

VIDEO CODING USING 3-D SUBBAND DECOMPOSITION FOR CHANNEL ERROR COMPENSATION ON AN ATM NETWORK

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ABSTRACT

To transmit a video signal over the broadband networks, the first step is to compress the video stream in order to reduce the bit rate. However, the lossy nature of the broadband networks will degrade the quality of loss sensitive applications as compressed video signal. In this paper, a video subband coding system is discussed, which allows us to compensate the information losses due to packet loss. This subband coding system treats the video over its three dimensions. one in time and two others in spatial. For the two spatial dimensions, the non-separable filter bank is used which provides the better performances. A main principle idea in this coding system is that several channels with different priorities are offered. This novel scheme propose to transmit the video signal over the network with different levels of protection. So, even the packet loss occurs in the network, the most important part of information will be transmitted over a very protected channel and the rest of information which allows us just to increase the quality is sent over a normal channel. The simulation results prove the 3-D subband coding performance which is compared to the conventional coding system as MPEG in the same circumstances.

1. INTRODUCTION

The Broadband Integrated Services Digital Network (B-ISDN) is expected to become the prime multi-media broadband network. An Asynchronous Transfer Mode (ATM) network is attracting the attention of researchers as a solution to integrate B-ISDN services and since the ATM network provides a high degree of flexibility at the user-network interface, video signal will probably be the dominant traffic through such networks. To transmit video signals, multiple encodings and decodings of signals, without any visible degradation is required. The video signal transmission requires the robust channels with $10^{-6} \leq$ bit error rate probability (BERP) $\leq 10^{-9}$ and a packet loss ratio (PLR)

$\leq 10^{-8}$ in the case of cell-structured transmission such as ATM network. Transmitting video signals over digital networks requires sophisticated compression techniques in order to limit bit-rate requirements and to provide high-quality. Procedures for dealing with transmission or switching errors and lost packets will play an important role in these networks [1].

In general, in an ATM network the causes of packet loss are transmission burst errors; loss of cells and packets due to multiplexing overload; misrouting due to inaccurate addresses or entries in address tables, and delay above the acceptable threshold. Undetected loss in a signal can place encoders and decoders out of phase. In either case the result is loss of data in units of packets, and occasionally a burst of packet losses will occur. This results in a serious degradation of the quality of service, which is not acceptable for video signals either at variable and or constant bit rates.

This paper first describes the three dimensional filter bank approach. Next, it proposes the appropriate coding scheme for each of the frequency branch of the signal and in the end the results provided by the simulation will be presented and compared with these of MPEG coding system.

2. 3-D SUBBAND CODING

A natural approach to protecting the packets is to ensure an appropriate level of quality for each service class by assigning some sort of priority to packets. The actual prioritization of signals can be accomplished by subband coding technology. Subband coding for packet video systems refers to compression methods that divide the signal into multiple bands to take advantage of a bias in the frequency spectrum of the video signal.

As figure 1 depicts the 3-D subband coding system consists of three parts: a filter bank section which is a combination of analysis/synthesis filters and up-sampling/down-sampling, the encoding/decoding section and the transmission section which is an ATM

network environment.

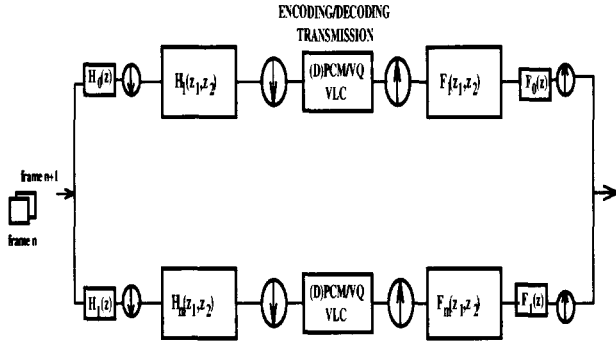


Figure 1: The global scheme of 3-D subband coding system, where l and m indicate the frequency branch position for each subband image, $1 \leq (l, m) \leq 8$.

2.1. Design of 3-D filter bank

The video signal is partitioned into multiple bands by a filter bank which should guarantees a perfect reconstruction. This partitioning takes into account the statistical and visual significance of each band. Each subband image is decimated to reduce as much as possible the bit rate of the signal and then the decimated subband images are individually coded for transmission over the channels of the ATM network. In the receiver, the coded subband images are decoded, interpolated, and recombined for reconstruction the video signal.

Since video is a 3D signal, the video codec is based on a three dimensional subband decomposition, one dimension in the time and two others in spatial dimensions, thus the analysis part of 3D filter bank has a structure as:

$$H(z_t, z_h, z_v) = H_t(z) \otimes H_{h,v}(z_1, z_2)$$

in which $H_t(z)$ is the temporal transfer function and $H_{h,v}(z_1, z_2)$ represents the horizontal and vertical non-separable transfer function in spatial dimensions.

The processing of video sequences in time dimension is different as those of spatial dimensions. Filtering the frames along the temporal axis allows us to exploit the vast amount of redundancy in the time. Since long filters will smear motion in the lowpass channel and create artificial high frequencies in the highpass channel. We use the very short filters in time dimension which also allow us to reduce the number of frames to be buffered and consequently the reduction of the delay. For this purpose, the Haar filters which are considered to have the ideal low-pass and high-pass filters are the best candidates in this application and they are defined as:

$$H_t(z) = \begin{cases} H_0(z) & = \frac{1+z^{-1}}{\sqrt{2}} \\ H_1(z) & = \frac{1-z^{-1}}{\sqrt{2}} \end{cases}$$

where $H_0(z)$ and $H_1(z)$ are respectively the low pass and high pass filters.

In order to achieve a perfect reconstruction on temporal filter bank, the synthesis filters are designed as the mirror of the analysis filters in frequency domain, so:

$$F_0(z) = H_1(-z), F_1(z) = -H_0(-z)$$

Reduction of the redundancy in the spatial dimensions is achieved by using a two dimensional paraunitary filter banks which guarantees a perfect reconstruction by alias cancelation and the linear phase requirement [2, 3]. The condition of the paraunitary system is defined as:

$$H_{h,v}(z_1^{-1}, z_2^{-1})^T H_{h,v}(z_1, z_2) = I$$

where this expression is based on $H_{h,v}(z_1^{\lambda 00}, z_1^{\lambda 01} z_2^{\lambda 11})$. For the sub-sampling step in the spatial filter bank, we have used a non-separable lattice [4]. The $\lambda 00$, $\lambda 01$ and $\lambda 11$ are the elements of the sub-sampling hexagonal lattice:

$$\Lambda = \begin{pmatrix} \lambda 00 & \lambda 01 \\ \lambda 10 & \lambda 11 \end{pmatrix} = \begin{pmatrix} 2 & 1 \\ 0 & 2 \end{pmatrix}$$

In some applications such as video compression, a problem arising with separable sampling structures is that just rectangular divisions of the spectrum can be obtained. As a result, some of the subbands obtained contain mixed orientations. A possible remedy which we have chosen, is to consider the hexagonal sub-sampling lattice which produces subbands with pure directional orientation.

2.2. Coding

After the analysis filter banks we find that, most of the energy is concentrated in the subband which goes through lowpass filtering in temporal and spatial dimensions and all other subbands containing the contour information which intervene only to ameliorate the quality. Thus, in view of this fact it is suitable to code this lowest frequency subband which has a high degree of spatial correlation and also to minimize the bit rate, by the Differential Pulse Code Modulation(DPCM) technique. Consequently, the other subband signals show little correlation among pixels, they are encoded using PCM technique.

To further reduce the information bit-rate, arithmetic coding [5] is applied to the quantized sub-band signals. In the receiver, the signal will be reconstructed after passing through the decoder, up-sampling and synthesis filter banks stages.

In the transmission section in an ATM network, since the important energy is conserved in the first subband signal, it is sent over the network with better protection against packet loss. If ever the packet loss should occur in the network, this subband signal

allows us to recover those parts of the image that have been damaged during the transmission over the network.

3. SIMULATION AND RESULTS

We assume that the forward channel is a random error channel. The different types of situations according to channel bit error probability are used to show their impacts on image quality. Image quality evaluation in term of the SNR is carried out for a video signal ('Tennis Table' sequence) in which the MPEG-2 [6] and the proposed scheme are used. In MPEG-2 case, it is considered that there is not any service classes and the packet loss is applied in the same circumstance for the lower and higher priority packets. The figures 2,3 and 4 shows the performances of these codecs for $BERP = 10^{-3}$, 10^{-5} and 10^{-8} . In the case of MPEG-2 coding system, the simulations indicate that it is not evident to obtain a good picture quality for channel BERP greater than 10^{-3} . Below this range of bit error rate, MPEG-2 performance degradation is indicative. In this situations, the decoded video signal contains the empty blocks that corresponds to the lost packets.

Analysis results are compared with the MPEG-2 codec showing that the quality of the picture (SNR) is much better than the MPEG system coding under the same circumstance ($10^{-3} \leq BERP \leq 10^{-8}$). The computing complexity is reduced as compared with classical method (MPEG-2) because we do not apply any motion compensation, DCT or motion estimation algorithm in the coding system. With an MPEG-2 codec, when BER goes beyond 10^{-5} , the important informations in the packets are discarded without regard to the content. The MPEG-2 replaces the discarded data with decoded data from the previous block, when the DC component has been lost from DCT block. Or, the lost informations are replaced with "0" when only block quantization data has been lost. In our codec, packets containing the high priority data have been preserved and the entire discard rate is absorbed by the low priority data which are the contour information of image. In this case, the SNR has been lowered by the packet loss, but because vital data has been preserved, degradation occurs only gradually and does not appear in obvious blocks. An original frame and its reconstructed frame at $BERP = 10^{-5}$ of the video sequence are shown on figures 5 and 6.

It is true that the SNR could be a good measure to express the quality of an image but to judge the quality between two images this kind of measurement is not sufficient. For example, in Figures 2,3 and 4 our coding system offer some degree of dB comparing to MPEG-2 but by visualising the video sequences we find that when the bit error rate goes up there is not any empty blocks to mask the scene, in contrary to MPEG-2 coding system.

4. CONCLUSION

In this paper, we have presented the simulation of a video signal codec for transmission over ATM using the 3-D subband coding system which is of importance for improving network quality and security.

The coder was applied on the "Tennis Table" sequence without using error control codes. It has been shown in simulation experiments, that this system offers some improvements compared the classical methods especially in the range of $10^{-3} \leq BER \leq 10^{-8}$.

5. REFERENCES

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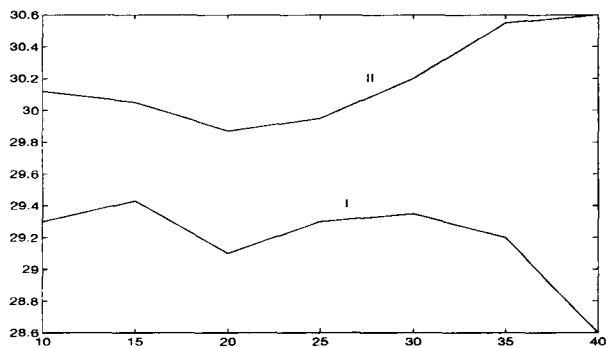


Figure 2: SNR vs. frame number at $BERP = 10^{-3}$, I. 3-D subband coding scheme and II. MPEG-2 coding scheme

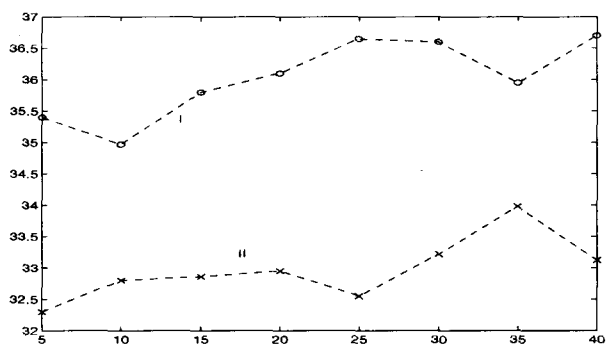


Figure 3: SNR vs. frame number at $BERP = 10^{-5}$, I. MPEG-2 coding scheme and II. 3-D subband coding scheme

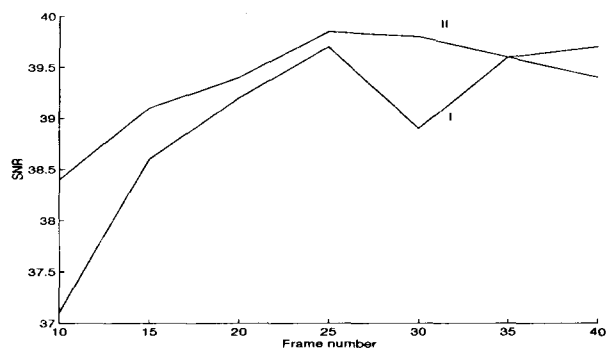


Figure 4: SNR vs. frame number at $BERP = 10^{-8}$, I. MPEG-2 coding scheme and II. 3-D subband coding scheme

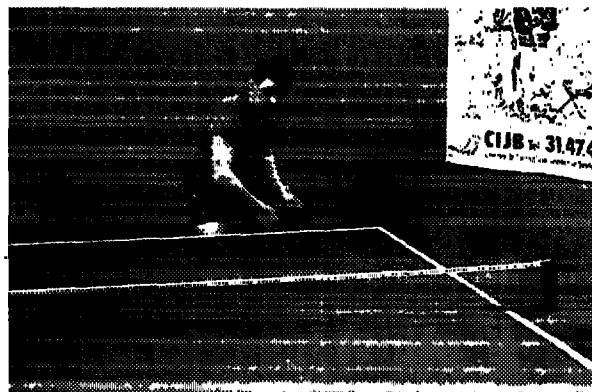


Figure 5: An original frame

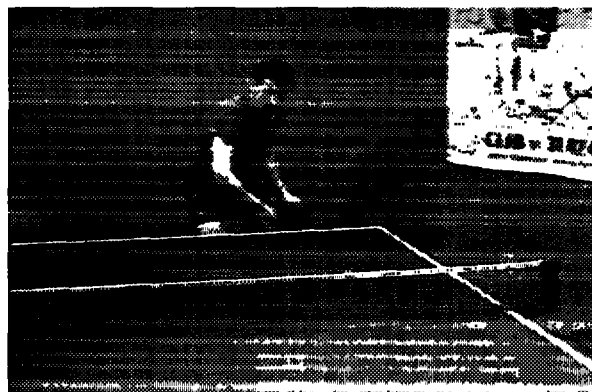


Figure 6: A reconstructed frame at $BERP = 10^{-5}$.