MOTION COMPENSATED DE-INTERLACING WITH ADAPTIVE GLOBAL MOTION ESTIMATION AND COMPENSATION

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ABSTRACT

A motion compensated de-interlacing method with adaptive global motion estimation and compensation is proposed to recover the defects of interlaced video sequence with camera panning, rotating or zooming. GME and GMC are used to recover the change of the whole picture due to camera motions. Two local motion compensated de-interlacing methods are proposed and applied to de-interlace interlaced video sequences with or without global motion respectively. SAD checking and global/local motion comparator can be used as a block based mode decision system for intra/MC/GMC modes. The Proposed algorithm could achieve higher image quality of interlaced video sequences than any other usual de-interlacing algorithm on progressive devices.

1. INTRODUCTION

De-interlacing is a key technique for displaying ordinary interlaced video sequences on progressive devices. Interlaced video sequences are shot with interleaved top fields and bottom fields in temporal domain consecutively. While displaying the interlaced video sequences on the progressive devices, the vertical resolution doubles and the information of the fields in the temporal domain cannot easily be transferred to that in the spatial domain. If two neighboring fields are directly combined into one frame on the progressive devices, there are defects such as line-crawling and flicker in some motion, scaling, or rotating areas. And it would be even worse while the video sequence is shot with camera panning, zooming or rotating.

The intra-field de-interlacing – BOB[1] which was commonly adopted on the software DVD player retains only the top fields or the bottom fields then do bilinear interpolation according to the retained fields. And a new frame is reconstructed with the data of only one field. However, the edge on the image would be blurred if bilinear interpolation is used. Directional interpolation methods, like ELA[2], EDDI[3] have been proposed to prevent jagging edges after interpolation.

Motion adaptive de-interlacing has become an easy method for hardware to achieve higher image quality on processing interlaced video sequences. Ville[4] proposed a motion adaptive technique with a fuzzy motion detector. Sugiyama and Nakamura[5] proposed a motion adaptive de-interlacing with motion compensation. The information in the backward and the forward field has been gathered into the current field through motion estimation. A low cost two-field morphological motion adaptive de-interlacing method has been proposed by S. F. Lin et al.[6] , and dilation and erosion operations are used for motion detection.

Motion compensated De-interlacing has become popular in these years in virtue of the growing needs for best image quality on HDTV. Tourapis et al.[7] proposed a motion compensated de-interlacing method with their zonal based motion estimation. Gerard de Haan et al.[8] proposed a sub-pixel accurate motion compensated interpolation with a post-processing based upon directional interpolation.

Nevertheless, camera panning, rotating, and zooming may cause severe defects like radial line-crawling on the interlaced video sequences, and these problems cannot be solved by ordinary motion detection and motion estimation. Global motion estimation (GME) and global motion compensation (GMC) are applied in this paper to solve these global motion problems. A motion compensated de-interlacing method with intra/MC/GMC decision is proposed in this paper for high-end progressive video devices. The proposed method would be introduced in Sec. 2. In Sec. 3, we show the PSNR, subject view and complexity of computation data of the experimental results. The conclusion is given in Sec. 4.

2. PROPOSED METHOD

The main problem which we want to solve in our proposed method is the camera panning/rotating/zooming problem. The picture quality will greatly level down when camera motion is panning or zooming because the picture in the forward field and the current field would be quite different and cannot be detected by usual motion detection methods. Camera motions, panning / rotating / zooming result in the "global motion" in video sequences. For example, if the camera is zooming out in the interlaced video sequence, the objects in the forward field will be larger than the current field. Local Motion Estimation or motion detection cannot find out where the true motion is in this kind of video sequence, so global motion estimation[9] is used first in our proposed method to detect if there are global motions in the video sequence.

2.1. Global Motion Exists

As in Fig. 1, the flow sheet of our proposed method, if global motion exists in the video sequence, global motion decision

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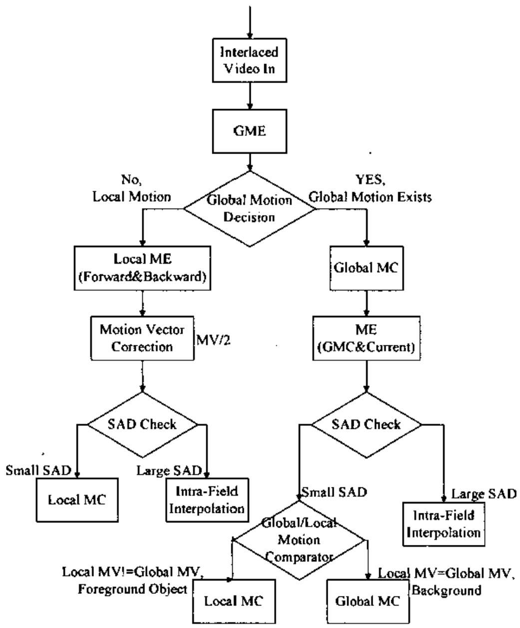


Fig. 1. Data flow sheet of the proposed method

would go into the global motion compensation (GMC) part and produce a new field which is reversely panned / rotated / scaled. The similarity between the new field and the current field will be much closer and then local motion estimation can be done with more accuracy. So we proposed a local ME method to estimate the motion in the current field and the new global motion compensated field in Fig. 2. If the camera is zooming in, the objects and background in the forward field will be smaller than it in the current field. The forward field should be scaled to a size which fits the current field, then a block really matching with the block in the current field could be found by local motion estimation in the global motion compensated forward field.

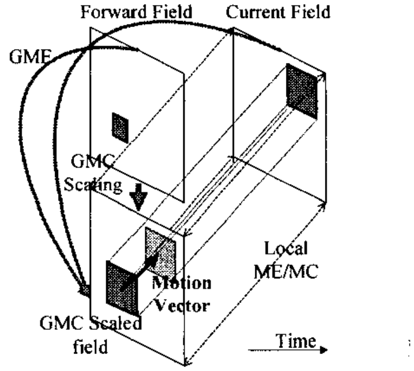


Fig. 2. Local ME/MC of the current field and the global motion compensated field

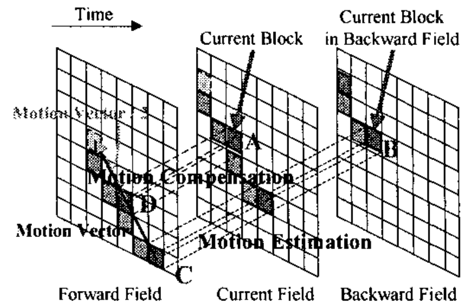


Fig.3. Backward-to-Forward Local ME/MC

After GMC and local ME, SAD Checking is used to prevent the local motion estimator from returning a block that is quite different from the current block. What to do in the SAD checking is to set a threshold of the SAD and check that the SAD of a returned block is smaller or larger than the threshold. If the SAD of a returned block is larger than the SAD threshold, the whole block would be reconstructed by intra-field interpolation. Since the information of the block in the forward field may be quite different from the current field, intra-field interpolation is much suitable than motion compensation to reconstruct the information in the current block now. Here the ELA algorithm is used for intra-field interpolation.

If the SAD of a returned block is smaller than the SAD threshold, local motion compensation or global motion compensation would be used to compensate the current block. The last step of the proposed de-interlacing method with global motion is to distinguish the foreground from the background. Foreground objects and background should be separated here for different processing. Local motion vectors and global motion vectors are of great use in this condition. The translation parameters of the global motion vectors can be compared with the value of the local motion vectors, and the comparator is called the global/local motion comparator. If the difference between the local motion vector of one block and the translation parameters of the global motion vector are less than one pixel, the block is considered to be a background block and the global motion compensation would be applied. Otherwise, the block would be regarded as a foreground block and local motion compensation is adopted. Finally, the de-interlacing procedure with global motion has been completed.

2.2. No Global Motion Exists

The de-interlacing procedure without global motion is almost the same as the one with global motion. There are two main differences between the two procedures. One is the local motion estimation, the other is the existence of global motion estimation / compensation. A different local motion estimation / compensation is proposed in the no global motion de-interlacing procedure.

If no global motion exists, local motion estimation of the backward field and the forward field will be used. Assuming there is an object moving to the up-left side of the screen as shown in Fig. 3, and the current block A in the current field is going to be processed. The block B with the same situation in the backward field is located. A block C that is most similar to B would be found in the forward field and a backward-to-forward motion vector could be gotten. Then dividing the motion vector by two (motion vector correction), another block D would be found in the forward field. The motion compensation method is to paste the pixel data of the block D to the current block A.

The Current-to-forward local ME/MC is not used here because the current field and the forward field are not of the same parity. Since the outputs of the interlaced video sequences possess the characteristic of both the top fields and the bottom fields, block-matching algorithms can not be used in the video sequences that the picture details differ from the neighboring fields. So, the same parity field motion estimation is used to match the correct block in the backward field and the forward field.

After local ME and motion vector correction, SAD checking is done to determine whether a real-matching block can be found by motion estimation. If not, the information of the current block would be recovered by intra-field interpolation. Otherwise the motion compensation mentioned above would be adopted to compensate the current block. And this is the final step in the no global motion de-interlacing procedure.

3. RESULTS

Results have been simulated by software with C language. Motion estimation is done by full search with block size 16x16 and search range -16~+16. Computational Instruction profile, Objective PSNR results and subject view are discussed in this section.

3.1. Instruction Profile

Instruction profile is shown in Table 1. The average instructions to be executed for video sequences (CIF format, 30FPS) are 87GIPS. Because of the huge amount of data iterative operations of ME and GME, most of the computational instructions are data instructions. If hardware implementation issue is concerned, the data iterative frequency of GME must be enormously reduced.

Arithmetic Instructions	30.20314%
Data Instructions	52.93031%
Logic Instructions	1.11848%
Rotate and Shift Instructions	1.31174%
Jump, Test and Compare Instructions	12.15060%
Stack Instructions	1.24341%
Other Instructions	1.04232%
Total	100%
Total Instructions (CIF 30FPS)	87,399,298,641 87 GIPS

Table 1 Instruction Profile for proposed method

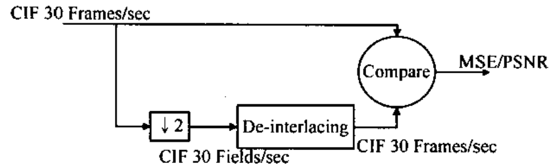


Fig. 4. CIF PSNR Comparison Method

3.2. PSNR Comparison

Several CIF progressive video sequences have been converted into interlaced video sequences according to the algorithm shown in Fig. 4. A frame is half-sampled into a top field or a bottom field. After the de-interlacing procedure, the interlaced sequence would be recovered into a progressive sequence. Then the original input sequence can be compared with the output sequence.

The PSNR comparison is presented in Table 2. There are eleven Sequences and six methods compared. The methods are directly merged frame, bilinear interpolation, ELA, 2 field motion adaptive de-interlacing, 2 field morphological motion adaptive de-interlacing, and the proposed method. The proposed method possesses almost the highest PSNR over these methods, especially for video sequences with static background, like "mother and daughter" and "Hall monitor". That is to say, the detailed texture of the picture can be preserved by the proposed local ME/MC without global motion. Although the PSNR of the proposed method is not as high as the 2 field motion adaptive method in some fast-motion video sequences like Stefan and Table Tennis, the subject view would be much better for the proposed method.

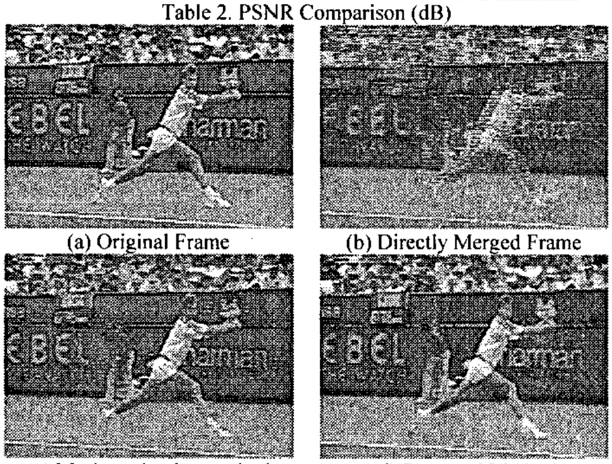
3.3. Subject View Comparison

Two subject view of video sequences are shown in Fig. 5 and Fig. 6. The original frame, interlaced frame, 2 field motion adaptive de-interlaced frame, and the proposed de-interlaced frame of "Stefan" are shown in Fig. 5(a), Fig. 5(b), Fig. 5(c), and Fig. 5(d). The camera is panning in Stefan and there are severe line-crawling over the whole interlaced frame. Most part of the picture can be de-interlaced with the common motion adaptive de-interlacing method, but there are still many line-crawling defects on the Stefan's body and the words on the wall. But for the proposed method, line-crawling defect is no more seen in the picture. Because the camera panning problem has been solved by global motion compensation, the processed video sequences possess high quality subject view.

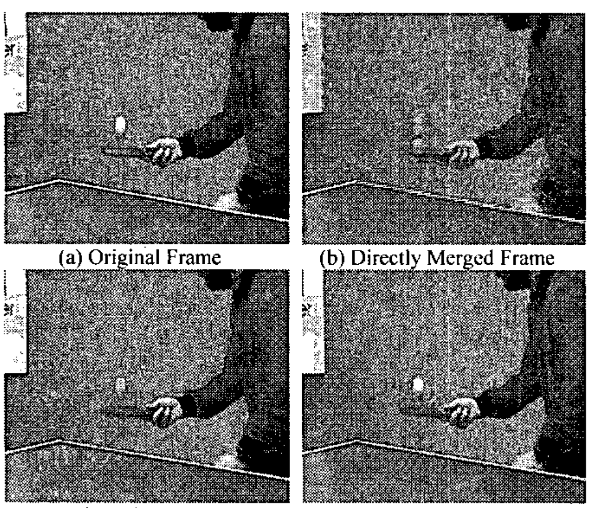
The original frame, directly merged frame, motion adaptive de-interlaced frame, and the proposed de-interlaced frame in "Table Tennis" are shown in Fig. 6(a), Fig. 6(b), Fig. 6(c), and Fig. 6(d). The camera is zooming out in this video sequence and there are lots of radial line-crawling defects on the wall. There are still many radial line-crawling defects in the picture processed by the common motion adaptive method. The fields would be scaled by the proposed method for de-interlacing, so the proposed method possesses higher quality subject view in this kind of camera-zooming video sequences than usual motion adaptive or motion compensated methods.

Name	Merged	Bilinear	ELA	2 Field	2 Field + Morphology	Proposed Method
Silent	29.52	29.15	26.72	37.86	39.22	39.53
Weather	31.01	26.93	25.55	37.96	37.49	36.89
Mobile	17.83	24.92	23.99	26.20	25.17	25.04
Mother Daughter	33.59	32.89	30.82	37.76	38.05	42.42
Container	31.01	28.14	25.04	40.27	35.33	33.97
Stefan	11.86	26.91	25.49	24.90	27.38	26.60
Dancer	23.19	36.15	33.41	31.94	32.95	36.20
Foreman	23.30	29.96	27.41	30.44	30.83	32.18
Hall Monitor	30.61	30.68	27.75	35.34	35.31	38.50
Table Tennis	23.89	27.32	25.85	31.55	32.46	33.95
Coastguard	22.59	27.84	26.32	29.32	29.00	28.13

Table 2. PSNR Comparison (dB)



(a) Original Frame (b) Directly Merged Frame
(c) Motion adaptive method (d) Proposed Method
Fig. 5. Video Sequence "Stefan" CIF 30FPS



(a) Original Frame (b) Directly Merged Frame
(c) Motion adaptive method (d) Proposed Method
Fig. 6. Video Sequence "Table Tennis" CIF 30FPS

4. CONCLUSIONS

A motion compensated de-interlacing method with global motion considerations is proposed to recover the defects of interlaced video sequence with camera panning, rotating or zooming. GME and GMC can reversely produce a new field with actual picture size and position to adopt local ME/MC to the current field and the forward field for de-interlacing. Another backward-to-forward local ME/MC method is applied to de-interlace the pictures without global motion. And SAD checking is proposed for decision of intra-field interpolation or motion compensation. Finally, a global/local motion comparator is used to distinguish the foreground objects from background, where global motion compensation can be used in the background. The experiment results show that the PSNR is high and the subject view is the best among the existing methods.

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