EXTENDED ERROR CONCEALMENT ALGORITHM FOR INTRA-FRAMES IN H.264/AVC

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ABSTRACT

The audiovisual and multimedia services are seen as important sources of data transmission within mobile networks these days. One of the limitations within the mobile networks is the low transmission bit rate which demands the reduction of the used video resolution and a high efficient video compression technique. Standard H.264/AVC, which is explained in this paper, is the newest codec of video compression, which provides a distinct improvement of quality in comparison with the previous video standards. Video stream transmission via wireless area results in data lost. It causes the emergence of the visual artefacts, and so the distinct fall of the picture quality. Since video stream transmission in real time is limited by transmission channel delay, it is not possible to transmit all faulty or lost packets. It is therefore inevitable to conceal these defects. In this paper, we analysed the error concealment algorithms, which are used in video transmission via wireless network, which are based on standard 802.11x. The simulation of the Improved Error Concealment Algorithm for Intra-frames was made in the computing environment Matlab, performed with standard model video-sequences.

Keywords: *error concealment, videostreaming, frame, macroblock*

1. INTRODUCTION

MPEG-4 /H.264 AVC (Advanced Video Coding) is standard for the coded representation of visual information. It is a latest block-oriented codec standard based on motion-compensation developed by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/ IEC Moving Picture Experts Group (MPEG). It was a product of a partnership effort know as the Joint Video Team (JVT).

The H.264/AVC standard primarily defines two things, a coded representation (or syntax), that describes visual data in a compressed form and a method of decoding the syntax to reconstruct visual information [3]. In terms of coding efficiency, the new standard is expected to provide at least 2x compression improvement over the best previous standards. The Standard supports video applications including low bit-rate wireless applications, standard-definition and high-definition broadcast television, video streaming over the Internet, delivery of high-definition DVD content, and the highest quality video for digital cinema applications.[6]

The H.264/AVC standard consists of two layers, the video coding layer (VCL) and the network abstraction layer (NAL). The VCL specifies an efficient representation for the decoded video data. It is designed to be as network independent as possible. The coded video data is organized into NAL units, each of which is a packet that contains an integer number of bytes. The first byte of each NAL unit is a header byte that contains an indication of the type of data in the NAL unit, and the remaining bytes contain payload data of the type indicated by the header [1]. In the video transmission, the order in which the NAL units have to be sent is constant. The first NAL unit, that has to be send is the sequence parameter set (SPS) followed by the picture parameter set (PPS). Both SPS and PPS include some parameters which have been set in the encoder configuration for all pictures in the video sequence.

2. ERROR CONCEALMENT TECHNIQUES IN H.264/AVC

The loss of transmitted data packets influences the quality of the received video. This problem is caused by the limited channel bandwidth used by the mobile communication networks. Since the real time transmission of video stream limits the channel delay, it is not possible to retransmit all erroneous or lost packets. Therefore there is a need for post-processing methods, which try to reduce the visual artifacts caused by bit stream error after locating the missing or defected parts of video data [4]. Error concealment methods which shall be implemented on the receiver side restore the missing and corrupted video content using the previously decoded video data. There are several error-resilience techniques: forward, concealment, and interactive techniques. [7]. Almost all forward techniques increase the bit rate since they add redundancy to data. Some of them may also require modifications to the encoder. Most interactive techniques need a feedback channel between the encoder and the decoder. Interactive techniques will also introduce some delay and may, therefore, be unsuitable for real-time applications like mobile video communications. On the other hand, concealment techniques do not increase the bit rate, do not require any modifications of the encoder, and do not introduce any delay. This makes them a very attractive choice for mobile video communications [5].

2.1. Error concealment in space domain

All error concealment methods in space domain are based on the same idea which says that the pixel values (luma and chroma) within the damaged macroblock can be recovered by a specified combination of the pixels surrounding the damaged macroblock.

The simplest and often used method is weighted averaging. Each pixel of a missing macroblock is interpolated as a linear combination of the nearest pixels in the boundaries. Only "Correctly received" neighboring macroblocks are used for concealment, if at least two such macroblocks are available. Otherwise, neighboring "Concealed" macroblocks are also used in the averaging operation. Some of the other important error concealment methods in space domain are maximal smoothing algorithm or directional interpolation [9].

2.2. Error concealment in time domain

Temporal error concealment is one of the most important error concealment techniques. To conceal the errors in the current frame, it utilizes temporal neighbors, that are, the previous frame or the next frame. In temporal error concealment, correlation between current decoded frame and previous decoded frames, is exploited. A damaged macroblock of the current decoded frame is replaced by a macroblock in the reference frame using the estimated motion vector of the lost macroblock. For temporal error concealment, the motion activity of correctly received slices in the current picture is investigated in advance [8]. If it is smaller than a predefined threshold, all lost macroblocks are concealed by replacing them with macroblocks from spatially corresponding positions in the reference frame.

Boundary matching and block matching algorithms are the most used and the most efficient error concealment methods in time domain.

3. AN IMPROVED ERROR CONCEALMENT ALGORITHM FOR INTRA-FRAMES IN H.264/AVC

Proposed algorithm for error concealment first explores the temporal correlation between successive frames. If similar blocks to the ones that are neighbours of the missing MB cannot be found, then the spatial-based error concealment algorithm is used [2].

In order to find an estimate of the missing MB, 8x8 subblocks adjacent to it are used - U1, U2, R1, R2, B1, B2, L1 and L2 as shown in Fig. 1. First, for each of these subblocks, a matching subblock in the previous frame is determined. This matching subblock is found by searching a small area around the point corresponding to the center of each of the subblocks in the previous frame. The sum of absolute differences is used as the measure of similarity. Four of eight of these corresponding subblocks U1', U2', R1', R2', B1', B2', L1' and L2' in the previous frame are shown in Fig. 2.

Then, eight blocks, namely X_U1, X_U2, X_R1, X_R2, X_B1, X_B2, X_L1, and, X_L2 which are connected to U1', U2', R1', R2', B1', B2', L1' and L2', respectively, are determined.

The sum of squared border errors, between the estimated macroblock and its closest blocks, is computed for each of these eight blocks. One block from the above eight blocks, which value of sum is the smallest (is the most similar to lost macroblock) is chosen as a candidate to replace the lost macroblock. And so, calculations are realized using (1) and (2):

$$\hat{X} = \arg_{X\_U1, X\_U2, \ldots, X\_L2} \min \varepsilon^2 \qquad (1)$$

where $\varepsilon^2 = \varepsilon_U^2 + \varepsilon_R^2 + \varepsilon_B^2 + \varepsilon_L^2$ (2)

Each of the border errors is defined in terms of adjacent pixels by (3), (4), (5) and (6):

$$\varepsilon^2{}_U = \left\| (\hat{x}_U - p_U) \right\|^2, \quad \varepsilon^2{}_R = \left\| (\hat{x}_R - p_R) \right\|^2 \qquad (3), (4)$$

$$\varepsilon^2{}_B = \left\| (\hat{x}_B - p_B) \right\|^2, \quad \varepsilon^2{}_L = \left\| (\hat{x}_L - p_L) \right\|^2 \qquad (5), (6)$$

where the vectors p_U, p_R, p_B and p_L consist of the outside boundary pixels of the upper, right, bottom and left sides of the missing MB, respectively. The upper, right, bottom and left inner boundary pixels of the candidate macroblock are represented by the vectors $\hat{x}_U$, $\hat{x}_R$, $\hat{x}_B$ a $\hat{x}_L$.[2]

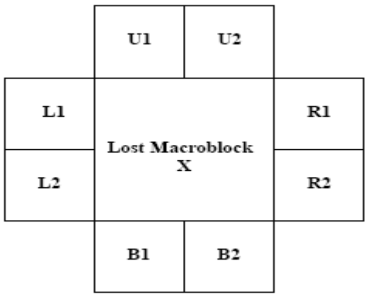

Fig. 1 8 subblocks adjacent to the lost macroblock

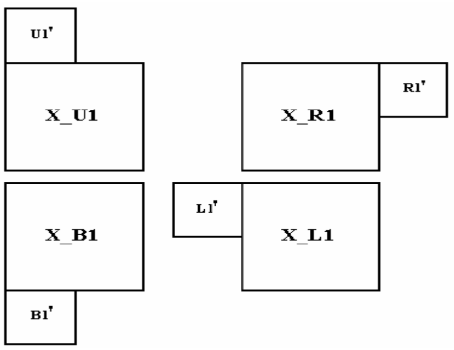

Fig. 2 4 of 8 corresponding subblocks in the previous frame and the candidate macroblocks connected to them

Once we have chosen a macroblock, we need to test its integrity as a suitable substitute to the lost macroblock. To do this, we compare the parameter ε2 with a local threshold. If ε2 is larger than this threshold, then we drop temporal concealment and use the spatial concealment.

The local threshold is computed for each lost MB by calculating the sum of square distances of the inner-boundary pixels of the chosen MB in the previous frame and the outer-boundary pixels of that MB in the same frame as shown in Fig. 3.

The choice of boundary pixels is made according to the condition of the neighboring macroblocks of the lost MB in the current frame. Fig. 3 shows that if any of the neighboring macroblocks is corrupted, then the pixels that lie on that boundary of that macroblock are disregarded in the calculation of the local threshold and the ε2 parameter.

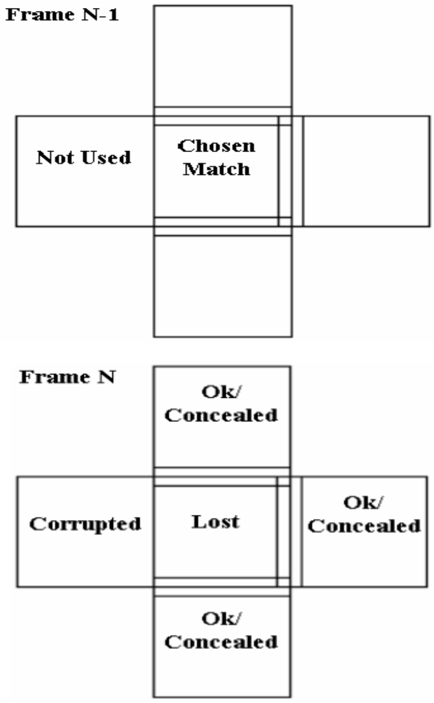

Fig. 3 Choice of boundary pixels used in calculating the local treshold and the boundary matching parameter ε

4. SIMULATIONS

4.1. Simulation results of presented algorithm

Presented algorithm was simulated in computing environment Matlab using three model video sequences : ‘Foreman’, ‘Mother and Daughter’ and ‘Mobile’.

‘Foreman’ was the first tested video sequence. Fig. 4 and Fig. 5 show corrupted and concealed frame no.288. This frame is affected by slight ‘floating’ effect of camera. Other movement is represented by man’s eyes, that are closing at that moment. Visible artifacts occurs in this corrected frame only in the area of man’s face and neck. Since in this part of video sequence camera turns from right to left, there is a lot of movement in this frame. Thus, the algorithm uses spatial concealment method for concealment of lost macroblocks. The efficiency of recovery of lost macroblocks is quite good, which proves Table 1.

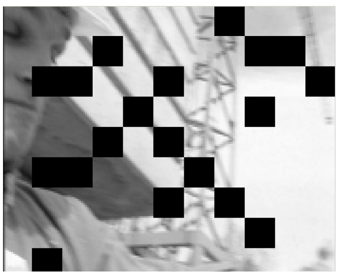

Fig. 4 Corrupted frame No. 288 of video sequence ‘Foreman’

Fig. 5 Concealed frame No. 288 of video sequence ‘Foreman’

Table 1 Objective criteria and their values representing the quality of reconstructed information for video sequence ‘foreman’ for frame No.288

MSE	MAE	NMSE	**SNR [dB]**
0.0015985	0.010666	0.0027966	**25.5337**

Generally, video sequence ‘Mother and Daughter’ is video sequence containing little amount of movement, which is shown in Fig. 7. Algorithm uses in this case mainly temporal concealment technique. Also in the frame no.191 majority of the scene is static. Where were lost macroblocks generated is shown in Fig. 6. The movement occurs only in the area of woman’s head rotating towards the camera and in the area of her hand, which she moves down from top with. Since the background is static, this part of the frame was concealed almost perfectly. Some little artifacts occur in the area of hand, but during watching this sequence is almost impossible to recognize them. Also in this case, algorithm concealed lost macroblocks very good, as is shown in Table 2.

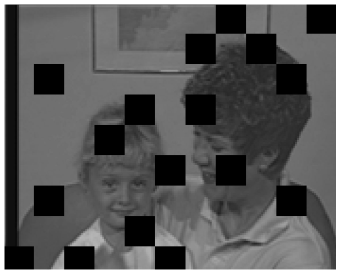

Fig. 6 Corrupted frame No. 191 of video sequence ‘Mother and Daughter’

Fig. 7 Concealed frame No. 191 of video sequence ‘Mother and Daughter’

Table 2 Objective criteria and their values representing the quality of reconstructed information for video sequence ‘Mother and Daughter’ for frame No.191

MSE	MAE	NMSE	**SNR [dB]**
0.00014643	0.0027057	0.00094721	**30.2355**

The last concealed frame presented in this paper is frame no.276 of the video sequence ‘Mobile’, as show Fig. 8 and Fig. 9. There are more types of movement on this frame. Movement of the train, movement of the calendar and movement of the pendulum, finally. All this types of movement make concealment of this frame more difficult. According to that, algorithm exploits particularly spatial concealment technique. Incurred artifacts are almost invisible, efficiency of used algorithm is sufficient. Table III shows objective criterions representing the quality of reconstructed information.

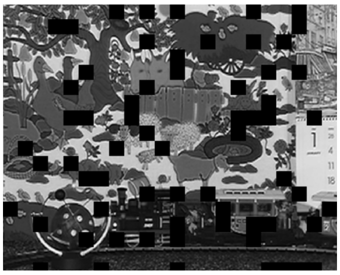

Fig. 8 Corrupted frame No. 276 of video sequence ‘Mobile’

Fig. 9 Concealed frame No. 276 of video sequence ‘Mobile’

Table 3 Objective criteria and their values representing the quality of reconstructed information for video sequence ‘Mobile’ for frame No.276

MSE	MAE	NMSE	**SNR [dB]**
0.00055976	0.0043751	0.0026463	**25.7737**

4.2. Efficiency of algorithms comparison

In this chapter we have compared presented temporal-spatial algorithm efficiency with efficiency of algorithm implemented in JVT reference software (with method weighted averaging) [4]. SNR (Signal to noise ration) value is the most important parameter showing efficiency of algorithm. For both algorithms we performed 10 consecutive simulations. We performed it for three different frames of video sequence ‘Foreman’. The simulations are independent on each other, because macroblocks losses in each frame are generated randomly (every time in different place). Finally, we arithmetically averaged and compared the result values. Since the results are very similar in each of three chosen frames, we presented simulation results in one frame of video sequence ‘Foreman’.

As is shown in Table 4, the temporal-spatial algorithm concealed the lost macroblocks more efficient than algorithm exploiting concealment only in space domain.

Table 4 SNR values for proposed temporal-spatial algorithm and for algorithm implemented in JVT reference software for the frame No.120 of video sequence ‘Foreman’

Number of simulation in frame No.120	**SNR[dB] Proposed temporal-spatial algorithm**	**SNR[dB] Weighted average**
1.	23,4943	21,7027
2.	26,5928	22,337
3.	22,9708	19,7381
4.	34,6149	22,4899
5.	20,6857	21,0407
6.	25,9089	20,4532
7.	25,5279	22,5925
8.	26,4323	23,2263
9.	32,2962	21,3735
10.	32,1147	24,9715
Arithmetic average	**27, 0639**	**21, 9925**

5. CONCLUSION

We have described in this paper a low complexity but effective algorithm for error concealment of intra coded frames. This algorithm first checks whether temporal concealment is feasible for the intra frame. If not, then spatial concealment implemented in the test model [2] is used. This algorithm does not require very complicated computations, hence is usable for various applications. Our simulations have shown, that by exploiting temporal correlation between adjacent frames, error concealment can be improved significantly.

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Stanislav Marchevský received the M.Sc. in electrical engineering at the Faculty of Electrical Engineering, Czech Technical University in Prague, in 1976 and PhD. degree in radioelectronics at the Technical University of Košice in 1985. Currently he is a Professor of Electronics and Multimedia Communications Department of Faculty of Electrical Engineering and Informatics of Technical University of Košice. He teaching interests include switching theory, digital television technology, and satellite communications. His research interests include image nonlinear filtering, neural networks, genetic algorithms, and multiuser detection, spacetime communication, diversity communication over fading channel, and power and bandwidthefficient multiuser communications.