TUAM 2.5

AN IMAGE COMPRESSION SCHEME FOR DIGITAL VIDEO CASSETTE RECORDING*

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ABSTRACT

A source coding algorithm based on MPEG-1 standard is proposed for home-use digital VCR. By combining forward analysis with table look-up implementation, we can maintain a constant bit rate of every IBP unit and provide a nearly uniform perceptual quality across a video sequence. Furthermore, in order to update each segment of a picture frame contiguously, a new data shuffling method for variable speed playback is also investigated in this paper.

Introduction

Several bit rate reduction technique has been proposed for home-use digital VCRs[1-3]. In the foreseeable future, the data rate produced by DVCR is incapable of delivering plain digital video without heavy compression. Note that the bit rate reduction technique for DVCR should support functions not found in other applications. The variable speed playback capability is the most important and difficult problem. Besides, under limitations of the sequential access and the constant tape track capacity, the output bits of DVCR should also be controlled more precisely than the other video system. In our proposed algorithm, every three I-frame, B-frame and P-frame are coded as a single unit. The bit allocation algorithm that combines forward analysis with table look-up implementation is used for maintaining a constant bit rate of a three-frame group. The coded bit stream is partitioned into IDC portion and DDC portion[5]. Each IDC data segment is placed on the tape following a regular pattern. This carefully designed tape format enables us to use interframe coding schemes, which are more effective than the intraframe coding methods suggested by many conventional DVCR proposals.

Image compression system

MPEG-like coding method

The modified algorithm is based on the coding methodology of MPEG-1 standard. We choose the sequential order of IBPIBP...IBP for digital video tape recording. Interframe coding removes temporal redundancy quite effectively. The prediction errors and intraframe pixels are highly spatial redundant. Hence, 8x8 DCT is applied to reduce spatial redundancy. The DCT coefficients are quantized to further reduce data rate. Quantized coefficients are partitioned into two groups. The DC and low frequency coefficients of I-frames form one group called IDC portion. The other group includes the high frequency coefficients of I-frames and all the coefficients of B-frames and P-frames called DDC portion.The block diagram of the overall system is shown in Fig.1. IDC and DDC can be regarded as two coding layers. In normal speed playback, IDC and DDC provide the full resolution pictures. In high speed playback, only IDC data are decoded for lower spatial and temporal resolution pictures.

Rate-constrained bit allocation

From the experimental and statistical analysis, we propose a rate-constrained bit allocation algorithm for DVCR. First, a picture frame is divided into several segments because each segment with different complexity will be coded using different number of bits. The activity function is defined as the sum of absolute value of AC coefficients in a segment to measure the complexity. Second, to make effective use of bits, certain human visual characteristics is also taken into consideration. Accordingly, we assign the bits to each frame as follows:

$$BITS_I+BITS_B+BITS_P= RATE/10 \quad (1a)$$

$$BITS_I:BITS_B:BITS_P = ACT_I:ACT_B:ACT_P. \quad (1b)$$

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Then the number of bits of each segment is decided by Eq.(2a) and (2b):

$$BITS_{S0}+BITS_{S1}+\cdots\cdots = BITS_{I,B,P} \quad (2a)$$

$$BITS_{S0}:BITS_{S1}:\cdots=\log(ACT_{S0}):\log ACT_{S1}):\cdots(2b)$$

where S_i is the i-th segment of the frame. The log operation in Eq.(2b) would make the entire picture have a more uniform quality. Third, search the statistical table and select the proper quantization stepsize for each segment. Our experiments show that the relation between coded bits and activity is approximately linear for fixed quantization stepsize. The statistical table records these linear relations for every available quantization stepsize. Thus, when the number of bits of each segment is decided, the table look-up method is used to select the stepsize that produces the closest amount of the estimated bits.

Recording sequence format

The coded bit stream is allocated on the tracks using the location map in Fig.2. The IDC part is located at the bottom and the DDC part is placed in the remaining portion of the track. We systematically shuffle the recording sequence of the segments. As shown in Fig.2, the IDC part of S_1 and S_2 are not used for fast-forward $FRAME_{i-1}$, but they are reconstructed in $FRAME_i$ and $FRAME_{i+1}$ respectively. Not only this proposed format will make the synchronization mechanism been designed easily for variable speed playback, but also it incorporates the human visual masking effect.

Simulation and conclusions

We propose a video source coding scheme and a data allocation method that are suitable for digital VCR applications. This coding scheme has the advantage of high compression efficiency because of the use of interpolative coding schemes. Computer simulations show that the image compression algorithm and the data allocation scheme produce a quite good overall performance. Under the good control of bit rates, this system not only provides the uniform picture quality in normal speed playback, but also it offers acceptable quality in high speed playback.

References

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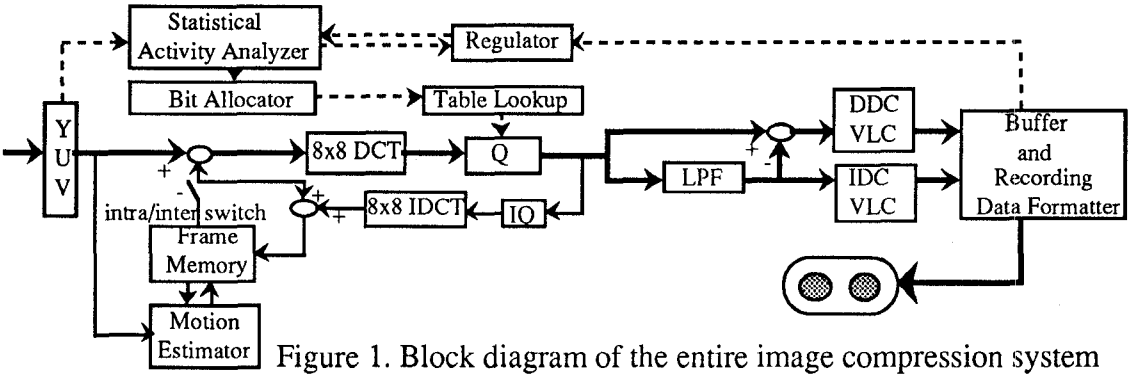

Figure 1. Block diagram of the entire image compression system

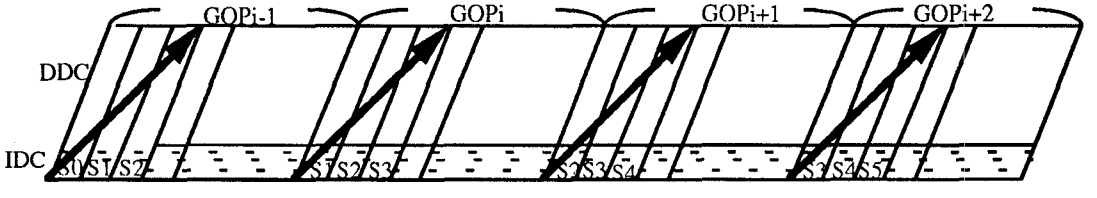

Figure 2. Data arrangement of the tape