

Applications of Chrominance Vector Quantization to Intraframe and Interframe Compression of Colour Video Sequences

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Summary

A video compression technique for applications in very low bit rate coding is presented. The technique is based on vector quantization of chrominance and compression of the image with scalar representation of chrominance. The general idea is to represent the two components of the chrominance vector (C_B, C_R) using single scalar values. Experimental results of computer simulations using standard video sequences are presented.

Keywords: Video compression, very low bit rate coding, colour, chrominance, vector quantization.

1. INTRODUCTION

In very low bit rate coding, intended for visual communications through telephone networks, which requires very low bit rate coding, motion compensated hybrid coding is commonly applied, as specified in industrial standards, namely H.261 [1], and H.263 [2]. Such codecs operate in switched *intraframe/interframe* mode using a block DCT-based scheme to encode either the frame content or the frame prediction error [3], [4], [5]. High compression is usually achieved by processing of video sequences with spatio-temporal resolution being strongly reduced as well as by very lossy coding. Typically, most of the bitstream is allocated to the luminance component which results in poor quality of colour in the reconstructed images.

The proposed coding scheme involves replacing the standard coding path of both chrominance components by coding of scalar representation of chrominance [9]. The latter is obtained through vector quantization using adaptively designed chrominance codebook [6]. The scalar representation of chrominance is a signal formed from scalar indices to a chrominance 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

Obtaining scalar representation of chrominance requires two steps. At first, some set of chrominance pairs called a codebook is chosen. Then, each chrominance pair from the input picture is substituted by its nearest neighbour 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 its entries is defined in this way. A stream of such labels constitutes the scalar chrominance [9]. Experimental results show that the way the codebook is designed and ordered deeply influences the statistical and spectral properties of resulting scalar chrominance signal, therefore special design and ordering algorithms have been developed for codebook optimization, which are discussed elsewhere [6], [7].

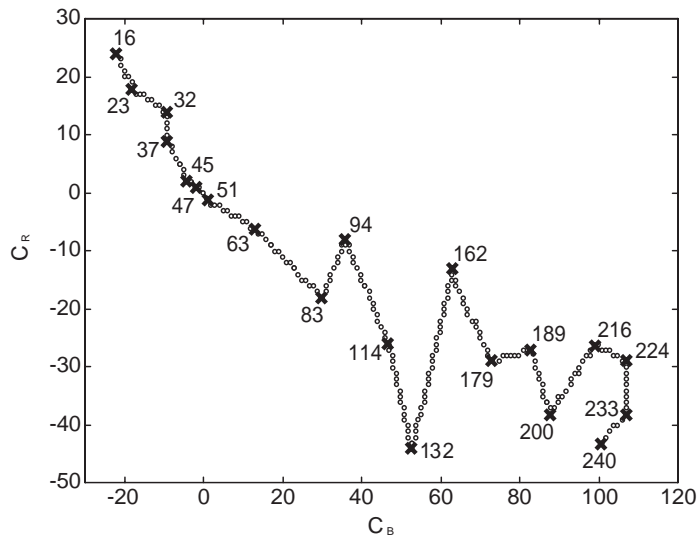


Fig. 1.: Initial codebook obtained for AKIYO sequence (\times) with the assigned label values shown, and the codebook resulted from insertion of interpolated entries (\circ).

Since transform-based coding exploits first-order and higher-order correlation between spatially neighbouring pixels, it benefits from signal smoothness. Unfortunately, quantization leads to abrupt changes in the signal value, also known as banding artifacts. On one hand, retaining the desired property of smoothness requires high number of codebook entries which generate lower quantization error and implicitly smaller the steps in the quantized signal. On the other, this number should be kept as small as possible in order to achieve high coding efficiency and also to make the codebook ordering possible and easy.

Experimental results show that the chrominance values of a typical video frame may be quantized to very few representatives (15-30 chrominance pairs) without visible degra-

ation [9]. 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 proposed. Such scheme involves inserting of additional codebook entries between those entries which have been initially chosen (cf Fig. 1.). The same interpolation procedure is repeated at the decoder side.

In fact, it is not necessary 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. Therefore, 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.

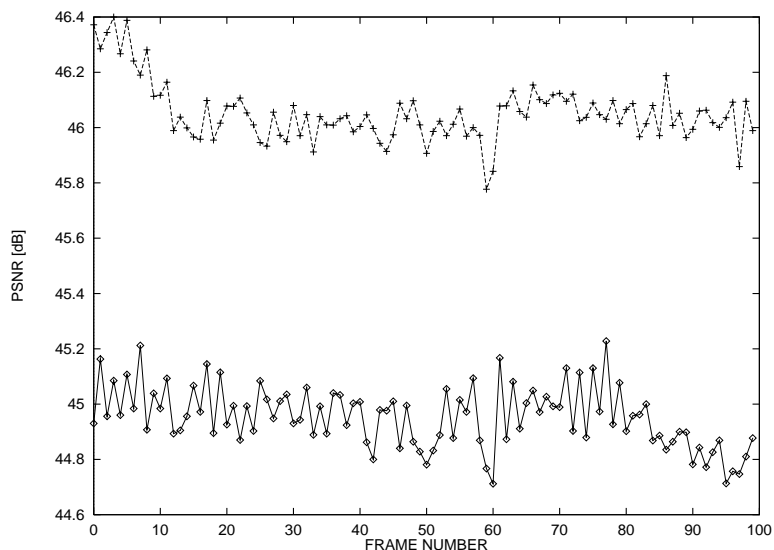


Fig. 2.: Quantization error of the chrominance components C_B (\diamond) and C_R (+) for consecutive frames from the test sequence SALESMAN. Here, a constant chrominance codebook consisting of 30 entries which has been designed for the first frame is applied to the whole sequence.

It can be demonstrated (cf Fig 2.), that even in case of video sequences of significant amount of motion the quantization error related to application of this codebook to following frames is almost constant, unless a *scene cut* occurs in the sequence.

3. INTRAFRAME CODING OF SCALAR CHROMINANCE

In video compression, 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.

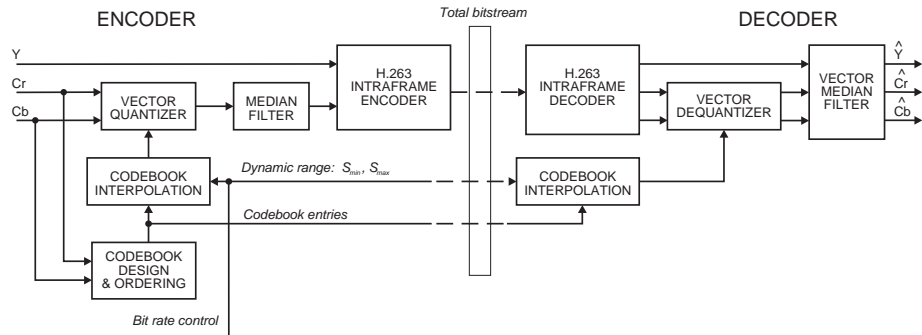


Fig. 3.: Proposed modification of the *intraframe* mode of the H.263 codec with chrominance vector quantization.

A transform–based compression scheme of the scalar chrominance representation is proposed for intraframe coding at very low bit rates (cf Fig. 3.). This scheme involves codebook design, ordering and interpolation for each *intra* frame. The image of scalar chrominance is typically split into square blocks, DCT coefficients are calculated, quantized and further encoded identically as it is implemented in the standard H.263 coder.

One of the most important difficulties in low bit rate coding is an effective way to control the bitstream [8]. Experiments show that the trade–off between compression and quality in the scalar chrominance domain is not as straightforward as in case of coding of natural colour components [6]. For the sake of simplicity, the dynamic range of the scalar chrominance is appropriately scaled, in order to achieve the target bit rate.

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 frame prediction error (the difference between the input frame and its estimate) is encoded by DCT–based transform coding. In case of standard codecs operating at very low bit rates, propagation of quantization error within motion compensation loop leads to strong colorful artifacts.

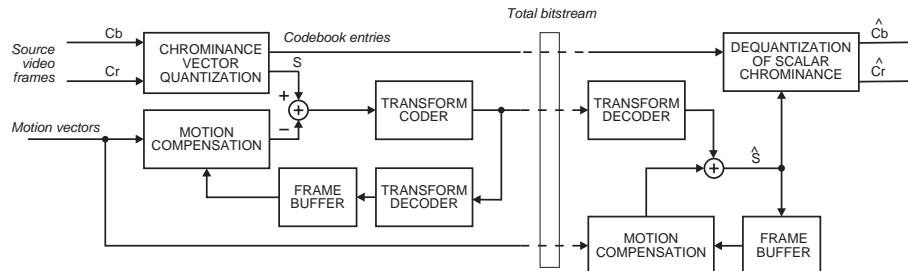


Fig. 4.: Proposed application of chrominance vector quantization to video coding in *interframe* mode. In this diagram, the luminance path has been omitted for the sake of clarity.

Therefore, chrominance vector quantization is also used in *interframe* coding (cf Fig. 4.). 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 data. 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 coloured 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”, or even zero-valued areas, corresponding to static background.

Application of chrominance vector quantization restricts the output set of colours to the colours present in the original image, thereby strongly reducing the probability of “alien colour” effect.

5. EXPERIMENTAL RESULTS AND CONCLUSIONS

The proposed compression scheme has been tested experimentally using a codec compliant with the H.263 standard with default quantization factor, 20 to 30 codebook entries and dynamic range of the scalar chrominance varying from 20 to 200. For comparison purposes, the first frames from standard video sequences in QCIF format were compressed using H.263 operating on the scalar chrominance signal as well as on the $Y C_B C_R$ components.

For fair comparison with standard coding techniques, quantization tables and Huffman codes which have been optimised for scalar chrominance should be used. Experimental results show however, 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 optimization).

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 these of the standard H.263 technique. In general, however, the proposed compression technique often outperforms the H.263 standard in terms of PSNR values at extremely low

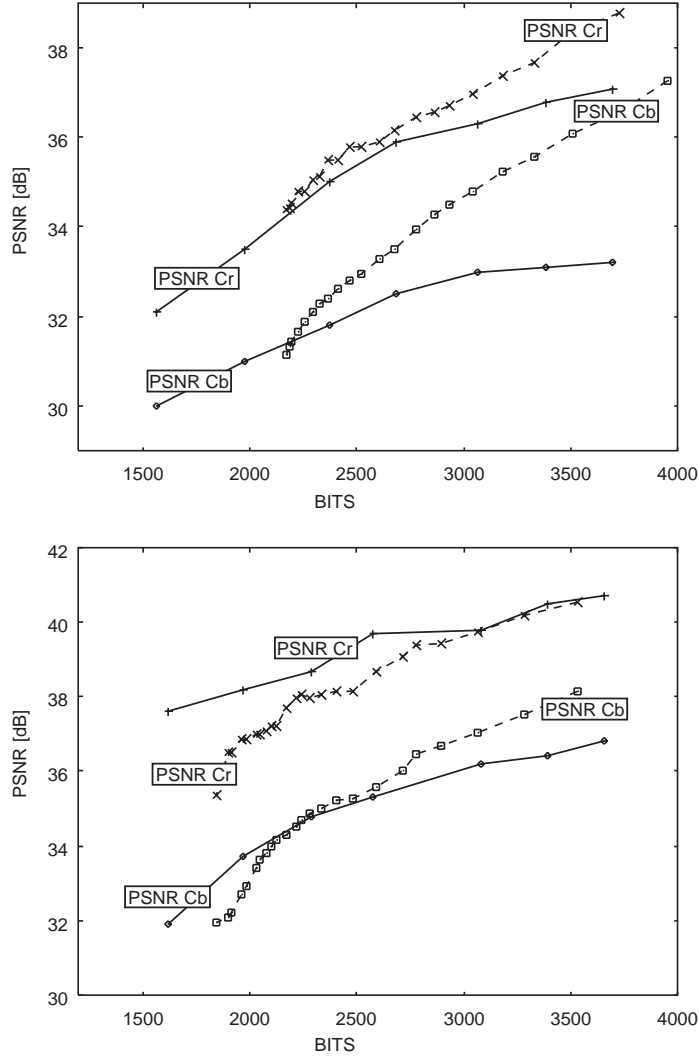


Fig. 5.: PSNR for the reconstructed chrominance components versus the total number of bits allocated to chrominance for the first frame from the test sequence CLAIRO (upper plot) and AKIYO (below). Dashed line: H.263 codec, solid line: DCT-based coding of scalar chrominance.

bit rates. The subjective evaluation of reconstructed frames proves that PSNR values are often very inadequate. In fact, application of chrominance vector quantization to H.263 intraframe and interframe coding results in better visual quality. Particularly, the annoying colour artifacts, like unnatural face coloration and abrupt hue variations which are observed in the standard coding scenario are visibly reduced by the proposed scheme.

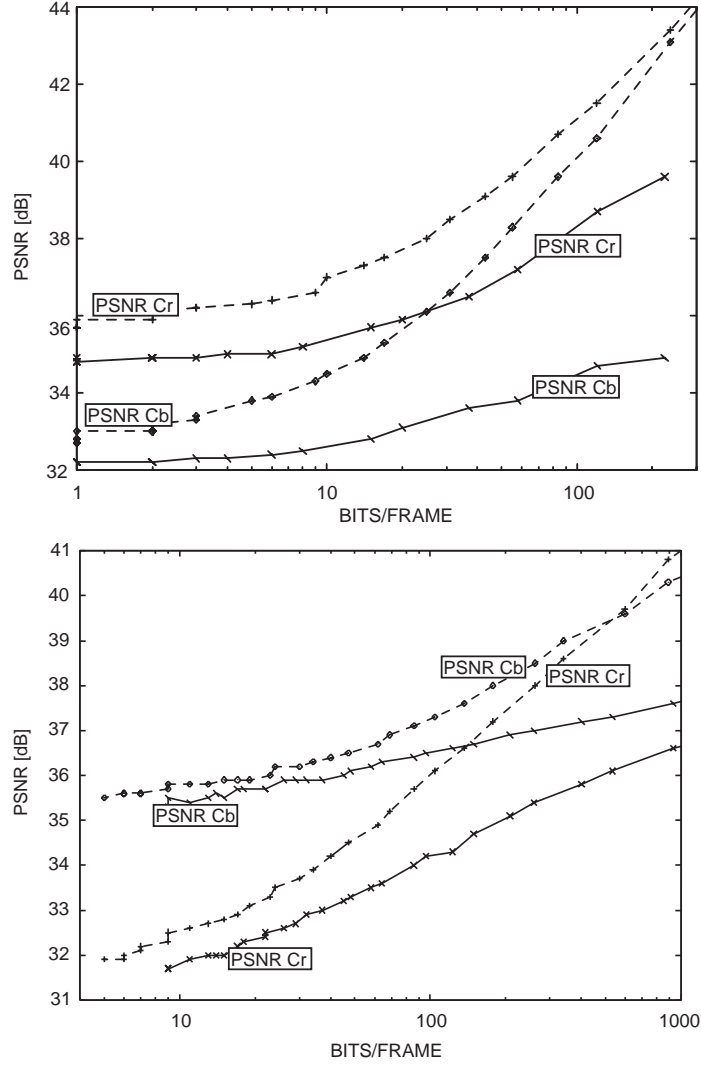


Fig. 6.: PSNR of the reconstructed chrominance components versus the number of bits allocated to one *inter* frame averaged over 100 frames of the video sequences AKIYO (upper plot) and MISSA (lower plot). Here, C_B (\diamond) and C_R (+) components obtained from the standard H.263 codec are compared to C_B (\square) and C_R (\times) components obtained by the application of scalar chrominance.

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