Enhancement of digital television signals corrupted by channel errors

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1 Introduction

Most of image coding algorithms are based on hybrid predictive/transform coding (HPTC) schemes which are very efficient in terms of compression rates and quality. However, the resulting redundancy reduction systematically implies a high sensitivity to transmission errors. To alleviate such drawback, some investigations tend to improve the robustness of the existing coding algorithms, in order to detect and correct the errors introduced by noisy channels. The present study belongs to such approach. More precisely, its purpose is to analyse the effects of channel errors and to suggest some error protection methods for the HPTC system specified in [1] for the transmission of component–coded digital television signals. Section 2 describes the basic codec system where two coders (denoted respectively A and B) are introduced. Section 3 presents the retained strategy for the delicate problem of block synchronization. Section 4 is devoted to the effects of non–detectable errors which corrupt the amplitude.

2 The basic Codec system

The coder is based on the classical HPTC scheme (Fig. 1). The input signal is a 4:2:2 digital video signal 625–lines standard. The module LS/BS operates the line and block scannings. It forms 8×8 blocks x from 8 consecutive lines of one field. A group of 2 adjacent luminance blocks and the 2 co–positioned chrominance ones is called a macroblock (MB). The lines are organized in stripes constituted by 8 lines. Three modes (intra–field, inter–field, inter–frame) are used. The following processings are applied either on intra–field blocks or on differential blocks obtained by difference between the current block x and a reference block x_r. In the inter–field mode, x_r is taken in the previous field according to an interpolation technique. In the inter–frame mode, x_r is determined in the previous frame by a motion estimation procedure. More precisely, a block–matching method is applied. Then, the transmitted mode is selected by a criterion minimization. Next, the Discrete Cosine Transformation (DCT) is applied on the y blocks [2]. A different quantizer Q is used according to the block type (luminance/chrominance) and the DCT coefficient position. Its characteristics depend on both the image features (criticality parameter) and the buffer occupancy (transmission factor f_L). Indeed, f_L is calculated so as to maintain

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a mean rate of either 34 or 17 Mbit/s at the output of the coder equipment. All the quantization laws are nearly linear [3], [4]. The field–start–code and the stripe–header contains only fixed–length codes. Variable length codes (VLC's) are used to encode the non–zero quantized DCT coefficients and run–lengths of zeros according to preset scanning patterns. VLC is also used to encode some parameters which describe a block as the motion vector. Two kinds of VLC's (denoted A and B) are considered. Their complete description is given in the annexes of [3] and in [4]. Both can be implemented with a very simple hardware. The codec A is based on the ACVLC and, it is very efficient because up to 16 different sets of variable length words are avalaible. In other respects, the system B involves both B2 code and packet structure. It is efficient since an easy word detection is possible due to the assignment of codewords for special purposes. Indeed, two EOB's words are used to delimit VLC coded data.
The channel used for transmission is assumed binary, symmetric, stationary and memoryless, with a bit error probability P_b. A first protection is carried out by incorporating into frame replenishment coders a forward acting error control. More exactly, a BCH[255,239] is applied as a channel error correcting code. Thus, P_b decreases from 10^{-3} (resp. 5×10^{-4}) to 4.4×10^{-5} (resp. 0.6×10^{-5}) after error correction [5]. Furthemore, a forced updating is performed by sending periodically in the frame columns in the intra–frame mode. In this way, every pel is updated with correct values, thus wiping out the residual error effects. In spite of these precautions, however, the adaptivity of the considered algorithm and the use of VLC's are the principal possibility that channel transmission errors are bound to appear in the picture. Next section proposes a method to deal with the delicate re–synchronization problem.

3 Macroblock Synchronization

EOB impairment is the most annoying error effect. Due to the special properties of VLC's, such an error is propagated in horizontal direction up to the right border of the field. Therefore, the first task is to limit the effects of this type of error by preserving the MB synchronization. The approach obviously depends on the chosen coding system. So, the two strategies associated to codecs A and B will be presented separately.

Coder A To avoid an error contamination, we propose to transmit the length of each MB codes, at each stripe. The resulting information overhead is of 3% (resp. 6%) for the 34 (resp. 17) Mbit/s. The suggested method has been successfully applied on test sequences. All the detected errors were detected within the MB's where they are localized. Besides, the non–detected errors did not contaminate the surrounded MB's.
Another alternative is to insert the bloc lengths at each stripe–start–code. The bit stream related to each block is changed into: $[A_0C_0\ldots A_kC_k\ldots]$ where A_k is the relative address and C_k the coefficient. The additional information ratio is of 3.2% for the 34 Mbit/s channel. This approach is more accurate than the first one since it allows to localize the erroneous block and not only the related MB.
In case of error detection in a MB, the proposed processing depends on the selected mode. Indeed, in the predictive mode, a simple inter–field concealment is applied with a zero prediction error. In other respects, in the intra–mode, all the bits in the MB are sequentially inverted. The possible candidates are those providing the exact MB length, when this latter is re–decoded. If there are several candidates, then the retained bit is that minimizes the coherence criterion defined in [6].

Coder B At the difference of system A, no additional redundancy is introduced. Indeed, at a head of each stripe, a predetermined sequence indicates which of the two EOB's is used, for each block. This pseudo–random sequence is given by the generator polynomial $g(x) = 1 + x^3 + x^9$. An error is detected when the 4 EOB's of the decoded MB differ from those lying in the stripe head. Four events can occur: lost of 1 or 2 EOB's, insertion of 1 or 2 EOB's. Errors affecting 2 EOB's have a very low probability, and we focus only on the lost or insertion of 1 EOB. If an error is detected then, decoding the next MB is required. All the error configurations are then examined [6]. The multiple possible hypothesis are tested in order to find the right position of the lost (or inserted) EOB. In case of insertion, we suggest a test based on the number of bits per luminance block. The retained choice minimizes the dispersion between the lengths of the two luminance blocks of a MB. Since the mode can change from a MB to another, affecting the code length, only the same MB is considered. The chrominance blocks can not be used because they are of different kinds. If an EOB is lost then, a similar procedure is carried out. 80% of detected errors are corrected or concealed, then they do not induce visible degradations.

4 Corrupted amplitude coefficients

In addition to errors affecting the bit–stream length, some transmission errors can corrupt the amplitude coefficients while preserving the code length. Obviously, it is impossible to detect this kind of errors and we can only study its effect. Using reference [7], it can be proved that no more than 1 error of such type can affect a codeword. Therefore, we try to evaluate the involved mean square error, according to the chosen VLC.

Codec A The low–frequency coefficients are not considered because even erroneous, their contribution to the reconstructed image quality is weak. We focus only on the high–frequency coefficients C_j. The erroneous codeword have the same length than the considered C_j, which is provided by a determined tree. Directly related to $|C_j|^2$, the quadratic error can be assessed. For instance, an error on the DC coefficient, for the sequence "Girls", the cost is of 16.8 dB ($f_L = 76, cr = 1$).

Codec B Only errors which do not affect the continuation bit are retained. Taking into account the coding table, and following a similar procedure, the mean square error conditioned by the considered length can be calculated [6].

5 Conclusion

We have studied the annoying problem of MB synchronization, for the two considered systems. Thus, for system A, we have proposed a solution which consists in introducing a low amount of additional redundancy. However, System B intrinsically presents good properties of re–synchronization. Finally, the adopted method of detection–concealment allows a noticeable enhancement of the images.

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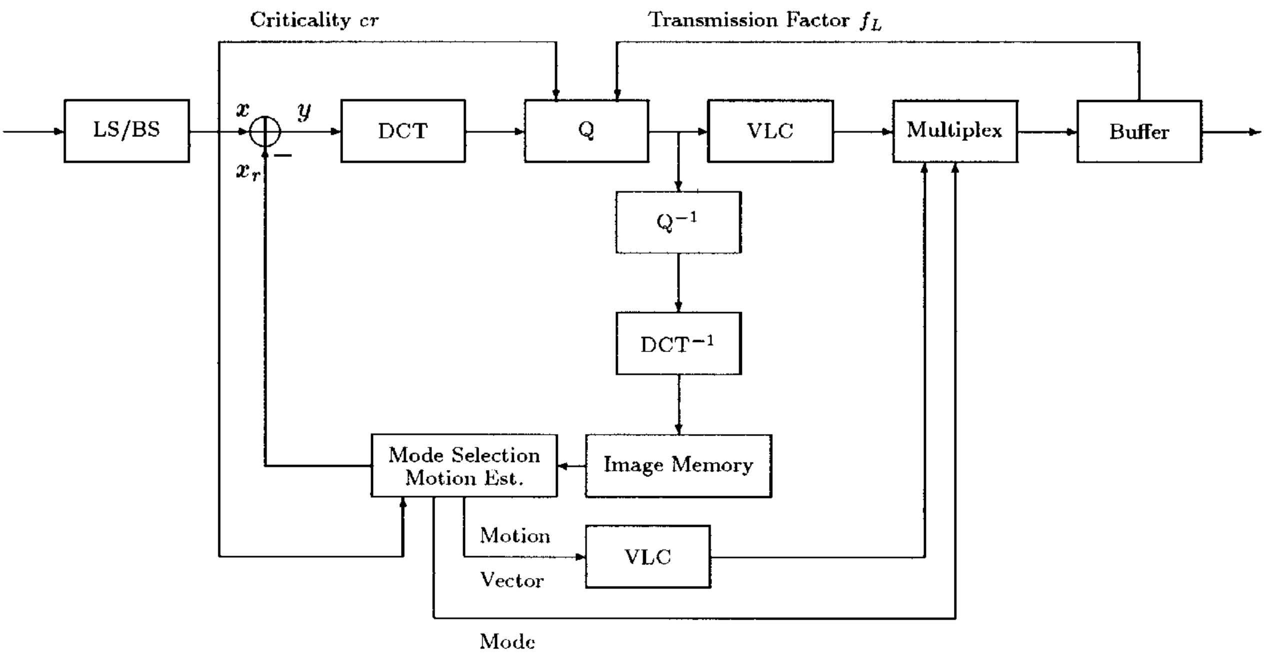

Figure 1: Hybrid Coder