NOVEL ERROR CONCEALMENT TECHNIQUES FOR IMAGES IN ATM ENVIRONMENTS

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ABSTRACT

Images transmitted via ATM networks suffer from quality degradation due to buffer overflow or cell header errors which cause ATM cells to be lost. This paper presents a new approach to conceal the errors in the received images by the application of novel error recovery techniques to the decomposed DCT-coefficient subimages of the corrupted image. These techniques were developed to recover images corrupted by impulsive noise. Since decomposing the corrupted image into the DCT-coefficient subimages generates low resolution images corrupted by impulsive noise, all the techniques used to recover images corrupted by impulsive noise can be used to recover the subimages and hence the corrupted image. In this paper, we study the performance of new techniques to recover the corrupted subimages. The quality of the recovered image using these techniques is better than the quality obtained by many classical error concealment techniques.

1. INTRODUCTION

In ATM networks, low priority cells are discarded whenever an overflow occurs in the buffers. The corrupted blocks corresponding to the lost ATM cells are declared to be lost and all the correctly received data for these blocks are discarded. Many techniques have been proposed to conceal the erroneous blocks in the damaged image. Some techniques are related to the Projection Onto Convex Sets (POCS) method [1]. Other techniques implement various spatial interpolation [2] and temporal extrapolation [3] methods. Subband decomposition was used in [4, 5] to interpolate the missing subband coefficients from the neighboring ones. In this paper, we present a new technique in which the corrupted image is converted into a set of subimages which can be considered as small images corrupted by impulsive noise. Errors in these images can be concealed by the application of cascaded and hybrid iterative and non-linear techniques designed for such type of corrupted images. The organization of the paper is as follows: In section 2, we present the iterative and non-linear techniques used to recover the errors in the corrupted subimages. Section 3 presents the proposed algorithms. A comprehensive discussion of the obtained results with a performance comparison- in terms of the signal-to-noise ratio (SNR)- among the different variations of the proposed technique and some other classical techniques is presented in section 4. Finally, a summary and some conclusions are presented in section 5 of the paper.

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2. ITERATIVE & NON-LINEAR ERROR RECOVERY TECHNIQUES

Any discrete signal with missing samples can be considered as a non-uniformly sampled signal and the values of the missing samples can be recovered if certain constraints on the average sampling rate are met. Many techniques based on the non-uniform sampling theory have been developed to recover the corrupted speech and image signals [6, 7]. Some recovery techniques use the concept of error reduction in the recovery process [6, 7]. In the following subsections, we present two of these techniques which are used in our algorithm to recover the missing DCT coefficients in the DCT subimages.

2.1. The Iterative Technique

In this technique [8], each iteration improves the SNR of the recovered image if the average sampling rate is greater than or equal to the Nyquist rate. Fig. 1 presents a block diagram of the Iterative technique where $x[i,j]$ is the corrupted image, S is a non-uniform sampling operator and BLO is a BandLimiting Operator which can be as simple as a lowpass or a bandpass filter.

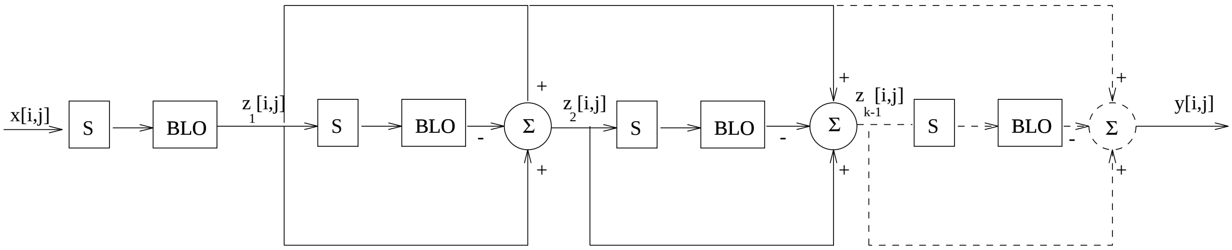

Figure 1: The Iterative Error Recovery Technique.

2.2. The Non-linear Technique

The Non-linear technique achieves similar SNRs to the iterative technique by the application of a single-step, nonlinear operation to the corrupted signal [9]. This technique analyzes the spectral content of the lowpass version of the corrupted image and the lowpass version of the nonuniform sampling image. The nonuniform sampling image is composed of unit impulses, $\delta[i-i_m, j-j_m]$, at the good pixel locations, $[i_m, j_m]$. A block diagram of the non-linear technique is shown in Fig. 2.

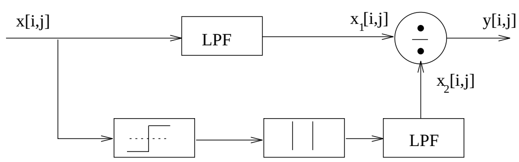

Figure 2: The Non-linear Error Recovery Technique.

3. THE ERROR CONCEALMENT ALGORITHM

The above recovery techniques can not be used directly to recover the lost blocks in the corrupted image since they are not suitable to recover bursts of errors. By converting the image to its equivalent subimages using the Subimage Decomposition technique mentioned in the next subsection, the above iterative and non-linear techniques can be used to conceal the errors in the decomposed subimages and hence to recover the original image.

3.1. Subimage Decomposition

In order to apply the above iterative and non-linear techniques, we decompose the image into DCT subimages with equal resolutions. After obtaining the 8×8 DCT transform of the original corrupted image, the resulting DCT coefficients of each block are grouped together to form 64 subimages. The DC coefficients of all the blocks are grouped together to form the first subimage, then the first AC coefficient (AC1) of each block is used to form the second subimage and so on. For all the formed subimages, the relative spatial location of each DCT coefficient in the original image is preserved in these subimages. Decomposing an $N \times N$ image using an 8×8 DCT transform results into a set of 64 ,$\frac{N}{8} \times \frac{N}{8}$, subimages. A general block diagram of the proposed algorithm is shown in Fig. 4.

3.2. The Iterative/Non-linear Hybrid Technique

In this technique, both the Iterative and the Nonlinear techniques are combined together to yield a hybrid technique to recover the errors in the decomposed subimages. The block diagram of the hybrid technique consists basically of the iterative technique block diagram with the bandlimiting operator (BLO) replaced by the Nonlinear technique. Fig. 3 presents a single iteration of the Iterative/Non-linear Hybrid technique. The efficiency of the Nonlinear block in the hybrid technique can be improved by filtering the intermediate subimages before being fed to the Nonlinear block.

After concealing the errors in each subimage individually, the recovered subimages are recombined and then inverse-DCT transformed to yield the recovered image. For the results presented in this paper, we ran all the experiments for 25 iterations and we used the first 6 subimages (the DC subimage and the first five AC subimages) in the recovery process since most of the energy is concentrated in these subimages. The Iterative/Non-linear Hybrid technique is supposed to converge faster than the simple iterative technique since for each iteration we get a better approximation

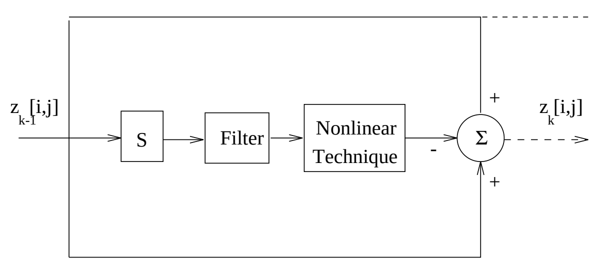

Figure 3: A single iteration of the Hybrid Technique.

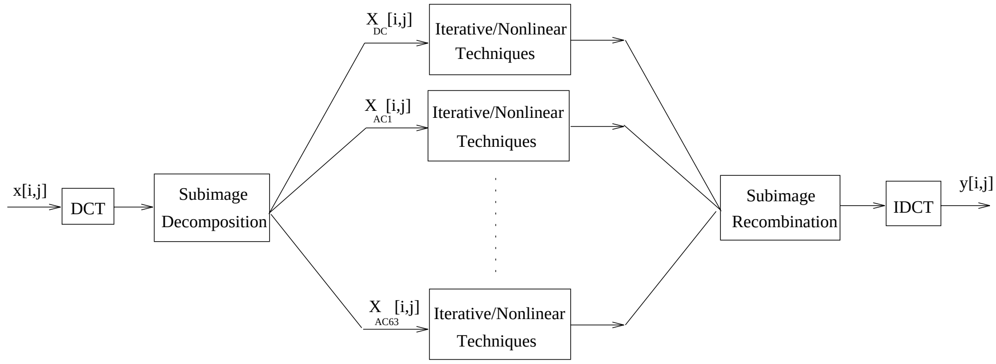

Figure 4: A general block diagram of the subimage error concealment technique.

of the missing samples due to the sophisticated bandlimiting operator used.

3.3. The Cascaded Non-linear/Iterative Technique

In this technique, the decomposed subimages are processed by the Nonlinear technique as the first stage and then they are passed to the Iterative technique. A basic block diagram of the Cascaded Non-linear/Iterative technique is presented in Fig. 5. This technique pro-

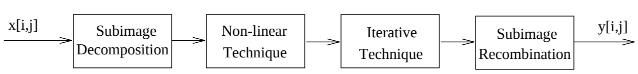

Figure 5: The Cascaded Non-linear/Iterative Technique.

vides subimages with better quality at the first stage and hence should converge faster than the basic Iterative technique to the desired image quality.

3.4. The Iterative with Initial Guess Technique

Another way to improve the performance of the basic iterative technique is to provide the iteration stages with an intelligent guess of the missing samples to start with. This can be done by replacing the first iteration of the classical iterative technique with either an Averaging or a Non-linear block. The output of the first stage (averaged or non-linearly processed) should form a good guess for the succeeding iterations and hence should improve the performance of the whole iterative technique. The block diagram in the Fig. 6 shows how this variation works.

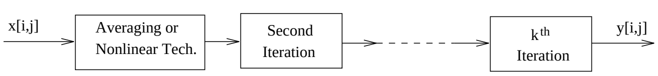

Figure 6: The Iterative with Initial Guess technique.

4. EXPERIMENTAL RESULTS AND PERFORMANCE COMPARISONS

In this section, we report the results obtained by running the proposed techniques to recover the errors encountered in the standard Lenna JPEG-coded image. All the results are reported for 256×256 Lenna image coded using the standard JPEG algorithm. To simulate the loss incurred in this image when transmitted via an ATM network, we consider the whole ATM network as a discrete channel since we are dealing with losses of discrete cells rather than losses in continuous waveforms. We assume that the cell loss pattern in the ATM environment follows Gilbert Model which is a Two-state Markov Chain [1].

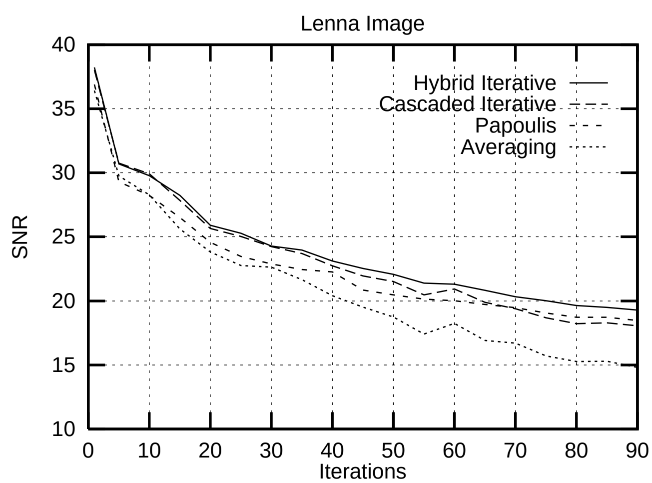

Figure 7: SNR vs. Loss % for the Cascaded and Hybrid Iterative Techniques - 25 iterations.

By varying the Cell Loss percentage from 1% to 90% for Lenna image, the SNR of the recovered image decreases with the increase in the percentage of cell loss as seen from figures 7 and 8. The performance of the Iterative/Non-linear Hybrid technique is better than that of the Cascaded Non-linear/Iterative technique as seen from Fig. 7. At high cell loss percentages, the image quality obtained by the Iterative/Non-linear Hybrid technique offsets the one obtained by the classical Averaging technique by 4.5 dB which is a huge improvement in the image quality. Compared to the Averaging technique, the Iterative/Non-linear Hybrid, the Cascaded Non-linear/Iterative and Papoulis-Gerchberg [10, 11] techniques maintain better SNR measures for high cell loss rates. For the Iterative with initial guess

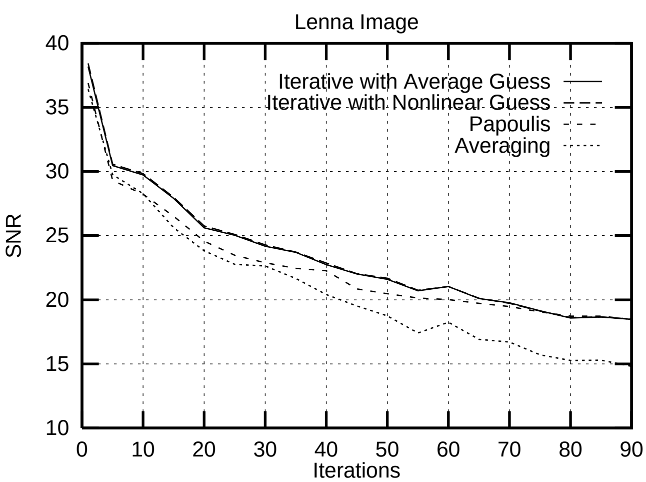

Figure 8: SNR vs. Loss % for the Iterative with Initial Guess Techniques - 25 iterations.

technique, it can be seen from Fig. 8 that both the nonlinear and the average guesses give almost the same recovered image quality. The Iterative with initial guess technique yields comparable image quality to the Cascaded Non-linear/Iterative technique.

4.1. Comparison with the Classical Methods

From the above discussion, it is apparent that all the proposed techniques give better SNR performance than the classical techniques such as Papoulis-Gerchberg and the Averaging techniques. The Iterative/Non-linear Hybrid technique, which can be considered as the best among the other techniques presented, gives an average SNR improvement of about 2 dB over the performance of Papoulis-Gerchberg technique and 4 dB over that of the Averaging technique.

5. CONCLUSION

Subimage error recovery techniques were presented and tested in this paper to conceal the errors in an error-prone environment. These techniques rely on the idea of decomposing the corrupted image into subimages which can be considered as images with missing samples. All these techniques give better SNR performance than the classical techniques even for very high rates of cell loss. These techniques are suitable for any error-prone environment such as the ATM and the wireless ATM environments where a high percentage of cells is expected to be lost.

6. REFERENCES

[1] Huifang Sun, Wilson Kwok, “Concealment of Damaged Block Transform Coded Images Using Projections onto Convex Sets”, IEEE Transactions on Image Processing, vol. 4, no. 4, April 1995.

[2] Wai-Man Lam, Amy R. Reibman, “An Error Concealment Algorithm for Images Subject to Channel Errors”, in IEEE Transactions on Image Processing, vol. 4, no. 5, May 1995.

[3] Mohammed Ghanbari and Vassilis Seferidis, “Cell-Loss Concealment in ATM Video Codecs”, in IEEE Transactions on Circuits and Systems for Video Technology, vol. 3, no. 3, June 1993.

[4] Y. Wang and V. Ramamoorthy, “Image reconstruction from partial subband images and its application in packet video transmission”, in Signal Processing: Image Commun., vol. 3, pp. 197-229, June 1991.

[5] Sheila S. Hemami and Robert M. Gray, “Subband-Coded Image Reconstruction for Lossy Packet Networks”, in IEEE Transactions on Image Processing, vol. 6, no. 4, April 1997.

[6] F. Marvasti, Mostafa Analoui and Mohsen Gamshadzahi, “Recovery of Signals from Nonuniform Samples Using Iterative Methods”, in IEEE Transactions on Signal Processing, vol. 39, no. 4, April 1991.

[7] F. Marvasti, Peter M. Clarkson, V. Dokic, U. Goenchanart and Chuande Liu, “Reconstruction of Speech Sigals with Lost Samples”, in IEEE Transactions on Signal Processing, vol. 40, no. 12, December 1992.

[8] F. Marvasti, “Spectral Analysis of Random Sampling and Error Free Recovery by an Iterative Method”, in IECE Transactions of Japan, vol. E 69, no. 2, February 1986.

[9] F. Marvasti, Chuande Liu and Gil Adams, “Analysis and recovery of multidimensional signals from irregular samples using nonlinear and iterative techniques”, in Signal Processing 36, Elsevier, pp. 13-30, 1994.

[10] A. Papoulis, “A New Algorithm in Spectral Analysis and Bandlimited Extrapolation”, in IEEE Transactions on Circuits and Systems, vol. CAS-22, no. 9, September 1975.

[11] R. Gerchberg, “Super Resolution through Error Energy Reduction”, in Optica Acta, vol. 21, no. 9, pp. 709-720, 1974.