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A JPEG 2000 BASED HYBRID IMAGE COMPRESSION TECHNIQUE FOR MEDICAL IMAGES

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Use of lossy compression for medical images could result in compression error that may be considered as diagnostic problem by medical doctor. Hybrid schemes, a combination of lossy and lossless compression are used to achieve higher compression ratio without compromising the subjective quality of medical images. This paper proposes a new hybrid compression method for medical images. Different combinations of lossy and lossless compression schemes: RLE, LZW, JPEG LS, JPEG and JPEG2000 are implemented to find out the best hybrid compression combination by keeping subjective quality of medical image as a benchmark. X-ray images are used for experimentation. Experimental results show that hybrid combination of JPEG2000 lossless and lossy JPEG2000 produce optimized results without compromising subject quality of medical images required for diagnostics. The proposed hybrid combination has average compression ratio, space saving, MSE and PSNR of 0.21, 78.97, 1.16 and 47.58 respectively for all the medical images used in experimentation. The proposed hybrid scheme can be used for medical image compression.

Keywords : Medical imaging, Compression, Lossy, Lossless, Hybrid.

1. Introduction

Hospitals have been moved toward digitization for processing, storage and transmission of medical images [1]. The basic idea is to represent medical images in a digital format to support image transfer, archiving and handling of visual diagnostic information in new and more efficient ways. However, high quality digitized medical images need large memory for storage and high bandwidth for error-free transmission. Compression of medical images is required for minimizing storage requirements and speeding up transmission rates across low bandwidth channels [2].

Medical images can be compressed using lossless or lossy compression techniques. Lossless techniques (also known as reversible compression) allow the image to be compressed and then decompressed back to original state without any loss of data. However, the compression ratio for lossless methods is not very high. On the other hand, lossy compression techniques can achieve high compression ratios but cannot recover the 100 % original image once it is compressed. If we use only lossy compression for medical images, compression error may be considered as diagnostic problem by medical doctors [3]. Therefore, lossless compression is predominantly used in medical imaging industry. Recently, significant attention has been given to use of hybrid compression for medical images [4-5]. The basic idea behind it is to apply lossless compression to clinically relevant image area (called as region of interest) and rest of the image is compressed by use of lossy compression methods [6]. In literature, region of interest is extracted from medical image compression by two ways: (1) comparison of the image under observation with pre-stored template image, (2) by using filtering methods (edge detection etc.) [7-10]. Zukoski et al. [7] discussed hybrid techniques for medical images. The ROI is defined by matching the medical image under consideration with a database of images (atlas). Any major or minor matching error can lead to wrong selection of ROI. In the proposed research, ROI is defined in real time. Moreover, in-depth analysis of different medical images by various hybrid combinations is done and their performance is evaluated using multiple statistical parameters like compression ratio, space saving, mean square error and peak to signal noise ratio. The rest of the paper is organized as follows: Section 2 describes the implementation of different hybrid compression techniques for medical images while results and discussion is done in section 3. Finally section 4 summarizes the paper.

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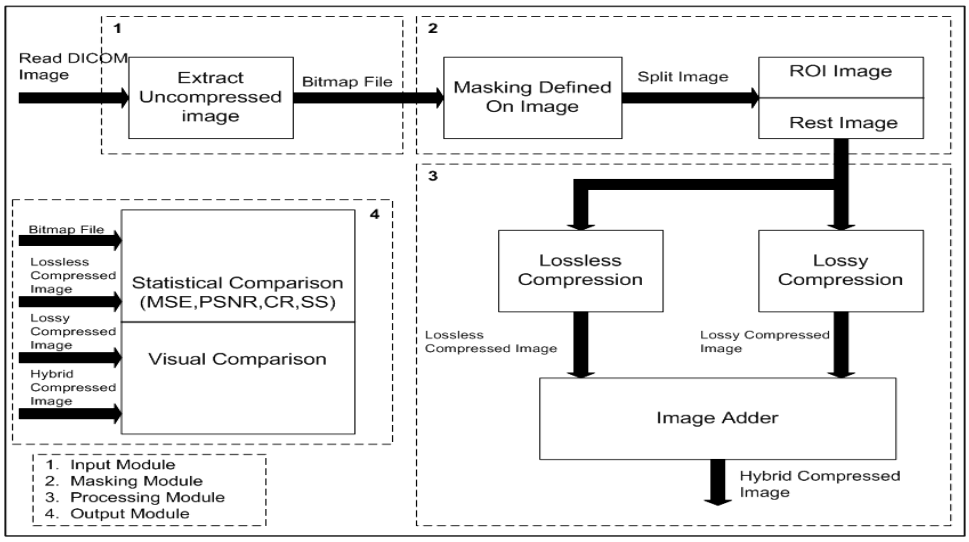

Figure 1. Block diagram of implemented hybrid scheme.

2. Implementation of Hybrid Compression Techniques

The block diagram for implementation of various hybrid compression schemes is shown in Figure 1. There are four main functional modules shown in dashed line blocks as given by Figure 1 are explained below:

1. Input Module
2. Masking Module
3. Processing Module
4. Output Module

The input module extracts the uncompressed image and converts the DICOM format image into uncompressed bitmap file image. The desired Region of Interest (ROI) mask is defined by masking module. Based on the mask defined, the bitmap image is separated into two segments: ROI image and Rest image. The core module of implemented scheme is the main processing module as depicted as 3rd module in Figure 1. It takes two segments of images, one having ROI image (critical area) and second containing non-critical area (rest image) generated by masking module. Lossless and lossy compression schemes are implemented in this module. There are two main steps in most lossless compression algorithms: (1) statistical model generation and (2) mapping of data to bit sequence. In first step, statistical model for input data is generated. The second step uses model generated in previous step to code input data to bit stream in such a way that frequently occurring data produce a shorter bit code and vice versa. On the other hand, three main steps in lossy compression method are: (1) transform (2) quantization and (3) entropy coding. The image is first divided into small blocks and block's raw data are transformed into new domain like frequency domain. The resultant data is quantized and entropy coded by assigning shorter codes to frequent data and vice versa. ROI image is compressed using lossless compression technique while lossy compression is applied on the rest image through lossless and lossy compression sub-modules of main processing module. The two separate generated compressed images from aforementioned module are fed to image adder sub-module, which generates a single hybrid compressed image. Finally the output module performs statistical analysis to compare performance of achieved results with the original uncompressed image.

3. Results and Discussion

Various hybrid combinations of lossless and lossy compression methods are implemented in MATLAB to find out the best hybrid combination for medical images. The compression techniques and their combination used in experimentation are elaborated in Tables 1 and 2 respectively. The performance metrics used for evaluation of various hybrid combinations are compression ratio (CR), space saving (SS), mean square error (MSE) and peak to signal noise ratio (PSNR). The CR and SS are defined by Eq. (1) and Eq. (2) respectively.

Table 1. Basic techniques of lossy and lossless compression.

Lossless Compression	Lossy Compression
JPEG LOSSLESS	JPEG LOSSY
RLE	JPEG 2000 LOSSY
LZW	
JPEG 2000 LOSSLESS	

Table 2. List of individual and hybrid combination of techniques analyzed.

No.	Type	Description
01	Individual	JPEG LOSSLESS
02	Individual	RLE
03	Individual	LZW
04	Individual	JPEG 2000 LOSSLESS
05	Individual	JPEG LOSSY
06	Individual	JPEG 2000 LOSSY
07	Hybrid	JPEG LOSSLESS + JPEG LOSSY
08	Hybrid	RLE + JPEG LOSSY
09	Hybrid	LZW + JPEG LOSSY
10	Hybrid	JPEG 2000 LOSSLESS + JPEG LOSSY
11	Hybrid	JPEG LOSSLESS + JPEG 2000 LOSSY
12	Hybrid	RLE + JPEG 2000 LOSSY
13	Hybrid	LZW + JPEG 2000 LOSSY
14	Hybrid	JPEG 2000 LOSSLESS + JPEG 2000 LOSSY

$$CR = \frac{\text{size of compressed image}}{\text{size of uncompressed image}} \quad (1)$$

$$SS = (1 - CR) \times 100 \quad (2)$$

The MSE can be defined by Eq. (3) [11-12].

$$MSE = \frac{1}{M.N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} [f(x,y) - f^{*}(x,y)] \quad (3)$$

where *M* and *N* parameters define the size of image in *x* and *y* direction respectively. The functions *f(x,y)* and *f*(x,y)* are input and reconstructed image respectively. The PSNR can be computed using MSE as defined by Eq. (4) [11-12].

$$PSNR = 20 \log\left(\frac{255}{\sqrt{MSE}}\right) \quad (4)$$

A graphical user interface (GUI) as shown in Figure 2 was also developed to carry out the experimentation efficiently. The various medical images of x-rays used for experimentation are: HEAD, KNEE, FOOT, CHEST and HAND. The images and amount of masks (ROI) used for HAND and HEAD are shown in Figure 3.

The compression ratio (CR) for medical images HAND and HEAD using various individual and hybrid compression schemes is shown in Figure 4. The CR closer to unity show poor compression achieved and vice versa. The CR values achieved by lossless techniques were close to unity showing minimum compression achieved whereas lossy techniques achieved values close to zero showing maximum compression. Most of hybrid techniques have CR between lossless and lossy methods.

Figure 5 shows space saving (SS) for various compression combinations for HAND and HEAD images. The SS index closer to 100 indicates larger compression achieved and hence saved more space. The lossy techniques achieved SS around 98% i.e. maximum compression achieved where lossless techniques were on lower side. The hybrid techniques produced SS of an average of 68%.

The mean square error (MSE) for HAND and HEAD using different individual and hybrid combinations is shown in Figure 6. The lower value of MSE depicts a good quality compressed image and vice versa. The lossless techniques achieved MSE near to zero whereas MSE is on higher side for lossy methods. Almost all hybrid combinations are having MSE between lossless and lossy compression methods.

Figure 7 shows the peak to signal noise ratio (PSNR) comparison using various individual and hybrid combinations of lossless and lossy compression for HAND and HEAD images. The higher values of PSNR indicate good quality image. The PSNR of lossless techniques is infinite whereas various individual and hybrid combinations are having PSNR in the range between 42 to 47 dB.

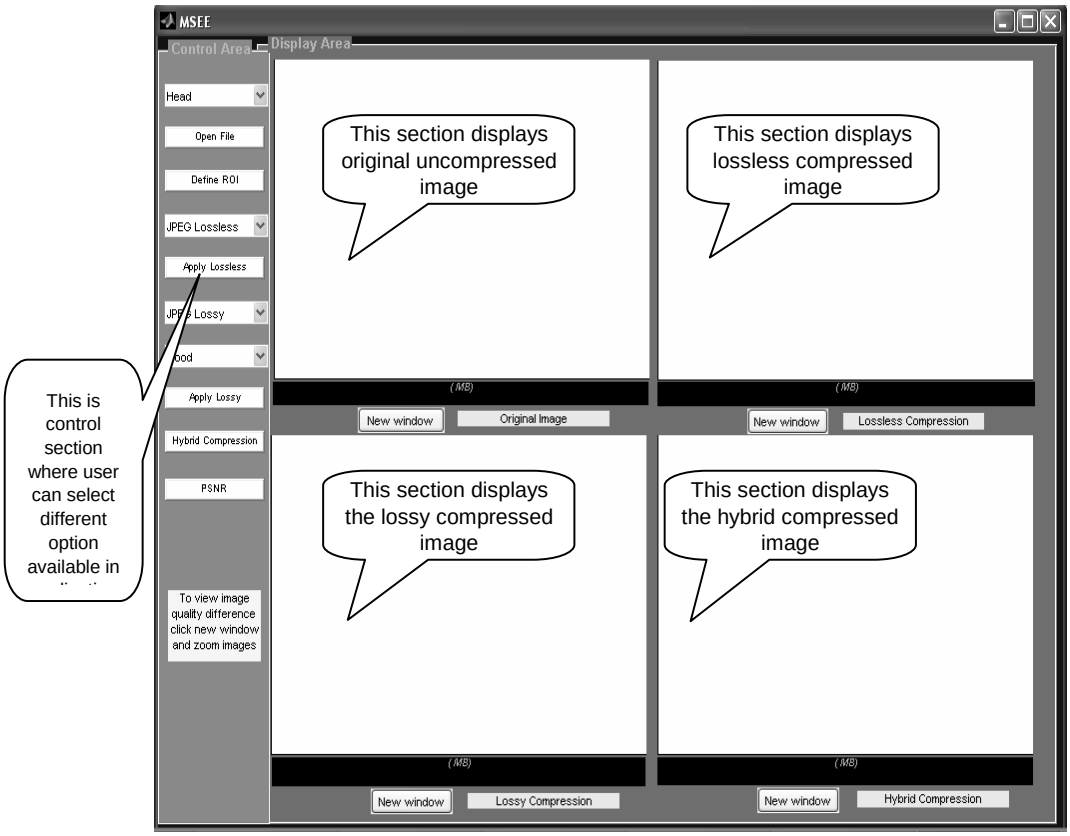

Figure 2. Developed Graphical User Interface (GUI) .

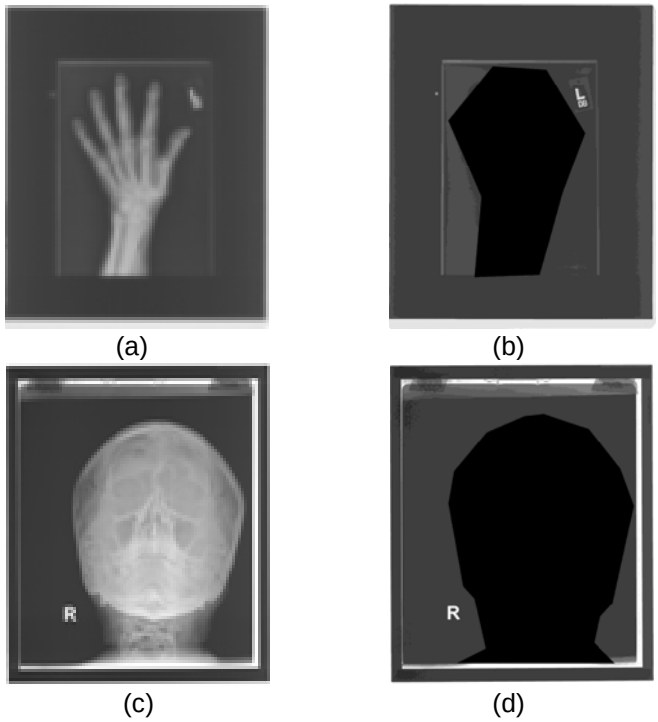

Figure 3. (a) Hand x-ray (b) masked hand x-ray (c) head x-ray (d) masked head x-ray.

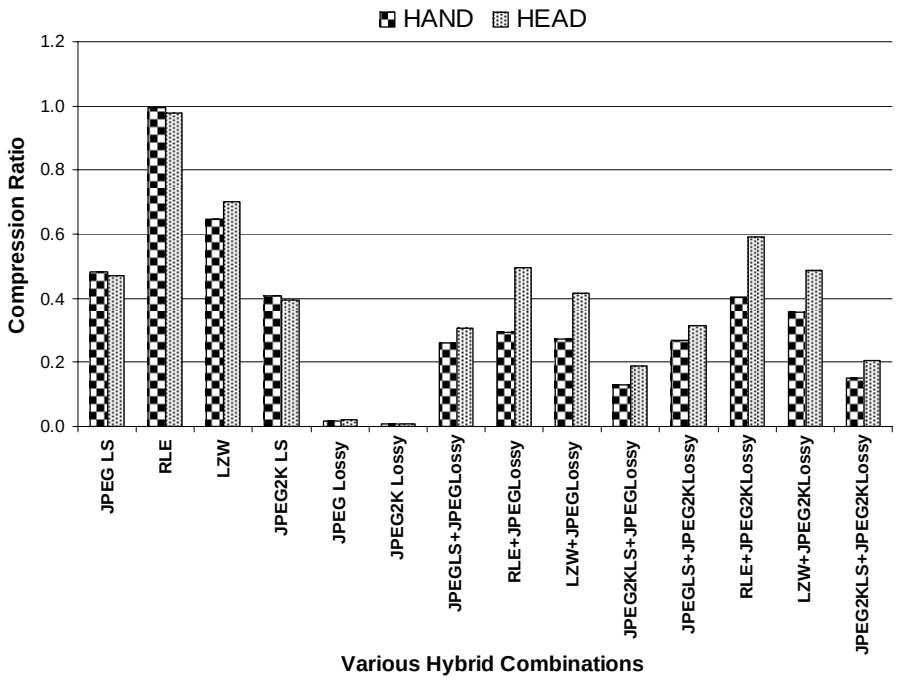

Figure 4. Compression ratio for HAND and HEAD medical images for various hybrid compression schemes (Here LS = Lossless and 2K = 2000) .

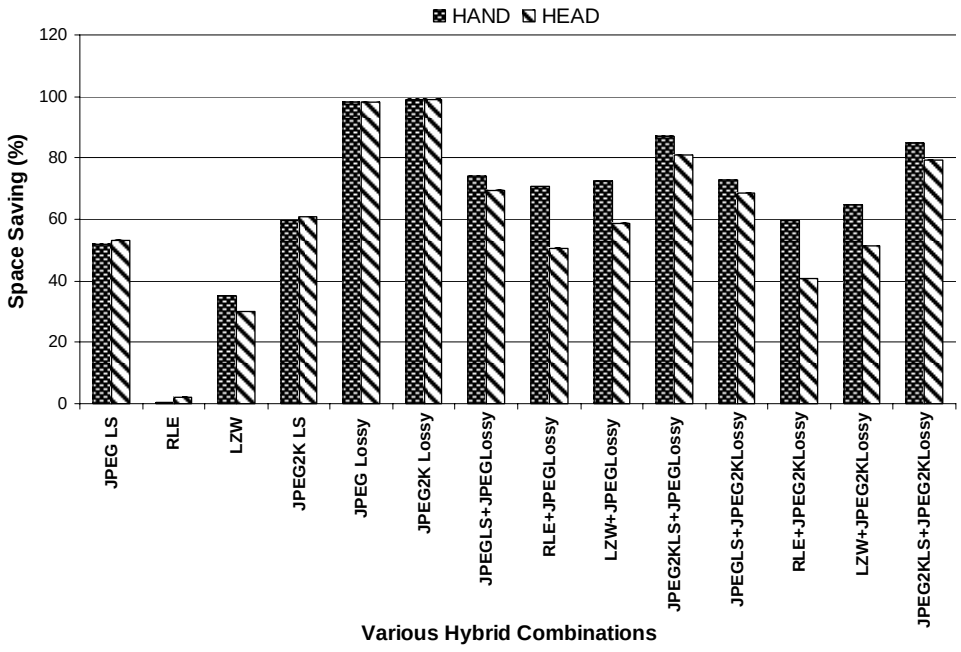

Figure 5. Space Saving (SS) for HAND and HEAD medical images for various hybrid compression schemes (Here LS = Lossless and 2K = 2000).

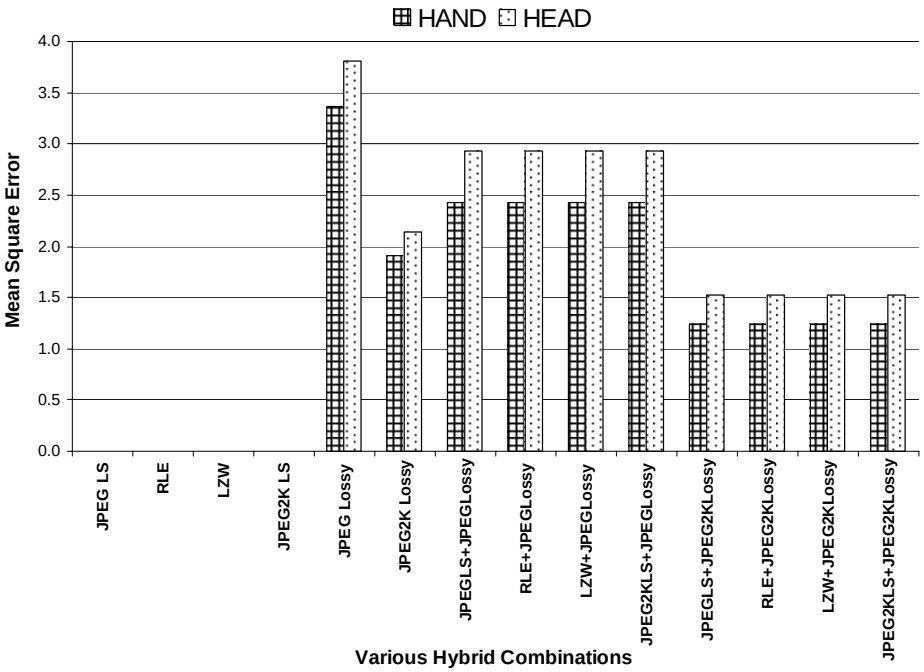

Figure 6. Mean Square Error (MSE) for HAND and HEAD medical images for various hybrid compression schemes (Here LS = Lossless and 2K = 2000) .

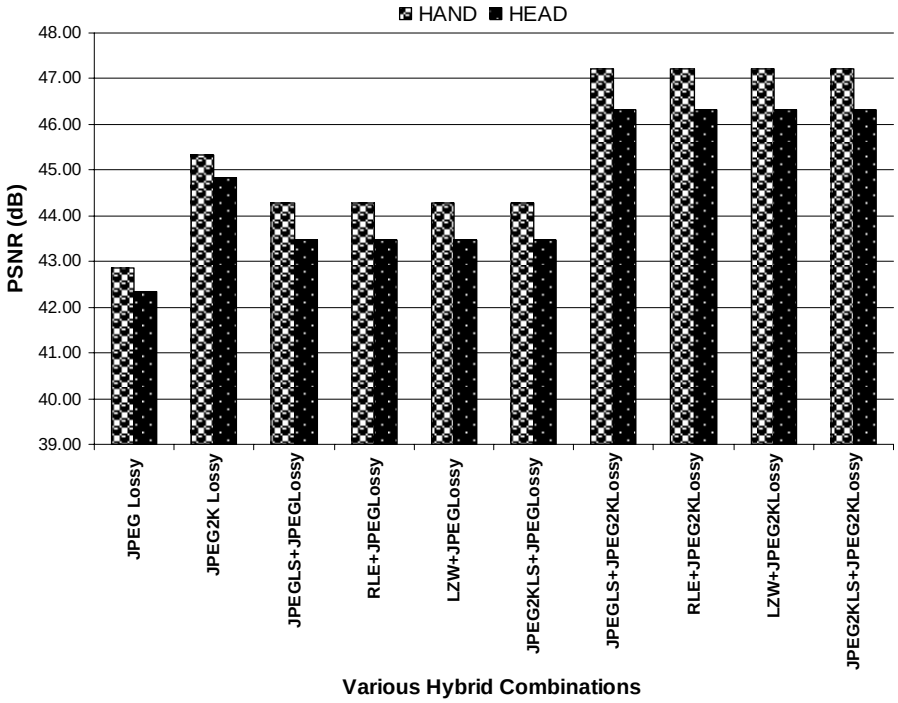

Figure 7. Peak to Signal Noise Ratio (PSNR) for HAND and HEAD medical images for various hybrid compression schemes. The PSNR of lossless methods: JPEG LS, RLE, LZW and JPEG2K LS is infinite (Here LS = Lossless and 2K = 2000)

After in-depth analysis using aforementioned performance metrics, it is found that hybrid combinations can achieve higher compression ratios without compromising on subjective quality of medical image in comparison with lossless compression methods. None of lossless techniques was efficient enough to attain a compression ratio below 0.40 and space saving above 60%. On the other hand, lossy compression methods yield more compression and higher space saving (99%) but on the cost of poor subjective quality of image hybrid compression methods showed promising results by attaining significant space saving and maintaining high subjective (visual) quality in area of interest of image. It is further revealed that combination of *JPEG2000 LOSSLESS and JPEG2000 LOSSY* gives the overall optimized results out of all hybrid combinations implemented in this research.

4. Conclusion

In this paper, various individual and hybrid combinations of lossless and lossy compression methods have been implemented. The performance of the various methods was evaluated using mean square error, peak to signal noise ratio, compression ratio and space saving performance metrics. It is found that hybrid combinations of lossless and lossy compression are the trade-off between compression ratio and subjective image quality. Furthermore, it is revealed that combination of *JPEG 2000 LOSSLESS + JPEG 2000 LOSSY* gave best results.

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