# Improving multiresolution motion compensating hybrid coding by drift reduction

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***ABSTRACT***—*A drift reduction method which consists of Wiener filtering and overlapped block motion compensation is evaluated for the base layer performance in a multiresolution hybrid coding scheme. At constant bit rates average gains in PSNR of 1.9–2.4 dB have been achieved for critical test signals compared to MPEG–2 compatible coding. This corresponds to a bit rate reduction of 33%. The drift reduction method can be used as an efficient tool to improve the performance of a multiresolution hybrid coding system.*

## 1. INTRODUCTION

Multiresolution source coding requires that parts of the encoded and transmitted data can be decoded separately by a base layer decoder to reconstruct low resolution images. Specifically, an application is addressed where low resolution images can be used simultaneously to serve either a low resolution display (e.g. TV, TV/4) or to function as fall back mode for a high resolution display (e.g. HDTV, TV) in case of transmission errors. In general, multiresolution source coding leads to a reduced overall coding efficiency. One reason for the decrease in coding efficiency is drift that occurs in motion compensation of low frequency signal components when a multiresolution coding scheme is compared to a single resolution coding scheme. Motion compensation of the low frequency signal components is more efficient in a single resolution scheme where both low and high frequency signal components can be exploited. However, the base layer decoder of a multiresolution coding scheme has access only to the low frequency signal components, and this leads to a degenerated prediction. Drift reduction can be used to improve the base layer performance of a multiresolution coding scheme.

## 2. THE DRIFT PROBLEM

In motion compensating hybrid video coding the prediction error instead of the original signal is coded and transmitted. Hence, the prediction error instead of the original signal has to be scaled for efficient multiresolution coding. Motion compensation is carried out in a single prediction loop at the multiresolution encoder. After motion compensation the prediction error is scaled by low–pass filtering and subsequent subsampling. However, causal prediction becomes a problem when only the coded low frequency information is used to derive low resolution images at a base layer decoder. In general, a drift between the predictors of the multiresolution encoder and the base layer decoder occurs. This drift results in an additional reconstruction error of the low resolution images.

Fundamentals of drift analysis and drift reduction relevant to this work are presented in [8]. Drift is invoked by low–pass filtering and subsampling in combination with motion compensation. A two step drift reduction method is proposed in [8]. It consists of Wiener filtering to interpolate luminance amplitudes for fractional pel locations and Overlapped Block Motion Compensation (OBMC) [1] [6].

Drift can completely be avoided by the use of several prediction loops at the multiresolution encoder. However, this approach to solve the drift problem increases the prediction error of the low frequency signal components. It is pointed out in [8] that the above mentioned drift reduction method can also be used to reduce this prediction error.

In this contribution we evaluate the impact of the drift reduction method on the coding efficiency of the base layer in a multiresolution coding scheme with several prediction loops at the encoder.

## 3. IMPLEMENTATION OF THE DRIFT REDUCTION METHOD

The MPEG–2 encoder TM5 [4] [5] is used as a reference for motion compensating hybrid coding of the low resolution images. In MPEG–2 motion compensation is constrained to block motion compensation of block size 16x16 pel and displacement vectors of half pel resolution. Luminance amplitudes for half pel locations are interpolated by bilinear filtering.

OBMC is introduced as an additional macroblock attribute for the implementation of the drift reduction method in TM5. For each 16x16 macroblock one additional bit is coded which indicates if block or overlapped block motion compensation is selected. This is decided based on the MSE of the prediction error. In case of OBMC a $\sin^2$–weighting matrix [1] of support 32x32 pel is used.

For motion compensation different displacement vectors of half or quarter pel resolution are tested. Luminance amplitudes for half pel locations are interpolated by separate Wiener filtering in horizontal and vertical direction. An 8 tap Wiener filter of impulse response $g_w$=[–8,23,–48,161,161,–48,23,–8]/256 proposed in [8] is used. Luminance amplitudes for quarter pel locations are interpolated by bilinear filtering among luminance amplitudes for full and half pel locations.

## 4. EXPERIMENTAL RESULTS

In the experiments low resolution images of non–interlaced format 352 pel per line, 288 lines per frame and 50 Hz frame rate are coded. The low resolution images are derived from CCIR 601 [2] formatted signals in two stages : first motion compensated de–interlacing [7] is applied, second low–pass filtering of impulse response h=[–29,0,88,138,88,0,–29]/256 [3] and subsequent subsampling by 2:1 in horizontal and vertical direction is carried out. The resulting low resolution images were found to give a good subjective quality both on a low resolution display and when upconverted and displayed on a CCIR 601 sampling grid. Due to the non–interlaced input format of 50 Hz frame rate the group of pictures parameters specified in TM5 have been adjusted to N=24, M=6.

For MPEG–2 compatible coding of low resolution images, displacement vectors of half pel resolution are estimated with conventional block matching as described in TM5. This estimation technique is also carried out for the drift reduction method, but in view of hierarchical coding the displacement vectors are estimated for the corresponding high resolution images. The same displacement vectors are used for block and overlapped block motion compensation.

The coding efficiency that can be achieved by the drift reduction method is evaluated for constant bit rate coding at 2 Mbit/s and 3 Mbit/s. For motion compensation different block sizes of 16x16 and 8x8 pel and different displacement vectors of half or quarter pel resolution with respect to the sampling grid of the low resolution images are tested. The results for the drift reduction method and the reference MPEG–2 TM5 are given in Fig. 4.1.

At 3 Mbit/s, for the critical test signal Flower Garden compatible MPEG–2 coding with TM5 yields a Peak Signal–to–Noise–Ratio (PSNR) of 29.6 dB between encoder input and decoder output. Wiener filtering instead of bilinear interpolation for half pel locations leads to a PSNR of 30.4 dB (16x16, 1/2). If OBMC is enabled, the PSNR value is further increased to 30.9 dB. Refining the amplitude resolution of the displacement vectors from half to quarter pel gives an additional gain of 0.7 dB, resulting in a PSNR of 31.6 dB (16x16, 1/4). This peak value is also achieved for a block size of 8x8 pel (8x8, 1/4). Compared to MPEG–2 the drift reduction method gives a maximum gain of 2.0 dB. For the test signal Mobile & Calendar a maximum gain of 2.4 dB is achieved. At 2 Mbit/s the maximum gain for the drift reduction method is 1.9 dB for Flower Garden and 2.4 dB for Mobile & Calendar.

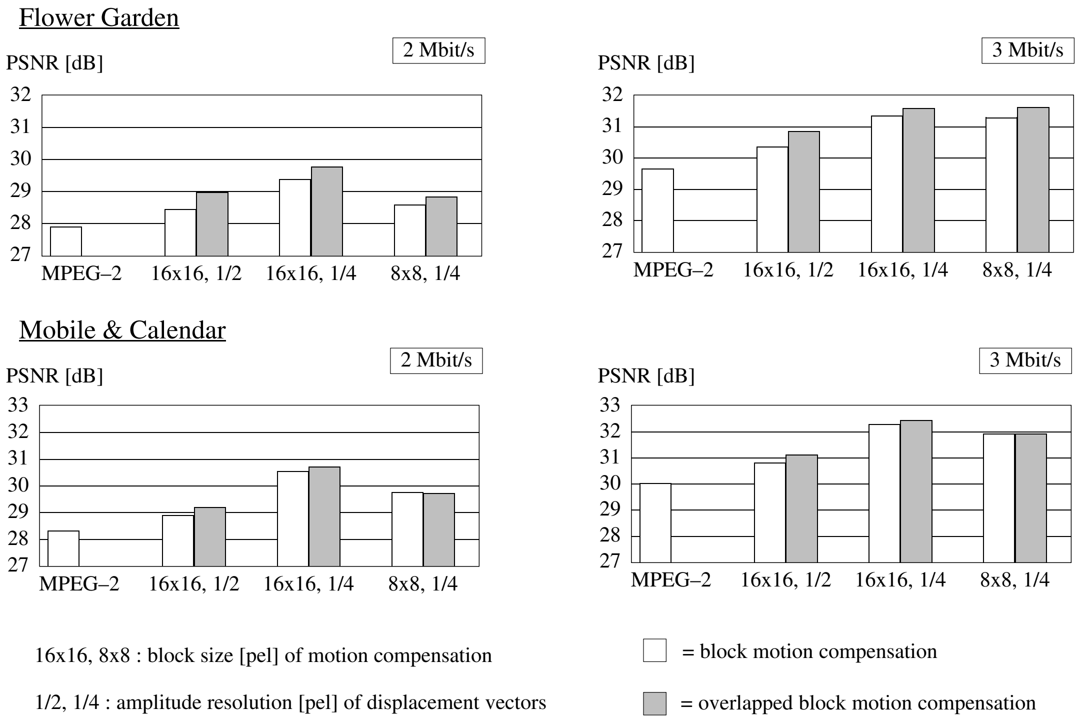


Fig. 4.1 average PSNR values for the luminance component in the cases of MPEG–2 compatible coding and the drift reduction method with different block sizes of motion compensation and amplitude resolutions of displacement vectors, constant bit rate coding at 2 and 3 Mbit/s, coding format: 352x288x50 Hz, non–interlaced, 91 frames

These substantial improvements in PSNR values correspond to a visible improvement in the subjective quality of the low resolution images. Complementary, the PSNR values of MPEG–2 compatible coding at 3 Mbit/s can already be achieved at 2 Mbit/s with the drift reduction method. This corresponds to a bit rate reduction of 33%.

Concerning PSNR values OBMC gives a rather small gain of order 0.2–0.5 dB. This indicates that most of the gain is due to Wiener filtering and quarter pel resolution of displacement vectors. However, OBMC significantly reduces the so–called 'mosquito effects' at the boundaries of moving objects.

For a block size of 8x8 pel the number of displacement vectors to be coded is increased by a factor of four compared to 16x16 pel. At 3 Mbit/s, this increased amount of coded side information is outweighed by the more accurate motion compensation, and the PSNR values are comparable for 8x8 and 16x16 pel. At 2 Mbit/s this does not hold, and 16x16 pel gives better results. This is due to the fact that in case of 8x8 pel the bit amount for coded displacement vectors is increased up to 45% of the total bit rate, and only an insufficient number of coefficients can be coded for the remaining prediction error.

## 5. CONCLUSIONS

The drift reduction method significantly improves the coding efficiency for low frequencies derived from a high resolution signal. If the low frequencies encoded in the base layer of a multiresolution coding scheme are used to reconstruct low resolution images, the experimental results show that the picture quality is visibly improved. Of course, the improved coding efficiency for the base layer gives also a benefit when the encoded low frequencies are used to reconstruct the high resolution signal.

In the experiments the displacement vectors encoded in the base layer are estimated with respect to the high resolution signal. Therefore they can directly be applied to the motion compensation of the high resolution signal, thus reducing the amount of additional side information necessary to reconstruct high resolution images.

If different displacement vectors are used to reconstruct the low and high resolution images, the coding efficiency for the base layer can further be improved if the displacement vectors are estimated with respect to the low resolution images.

In some applications due to a given bit rate constraint a reduced format is used for coding instead of the original source format, e.g. a CCIR 601 sequence may be coded in MPEG–1 format SIF [3]. Although these cases do not explicitly address multiresolution coding, the drift reduction method which consists of Wiener filtering and OBMC can beneficially be applied to improve the coding efficiency even there. Additionally, the proposed Wiener filtering can also be used for post–processing if the decoded images have to be upconverted from the coding format back to the original source format.

## 6. REFERENCES


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