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MOTION VECTOR RECOVERY USING OPTICAL FLOW

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ABSTRACT

A compressed bitstream generated by an MPEG-2 video coder is sensitive to channel errors. Due to the coding structure of the MPEG-2 video compression algorithm, a bit error can affect not only the current picture frame but also succeeding frames. In this paper, we propose a temporal error concealment algorithm to recover lost or erroneously received motion vectors. In order to estimate the motion vector of the erroneous macroblock at the decoder, we use the average value of optical flow vectors of neighboring luminance intensity values.

INTRODUCTION

If all the coded bitstream of a video sequence is received correctly, the receiver can reconstruct image frames of desired picture quality. However, due to the nature of broadcasting, it is nearly impossible to design a system to be totally error-free. Therefore, if some coded bits are lost or corrupted during the transmission, an appropriate data recovering process is needed to obtain reconstructed pictures of acceptable visual quality.

Several methods, including forward error correction (FEC) coding and interleaving technique, have been proposed to solve the above problem. However, they are often ineffective, since FEC coding usually requires too many additional parity bits for error detection and error correction. Interleaving techniques may require considerable time delay and some modification of the codec configuration.

An alternative approach is error concealment. In error concealment schemes, we exploit both redundancies in the correctly received data and limitations of the human visual system without requiring any additional information. There are spatial-domain methods and temporal-domain methods, which exploit the spatial or temporal correlation in the video sequence [1,2]. In the temporal-domain methods, we can make use of neighboring motion vectors (MVs) of the lost macroblocks (MBs) and previously reconstructed reference frames.

TEMPORAL-DOMAIN TECHNIQUES FOR ERROR CONCEALMENT

The simplest way of motion vector recovery is temporal replacement, where we regard the lost MV to be zero. When a MB is lost in the current picture, we copy the MB that corresponds to the same location in the previous anchor picture, assuming that no motion has occurred between the previous and the current pictures [1]. This technique would produce reasonably good results in stationary areas; however, temporal replacement would produce significant degradations in dynamic regions.

Since neighboring MBs of the picture often move in the similar fashion, an estimate for the lost MV can be found by taking the average value of MVs of the vertically adjacent MBs [2,3].

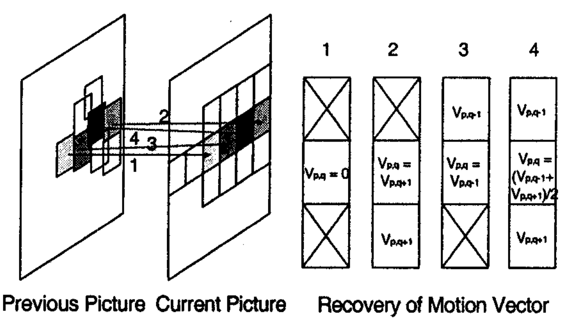

Figure 1: Averaging Method

In Figure 1, $V_{p,q}$ represents the MV of the lost MB at the p-th column and the q-th row. If the upper and the lower MBs have MVs, the MV of the lost MB is replaced by the average of the two MVs (Case 4). If only one of the vertical neighbors has a valid MV, we substitute that MV for the lost MV (Case 2 or 3). Unfortunately, if no valid MV of the vertical neighbors is available, we use the simple temporal replacement with the zero MV for the lost MB (Case 1). For Case 4, image quality of reconstructed MB is fairly good; however, the other cases generate unsatifactory results.

In this paper, we propose a new method for motion vector recovery using the optical flow equation (OFE) with some smoothness constraints [4,5].

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MOTION VECTOR RECOVERY

The OFE-based motion estimation method attempts to estimate the optical flow field in terms of spatio-temporal image intensity gradients. The Horn and Schunck method minimizes a weighted sum of the error in the OFE and a measure of the pixel-to-pixel variation of the velocity field to estimate the velocity vector [4,5].

$$\iint F(u,v,u_x,u_y,v_x,v_y)dxdy \qquad (1)$$

$$F(u,v,u_x,u_y,v_x,v_y)=\alpha^2(u_x^2+u_y^2+v_x^2+v_y^2)+(E_x u+E\,v+E_t)^2$$

$$u=dx/dt \text{ and } v=dy/dt$$

where $(E_x u+E_y v+E_t)$ denotes the error in the optical flow equation. $(u_x^2+u_y^2+v_x^2+v_y^2)$ denotes the squared sum of the spatial gradients of the velocity vector components. E_x, E_y and E_t denotes partial derivatives of image brightness with respect to x, y and t, respectively.

The minimization of the functional (1), using the calculus of variations, requires solving the two equations simultaneously.

$$\begin{aligned}\alpha^2\nabla^2 u&=(E_x u+E_y v+E_t)E_x,\\ \alpha^2\nabla^2 v&=(E_x u+E_y v+E_t)E_y\end{aligned} \qquad (2)$$

where ∇^2 denotes the Laplacian.

Consequently, by using Gauss-Seidel methods [5], we can compute a new set of velocity estimates (u^{n+1}, v^{n+1}).

$$\begin{aligned}u^{n+1}&=\bar{u}^n-E_x(E_x\bar{u}^n+E_y\bar{v}^n+E_t)/(\alpha^2+E_x^2+E_y^2),\\ v^{n+1}&=\bar{v}^n-E_y(E_x\bar{u}^n+E_y\bar{v}^n+E_t)/(\alpha^2+E_x^2+E_y^2)\end{aligned} \qquad (3)$$

where n is the iteration number and $(\bar{u}, \bar{v})$ is a local average of the velocity.

We take average of optical flow vectors in the boundary pixels of the lost MB. The value is used as the MV for the lost MB.

SIMULATION RESULTS

For performance evaluation of the proposed error concealment algorithm, we perform computer simulation on FOOTBALL sequence. It has the 4:2:0 format of 720 x 480 pixels and coded at the rate of 5 Mbits/sec. Each GOP consists of 12 pictures (N=12, M=3). A MB slice is composed of 45 MBs.

Assuming that we have lost a TS packet in the first P-frame, we compare performances of different error concealment algorithms: simple temporal replacement (TR) [1], average of the MVs of the vertically adjacent MBs (AVG) [2,3], and optical flow method (OP) [4,5]. Figure 2 shows PSNR values of the reconstructed pictures within one GOP.

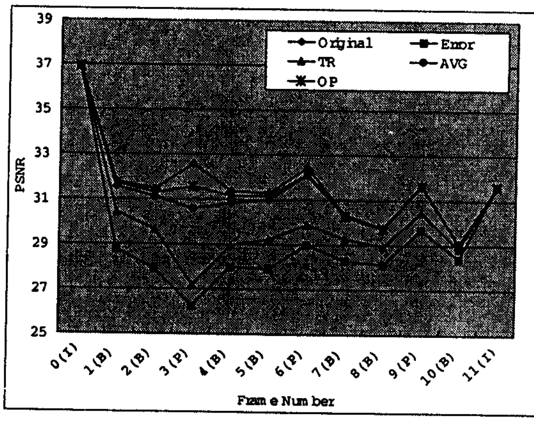

Figure 2: PSNR Comparison

The simple TR algorithm provides good results in the stationary areas; however, we observe significant degradations in the dynamic areas. We can improve picture quality of the reconstructed images by the AVG algorithm.

CONCLUSIONS

When vertically neighboring MBs have valid MVs, we can obtain reasonably good picture quality of the reconstructed image. When only one or no MV is available in the vertically adjacent MBs, we estimate the MVs of vertically adjacent MBs using the optical flow method. Simulation results demonstrate that the proposed optical flow algorithm is very effective in recovering good picture quality at the video decoder. However, it increases computational complexity.

ACKNOWLEDGMENT

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