

# HIGH COMPRESSION OF CHROMINANCE EXPLOITING ITS CORRELATION WITH LUMINANCE

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## ABSTRACT

The paper reports research on original techniques for compression of chrominance data in video sequences transmitted at very low bit rates. Two chrominance components are converted into one scalar chrominance signal using vector quantization in chrominance plane. Three methods for scalar chrominance compression based on transform and predictive coding are described. The important issue is that presented algorithms exploit mutual correlation between vector quantized chrominance and the luminance component of video data. In transform coding techniques, the activity of reconstructed luminance estimated for its transform coefficients controls quantization steps of respective transform coefficients of scalar chrominance. In the approach based on predictive coding, detection of active areas in the luminance component allows for efficient coding of chrominance prediction error, where unnecessary transmission of zero-valued errors is avoided. The paper presents experimental results obtained for the proposed methods.

## 1 CHROMINANCE REPRESENTATION BASED ON VECTOR QUANTIZATION

### 1.1 Introduction

In typical colour video coding schemes, chrominance data is processed separately from luminance, which allows to exploit the limited resolution of colour perception in human visual system as related to perception

of the light intensity. Also, a lower information content of the chrominance channels is exploited. However, typical colour artifacts observed in video sequences coded at very low bit rates are related to very low number of bits allocated to both the chrominance channels. As the chrominance components of colour video data are processed independently, false alien colours often occur in some portions of the image, caused by high relative error resulting from even small absolute error introduced to a chrominance component that has little dynamic range. These phenomena may be very annoying because the human visual system, in some contexts exhibits high sensitivity to colour inaccuracy. For example, even slight erroneous coloration of image in areas representing human skin results in strong negative impressions.

### 1.2 Colour Video Coding Based on Chrominance Vector Quantization

Statistical properties of the colour information in video data have been studied recently [?],[?] which led to the conclusion that mutual dependencies between colour components can be exploited using joint compression of them.

An original scheme (Fig. ??) based on chrominance vector quantization has been developed [?]. Both chrominance components are represented as one scalar chrominance signal obtained by means of vector quantization [?],[?] in chrominance plane. The scalar chrominance signal is a stream of labels representing particular

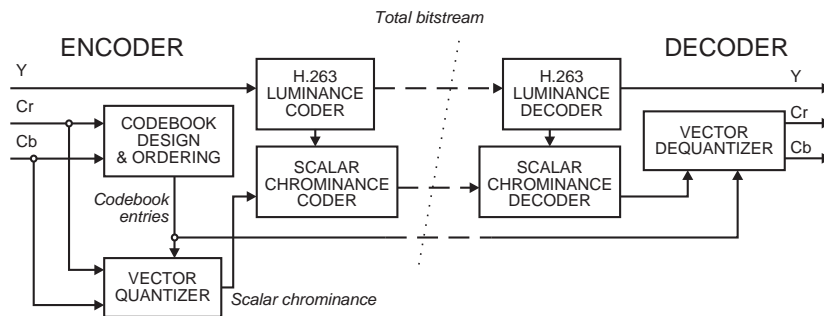


Figure 1: General structure of the compression scheme based on chrominance vector quantization

combinations of chrominance component values.

At the beginning of the vector quantization procedure, a small set of representative chrominance pairs is determined to act as a codebook for the first frame. Next, an unique number labels each pair, and an order in the codebook entries is defined in this way. The ordering is optimized in such a way that consecutive indices are assigned to chrominance pairs neighbouring in the chrominance plane, and distant indices represent distant chrominance pairs.

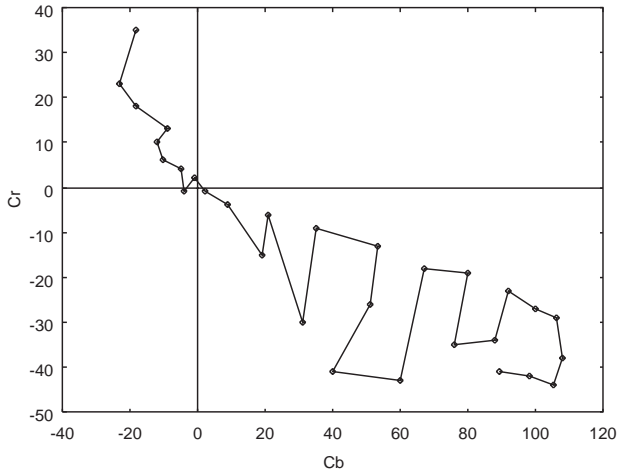


Figure 2: Typical chrominance codebook for a test video sequence AKIYO. A solid line between neighbouring entries represents their ordering.

For each input pair of chrominance samples, its nearest pair in the codebook is found and a value of a respective label is passed to the scalar chrominance coder. At the decoder side, a codebook look-up is required to reconstruct the output chrominance pair from decoded scalar chrominance values.

The major advantage of vector quantized representation of chrominance is the reduced entropy of the input data. The important issue is also joint processing of mutually dependent components, which leads to better control of the coding artifacts. The most important difficulty related to chrominance coding is a strong non-linearity of the mapping between perceptual colour features as hue or saturation and the scalar values used to represent them (see Fig. ??). This nonlinearity imposes a need to develop efficient compression algorithms to deal with statistical properties of the scalar chrominance signal that are very different from properties of standard video components.

## 2 DCT-BASED SCALAR CHROMINANCE CODING

### 2.1 Intraframe Coding

A typical block-based compression technique employed in standard H.263 codec has been adopted to encode the

scalar chrominance signal [?],[?].

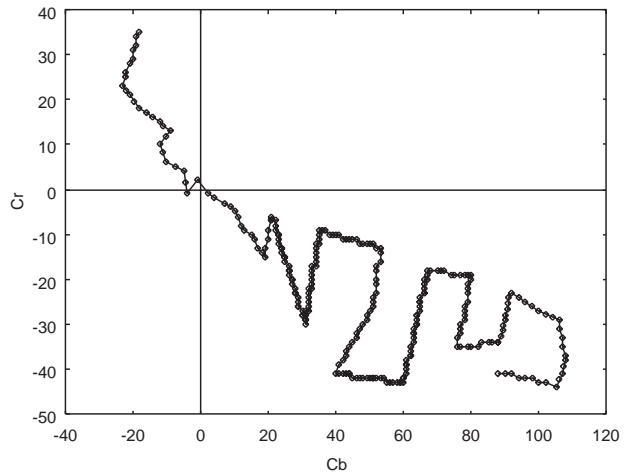


Figure 3: Interpolated codebook for a sequence AKIYO.

In order to make the signal more suitable for approximation using cosine function basis, the codebook is enlarged by insertion of additional interpolated entries between each pair of original entries neighbouring in the ordering chain (cf Fig. ?? and Fig. ??). The scalar chrominance signal obtained from vector quantization with interpolated codebook contains however a significant amount of high-frequency impulses related to the previously mentioned nonlinearity of the mapping. Often, slight change in the colour of neighbouring image points results in significant jump of the scalar chrominance value. Therefore median filtering is applied to the scalar chrominance in order to remove the unimportant details which have been exaggerated by nonlinear mapping.

DCT-based compression of such carefully prepared scalar chrominance is efficient if adequately tuned quantization algorithm is employed. Therefore, instead of flat quantization table typical for H.263, a sharp one, containing coefficients growing with frequency.

Unfortunately, after decoding, sharp edges in scalar chrominance are often blurred because of rejection of high frequency components. At blurred edges, intermediate values of scalar chrominance are introduced. These values do not necessarily represent intermediate colours. This sometimes leads to severe artifacts which can be reduced with the aid of vector median filtering [?]. Vector median filter, operating on three colour components simultaneously, smoothes out undesirable impulses in chrominance taking into account also the local smoothness of reconstructed luminance.

This technique has been tested in application to the most demanding intraframe mode of the video coder. The first frames from standard video sequences in QCIF format were compressed using unmodified H.263 codec and the proposed technique, and the results were compared (Fig. ??).

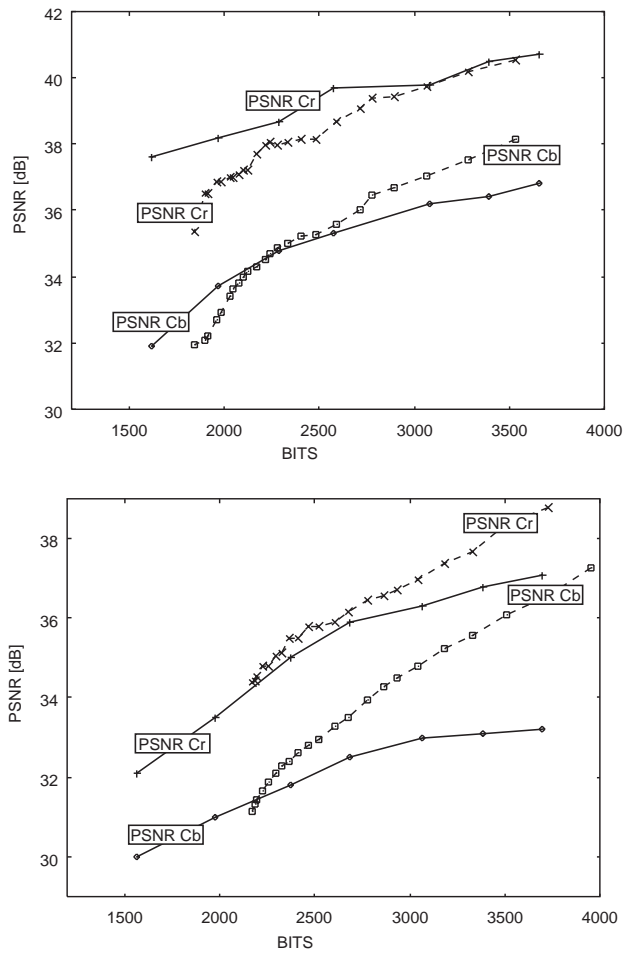


Figure 4: PSNR for the chrominance components ( $C_r, C_b$ ) versus the total number of bits allocated to chrominance for the first frame from the sequence CLAIRE (upper plot) and AKIYO (lower plot). Dashed line: standard H.263 coder, solid line: the proposed scheme.

Presented plots suggest that the performance of our technique leads to results slightly worse than standard H.263. However, in contrary to the PSNR ratings, the subjective quality of reconstructed frames is improved. Particularly, the annoying colour artifacts, like unnatural face coloration and abrupt hue variations in the background have been visibly reduced at the same compression ratio.

## 2.2 Interframe Coding

Because colour histograms are usually stable in longer parts of video sequences [?],[?], the same codebook is applied for consecutive frames.

DCT-based hybrid coding is applied to scalar chrominance in interframe mode. Motion compensation utilizes motion vectors estimated for the luminance component as in the standard H.263 implementation. Additionally, transform coefficients of chrominance are discarded depending on respective luminance coefficients.

If a transform coefficient in four luminance blocks forming a macroblock is equal to zero, the corresponding scalar chrominance transform coefficient is also zeroed.

The intraframe technique is currently being tested. Preliminary results indicate, that this scheme needs further improvements.

## 3 DISCRETE WALSH TRANSFORM BASED CODING

In this approach, which is also block-based transform coding, instead of modifying the scalar chrominance to obtain desired spectral properties suitable for approximation with limited bandwidth, the transform is modified to match the signal properties. Observation of the scalar chrominance leads to a conclusion that coding using transform basis of flat functions as in Walsh function set is appropriate for the staircase character of the signal. Thanks to existing fast Walsh transform, the coding task is even less computationally intensive, requiring no multiplications.

Various compression algorithms for the transform coefficients are currently studied. For example, a scheme related to the concept of zonal coding [?] is tested. The DWT coefficients are linearly ordered using classic “zig-zag” scan. All  $N$  last coefficients are discarded, with  $N$  controlled by the activity observed in reconstructed luminance in corresponding four blocks.

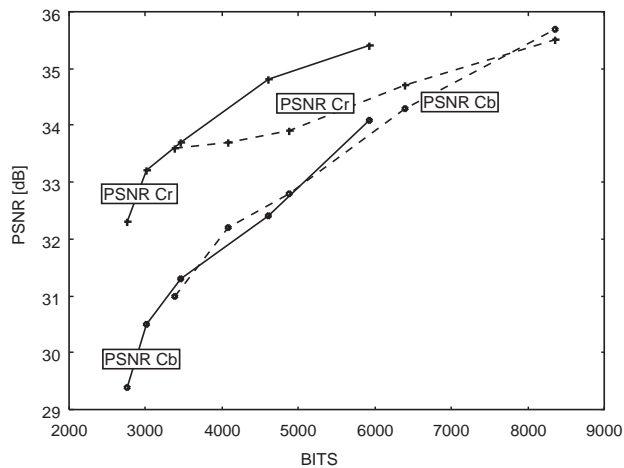


Figure 5: PSNR for the chrominance components ( $C_r, C_b$ ) versus the total number of bits allocated to chrominance for the first frame from the sequence AKIYO. Solid line: 20-element codebook, dashed line: 30-element codebook.

For interframe modes, the reconstructed frame is used as a basis for prediction in standard codec implementation. The experimental results demonstrate interesting properties of this technique.

## 4 ADAPTIVE DIFFERENTIAL CODING

The specific morphological properties of the scalar chrominance containing flat areas of constant value make it well suitable to differential coding, where at each point the actual signal value is estimated on the basis of its already transmitted neighbors and only the difference between the estimate and the actual value is transmitted. Since the probability of zero valued difference is very high, variable length entropy code benefits from this nonuniform distribution of transmitted values.

Experiments show that in images with vector quantized chrominance, the location of borders between constant valued chrominance regions usually corresponds to edges and object borders in the luminance component. In the proposed technique the chrominance coder and decoder use the reconstructed luminance in order to exploit these mutual dependencies.

Edge detectors are employed as the luminance activity estimators in order to identify locations, where significant luminance changes are encountered. The activity map is determined on the basis of reconstructed luminance image and does not need to be transmitted. Separate estimation of vertical and horizontal luminance activity allows to select the best prediction direction, i.e. the direction in which previous chrominance label has most likely identical value.

The difference between actual and estimated scalar chrominance is coded with the aid of adaptively designed Huffman code. Thanks to luminance activity estimation, only the points in active regions need to be transmitted and points with zero-valued prediction error are mostly neglected. Additionally, a signaling information about pixel locations where the mechanism fails, must be transmitted. In these rare locations, a change in scalar chrominance is not associated with luminance activity, therefore additional bits must be used.

More detailed description together with some experimental results can be found in [?]. Similarly as DWT-based approach, this technique has also been tested exclusively in intraframe mode. The possible extension to interframe coding is currently investigated.

## 5 CONCLUSIONS

Since for very high compression ratios the PSNR ratings do not reflect perceived quality, the subjective evaluations are very important.

Chrominance coding based of chrominance vector quantization is a promising scheme that combined with carefully designed compression algorithm allows to compress the colour video data more efficiently if very low bit rate is required.

The computational complexity of the proposed technique depends strongly on the applied algorithms for codebook design and vector quantization. In our experiments the procedure running on a SUN workstation with HyperSparc 150 needs about 0.2 sec for one frame

of a sequence in QCIF format. Note also, that the complexity of the channel coding is reduced by application of one chrominance component instead of two.

## ACKNOWLEDGEMENTS

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