	44.00	2.59	4.07	0.9992	0.9995
	8	38.76	40.11	8.65	6.345	0.9983	0.9988
	12	35.80	37.46	17.10	11.68	0.9967	0.9977
	18	34.70	35.58	22.01	17.98	0.9957	0.9965
MRI Brain	7	49.68	52.21	0.70	0.39	0.9998	0.9999
	8	47.31	49.97	1.21	0.66	0.9997	0.9998
	12	43.21	45.09	3.10	2.29	0.9992	0.9995
	18	39.32	40.45	7.60	5.87	0.9981	0.9985



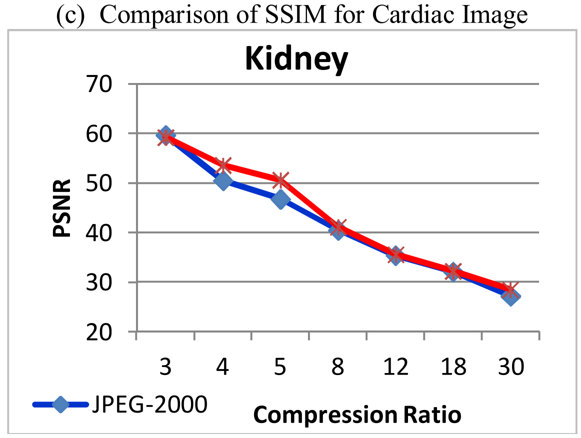
(a) Comparison of PSNR for Cardiac Image



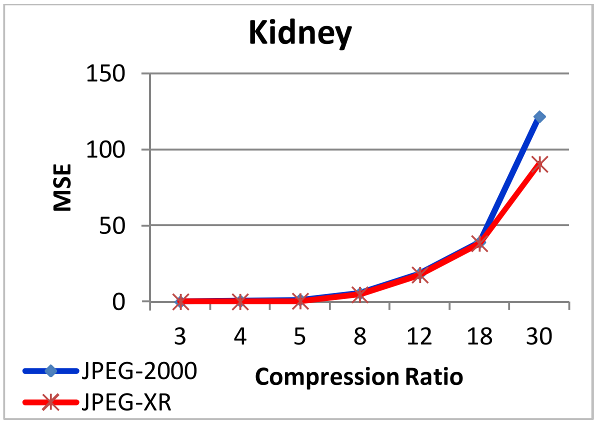
(b) Comparison of MSE for Cardiac Image



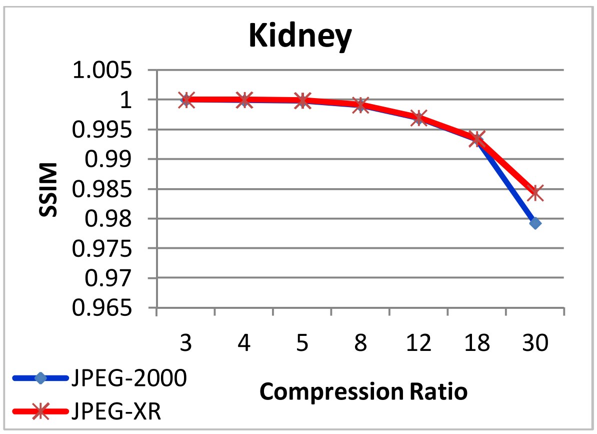
(c) Comparison of SSIM for Cardiac Image



(d) Comparison of PSNR for Rabbit Kidney



(e) Comparison of MSE for Rabbit Kidney



(f) Comparison of SSIM for Rabbit Kidney

Figure 3. Performance Comparison of JPEG-XR with JPEG-2000

4. Conclusion

Different medical images were selected from a dataset. ROIs were selected in each image. The regions in an image were encoded separately by at different compression ratios. JPEG-XR and JPEG-2000 standards were utilized for image compression. Encoded images were decoded by respective decoders to get uncompressed bitmap images. The decoded images were compared with the original images to calculate image metrics like PSNR, MSE and SSIM. The overall performance of JPEG-XR is slightly better than or at par with JPEG-2000. Since the JPEG-XR is computationally less intensive it is more suitable for embedded applications or for systems with limited memory and computation resources.

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