Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
J. Vis. Commun. Image R. 18 (2007) 331–340
Journal of VISUAL Communication & IMAGE Representation
www.elsevier.com/locate/jvci

Efficient hybrid error concealment algorithm based on adaptive estimation scheme ☆

Kuo-Liang Chung [a,*], Tzu-Huang Huang [b], Po-Hsuan Liao [a]

[a] Department of Computer Science and Information Engineering, National Taiwan University of Science and Technology, No. 43, Section 4, Keelung Road, Taipei 10672, Taiwan, ROC
[b] Institute of Automation and Control, National Taiwan University of Science and Technology, No. 43, Section 4, Keelung Road, Taipei 10672, Taiwan, ROC

Received 14 June 2006; accepted 27 April 2007
Available online 10 May 2007

Abstract

Video transmission plays an important role in multimedia communication. Due to transmission error; robust video transmission has become increasingly important in providing better quality of services. Based on our proposed novel adaptive estimation scheme, this paper presents an efficient hybrid error concealment algorithm for robust video transmission. Using the information of neighboring macroblocks (MBs) of the corrupted MBs, the corrupted MBs are first classified into three types. According to the type of the corrupted MB, our proposed adaptive estimation scheme could adopt the Bézier surface estimation, the first-order plane estimation, or the centroid of major cluster estimation to conceal the corrupted MB efficiently. Based on six testing video sequences, experimental results demonstrate that our proposed hybrid error concealment algorithm can improve the video quality and the execution-time performance over different loss rates.

Keywords: Bézier surface; Centroid; Cluster; Error concealment; First-order plane; Motion vector

1. Introduction

Most video sequence coding systems use the block motion compensation to remove temporal redundancy for video compression. In real world, due to the transmission error, the video sequence coding systems cannot provide a completely guaranteed quality of services. Thus, error concealment for corrupted macroblocks (MBs) is necessary in decoding phase to increase the transmission quality. In this research, we assume that the corrupted MBs in the current frame are known in advance. The readers are suggested to refer to the previous efficient algorithms [4,11,14,22] for detecting the damaged MBs. In the past years, based on this assumption, many error concealment algorithms have been developed. These developed error concealment approaches can be classified into three types, namely the temporal error concealment, the spatial error concealment, and the temporal- and spatial-based error concealment.

Among these temporal-based error concealment algorithms, the corrupted MB can be estimated by using the information of the neighboring regions of the reference MB with the same location of the corrupted MB; the best matching MB in the search region of the previous frame is used to replace the corrupted MB. Al-Mualla et al. [1] presented a temporal error concealment algorithm using two techniques, the bilinear motion field interpolation and the boundary matching scheme. Zhang et al. [19] presented an efficient motion vector-based algorithm to estimate the corrupted MBs. In order to reduce the error propagation to the succeeding frames, Lee et al. [12] presented a multi-frame boundary matching algorithm which utilizes the boundary smoothness property in the decoded

☆ Supported by National Science Council of ROC under contracts NSC94-2213-E-011-041 and NSC95-2221-E-011-152.
* Corresponding author. Fax: +886 2 273 76777.
E-mail address: k.l.chung@mail.ntust.edu.tw (K.-L. Chung).

1047-3203/$ - see front matter © 2007 Elsevier Inc. All rights reserved.
doi:10.1016/j.jvcir.2007.04.007

and succeeding frames. Feng et al. [5] presented a modified boundary matching algorithm to determine the best matching block in the reference frame for recovering the corrupted MB. Based on the motion estimation of enlarged block, Jang and Ra [8] presented an efficient error localization and temporal error concealment algorithm. Using the concept of block-wise similarity within a frame, Wang et al. [17] presented a best neighborhood matching algorithm for error concealment. Among these spatial-based error concealment algorithms, the damaged MB is recovered by using the spatial information within the current frame. Park and Lee [13] utilized a non-uniform rational B-spline approximation to estimate the damaged MB. Zhao et al. [20] presented a spatial error concealment approach based on the directional decision and the intra-prediction. Zeng and Liu [18] presented a directional filtering scheme which uses the extracted geometric information to preserve the geometric structure of the corrupted MB. Among these developed temporal- and spatial-based error concealment algorithms, both temporal and spatial information are used to estimate the corrupted MB. Kang and Leou [10] concealed the lost MB occurred in the intra-frames and inter-frames by using the spatial linear interpolation and the boundary matching technique. Combining the side-match criterion [9] and the overlapped motion compensation, Chen et al. [2] presented an efficient error concealment algorithm. Tsekeridou et al. [16] presented a block-matching principle which consists of the split-match and the forward–backward block-match techniques. Recently, Chen et al. [3] presented a more efficient error concealment algorithm using the recursive block-matching principle. Zheng and Chau [21] presented an efficient first-order plane estimation to conceal the corrupted MB for the video coding standard H.26 L [15]. In their error concealment method, the motion vectors of four neighboring of the corrupted MB are used to estimate the four corners of the corrupted MB. Although a 16×16 MB in H.26 L can be divided into different block division modes, their method can be applied to the other video coding systems. The simulation results demonstrate that the first-order plane estimation outperforms the temporal replacement method.

Based on our proposed novel adaptive estimation scheme, this paper presents a hybrid error concealment algorithm for robust video transmission. Based on the eight neighboring MBs of the corrupted MBs, the corrupted MBs can be classified into three types, the tie and high variance type (TAH), the tie and low variance (TAL) type, and the dominance type. According to the classified type of the current corrupted MB, our proposed hybrid error concealment (HEC) algorithm can determine what kind of error concealment method should be used to recover the damaged MB. If the corrupted MB belongs to the TAH (TAL) type, the proposed Bézier surface (the existing first-order plane) estimation is used to conceal the corrupted MB. The reason to explain why the Bézier surface estimation is better than the first-order plane estimation for the TAH type and why using centroid instead of first-order plane estimation for the dominance type will be described in Section 3. If the corrupted MB belongs to the dominance type, the centroid of major cluster estimation is used to conceal the corrupted MB. Experimental results demonstrate that our proposed algorithm can efficiently improve the video quality and the execution-time performance over different MB loss rates when compared to the currently published error concealment algorithm by Zheng and Chau [21].

The remainder of this paper is organized as follows. Section 2 surveys the previous first-order plane estimation for error concealment by Zheng and Chau. Section 3 presents our proposed hybrid error concealment algorithm. Experimental results are demonstrated in Section 4. Conclusions are addressed in Section 5.

2. The past work by Zheng and Chau

In this section, the currently published error concealment algorithm by Zheng and Chau is surveyed. Their algorithm is based on the first-order plane estimation. In Zheng and Chau's result, for one 16×16 MB, there are seven different block division modes to fit the requirement of H.26 L [15]. We only consider the case for mode 0, i.e. the 16×16 MB, to introduce the first-order plane estimation. In fact, the concept of plane equations and bilinear interpolation technique used in the first-order plane estimation can be easily applied to the remaining six different block division modes for error concealment.

The corrupted MB and its eight neighboring MBs are shown in Fig. 1a where $\mathrm{MB}_{i,j}$ denotes the corrupted MB and the set $\mathrm{NB} = \{\mathrm{MB}_{i-1,j-1}, \mathrm{MB}_{i,j-1}, \mathrm{MB}_{i+1,j-1}, \mathrm{MB}_{i-1,j}, \mathrm{MB}_{i+1,j}, \mathrm{MB}_{i-1,j+1}, \mathrm{MB}_{i,j+1}, \mathrm{MB}_{i+1,j+1}\}$ denotes the eight neighboring MBs of $\mathrm{MB}_{i,j}$. In Fig. 1b, the eight motion vectors of the set NB are denoted by $\mathrm{MV}_{i-1,j-1}$, $\mathrm{MV}_{i,j-1}$,..., and $\mathrm{MV}_{i+1,j+1}$. The motion vector of $\mathrm{MB}_{i,j}$, $\mathrm{MV}_{i,j}$, is estimated by two-phase approach. In the first phase, the motion vectors of the four corners of the corrupted MB, $MV^1_{i,j}$, $MV^2_{i,j}$, $MV^3_{i,j}$, and $MV^4_{i,j}$, are estimated by using the first-order plane estimation. For simplicity, we only introduce how to estimate the left-top motion

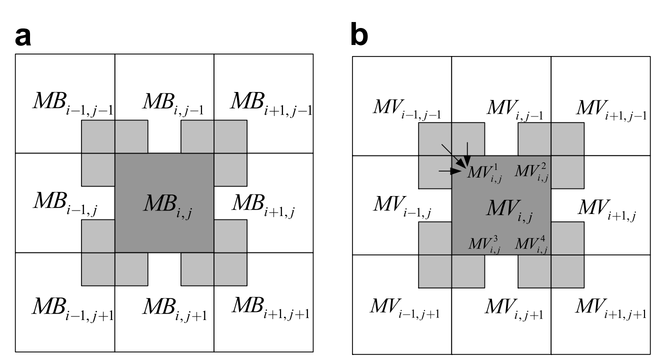

Fig. 1. The depiction of first-order plane estimation. (a) The corrupted MB and its eight neighboring MBs. (b) The estimation of left-top motion vector for corrupted MB.