

A POSTPROCESSING TECHNIQUE FOR BLOCK EFFECT ELIMINATION USING A PERCEPTUAL DISTORTION MEASURE

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ABSTRACT

One of the drawbacks of the Discrete Cosine Transform (DCT) is visible block boundaries due to coarse quantization of the coefficients. In this paper, an algorithm for the reduction of blocking artifacts is presented. The proposed method allows to produce higher quality reconstructed images by adaptively filtering the video signal according to the noise visibility. A visual model is therefore defined for predicting the block edge visibility across each picture of the coded sequence. This model that accounts for the perceptual characteristics of the block distortion is widely described in the main section of the paper. Then experimental results are presented for low bit-rate coded sequences ; they show that the postfiltering operation yields significant results with enhanced visual quality.

1. INTRODUCTION

Discrete Cosine Transform (DCT) has been widely used in video compression standards (JPEG, MPEG, H26x, ...). For high compression ratios, these block coding methods produce a highly noticeable distortion called blocking effect in the reconstructed images. It traduces itself as discontinuities near the adjacent block boundaries.

Several methods [1-3] have been developed in order to remove blocking effect. Preprocessing techniques are generally avoided as they affect the bit rate or modify the coding process. Among postprocessing techniques, it turns out however that linear, space-invariant filtering is not adequate.

In this paper, we propose a varying postfiltering method which adapts to the local visibility of the block distortion. This paper is organised as follows : section 2 provides some perceptual characteristics of the block distortion in images. The filtering algorithm is then described in section 3, and the computation of edge visibility is detailed in section 4. Finally, we conclude by presenting some experimental results obtained on low bit-rate coded sequences.

2. PERCEPTUAL CHARACTERISTICS OF THE BLOCK DISTORTION

It can be noted that the blocking effect is an excellent example of the influence of properties of the Human Visual System (HVS). Blockiness has different visual effects depending on image characteristics.

In monotone areas of the original image where the intensity is changing gradually, the corresponding intensity in the coded image tends to change abruptly from one block to another.

These abrupt luminance increments ΔL are visible only if their amplitude is greater than a visibility threshold that is proportional to the mean luminance level according to the Weber law : $\Delta L = k.L$, where k is a constant and L is the background luminance.

Furthermore, this particular kind of noise is highly correlated and appears like a regular geometric pattern in monotone areas, where it is therefore very objectionable. Typically DCT is applied on squared blocks of 8×8 pixels. A block subtends then a visual angle of 15 min in the case where the viewing distance is 6 times the height of the picture. This corresponds to the most sensitive case, and hence, the human eye is very sensitive to block distortion for blocks of that size.

In fact, the sensitivity of the human eye varies according to the spatial and temporal frequency content of the visual stimuli. The contrast sensitivity has been widely studied. In particular, Robson [4] shows that the joint sensitivity is not separable.

A visual phenomenon called masking should be also accounted for, while it increases the detection threshold of blockiness in a noticeable way. Indeed, normal pictures may contain large changes of luminance and these changes inhibit the ability of the eye to detect distortions in the local neighbourhood. The effect occurs both in the spatial as well as in the temporal domain.

3. DESCRIPTION OF THE FILTERING ALGORITHM

Blocking artifacts are composed of horizontal and vertical edge distortions located at *a priori* known positions across the picture. For each block boundary in the image, we determine whether a blocking artifact is visible or not. This decision is based on a visual perception criterion (see section 4) that integrates the perceptual characteristics previously described.

Thus, we obtain a map of edge block visibility that is correlated to the visual magnitude of the defect across the image. A non linear adaptive filter is then applied to block boundaries. Typically, a one-dimensional filter is used in areas near edges, in the direction orthogonal to the edge. We employ a FIR filter that operates only on the boundary pixels. The adaptation is achieved by changing filter coefficients according to the non-linear relation presented in Figure 1.

If visibility is too small, the filter leaves the block boundary unsmoothed, and so preserve the image sharpness. Otherwise, the boundary pixels are smoothed as much severely as the defect is visible.

4. DISTORTION MEASURE OF BLOCKING EFFECT

The key aspect of our method is the ability to predict distortions visible in an image sequence. For this purpose, a modelling of block effect visual perception is proposed. Recently, some techniques [5][6] formulate a distortion measure for blocking effect in still images. We propose to extend these approaches to the case of video sequences, by taking into account the temporal aspects of the visual perception.

Our visual model, for evaluating the blocking effect visibility in block coded video sequences, is presented in Figure 2 ; these different parts are detailed in the following subsections.

4.1 EDGE SENSITIVITY

The visibility of blocking artifact depends on their amplitude as well as their spatio-temporal variation. It can be expected to vary nonlinearly due to the characteristics of the earlier stage of the human vision.

Based on these observations, we first detect the presence of an intensity increment by proper high pass filtering. Then the effect of the non linear processing of the HVS is accounted for by a non linear transformation. A blocking artifact contrast, noted δC , is computed locally, according to the Weber's law, from the luminance values located on both sides of the inter block boundaries.

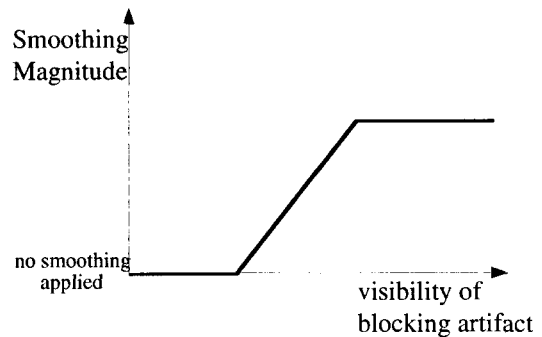


Figure 1 : Relation between the filter response and the edge visibility

Up to there, we have a detection map of the local artefact contrast for each image at the sequence. A contrast map seems to be a grid pattern that changes, from one frame to another, spatially as well as temporally. In the past, measurements of the spatio-temporal sensitivity of the human visual system, have been conducted by Robson [4]. A Contrast Sensitivity Function (CSF) have been derived in [7], as a function of the spatial and temporal frequencies. In order to incorporate this psychovisual phenomenon, we propose to weight each artifact by a contrast sensitivity term S , depending on its spatial and temporal frequency characteristics.

Let us consider one block artifact in the image. It is surrounded by other next artifacts in a spatial neighbourhood. These artifacts determine a local grid pattern with variable repetition frequency. To know this spatial frequency, we compute a Fast Fourier Transform (FFT) on a window corresponding to this neighbourhood that includes 8 artifacts (see Fig. 3). The calculation on 8 edges has been chosen to take account of the sensibility peak of fovea. In the case where the viewing distance is $6H$, the FFT window subtends a visual angle of 2° , which corresponds to this acuity peak.

On the other hand, the considered blocking artifact recur in the successive frames, at the same position, with a variable temporal repetition frequency. The temporal frequency corresponding to an edge is so computed from a procedure similar to the one in spatial domain. The FFT is computed on some causal pictures.

Finally, in both case, in two graphs, we search the centers of mass in order to have a significant value of spatial as well as temporal frequency local content ; these datas allow to find, in the approximate CSF contour-line, a sensibility value S for the artifact (see Fig. 3).

4.2 THE MASKING

The visibility of an edge artifact will be affected by the local surrounding blocks. This phenomenon called masking effect traduces the decrease of sensitivity to a

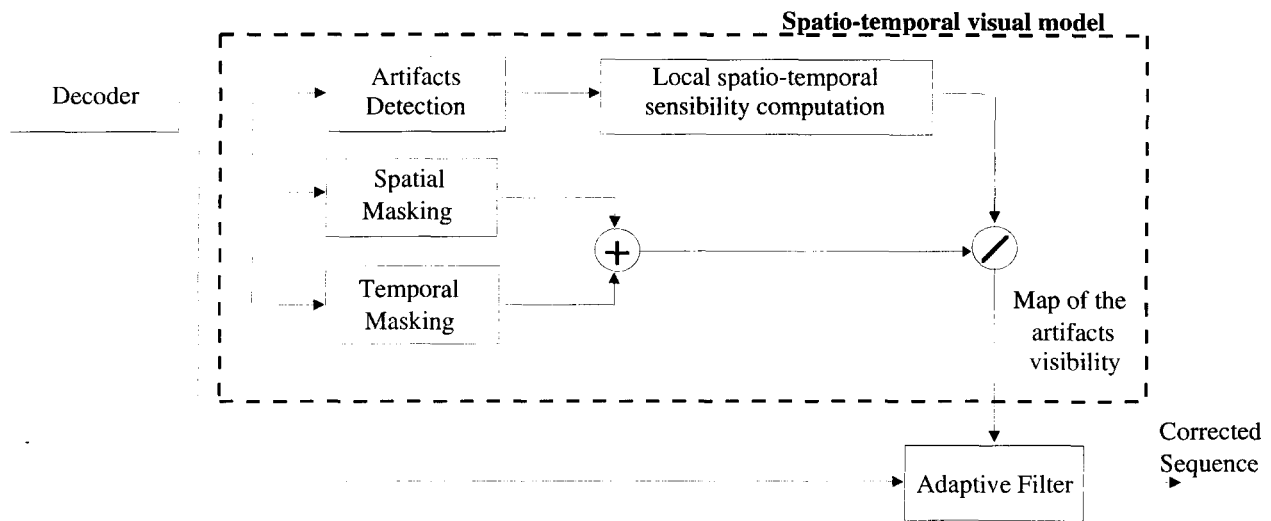


Figure 2 : Block diagram of our visual model

visual stimulus due to the amount of spatio-temporal activity in the neighbourhood. Television pictures typically may contain areas that are uniform ; they also contain high frequencies areas detail both spatial (edge, texture) and temporal (fast movement, scene cut) which affect the visibility of any impairment. These characteristics are incorporated into our definition of the masking function.

We make the simplifying assumption that the spatial and temporal masking are mediated by separate paths. Therefore, the overall masking term is roughly derived from its spatial and temporal components by straight summation.

We assume that the final spatial masking term for each artifact depends to the spatial frequency activity of both neighbouring blocks. Furthermore, Experiments show that the horizontal frequencies mask the vertical edge more than the vertical frequencies.

It leads us to compute two activity functions for each block located both sides of the edge boundary : one for horizontal frequency content and other for vertical frequency one. These are conveniently calculated in the frequency domain from a frequency weighted sum of the transformed coefficients of the considered block. The weighting is based on the sensitivity of the HVS to spatial frequencies [8], as well as the range of the coefficient.

The temporal masking effect should be also utilised for efficient measure of image degradation. To detect significant temporal variations between two successive frames of the decoded sequence, we use the difference between these ones. We assume that the temporal masking is proportional to the magnitude of temporal gradient. Our temporal activity function is based on the

absolute sum of difference between blocks both sides the edge. In the case where the scene have a lot of variations the visibility detection for one artefact decrease.

4.3 THE DISTORTION MEASURE

We propose a simple law to describe the visibility of blocking effect for an observer. Experiments show that the detection is generally high at the low values of the masking function and low at high values of the masking function.

We propose to calculate a measure of the visibility of blocking artifacts using a function given by :

$$V = \frac{|\delta C| \cdot S}{1 + (Act_{\text{spat}} + Act_{\text{temp}})} \quad (1)$$

In Eq. (1), δC is averaged over the block boundary length, in order to account for the inner correlation of the edge defect. The term S is the weighted contrast sensibility function value computed as described in section 4.1.

The terms Act_{spat} and Act_{temp} are the measures of the spatial and temporal masking, respectively.

Severely experiments have been performed in order to evaluate the proposed approach ; results obtained for differents video sequences show that the visibility term seems to be well correlated. Some subjective tests will be necessary in order to validate the model.

5. EXPERIMENTAL RESULTS AND CONCLUSION

In order to validate our method, software simulations have been performed on test sequences by

means of the MPEG and H263 coding algorithms. These sequences were coded at different bit rates (1.15, 0.75 and 0.5 Mbit/s). Some viewers participated in an informal experiment involved several coded sequences. In a pairwise comparison of postfiltered and unfiltered sequences, the postfiltered version was judged to be better in many cases.

Fig. 4 shows one decoded picture from the "Claire" sequence without postprocessing. Here blocking artifacts are very annoying. In Fig. 5 a postfiltered version of the previous image is given. It can be seen that the coding artifacts have been effectively reduced in the coded sequence by using the proposed method, without excessive blurring edges in the picture. It can be also noted that viewers do not perceive any excessive blurring on moving objects when they observe the postprocessed sequences.

We have presented an adaptive postprocessing algorithm that allows to remove artifacts in low bit rate coding sequences. A pointwise adaptive filtering is performed that varies according to the noise visibility across the coded picture. Moreover, the algorithm is of low complexity, and is in conformity with actual video compression standards. On the other hand, it allows to efficiently remove blocking effect while keeping image sharpness. Experimental results for several sequences show that the quality of the postfiltered video sequences is clearly improved.

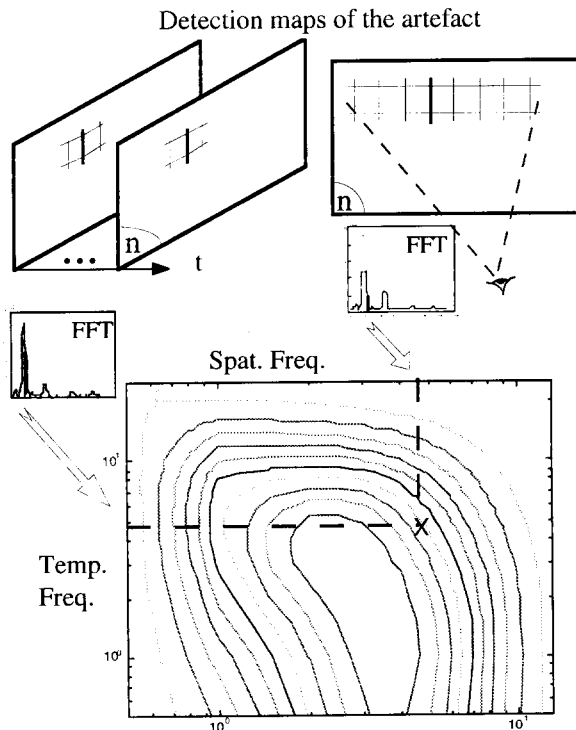


Figure 3 : Computation of the spatio-temporal sensitivity to the blocking artifact local contrast

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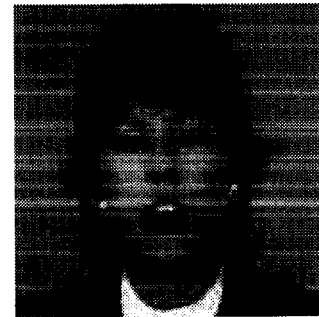


Figure 4 : Magnified version of encoded Claire



Figure 5 : Magnified version of the corrected image