ROBUST PACKET IMAGE TRANSMISSION BY WAVELET COEFFICIENT DISPERSEMENT

Tamás Frajka and Kenneth Zeger

Department of Electrical and Computer Engineering,
University of California, San Diego
La Jolla, CA 92093-0407
email: {frajka,zeger}@code.ucsd.edu

ABSTRACT

We present a packetization method for robust image transmission over packet erasure channels. The packets are formed in such a way that the image information is spread over different frequency bands and spatial locations to avoid complete disruption of certain image blocks in case of a packet loss. Experimental results are provided to demonstrate the performance of this method.

1. INTRODUCTION

Modern communication systems can experience a wide variety of channel conditions from individual bit errors to packet losses. In block based coders such as JPEG the effect of errors can be limited to a given block. Certain state of the art coders use wavelet transform and perform global coding of coefficients. These coders can experience catastrophic failures in case of bit errors or packet losses.

In order to maximize compression efficiency, wavelet based coders such as Shapiro's EZW [1] or Said and Pearlman's SPIHT [2] rely on state information. In such cases any error can lead to a break down at the decoder. In a packet network a lost packet frequently causes complete loss of synchronization at the receiving end.

One could use unequal Forward Error Control (FEC) coding to protect the image data and combine that with packetization as done in [3]. The amount of protection depends on the noisiness of the channel. In the case of the Internet, that may change very rapidly even during the transfer of an image. An alternate approach is to make the image coder more robust to prevent catastrophic failures. A Packetized Zerotree Wavelet (PZW) scheme is proposed in [4] that groups individual zerotrees into packets by changing the SPIHT encoding order. Thus any packet loss will only have effect on the spatial locations of the image that the given zerotrees correspond to. In [5] the robustness of the packetized coder is enhanced by using a macroscopic multistage compression method, with the first stage image data being protected by FEC.

In this paper we propose a new packetization scheme based on the MultiGrid Embedding (MGE) coding [6] by Lan and Tewfik. In zerotree based packetization methods, packets contain one or more zerotrees. Any loss of data tends to destroy the corresponding spatial location in the image. With our proposed method the effect of packet losses is not concentrated on a given spatial location but spread over different locations and frequencies.

In Section 2 an overview of the MGE coding is presented, Section 3 contains the description of the proposed algorithm. Section 4 shows the results and Section 5 concludes this paper.

2. MULTIGRID EMBEDDING

MultiGrid Embedding (MGE) coding, like SPIHT or EZW, is based on the wavelet transform, but uses an alternative to the zerotree structure for quantization. Both MGE and SPIHT perform bitplane coding; the difference is in the identification of significant coefficients for each bitplane. SPIHT uses zerotrees that try to exploit the spatial similarities between subbands. This introduces a hierarchical dependence into the coding. MGE uses a quadtree style decomposition instead. Starting from the entire image, a quadtree search is conducted to find the significant coefficients on the given bitplane. For each image block a single bit describes whether it contains significant coefficients or not. The quadtree decomposition is continued until it reaches the individual coefficient. The insignificant blocks are revisited in subsequent bitplanes (see [6]). The performance of the algorithm is similar to SPIHT for most images, but outperforms SPIHT on images with significant high frequency information where this search method reaches those coefficients faster than the zerotree description. The real significance of MGE for this work lies in the fact that the coding can be done without dependencies between subbands, thus allowing the coding to proceed in almost any arbitrary order.

3. SPREAD SPATIAL LOCATION PACKETIZATION

In a zerotree based coder coefficients on the same zerotree correspond to the same spatial location in the image. When packets are formed of several zerotrees, the loss of such packet results in the loss of information at the given spatial locations, forming a blank spot on the image. This property is the consequence of the zerotree structure. The coding of higher frequency coefficients at the same spatial location depends on the coding of lower frequency coefficients at the same location.

MGE is a flexible alternative to the zerotree structure. The coding dependencies only exist in the quadtree structure. Thus by choosing the appropriate initial block size for the quadtree identification process different spatial locations can be coded separately. This block size is different on each wavelet decomposition level to ensure it corresponds to the same block size in the spatial domain. These non-overlapping blocks form the starting blocks for the significance check as opposed to the entire image being the starting block in the original MGE algorithm. On one hand this change will decrease compression efficiency as many blocks that would normally be coded after a single significance check at a given bitplane will have to be individually compared. On the other hand this change makes it possible to code different spatial locations and frequency contents independently.

We partition the set of all wavelet coefficients into collections with the property that each collection contains one (rectangular) group of wavelet coefficients from each subband. Each such group corresponds to a different spatial location in the image, but of the same spatial location size. The assignment of the groups to collections is randomized. It guarantees that all wavelet coefficients are assigned to one and only one collection. The assignment also ensures that the spatial locations corresponding to the groups in a collection are non-overlapping. We call this partition a *randomized collection*.

Using a randomized collections has the effect of a packet loss spread over spatial locations. Each affected spatial location is missing a different frequency component making the visual loss less noticeable.

The coding proceeds in two phases. The first phase is a "dry run" when the encoder collects the rate information for each randomized collection for the given target bitrate. The second phase is the actual packet formation. The encoder tries to pack every packet as fully as possible, even allowing the sum of the rates to exceed the packet size by some margin if without the last randomized collection the packet is under filled. Thus some randomized collections will have more rate assigned to them than in the non-packetized coding, while others will have a lower rate description. The packing is carried out in the order known both to the encoder and decoder. The overhead information is limited to the sequence number of the starting randomized collection and the number of randomized collections in the given packet.

4. EXPERIMENTAL RESULTS

To demonstrate the performance of the proposed scheme we used the 512×512 greyscale Lena and Peppers images. The images were transformed with a 4-level wavelet transform using the $9-7$ filters from [7]. The assignment of wavelet domain blocks to randomized collections was generated ahead of time and used for all test images. There were a total of 256 randomized collections, corresponding to a block size of 32×32 in the spatial domain. A packet size of 384 bits was selected. In the channel model lost packets do not arrive to the decoder; the decoder must be able to perform independent decoding on each packet.

The PSNR results for the Lena and Peppers images are shown in Table 1. Its performance is comparable to that of the PZW algorithm over the different loss scenarios. It is known that PSNR values are sometimes poor indicators of the underlying image quality. While the above two methods yield similar PSNR results the corresponding image quality is quite different.

Figure 1 shows the visual comparison between a zerotree style packetization approach (like PZW) and the proposed method for packet loss rates of 1%, 10%, and 20% for the Lena image. As can be seen the images generated with the proposed method do not exhibit regions that are completely destroyed due to the packet loss. Rather, the losses are dispersed through different frequencies of different spatial blocks resulting in a visually less disturbing image.

The robust packetization method sacrifices the progressivity of the underlying coder. Any progressive refreshing is tied to the reception of the next packet. Furthermore, certain portions of the image improve in an uneven fashion as opposed to the gradual uniform improvement associated with progressive image coders.

5. CONCLUSION

We presented a packetization scheme that spreads the information within the packet among frequency bands and spatial locations to avoid complete loss of image information at any given spatial block. The coder is flexible in the coding of the information due to the MGE structure that is not limited by the zerotree interband dependencies. The coder loses progressivity at the expense of more robust performance on packet erasure channels.

Image	algorithm	no loss	1 % loss	10 % loss	20 % loss
Lena	PZW	32.19	31.33	26.29	24.63
	This work	31.90	30.91	26.24	23.70
Peppers	PZW	31.75	30.85	26.38	23.31
	This work	32.09	30.99	26.09	23.49

Table 1. Comparison of the proposed method and the PZW algorithm ([4]) for the Lena and Peppers images at a bit rate of 0.209 bpp.

6. REFERENCES

[1] J. M. Shapiro, "Embedded image coding using zerotrees of wavelet coefficients," *IEEE Transactions on Signal Processing*, vol. 41, no. 12, pp. 3445–3462, Dec. 1993.

[2] A. Said and W. A. Pearlman, "A new, fast, and efficient image codec based on set partitioning in hierarchical trees," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 6, no. 3, pp. 243–250, June 1996.

[3] A. E. Mohr, E. A. Riskin, and R. E. Ladner, "Graceful degradation over packet erasure channels through forward error correction," in *Proceedings of the Data Compression Conference*, Mar. 1999, pp. 92–101.

[4] J. K. Rogers and P. C. Cosman, "Robust wavelet zerotree image compression with fixed-length packetization," in *Proceedings of the Data Compression Conference*, Mar. 1998, pp. 418–427.

[5] P. G. Sherwood and K. Zeger, "Macroscopic multistage image compression for robust transmission over noisy channels," in *Visual Comm. and Image Proc.*, Jan. 1999, pp. 73–83.

[6] T. Lan and A. H. Tewfik, "Multigrid embedding (mge) image coding," in *IEEE International Conference on Image Processing*, Oct. 1999, vol. 3, pp. 369–373.

[7] M. Antonioni, M. Barlaud, P. Mathieu, and I. Daubechies, "Image coding using wavelet transform," *IEEE Transactions on Image Processing*, vol. 1, no. 2, pp. 205–220, Apr. 1992.

a b c d e f

Fig. 1. Comparison of proposed method (left column) and zerotree style packetization (right column) for the Lena image at 0.208 bpp, (a)-(b) 1% loss, (c)-(d) 10% loss, (e)-(f) 20% loss