HYBRID CONCEALMENT MECHANISM

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ABSTRACT

Video transmission over noisy channel leads to errors on video, which degrades the visual quality noticeably and makes error concealment an indispensable job. One approach that is especially suited for applications with real-time constraints, limited bandwidth, or multicast distribution, is to conceal the information loss at the receiver. In this paper we focused on hybrid concealment mechanism. Effectiveness of this algorithm was tried on several video sequences and the results are quite satisfying.

Keywords: *error concealment, block, video sequence, motion, videoconference.*

1. INTRODUCTION

The base problem with packet communications system is information lost due to network congestion. Thus, with growth popularity of the Internet, error concealment becomes more important. The main goal of error concealment is to modify received information so that losses will be imperceptible for human eyes.

There have been many techniques proposed in the literature that conceal information loss from different angles. These methods can be grouped into: 1) forward error concealment [1], 2) interactive error concealment [1], 3) error concealment by postprocessing [1]. Each group of methods has it advantages and disadvantages. Examples of forward error concealment include FEC [2] , joint source and channel coding, and layered coding. These techniques add a certain amount of redundancy at the source coder or transport coder. The main advantage of this group is good error resilience. We pay for it with increase in the transmission bandwidth. Examples of interactive error concealment include selective encoding [4] and retransmission without waiting [5]. This class of methods should give the best performance if backward channel from the decoder to encoder exist. The main disadvantage is significant increase of the transfer delay. In the third group, error concealment is performed by decoder. All postprocessing techniques make use of the correlation between a damaged macroblock and its spatial/temporal adjacent macroblocks [1], so no addition redundancy is needed. Resulting from these facts, it may not be possible to completely reconstruct the lost image blocks.

The loss concealment techniques are not mutually exclusive; they can be combined with other methods. For example, a videoconference application can use forward error correction loss recovery for the audio stream and error concealment by postprocessing for the video stream [3].

The loss concealment mechanism described in this paper fall into third group. Hence, it uses spatial and temporal redundancy presented at video signal. It is hybrid in the sense, that it masks a lost block using information from both the previous video frame (temporal concealment), and from the surrounding blocks of the current frame (spatial concealment), depending on the presence of motion in the area of the frame. Temporal concealment conceals loss of block with corresponding block from previous video frame. Spatial concealment expresses each lost pixel as a distant-dependant linear combination of all surroundings pixels [3]. This operation is performed for entire lost block with a single matrix multiplication. Performance of algorithm will be shown on several video sequences. The results of this algorithm are satisfactory for still and spatial smooth video sequences. In the areas with significant motion algorithm produce slightly blurred results.

Algorithm will be described for grey-scale video sequences. For YUV video sequences, we could also use this algorithm – it can be applied independently on the luminance and on the chrominance blocks [2].

2. A HYBRID CONCEALMENT MECHANISM

A hybrid concealment mechanism was introduced in [3] at first. In the next, we have used algorithm description from [3].

Let F be the video frame on which we perform loss concealment, and $\mathbf{F_p}$ be the previous video frame, in which losses have been already concealed. Let **X** be a missing block in **F** and **E** the estimate of **X** that results from the loss concealment. **P** is the block of $\mathbf{F_p}$ which resides in the same location as **X**. The adjacent blocks with **X** are **U** for up, **D** for down, **L** for left, and **R** for right. Some of the blocks **U**, **D**, **L**, **R** may be also lost, without having been concealed yet. In that case, we temporarily replace the missing adjacent block with the corresponding block from $\mathbf{F_p}$.

The described spatial concealment technique uses the pixels that are directly adjacent to **X** and that make up the four 8-by-1 surrounding vectors **u**, **d**, **l**, **r** (Fig. 1). If block **X** resides at the boundary of the image, we predict those vectors based on the closest known pixels. For example, if block **X** is at the top of the frame (but not at the corners), **u** is predicted as $\mathbf{u(i) = (l[1]+r[1]) / 2}$ for $\mathbf{i=1..8}$. If it is at the top-left corner, **u** is predicted as $\mathbf{u(i) = r[1]}$ and **l** as $\mathbf{l(i)=d[1]}$ for $\mathbf{i =1, .., 8}$.

If motion is detected in one of the adjacent blocks **U**, **D**, **L**, **R**, we mask lost block using a smooth estimate $\mathbf{X^S}$ of **X** computed based on the adjacent vectors **u**, **d**, **l**, **r** (spatial concealment). Otherwise, if there is no significant motion in that area of **X**, we replace lost block with the corresponding block **P** (temporal concealment).

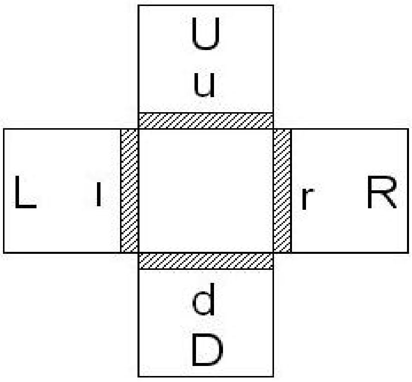

Fig. 1 The missing block **X**, its adjacent blocks **U, D, L, R**, and the corresponding surrounding columns **u, d, l, r**.

2.1. Spatial Concealment

Let **x** be a pixel of the spatially concealed block $\mathbf{X^S}$, and $\mathbf{x_u}$, $\mathbf{x_d}$, $\mathbf{x_l}$, $\mathbf{x_r}$ be the up, down, left, and right pixels, respectively (Fig. 2). We require that for all pixels **x** of $\mathbf{X^S}$:

$$x = \frac{x_u + x_d + x_l + x_r}{4}$$

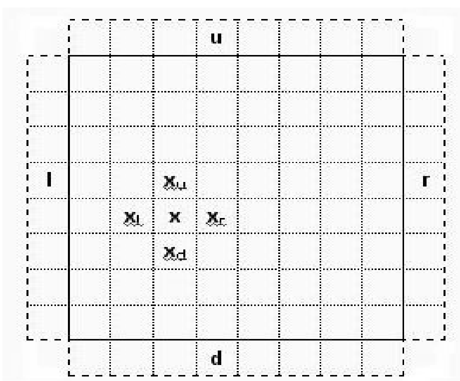

Fig. 2 Spatial concealment.

For an 8-by-8 block we can write 64 such averaging equations, one for each pixel **x**. The resulting system of linear equations has 64 unknowns, the pixels of **X**, while the constant terms depend on the surrounding vectors **u, d, l, r**. We can rewrite these 64 equations as a linear system:

$$\mathbf{A} \,.\, \mathbf{v} = \mathbf{c}$$

where the matrix **A** is the 64-by-64 block matrix:

$$\begin{bmatrix} L & -I_8 & 0 & 0 & 0 & 0 & 0 & 0 \\ -I_8 & L & -I_8 & 0 & 0 & 0 & 0 & 0 \\ 0 & -I_8 & L & -I_8 & 0 & 0 & 0 & 0 \\ 0 & 0 & -I_8 & L & -I_8 & 0 & 0 & 0 \\ 0 & 0 & 0 & -I_8 & L & -I_8 & 0 & 0 \\ 0 & 0 & 0 & 0 & -I_8 & L & -I_8 & 0 \\ 0 & 0 & 0 & 0 & 0 & -I_8 & L & -I_8 \\ 0 & 0 & 0 & 0 & 0 & 0 & -I_8 & L \end{bmatrix}$$

$\mathbf{I_8}$ is the 8-by-8 identity matrix and **L** is the Laplacian-like 8-by-8 matrix:

$$\begin{bmatrix} 4 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 4 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 4 & -1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 4 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 4 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 4 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 4 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 4 \end{bmatrix}$$

The vector of unknowns **v** is the pixels of $\mathbf{X^S}$ in anti-lexicographic order (the anti-lexicographic order of a matrix is to first read all the elements of the first column, then of the second column, and so on). The constant term **c** is the 64-by-1 vector that results from the anti-lexicographic order of the matrix:

$$\begin{bmatrix} l_1 + u_1 & u_2 & u_3 & u_4 & u_5 & u_6 & u_7 & r_1 + u_8 \\ l_2 & 0 & 0 & 0 & 0 & 0 & 0 & r_2 \\ l_3 & 0 & 0 & 0 & 0 & 0 & 0 & r_3 \\ l_4 & 0 & 0 & 0 & 0 & 0 & 0 & r_4 \\ l_5 & 0 & 0 & 0 & 0 & 0 & 0 & r_5 \\ l_6 & 0 & 0 & 0 & 0 & 0 & 0 & r_6 \\ l_7 & 0 & 0 & 0 & 0 & 0 & 0 & r_7 \\ l_8 + d_1 & d_2 & d_3 & d_4 & d_5 & d_6 & d_7 & r_8 + d_8 \end{bmatrix}$$

The matrix A is invertible, and so we can directly compute the pixels of $\mathbf{X^S}$, as:

$$X^S = A^{-1}c$$

The inverse of **A** can be a priori calculated, and so the spatial concealment operation is just a matrix-vector multiplication for each lost block.

2.2. Temporal Concealment

Motion in each of the surrounding blocks U, D, L, R is detected using the Pixel Difference Classification (PDC) method. The PDC distortion function compares each pixel of the target block with its counterpart in the candidate block and classifies each pixel pair as either matching or not matching. Pixels are matching if the difference between their values is less than some threshold:

$$\sum_{q=1}^{n}\sum_{p=1}^{m}[ord(|A[p,q]-B[p,q]|\geq T)]$$

Ord(e) evaluates to 1 if e is true and false otherwise.
The value of **T** has to be chosen based on the noise level of the image. A value around 10 lead to accurate motion detection most of the times.
Given two same-location blocks **A** and **B** from frames **F** and **Fp** respectively, we detect that there is motion present in the area of these blocks, and so we switch to spatial concealment, if

$$PDC(A,B) > M_T$$

where $\mathbf{M_T}$ is the motion threshold. The value of $\mathbf{M_T}$ can be determined through experimentation, and it certainly depends on the specific video streams. Values around 16 to 24 (for 8-by-8 blocks) lead to the best results.

3. SIMULATION

Effectiveness of introduced algorithm was tried on Foreman and Mobile video sequences.

Figure 3a shown 2nd frame of Foreman sequence, figure 3b shown frame after random block losses and the frame resulting from the hybrid concealment mechanism is shown on figure 3c. At the start of video sequence is motion caused by vibration of video camera, also by move of man's head and by his mimic. At the end of video sequence is motion caused by move of camera from left to right.

Fig. 3a 2nd frame from Foreman sequence

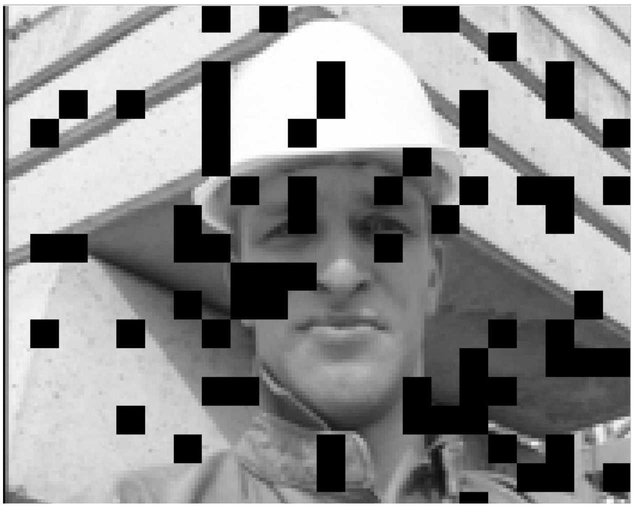

Fig. 3b 2nd frame after random block losses

Fig. 3c 2nd frame resulting from the hybrid concealment mechanism

At these frames we can see that algorithm leads to very good concealment in the areas where motion is not noticeable, what was expected. In the areas where motion was detected, algorithm mask lost block with blurred block. It is result of spatial concealment. But in video sequence we can very hardly recognize these areas. Thus, we evaluate the effectiveness of the hybrid concealment performed on Foreman video sequence as satisfactory and quality measures (Tab.1) confirm our opinion.

Error concealment in Mobile video sequence is really challenging for all error concealment algorithms. At the bottom of this video sequence is train moving from the right to the left and in addition it pushes a ball, which, of course, rotates. Also, there is a calendar, which is moving to the right, above the train. In addition camera movement is not only from the right to the left but also from down to up. Very hard task is correctly concealing errors, which occurs in the area of numbers.

Table 1 Quality measures, Foreman, frame no. 2

	MSE	MAE	NMSE	SNR
Foreman, frame no.2	0.0012419	0.0095642	0.0026508	25.766

Table 2 Quality measures, Mobile, frame no. 50

	MSE	MAE	NMSE	SNR
Mobile, frame no. 50	0.0026743	0.01306	0.0094311	20.2544

Fig. 4a 50th frame from Mobile sequence

Fig. 4c 50th frame resulting from the hybrid concealment mechanism

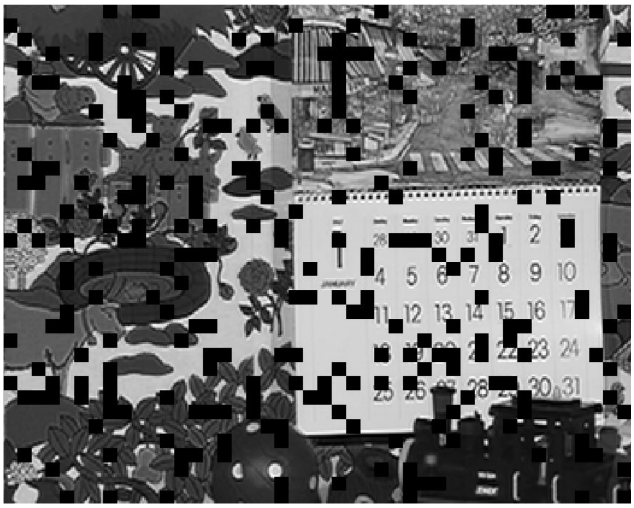

Fig. 4b 50th frame after random block losses

As we can see on these figures, algorithm failed in concealment of numbers. Some numbers we can not recognize, it is an effect of spatial concealment, which mask these errors with smooth estimation. Subjective perception confirm also quality measures (Tab. 2)

CONCLUSION

Hybrid concealment mechanism described in this paper could be used in such applications as videoconference, thus, applications which have not very high quality requirements. That can we see in Foreman video sequence, where hybrid concealment provides good results. On the contrary, for applications with high quality requirements, such as IPTV, where we can tolerate some delay or channel bandwidth is not a limit, it is better to use forward error correction techniques or interactive error concealment.

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Ján Mochnáč was born on 28.06.1984. In 2007 he graduated (MSc.) at the Department of electronics and multimedia telecommunications at Technical University in Košice. Since 2007 he is an internal PhD. student at the faculty. His research interests are in the fields of loss concealment methods for packet video.