Robust Image Transmission over Noisy Channel with Hybrid Transform and Error Recovery

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Abstract
Noisy channels have significant influence on the quality of image transmission as the error rates increase and a degrading affect at higher error rates. This paper presents a recovery scheme for image transmission over noisy channels based on a hybrid transform and error correcting codes with error replacement strategy. In this paper we describe allocating redundant bits based on some importance metrics. In addition, it describes in details the ECC and the used transforms. The effects of errors are measured and examined which show that are our scheme is robust for protecting image transmission over noisy channel and minimizes visual effects when compared with a single transform. The also paper describes the implementation of the recovery scheme and details the findings of our evaluation on the transforming choices.

Keywords: *Image Transformation,Image Protection**,** DCT, Wavelets, Error-correcting Codes,Error Recovery.*

1. INTRODUCTION

With the unparalleled explosive growth of the Internet and the development of communication techniques and its usage in many areas of science, industry, and mobile communications, images are the most frequently data exchanged . While network transmission and transmission channels are subject to all kinds of noise, the need for image protection and error tolerance is crucial in reducing transmission time and superior solution to the costly retransmission alternative. Many techniques have been proposed to tolerate errors and to reduce the bit-rate while achieving higher image quality [1]-[3]. While most image formats are based on compression, compressed formats remove redundant information; thus making it more difficult to decode and reconstruct images under error conditions while preserving acceptable viewing quality. Error correcting codes (ECC) [4][5] help in detecting errors in transmitted data and give the ability to correct these errors. ECC schemes have maximum number of errors that can be handled or corrected. If the number of errors exceeds the capability of the ECC code, two choices are available. The first option is retransmitting the corrupted portion if not the entire data, and the second choice is to use error protection technique to compensate for data loss and to preserve some data integrity for viewing purposes. The second alternative is more appropriate since it does not require the costly retransmission.
To achieve this goal, we implement wavelets [6] and DCT [8] transforms combined with error protection scheme that is inclined toward the important data in transmitted images as the case in most unequal protection techniques (UEP). Wavelet transformation of an image involves the decomposition of the image into a number of subbands, where each subband contains information of a particular frequency band [6][7]. The choice of wavelets influences the reconstruction quality of the image. DCT is applied on each subband and treated as a single block regardless of its size. Each subband is individually encoded using BCH coding [5] with unequal set of parameters added to the important subbands. These important bands carry the low-frequency components of an image since our *human visual system (HVS)* is more sensitive to such frequency components. Based on this, such bands are given more bits and the less important bands are allocated with fewer bits to allow for the ECC to

correct more errors, consequently increase the robustness of image transmission. Errors are injected into the stream to simulate channel errors at rates of 1-10%.
The paper is organized as follows. In the next section, image protection schemes are introduced including motivation for our work. In section 3 we elaborate on error correcting codes, DCT and the wavelet transforms. In section 4 we present our proposed technique and discuss the error simulation model utilized and the error compensation procedure. Section 5 presents our experimental results and the conclusion.

2. Existing Still Images Protection Schemes

Image protection with error correcting codes has received a tremendous attention due to its importance. Image formats such as JPEG [9] and the most recently JPEG2000 [10] employ DCT and wavelet transform respectively. While JPEG offers no error resiliency, JPEG2000 addressed such issue with varying performance. Recently, image coding with error correcting codes such as [11] [12] were proposed. These techniques provide better protection than the traditional DCT based schemes.
Other wavelet based transforms schemes [13][14] proved more suitable from the subjective point of view. Other encoding schemes that are based on *Embedded Zerotree Wavelet (EZW and LZW)* [15][16] addressed the issue of network errors on image transmission and provided graceful degradation of image quality under erroneous conditions. Besides, resilient techniques have been addressed utilizing FEC codes, packatization, or priority coding with varying results depending on the transforms used. In the case of DCT based coding, images suffer from the tiling affects under high error rates while wavelet based coding suffers from aliasing effects under similar conditions.
Hybrid coding [17]that combines two transforms for video transmission [18], video sequencing [19] and for medical image compression[20] that combines the two techniques to achieve better coding and eventually reduce the effects a single transform anomalies.

3. Review of Error Correcting Codes

Error correcting codes allow the detection and correction of bit/byte errors [4][5]. This process adds redundant bits to the stream of data and creates a structure that can detect and correct bits that are in error. ECC is a standard method for insuring data integrity of transmitted data over noisy channels and in media storage such as in compact disks and DVDs.
BCH [g] is an error correcting code where a block code is defined by (n,k) where n represent the size of the block in bits and k represents the number of bits to protect. A parameter t represents the maximum, number of errors the code can correct. For example, a BCH code (511,475) t=4, protects 475 bits using 36 redundant bits up to 4 errors. For a channel with additive white noise and a bit-error-rate (BER) P_c, the post-coded BER P_b is

$$\rho_\beta \approx \frac{1}{n} \sum_{i=t+1}^{n} i \binom{n}{i} \rho_c{}^{i} \left(1 - \rho_c\right)^{n-i} \tag{1}$$

And t is the maximum number of errors correctable by an (n,k) block code.
Both encoding and decoding require the two parameters. It is importance to note that the larger the k, the less error correcting capability and the less size of the transmitted stream. This tradeoff between size and the size of transmitted data should be carefully selected when using BCH codes. However the efficiency and effectiveness of any error technique depends mainly on the channel conditions.

3.1 Error Simulation Model

To better evaluate the performance of our scheme, we implemented a network error model with the capability of producing and injecting bit errors and burst errors into the transmitted stream with the ability to vary BER between 0-10 % to simulate channel conditions. While many error simulation models have been used, Gilbert error model proved to be the easiest to implement in addition to its closer error modeling for real noisy channels. The model consists of 2 two states, *Good* and *Bad* state when in state G, no error occurs. When in state B, an error is assumed to occur. The error rate is $(1-p)/(2-(p+q))$ where p is the probability of staying in a good state and q is the probability of staying in a bad state. We choose this model because of its simplicity and its bursty error modeling capability.

4. Proposed Scheme

Our hybrid transform-based approach to protection is outlined as follows (see figure 3). The wavelet transform is applied to the image several times and equally to all bands until the low-frequency subband becomes small enough mainly 8x8 pixels. All subbands can then be transformed with DCT, after which all bands would be divided into three groups in accordance with their importance such that LL-frequency in group 1, LH-frequency in group 2, and both the HL and HH frequency as the third group.

We adopted two approaches in the protection scheme, the first includes protecting all bands with variable protection according to the group they are in, while the second drops all the bands in the third level, but they would be replaced using our replacement strategy. All bands are compressed and fed to the protection scheme. The reverse process is performed at the receiving end.

Robustness of our scheme is

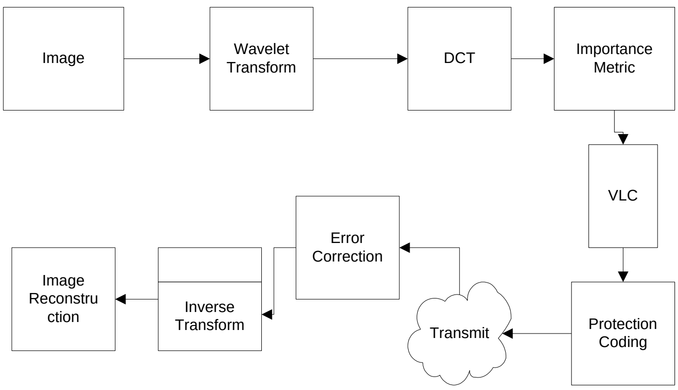

Figure 1. Outline of Proposed Scheme

4.1 Error Injection using Bose Chaudhuri Hocquenhem (BCH) Protection

In our scheme, and according to the importance criteria, the protection module distributes protection bits as follows: the band that is more important in the reconstruction of an image would receive more protection bits and those that contribute less would receive fewer bits. For example the important bands get a BCH code (511,466) t= 5, the less important bands would get a BCH code (511,475) t= 4, and the least important would get BCH code (511,484) t= 3. The obvious overhead presented by the redundant bits is also a parameter that needs to be further researched and optimized. And for the purpose of simulating errors, and after identifying the groups of bands, we inject the bands (stream) with random errors in accordance with the error bit rate that is assigned for the particular run.

4.2 Error Compensation

To compensate the presence of errors in the transmitted stream, which causes an unrecoverable reconstruction errors and no image reconstruction; we implemented a compensation strategy that takes effect once the number of errors exceeds the capabilities of the particular code or the complete absence of a certain band. In this strategy we substitute all the missing value with zeros. This strategy permits the reconstruction of the transmitted image with faulty values thus guaranteeing that the reconstruction process does not halt. The robustness of our scheme is highly dependent on the compensation strategy. Other compensation strategies can be implemented such as replacing only bits in error with zeros if known, or with an average of neighboring pixel values.

5. Performance Evaluation

We implemented our proposed protection scheme, and conducted a number of tests to generate acceptable averaging results. We used the *Lena* image to test the performance of our scheme. First we applied the wavelet multiple times only on the LL bands to generate subband with size 8x8 pixels (for the LL band). All subbands are then transformed by the DCT transform. We also injected errors in the rates between 2%- 10% to measure the robustness of our error recovery model and the efficiency of the replacement strategy.

The results are presented in terms of the *PSNR* of the reconstructed image within a given error rate. Subjective evaluation is also demonstrated to illustrate the quality of reconstructed images. Errors are applied equally to all subbands while maintaining the separation between the subbands based on their importance.

Our results in Figure 2(a) show that with the first approach, at which we provide variable number of protection bits among groups and equal bit within a group, show that for error rates 2% to 5% rate, the average PSNR drops gradually at low error rates and dramatically as we increase the error rates.

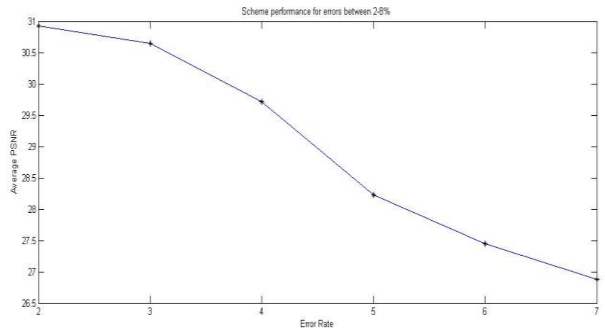

Figure 2(a) Scheme performance for errors between 2-8%

Figure 2 (b) Visual results of the first approach Results

This drop is predictable since some of the lower groups of bands which deemed unimportant were corrupted with errors beyond the correction capability of our correction code. Visual results are shown in figure 2(b).

In another group of run tests we applied the second protection scheme, where we removed all the bands in the third level from the transmission simulation and error ejection. In this scheme, the discarded bands are replaced at the reconstruction phase with 0 values for all bands. Figure 3(a) shows clearly that our results for the different bands did not show great improvements for error rates above 5%. However, for the error rates below 5%, we notice that the average PSNR values were lower than the first scheme. This is justified by the fact that some of the third groups of bands were recovered by our recovery scheme. In addition, reconstruction and thus the overall transmission time was higher when compared with the first scheme. Figure 3(b) shows subjectively some of these results.

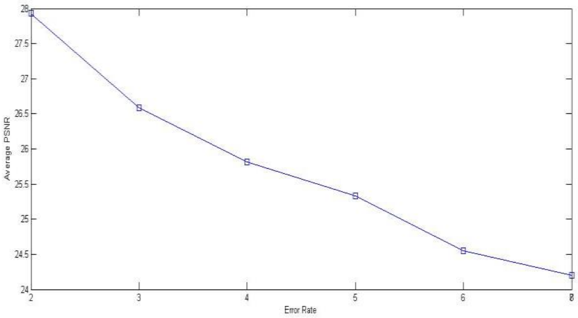

Figure 5 (a) 2nd Protection Scheme Results

Figure 5 (b) Visual Results

We must note that when compared with equal protection for all bands at all groups, the average PSNR values shows a drop at all error rates. This is anticipated since providing equal protection for the less important bands with the more important one causes the important bands in error not to be recovered specially at higher error rates.

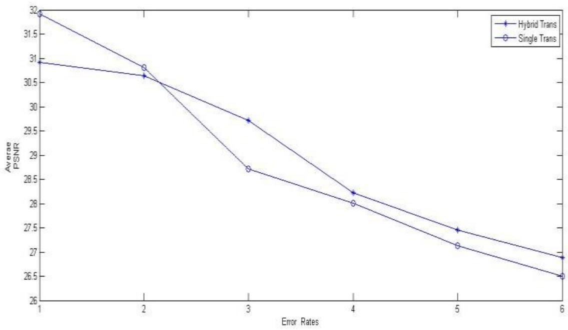

Figure 4 Single transform VS. Hybrid transform

When compared between our hybrid scheme and with only the wavelet transform under same conditions. Our scheme on the average outperforms a single transformer and it is more apparent in the subjective evaluation of reconstructed images, and with better performance for the single transform at the lowest error rates as shown in figure 4.

6. Conclusion

In this paper, we proposed a protection scheme for image protection and recovery based on transform techniques and error correcting codes. The results have shown the effectiveness of the hybrid transform to image data, in terms of unequal protection and grouping of bands based on their importance.
Our paper describes the implementation of the protection scheme, and presents the results of our extensive evaluation which clearly shows the superiority of providing variable protection bits among the group of bands in accordance with their importance.
Currently we are taking into consideration variations of our scheme to optimize the number of groups and the number of wavelet transformed bands.

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