FOUR FIELD VARIABLE BLOCK SIZE MOTION COMPENSATED ADAPTIVE DE-INTERLACING

Yu-Lin Chang, Ching-Yeh Chen, Shyh-Feng Lin, and Liang-Gee Chen

DSP/IC Design Lab,
Graduate Institute of Electronics Engineering,
National Taiwan University, Taipei, Taiwan

ABSTRACT

A four field variable block size motion compensated adaptive de-interlacing method is proposed to improve the accuracy of the motion vectors and lower the occlusions of motion compensated de-interlacing. The proposed de-interlacing method consists of variable block size motion estimation/compensation with four field SAD, interlaced block mode decision, and new block modes. The variable block size motion estimation/compensation improve the accuracy of the motion vectors, especially for spatially-periodic patterns. The new block modes and the interlaced block mode decision make block decisions more precisely, and special patterns that motion compensation cannot be compensated are correctly de-interlaced by these two methods. The subjective view shows the improvement of the accuracy of the motion vectors and the correctness of the mode decision.

1. INTRODUCTION

De-interlacing technique is an important part of digital television. It converts interlaced-scanned video sequences into progressive-scanned ones. If an interlaced-scanned video sequence is directly shown on a progressive-scanned display device, defects like feathering, line crawling, edge-flicker and jagged effect would make the viewer uncomfortable, so a good de-interlacing process is necessary for these applications.

There are three kinds of de-interlacing methods: intra-field de-interlacing, motion adaptive de-interlacing (MA), motion compensated de-interlacing. The intra-field deinterlacing methods have been broadly used in software and low-level digital televisions. Intra-field de-interlacing uses a single field to reconstruct a progressive frame through intra-field interpolation. The edge-based line average algorithm (ELA) and edge dependent directional interpolation (EDDI) are the most common intra-field interpolation algorithms. Zhao [1] proposed some adaptive methods to improve the the edge-directed interpolation algorithms.

Motion adaptive (MA) de-interlacing is the main stream of the de-interlacing method on digital televisions today. The motion adaptive de-interlacing processes the moving areas in a field with intra-field interpolation and the static areas with directly field merging. Lin proposed a four field horizontal motion adaptive de-interlacing method [2] to reduce the hardware complexity, and it achieves much more accurate motion detection. However, there are still some motion detection errors with these motion adaptive methods.

Motion compensated (MC) de-interlacing is the state-of-the-art de-interlacing techinique. Firstly, Nguyen proposed a same parity motion compensated de-interlacing algorithm [3], which finds a best matching block from neighboring fields to compensate with the current block and uses intra-field interpolation for occlusion areas. There are two kinds of methods to improve the accuracy of the motion vector for MC de-interlacing. One is to improve the search method, and the other is to improve the matching criterion. Haan [4] proposed a true motion estimator with 3DRS method to improve the search method of motion estimation in the MC de-interlacing. Chang [5] proposed a new matching criterion - the same parity four field SAD, which utilizes the same parity characteristic of the interlaced-scanned video. The four field SAD - can raise the accuracy of the motion vectors and reduce the motion vector errors. However, the accuracy of the motion vectors still has to be improved, and mode decision methods should make correct block mode decision more precisely. Because the more the pixel resolution is kept, the more natural the de-interlaced picture will be.

In this paper, a four field variable block size motion compensated adaptive deinterlacing system is proposed. The motivation for this new de-interlacing method will be described in section 2. The problems of MC de-interlacing will be stated. The proposed method will be discussed in section 3. And the simulation results will be shown in section 4. At last, the conclusion remarks the proposed system.

2. MOTIVATION

For MC de-interlacing, there are two kinds of techniques to improve the accuracy of the motion estimation - the search method and the matching criterion. There are many search methods for motion estimation, and they have their own characteristics, like fast computational speed, smooth motion vectors, or easy to implement. But, the matching criterion of MC de-interlacing is different from that of common video coding system. It is not to find a motion vector which makes the residual small after motion compensation, but to find a motion vector which makes the compensated block best match with the current block. The four field SAD matching criterion proposed by Chang[5] lacks of the information from different parity fields. That is to say, if there are some spatially-perioidic patterns moving in a video field sequence, the motion estimation with the four field SAD might not find a correct motion vector. However, this kind of spatially-periodic patterns are very common in the natural video sequences, this problem must be solved for MC de-interlacing. There are two approaches to solve the problem - one is to detect the spatially-periodic pattern, and the other is to change the block size of the motion estimation. Periodic patterns repeat themselves along any direction in a picture. It is hard to find all of them. So the change of the block size should be useful in this problem.

The smaller the block size is, the less the accuracy of the motion vector would be. But, if the block size is enlarged, occlusions appears at object boundaries. The tradeoff between block size and occlusion should be solved to preserve more motion compensated results for MC de-interlacing.

The block modes, and their decision methods are important parts for MC de-interlacing, too. Traditional MC de-interlacing methods adopt two block mode - MC mode or Intra mode. However, MC/Intra mode would fail while de-interlace an object which exists only in single parity field, and this increases the difficulty of the mode decision. And SAD values are often used to do the mode decision, but there are still a lot of miss-detection or false-alarm that degrade the picture quality.

3. PROPOSED METHOD

We proposed a motion compensated adaptive de-interlacing system to solve the above problems. The variable block size motion estimation with four field SAD is to solve the incorrect of the motion vectors caused by the spatially-periodic patterns and lower the occlusions on the object boundaries. The proposed two new modes - MC/MA mode can improve the picture quality and preserve the correctness of which part of an object should be processed by the intra-field interpolation. The proposed mode decision method is suitable with the two new modes and gets better results.

3.1. The proposed Motion Compensated Adaptive Deinterlacing method

The block diagram of the proposed motion compensated adaptive de-interlacing method is shown in Fig. 1. This system needs three field buffers to store the reference field data - the forward-forawrd field, the forward field, and the current field. The four field motion adaptive de-interlacing module uses the MA de-interlacing algorithm proposed by Lin[2]. After the four field MC de-interlacing module and the four field MA de-interlacing module processed its data, the MC/MA mode decision part will decide whether a block is going to use the result of MC or MA. The MA mode replaces the intra mode in the traditional MC de-interlacing. After the result is produced, it will be merged with the current field and output to the display device.

3.2. Variable Block Size Motion Estimation with Four Field SAD

As shown in Fig.2, The variable block size motion estimation with four field SAD accmulates three SAD values of a block - SAD_1, SAD_2, and SAD_3 . The variable block size motion estimation consists of two pass iteration. In the first pass, the motion estimation would find a best matching motion vector by SAD_1 and SAD_2 under three block sizes. We choose 32×16, 16×8, 8×4 as the three block sizes. In the second pass, the value of SAD_3 is used to determine which block size is going to be the output block size. So there are three kinds of produced block s, as shown in the right side of Fig.2, one 32×16 block, four 16×8 blocks, and three 16×8 blocks with four 8×4 blocks.

In the first pass, SAD_1 and SAD_2 are defined as following equations:

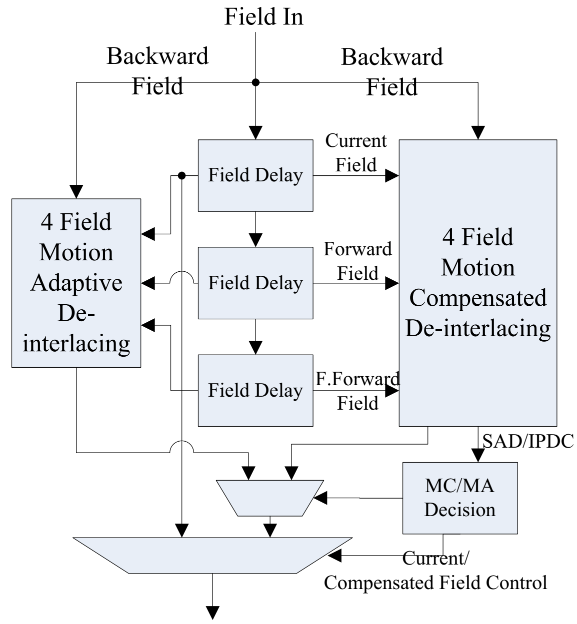


Fig. 1. Block Diagram of the Proposed Method

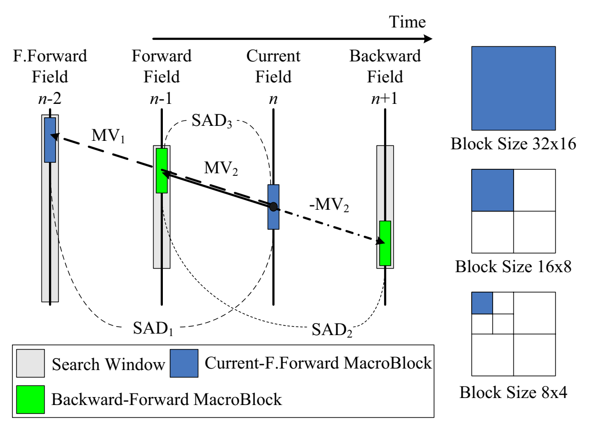


Fig. 2. Variable Block Size Motion Estimation with Four Field SAD

$$SAD_{1k|m} = \sum_{i,j \in MB} |f(i+MV_{kx}, j+MV_{ky}, n-2) - f(i,j,n)| \quad (1)$$

$$SAD_{2k|m} = \sum_{i,j \in MB} (|f(i+\frac{1}{2}MV_{kx}, j+\frac{1}{2}MV_{ky}, n-1) - f(i-\frac{1}{2}MV_{kx}, j-\frac{1}{2}MV_{ky}, n+1)|) \quad (2)$$

where $f(i,j,n)$ denotes the luminance intensity at the (i,j) location of the nth field, and the MV_{kx} and MV_{ky} means the x component and the y component of the kth motion vector candidate MV_k in the search window of the forward-forward field, where m means block size m, $m \in \{32 \times 16, 16 \times 8, 8 \times 4\}$. SAD_1 is the SAD value of the current block and the block in the forward-forward field along MV_2 with twice MV_2 length. SAD_2 is calculated by accumulating the absolute difference between the macroblock where the MV_2 indicated to in the forward field and the macroblock where $-MV_2$ indicated to in the backward field.

In order to find a motion vector in the first pass, the matching criterion of the four field motion estimation is minimizing the value of $SAD_1 + SAD_2$, as described in eq.3. And the motion vector MV_k is the found motion vector.

$$k = Arg(\min_{k \in SW}(SAD_{1k} + SAD_{2k})) \quad (3)$$

The found motion vectors of three block sizes are stored for the second pass block size decision.

In the second pass, the block size will be decided through SAD_3. SAD_3 is the SAD value from the current block to the block in the forward field with the best matching motion vector calculated in the first pass motion estimation. Thus, three SAD_3 with three block sizes will be produced - $SAD_{3,32x16}$, $SAD_{3,16x8}$, and $SAD_{3,8x4}$. The purpose of the second pass is to decide the block size, as the following equation:

$$b = Arg(\min_{m}(k_m SAD_{3,m})) \quad (4)$$

where $m \in \{32 \times 16, 16 \times 8, 8 \times 4\}$ and k_m is a constant for normalizing the SAD_3 with different block sizes. The block size b would be chosen after the second pass calculation. The motion compensation from the forward field will be done according to the block size in the form shown at the right side of Fig.2.

This variable block size motion estimation/compensation can avoid the motion vector errors caused by the spatially-periodic patterns and preserve good quality on complex texture areas through smaller block size motion estimation.

3.3. Block Mode Decision

The most suffering defects on video without de-interlacing is the feathering effect. We proposed a method to accumulate the pixels with the feathering effect. If there are many pixels with feathering effect in a compensated block, it means the motion compensated result may be wrong. So the pixels in that block should be the results of motion adaptive de-interlacing. And the proposed method shown in Fig.3 is called interlaced pixel distortion classification (IPDC). The feathering effect can be detected through IPDC. By IPDC and SAD, the mode decision can determine block mode more accurately.

As shown in Fig.3, there is a matching block in the forward field. And the IPDC calculation in a block is presented as the following pseudo code:

$diff_1 = abs(f_{n-1}(i + MV_x, j + MV_y) - f_n(i,j)$;
$diff_2 = abs(f_n(i,j) - f_n(i,j+1)$;
if ($diff_1 > th_1$ && $diff_2 < th_2$) IPDC++;

MV_x and MV_y are the found motion vector. The value of $diff_1$ represents whether a pixel in the compensated block is similar to its current block or not, and the value of $diff_2$ shows if the pixel will be placed in between two similar pixels with current block. If the pixel in the compensated block is placed in between two different pixels, the possibility for the viewer to suffer the feathering effect is increased, and the IPDC increased. If IPDC is larger than a certain threshold, it means there are too many pixels with feathering effect in the block. So the mode decision module

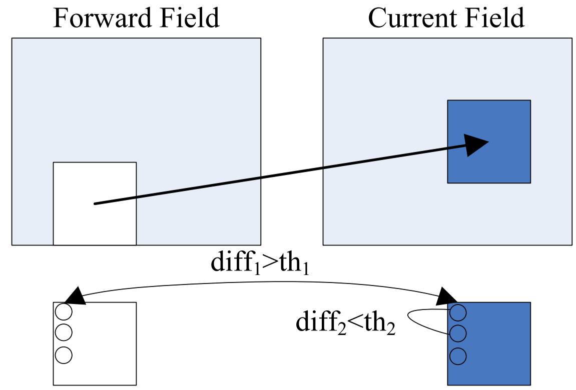


Fig. 3. Interlaced Pixel Distortion Classification

should choose the MA mode under large IPDC condition. And another condition that the mode decision module would choose the MA mode is the large SAD condition. If $SAD_1 + SAD_2$ of the best matching macroblock is too large, it means the motion estimation is incorrect. It is possibly occurred on the object boundaries. Under this condition, the MA mode should be chosen to recover the block with motion adaptive results. And other areas are also processed by MC mode to preserve the pixel resolution as much as possible.

4. SIMULATION RESULTS

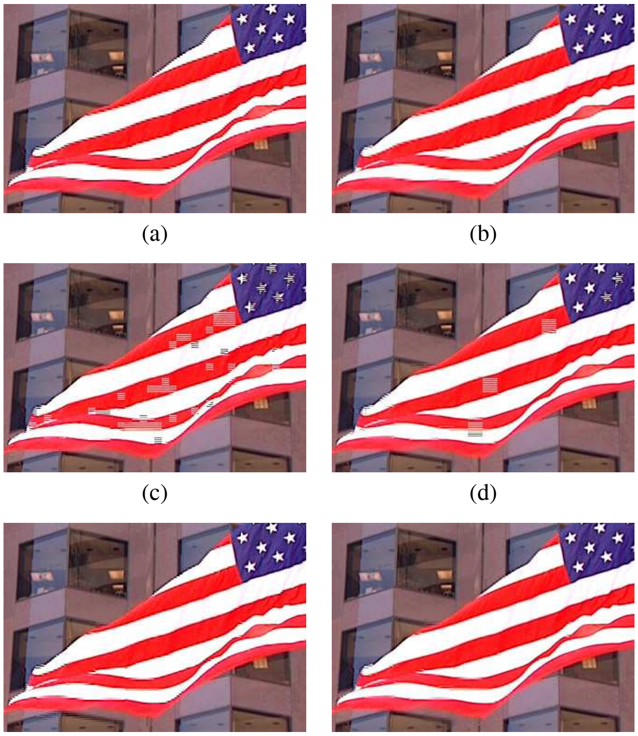
The simulation results can be divided into three parts. The first part shows the variable block size motion estimation help to find more accurate motion vectors. The second part demonstrates the picture quality of the mode decision module by IPDC and SAD. The third part brings out the difference between MC/intra mode and MC/MA mode. The test video sequences are flag, ice hockey, and pendulum, which are the common test video sequences used in the de-interlacing method development.

4.1. Variable Block Size Motion Estimation with four field SAD

The results in Fig.4 are produced only by motion compensation for the comparison of motion estimation. The search method has been changed to compare their accuracy. The search method 3DRS produces smooth motion vectors, but it cannot correctly determine the motion of non-rigid body, which is shown in Fig.4(b). So the full search method is still needed for complex or non-rigid objects. As shown in Fig.4(c)(d)(e), the full search results vary in different block sizes. For smaller block size(like 16×8 and 8×4, there are more motion vector errors because more blocks would become spatially-periodic patterns, and the motion estimation is prone to be wrong. For larger block size(32×16), occlusions and pixels with feathering effect appear on the flag boundaries. However, the variable block size motion estimation with four field SAD adopts proper block size for motion compensation. The result of the variable block size motion estimation with four field SAD in Fig.4(f) shows an acceptable result even without intra-field interpolation.

4.2. Block Mode Decision

In Fig.5(a), the traditional block mode decision determined that most of the blocks are MC mode because it only uses the SAD for



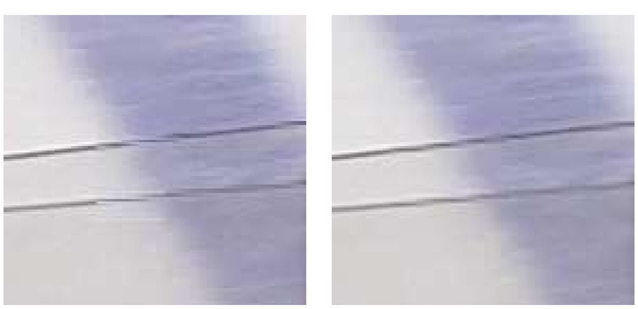
(a) (b) (c) (d) (e) (f)

Fig. 4. Subjective View Results of flag (a) Directly-Merged (b) Block Size 16x8 3DRS (c) Block Size 8x4 Full Search (d) Block Size 16x8 Full Search (e) Block Size 32x16 Full Search (f) Proposed variable block size Full Search

its criterion. The MC mode should not be assigned to the blocks in the middle area of Fig.5(a). As for our mode decision results shown in Fig.5(b), the blocks in the middle area of the picture are chosen as MA mode. The motion adaptive de-interlacing detects these parts as moving parts, then the intra-field interpolation is adopted in these blocks. So the proposed mode decision with SAD and IPDC is better than that with SAD only.

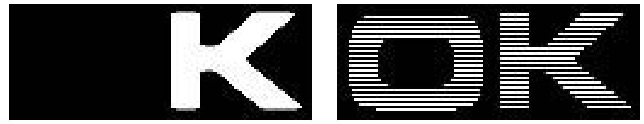
4.3. New Block Modes

The block modes - MC/Intra mode have been replaced by MC/MA mode to ease the burden of the mode decision module. For objects



(a) (b)

Fig. 5. Subjective View Results (a) No IPDC (b) With IPDC



(a) (b)

Fig. 6. Subjective View Results for block modes (a)MC/Intra Mode (b) MC/MA Mode

that only appear in single parity fields, the MA mode is much better than the Intra mode. As shown in Fig.6(a)(b), the word ”O” and ”K” in the pendulum sequence exist in the different parity fields. The mode decision module is prone to determine the blocks as non-MC mode because of its feathering texture. Traditional methods tried to detect this kind of objects and correct the motion vector and mode, or the result will be the intra-field interpolation result shown in Fig.6(a). If block modes are MC/MA mode, the motion adaptive de-interlacing part will choose the pixels that really need to do intra-field interpolation. And the de-interlacing method with MC/MA mode shows a normal result in Fig.6(b) at these blocks.

5. CONCLUSION

To find accurate motion vectors and to lower the occlusions are two important topics for motion compensated de-interlacing. However, special video patterns, like spatially-periodic patterns, objects only exist in single parity fields, often restrict the performance of motion compensated de-interlacing. A four field variable block size motion compensated adaptive de-interlacing method is proposed. It consists of the variable block size motion estimation/compensation to find more accurate motion vectors, block mode decision with IPDC and SAD to determine the block modes more precisely, and new block mode - MC/MA mode to ease the burden of mode decision and cope with special video patterns. The simulation results of the proposed method show higher quality pictures than before. And this method is suitable for advanced digital television to get better de-interlaced pictures.

6. REFERENCES

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