Temporal error concealment for video transmission

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Abstract

In this paper, we propose a temporal error concealment algorithm for video transmission in an error-prone environment. The error concealment algorithm employed an edge detection algorithm and progressive median motion vector concealment. First, the edges are detected and concealed portion by portion. Then, the corrupted MB is partitioned by the reconstructed edges and each partition is concealed by progressive median motion vector individually. The proposed algorithm shows better performance on both objective and subjective quality over existing temporal error concealment algorithm.

1. Introduction

Transmission of video over networks has been increasing significantly in recent years. However, many networks such as wireless network and the Internet are unreliable. The data packets can be corrupted or lost during the transmission. The loss of information caused by the transmission errors can produce an adverse degradation in visual quality. In such situation, retransmission mechanism such as automatic repeat request (ARQ) will be applied. However, retransmission of data packet is not suitable for real-time application because of the excessive delay, and hence, decoder error concealment provides a feasible solution for error handling.

Video codec achieves high compression ratio by exploiting temporal redundancy and statistical redundancy through predictive coding and variable-length coding. However, compressed video streams are very sensitive to error. An error occurs in a single frame would propagate to all successive frames in the same GOP; while a single bit error can incur a loss of synchronization in the decoder, causing the subsequent correctly-received bits to be un-decodable. Error concealment in decoder aims to conceal the lost information by exploiting the spatial and temporal correlation and hence improve the visual quality.

Error concealment algorithms can be divided into two categories: spatial and temporal error concealment. Spatial error concealment uses the information of neighboring macroblocks (MB) to recover lost information. A basic error concealment method is bi-linear interpolation [1], in which a bi-linear filter is applied to the available neighbouring MBs to recover the missing MB by interpolation in spatial domain. It works well for smooth areas; however, edges and textures tend to be lost or blurred in this method. Edge preserving algorithms such as [2,3] attempt to interpolate the pixels along the edge direction.

Temporal error concealment tries to recover the motion vectors and find the best block in the previous decoded frame to replace the missing MBs. Some basic methods of temporal error concealment are setting motion vectors to zeros, using the motion vectors of corresponding block in the previous frame, using the average or median of motion vectors from spatially adjacent blocks [4]. In another method called BMA algorithm [5], the best motion vector is determined by minimizing the variation of pixel intensity across the MB boundary or the side match distortion [6]. In [7], portion of the missing MB is recovered first and the block in previous frame, which has the best match with the portion, is chosen to conceal the missing MB. In [8], the motion field is interpolated and the motion vector for each pixel is interpolated, which has an advantage of smooth concealed motion vectors and less blocking artifacts. In general, temporal error concealment provides better results than spatial methods in terms of objective and subjective quality.

In this paper, we propose a temporal error concealment algorithm by using the texture information of neighboring macroblocks and partition the missing MB into smaller portion for error concealment. The algorithm is divided into two stages. In the first stage, the missing MB is partitioned into different portions according to the edge orientation. In
the second stage, each portion is concealed by progressive median vector error concealment.

This paper is organized as follows. The proposed algorithm is presented in Section 2. Section 3 shows the simulation results. Finally, concluding remarks are given in Section 4.

2. Proposed algorithm

The proposed algorithm, which we call temporal error concealment with edge reconstruction or TECER, is divided into two stages: Edge Reconstruction and Progressive Median Vector Concealment. In the first stage, the edges of the corrupted 16x16 MB are concealed first and the corrupted MB is partitioned into several portions by the edge information. In the second stage, each partition is further divided into 4x4 block and progressive median vector concealment is applied to conceal the corrupted pixel. The detailed algorithm is as follows:

2.1. Edge reconstruction

Each corrupted MB is first divided into sixteen 4x4 blocks. Then, the edge crossing the missing 4x4 blocks is detected as follows:

1. If the $B_{AB}$ is available, apply horizontal high pass filter ($H_H$) on the boundary pixel of $AB$. If the edge energy is greater than a threshold ($T$), mark $AB$ and $CB$ as edge block.
2. Similarly, perform vertical edge detection on $BB$.
3. If $LB$ is available, apply vertical high pass filter ($H_V$) for edge detection. If the edge energy is greater than a threshold ($T$), mark $LB$ and $CB$ as edge block.
4. Similarly, perform horizontal edge detection on $RB$.
5. Among the neighboring edge block (if any), select the one ($B_{target}$), which has the highest edge energy.
6. Let the motion vector of $B_{target}$ be $MV_C$.
7. Conceal $B_C$ according to $MV_C$ and mark it as available.
8. Repeat step 1-6 until no more blocks can be concealed by this method.

The Sobel operators $H_H$ and $H_V$

$$H_H = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 2 & 0 \\ -1 & 1 & 1 \end{pmatrix}, \ H_V = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ -1 & 2 & 1 \end{pmatrix}$$

are used as the highpass filter in steps 1 and 3 respectively. After the edge is reconstructed, the motion vector along the reconstructed edge block is smoothed to prevent edge discontinuity.

2.2. Progressive median vector concealment

After the first step, the MB is divided into several partitions by the edge blocks (figure 2). A 4x4 block based progressive median vector concealment is then performed.

Fig. 1 Definition of current 4x4 block and its neighbors

For each 4x4 block to be concealed, the following steps is performed:

1. If the $B_A$ is available, apply horizontal high pass filter ($H_H$) on the boundary pixel of $B_A$. If the edge energy is greater than a threshold ($T$), mark $B_A$ and $B_C$ as edge block.
2. Similarly, perform vertical edge detection on $B_B$.
3. If $B_L$ is available, apply vertical high pass filter ($H_V$) for edge detection. If the edge energy is greater than a threshold ($T$), mark $B_L$ and $B_C$ as edge block.
4. Similarly, perform horizontal edge detection on $B_R$.
5. Among the neighboring edge block (if any), select the one ($B_{target}$), which has the highest edge energy.
6. Let the motion vector of $B_{target}$ be $MV_C$.
7. Conceal $B_C$ according to $MV_C$ and mark it as available.
8. Repeat step 1-6 until no more blocks can be concealed by this method.

For each 4x4 block, its neighboring 4x4 block is said to be in candidate set $C$ if it is available and an not edge block. The median vector concealment method (MVC) chooses the median motion vector from the candidate set $C$ as the best motion vector for concealment.

The progressive median vector concealment algorithm is based on MVC, which applied the MVC recursively. The algorithm of progressive median vector concealment is presented as follows:

For each 4x4 block which is not concealed

1. Construct the candidate set $C$
2. If $C$ is not empty, get the median motion vector from the candidate set $C$, and conceal the 4x4 block
3. Repeat until all blocks are concealed
3. Simulation Results

The proposed algorithm TECEC is implemented in MPEG-4/AVC reference software JM5.0c [9]. In the simulation, the QP is set to be constant at 31. One reference frame is used, with search range set to 16. RD-optimization is enabled. In our simulation, we simulate the situation of using flexible macroblock ordering [9] in the MPEG-4/AVC standard. The dispersed slice group map type is used [10] - the odd number MB and even number MB are separated into different packets for transmission as shown in Fig. 3. Once a packet is lost the correctly received MB is used to conceal the missing MB.

Two QCIF sequences, namely table tennis and foreman, and two CIF sequence namely coast guard and news are tested and different temporal concealment algorithms are compared with the proposed TECER: Temporal recovery (TR), which replaces the missing MB by the co-located MB in the previous frame; the average MV method and median MV method, which recover the motion vector by using the average and the median respectively of the neighboring motion vectors and the boundary matching algorithm BMA in [5].

Table 1 shows the PSNR of the concealed video sequence of different temporal error concealment algorithm at 5% packet loss rate and table 2 shows the PSNR of concealed table tennis sequence from frame 1 to frame 30 with a slice is lost at frame 5. In the simulation, the whole video sequence is encoded and GOP is set at 30. Error was constrained to occur in P-frames only. Results show that the proposed algorithm provides better objective quality than others in terms of PSNR.

Figure 4 shows the perceptual quality of different temporal error concealment algorithms. In frame 39 of table tennis sequence, a slice has been lost. Results show that the purpose method gives a better perceptual quality. In frame 39, the “ping-pong” ball has a rapid movement while its neighbor block (the background) has no or little movement. The TR, average MV and median MV method cannot correctly recover the motion vector due to different movement of the object and the background while the proposed TECER shows a higher accuracy in recovering the motion vector and thus provides much better perceptual quality.

4. Conclusion

In this paper, a temporal error concealment algorithm with edge reconstruction is proposed. Experimental results show that the proposed algorithm is more efficient than other temporal concealment algorithms in terms of both subjective and objective quality.

5. Acknowledgement

This work has been supported in part by the Research Grants Council (HKUST6203/02E), and the Innovation and Technology Commission (ITS/122/03) of the Hong Kong Special Administrative Region, China.

6. References

Fig. 3. A example with a 7x5 MB and two slice groups. The odd number MB (gray) and even number MB (white) are separated into two different packets for transmission.

Table 1. PSNR of the concealed video sequence of different temporal error concealment algorithm at 5% packet loss rate

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Table Tennis</th>
<th>Foreman</th>
<th>Coast Guard</th>
<th>News</th>
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<tbody>
<tr>
<td>Error Free</td>
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<td>29.22</td>
<td>33.01</td>
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<td>TR</td>
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<td>29.22</td>
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<tr>
<td>Median MV</td>
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<td>31.04</td>
<td>28.91</td>
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<tr>
<td>Average MV</td>
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<td>30.63</td>
<td>29.08</td>
<td>33.17</td>
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<tr>
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<td>30.90</td>
<td>29.90</td>
<td>33.66</td>
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<tr>
<td>Proposed</td>
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<td><strong>31.56</strong></td>
<td><strong>30.68</strong></td>
<td><strong>33.74</strong></td>
</tr>
</tbody>
</table>

Table 2. PSNR of concealed table tennis sequence from frame 1 to frame 29 using different concealment algorithms.

Fig. 4. Frame 39 of table tennis sequence, in which one of the packet is lost. (a) the corrupted frame, (b)-(f) the concealed video by TR, median MV, average MV, BMA and the proposed TECER respectively.