COLOR VIDEO COMPRESSION BASED ON CHROMINANCE VECTOR QUANTIZATION

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Abstract: *This paper proposes a compression technique to improve the quality of color in very low bit rate coding of video. The general idea is to convert the two chrominance components to one scalar chrominance which is processed further. The scalar representation of chrominance is obtained through vector quantization in the chrominance plane. Each (C_B, C_R) vector is represented by a scalar index to a chrominance codebook. Experimental results show that coding of this scalar signal improves visual quality of frames both in intraframe and interframe modes as compared to standard codecs.*

1. INTRODUCTION

In very low bit rate coding of video, motion compensated hybrid coding is commonly applied. H.263 [1] and MPEG-4 [2] standard codecs operate in switched *intraframe/ interframe* mode using a DCT–based scheme to encode directly the frame content or the prediction error, respectively. High compression required for very low bit rate channels is usually achieved by processing of video sequences with spatio–temporal resolution being strongly reduced as well as by very lossy coding with most bits being allocated to the luminance component which results in poor quality of color in the reconstructed images, not reflected by the PSNR.

The proposed coding scheme (cf Figs. 1 and 6) involves replacing the standard coding path of both chrominance components by coding of scalar representation of chrominance [4]. Such representation is obtained through vector quantization using adaptively designed chrominance codebook [3]. The scalar representation of chrominance is a signal formed from scalar indices to the codebook. As shall be demonstrated, lossy compression is applicable to such signal and offers a significant coding gain. The main assumption here is to retain the basic structure of the typical hybrid coding scheme, moreover to interfere into the existing structure of existing standard codecs as little as possible.

2. CHROMINANCE VECTOR QUANTIZATION OF VIDEO SEQUENCES

Vector quantization of chrominance consists of two steps. At first, some set of chrominance pairs is chosen to form the chrominance codebook. Then, each chrominance from the input picture is substituted by its nearest neighbor from the codebook. The codebook is automatically designed for a frame. A unique number labels each chrominance pair in the codebook, and an order in

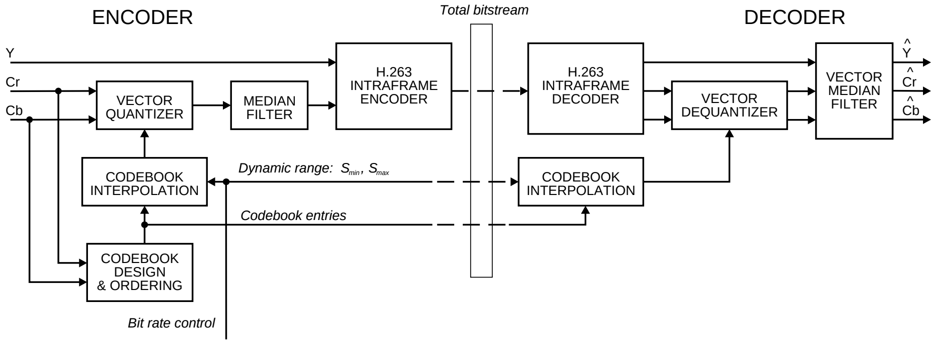

Figure 1: Proposed modification of the *intraframe* mode of the hybrid DCT-based codec with chrominance vector quantization.

its entries is defined in this way (cf Figs 2, 3). A stream of such labels (cf Fig. 4) constitutes the scalar chrominance.

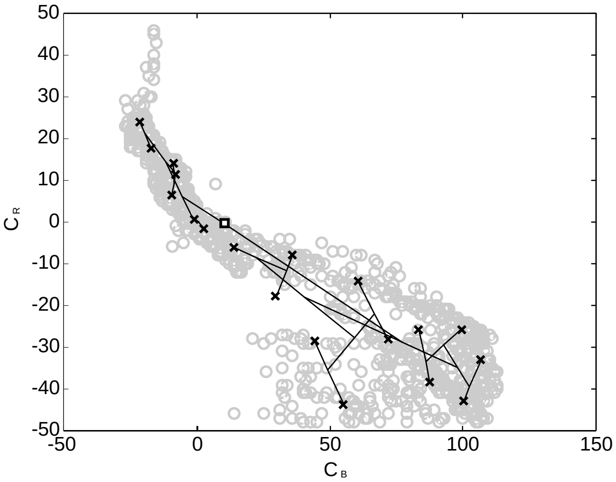

Figure 2: Tree structured codebook design process shown on the background of chrominance data of the test sequence AKIYO.

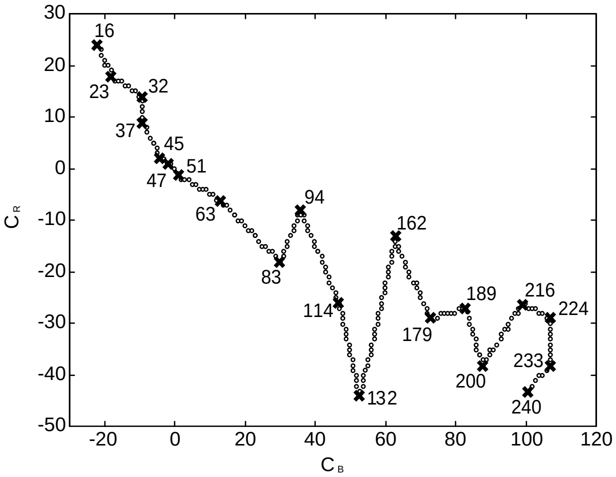

Figure 3: Initial codebook obtained for AKIYO sequence (×) with the assigned label values shown, and the codebook resulted from insertion of interpolated entries (○).

In order to achieve high coding efficiency and make the codebook ordering easy, its size should be as small as possible. On the other hand, a desired level of quality requires some minimum number of codebook entries. Experimental results show that the chrominance of a typical video frame can be quantized to very few representatives (15-30 chrominance pairs) [4]. A technique based on binary splitting is proposed for efficient codebook design (cf Fig. 2). A technique for codebook ordering has been developed in order to achieve the scalar chrominance representation as smooth and low–frequent as possible (cf Fig. 4).

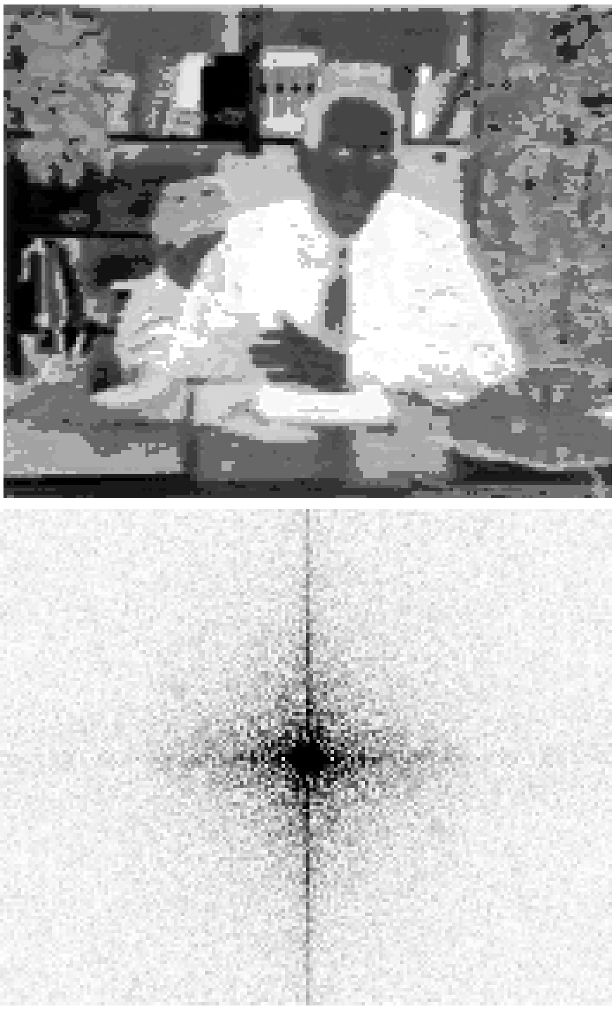

Figure 4: Scalar chrominance signal obtained with a codebook of size 30 for the test sequence SALESMAN (upper image) and its power spectra (below).

In order to obtain finer quantization without unreasonable increase of the side information, which is necessary to transmit the codebook to the decoder, an interpolation scheme is applied that inserts additional codebook entries between those entries which have been initially chosen (cf Fig. 3). The same interpolation procedure is repeated at the decoder side.

In fact, it is not reasonable to design a new chrominance codebook for each frame, since the statistical distribution of chrominance data in videophone sequences changes between consecutive frames only slightly [4]. A codebook which has been designed for the first frame may be sustained through several frames. In practice, the chrominance codebook is determined for each *intraframe* encoded picture. It can be demonstrated, that even in case of video sequences with significant amount of motion the quantization error related to application of this codebook to following frames is almost constant.

3. INTRAFRAME CODING OF SCALAR CHROMINANCE

The requirements for high coding efficiency make *intraframe* mode the most demanding one. For example, H.263 very low bit rates coder operating with default quantization parameters allocates 150–200 bits to an average luminance macroblock and only 10–20 bits to a corresponding C_B or C_R block. By application of vector quantization of chrominance, the same 20–40 bits are available for an average block of scalar chrominance signal.

A compression scheme very similar to the H.263 standard is proposed. The image of scalar chrominance is split into blocks, DCT coefficients are calculated, quantized and further encoded. A nonuniform quantization scheme is applied to the DCT coefficients in such a way that most bits are allocated to low frequency coefficients. Due to very low dynamic range of the DCT coefficients, precise control over quantization is difficult, therefore the quantization factor is fixed instead. In order to achieve the target bit rate, the dynamic range of the scalar chrominance is appropriately scaled.

Fig. 5 shows a comparison of the proposed technique with 20 codebook entries and dynamic range of the scalar chrominance varying from 20 to 200 to a codec complaint with the H.263 standard which is used to encode the YC_BC_R components.

4. INTERFRAME CODING

The objective of *interframe* coding is to update the content of reconstructed frames according to changes observed between consecutive frames at the input of the encoder. The prediction error is encoded by DCT–based transform coding. Unfortunately, in the standard H.263 and MPEG-4 coders, strong colorful artifacts result from propagation of quantization error within motion compensation loop.

Application of chrominance vector quantization is therefore proposed to interframe coding (cf Fig. 6). Whereas motion is estimated on the basis of the luminance component alone, so it is not affected by chrominance processing, motion compensation is applied directly to the scalar chrominance. Moreover, the prediction error is also calculated in the domain of scalar chrominance and subsequently lossy encoded. Experiments show that due to the chrominance codebook being constant over number of frames, similarly colored pixels within static portions of the scene are represented by the same value of the scalar chrominance signal. Therefore the frame prediction error exhibits large “flat” zero–valued areas, corresponding to static background. Application of chrominance vector quantization restricts the output set of colors to the colors present in the original image, therefore the probability of “alien color” effect is strongly reduced.

Experimental results show, that interframe compression of scalar chrominance is very efficient even using a standard block–based transform coder with default quantization scheme and default Huffman code tables (without special optimizations).

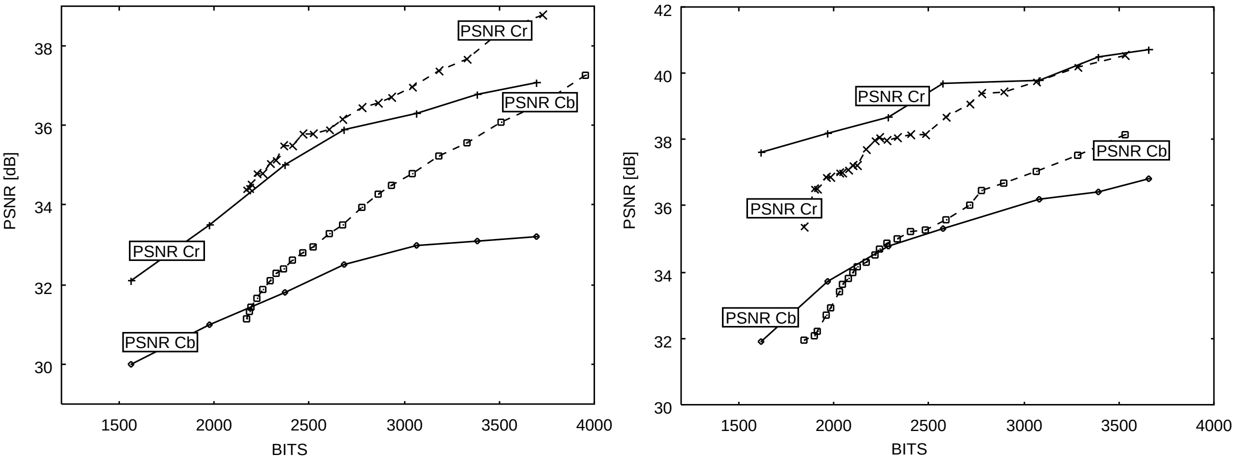

Figure 5: PSNR for the reconstructed chrominance components versus the total number of bits allocated to chrominance for the first frame from the test sequence CLAIRE (upper plot) and AKIYO (below). Dashed line: H.263 codec, solid line: DCT–based coding of scalar chrominance.

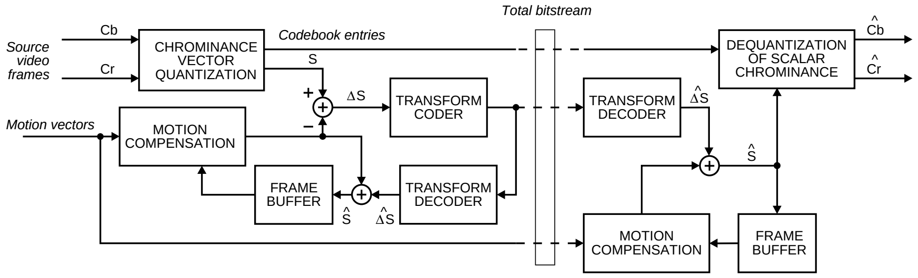

Figure 6: Proposed application of chrominance vector quantization to video coding in *interframe* mode. In this diagram, S denotes the scalar chrominance representation. The luminance path has been omitted for the sake of clarity.

5. CONCLUSIONS

Presented plots show that the PSNR ratings achieved using chrominance vector quantization are similar (*i.e.* slightly better or slightly worse, depending on case) to those of the standard H.263 technique. In general, however, the proposed compression scheme often outperforms the H.263 standard in terms of PSNR values at extremely low bit rates. On the other hand, the subjective evaluation of reconstructed frames proves that PSNR values are often inadequate. In fact, application of chrominance vector quantization to H.263 intraframe coding results in better visual quality. Particularly, the annoying color artifacts, like unnatural face coloration and abrupt hue variations in the background are visibly reduced.

6. REFERENCES

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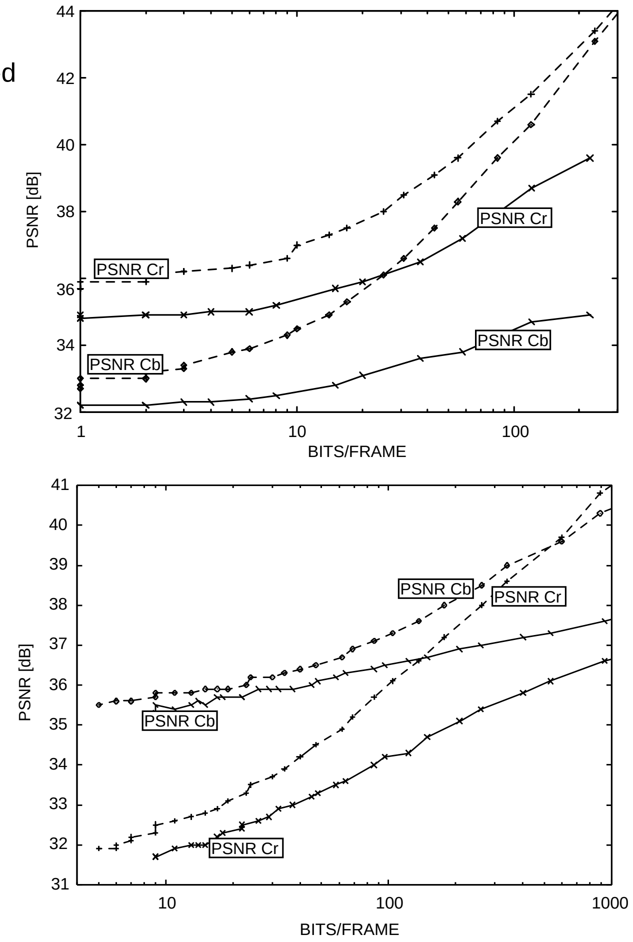

Figure 7: PSNR of the reconstructed chrominance components versus the number of bits allocated to one *inter* frame averaged over 100 frames of the video sequences AKIYO (left plot) and MISSA (right plot). Here, C_B and C_R components obtained from the standard H.263 codec (dashed line) are compared to C_B and C_R components obtained by the application of scalar chrominance (solid line).