A RECURSIVE APPROACH FOR DE-INTERLACING USING IMPROVED ELA AND MOTION COMPENSATION BASED ON BI-DIRECTIONAL BMA

Seungchan Byun, Jeongmoon Byun, and Gyeonghwan Kim

Dept. of Electronic Engineering, Sogang University
CPO BOX 1142, Seoul, 100-611 Korea
{byun2133, topus, gkim}@sogang.ac.kr

ABSTRACT

In this paper, we propose an algorithm for interlaced-to-progressive conversion by the weighed summation of the information collected from the spatial de-interlacing method, in which the weighted edge based line average is applied, and the temporal method, in which the motion compensation is employed by using bi-directional motion estimation and motion adaptive technique using a temporal filter. The main purpose of the approach is to overcome the shortcomings of each of the de-interlacing techniques without significant increment of the computational complexity. Experimental results prove the effectiveness of the algorithm.

1. INTRODUCTION

De-interlacing is the process by which interlaced video format is converted to progressively scanned video format. Interlaced scanning video formats have been used to save bandwidth though it has line flicker and serration of moving edge. As displays with progressive scan format are getting popular, necessity of the conversion from interlaced to progressive scan format is increased. Interlaced-to-progressive conversion(de-interlacing) algorithms can be classified into two: non-motion compensated(non-MC) de-interlacing and motion compensated(MC) de-interlacing algorithms [1].

In general, non-MC de-interlacing algorithms are simple and fast in terms of computation. ELA(edge based line average), in which edge directions are considered, and motion adaptive ELA(MAELA) are examples of non-MC de-interlacing algorithms. In the algorithm, however, it is not easy to avoid image artifacts when moving objects are involved as motion information is not considered. Therefore, de-interlacing algorithms with motion compensation have been used to produce higher performance.

It has been known that successive images in a video sequence have temporal correlation. If correct motion estimation between successive images is possible, we can implement a de-interlacing algorithm with high performance by incorporating the correlation. Motion compensation allows us to convert a moving sequence into a stationary one without artifacts. However, highly accurate motion estimation is required to achieve high performance de-interlacing. Also, the required accuracy brings to intensive computing power and depends on image conditions such as scene changes and abrupt brightness changes.

Therefore, we propose an approach to obtain high quality de-interlaced video images by combination of both the non-MC method and the MC method [2]. It is a type of hybrid de-interlacing method through adjusting a weight parameter and median filtering to take advantage of each method. The algorithm is motion adaptive as a temporal filter is involved in non-motion area [3]. Adjusting the weight parameter in recursive manner is applied as simple linear combination of the algorithms result in limited success.

2. PROPOSED METHOD

The proposed algorithm consists of 4 steps as shown in Fig. 1. In the first step, two field images and one de-interlaced frame image produced in the previous stage are used to detect areas with motion. In the second step, if there is no motion area, missing line is interpolated by field insertion. Otherwise, two field images are converted into two frames by adopting the improved ELA method. In the following step, we estimate the motion by the bi-directional BMA(block matching algorithm) using three frames which are obtained by the motion adaptive improved ELA. In the

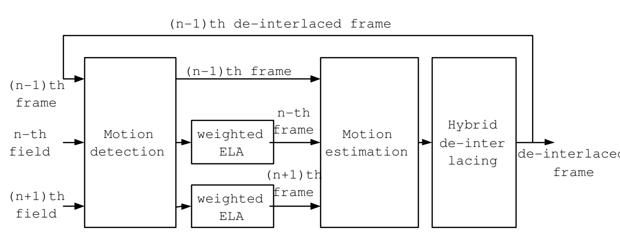


Fig. 1. Block diagram of the proposed de-interlacing algorithm

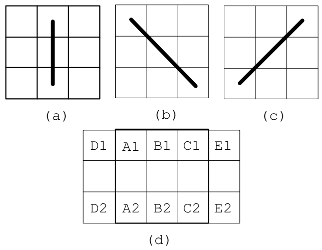


Fig. 2. Edge patterns for ELA

final step, combination of the spatial and the temporal information, which are obtained from the improved ELA and the recursive MC method, respectively, is performed by adjusting a weight parameter and using a median filter. The followings are details on each step.

2.1. Motion detection

In stationary area, de-interlacing using a simple temporal filter, such as field average and field insertion, can produce a result with optimal quality and reduce computational complexity by skipping the motion estimation which requires intensive computation. Therefore, we interpolate missing lines by using field average in the stationary area.

Motion detection from interlaced video sequences needs special treatment because two fields(even/odd) are different. Many approaches have been proposed for reliable motion detection using 4-field difference [4]. In this paper, as a recursive processing is applied, we perform motion detection using two field images and one frame image, which uses the same 4-field motion detection [4]. Motion detection is carried out based on pixel difference after applying a Gaussian operator to reduce influence from noise.

2.2. Weighted edge based line average

The ELA algorithm has been widely used to complement the simple line average, in which only the vertical direction is considered [5]. It interpolates missing line through the highest directional correlation by comparing three patterns that consist of vertical and two-diagonal ones. Though the ELA algorithms perform well for most images, it cannot interpolate missing line on various edge orientations. Enhanced ELA algorithms are proposed to overcome such problem by increasing ELA patterns [6]. However, because it is difficult to select a correct edge pattern with some explicit clues, the more patterns can bring to poorer performance.

We propose the improved ELA using weighted summation of ELA components. Eq. (1) and Fig. 2 describe how each ELA component is determined.

$$ELA_{p1} = \frac{A1+C2}{2}, ELA_{p2} = \frac{B1+B2}{2}, ELA_{p3} = \frac{C1+A2}{2} \quad (1)$$

As described in Eq. (3), interpolation for missing line is performed by adjusting weight parameters w_{p1}, w_{p2}, and w_{p3} based on the direction of the ELA patterns and the edge intensity shown in Eq. (2). Finally, we interpolate missing lines to reduce image artifacts due to an incorrect edge pattern, as shown in Eq. (4).

$$\begin{aligned} corr_1 &= \frac{|2 \cdot A1 - D1 - B1| + |2 \cdot C2 - B2 - E2|}{|A1 - C2|} \\ corr_2 &= \frac{|2 \cdot B1 - A1 - C1| + |2 \cdot B2 - A2 - C2|}{|B1 - B2|} \\ corr_3 &= \frac{|2 \cdot C1 - B1 - E1| + |2 \cdot A2 - C2 - B2|}{|C1 - A2|} \end{aligned} \quad (2)$$

$$\begin{aligned} w_{p1} &= \frac{corr_1}{corr_1 + corr_2 + corr_3} \\ w_{p2} &= \frac{corr_2}{corr_1 + corr_2 + corr_3} \\ w_{p3} &= \frac{corr_3}{corr_1 + corr_2 + corr_3} \end{aligned} \quad (3)$$

$$F_{ELA} = \begin{cases} ELA_{p2} & \text{if } (w_{p2} > w_{p1} \text{ and } w_{p2} > w_{p3}) \\ & \text{or } (w_{p1} + w_{p2} + w_{p3}) = 0, \\ \sum_{i=1}^{3} w_{pi} \cdot ELA_{pi} & \text{otherwise.} \end{cases} \quad (4)$$

2.3. Block based bi-directional motion estimation

In this paper, we perform bi-directional motion estimation which includes forward and backward estimation to avoid covered/uncovered background problems. The forward and backward estimation is performed using the BMA(block matching algorithm) which is the most widely used for motion estimation [7].

Bi-directional motion estimation is accomplished in frame-to-frame basis, not in field-to-field basis, by using the frame produced by the weighted ELA in the previous stage. The direction of estimation is selected by MAD(mean absolute difference) in block size of 8×8 between adjacent frames. If MAD between $(n-1)$-th frame and n-th frame is larger than one between n-th frame and $n+1$-th frame, backward block motion estimation is performed based on the MAD matching criteria with block size of 8×8. Otherwise, forward block motion estimation is performed.

2.4. Hybrid de-interlacing with MC

BMA can handle large displacement depending on the search area used and is known to be robust to noise. Also, it is apt to implement in hardware because of simplicity and easy realization. But, it can estimate the correct motion on the assumption that moving surfaces are parallel, and cannot avoid blocking effect. Therefore, our approach is accomplished by combination of the weighted ELA algorithm

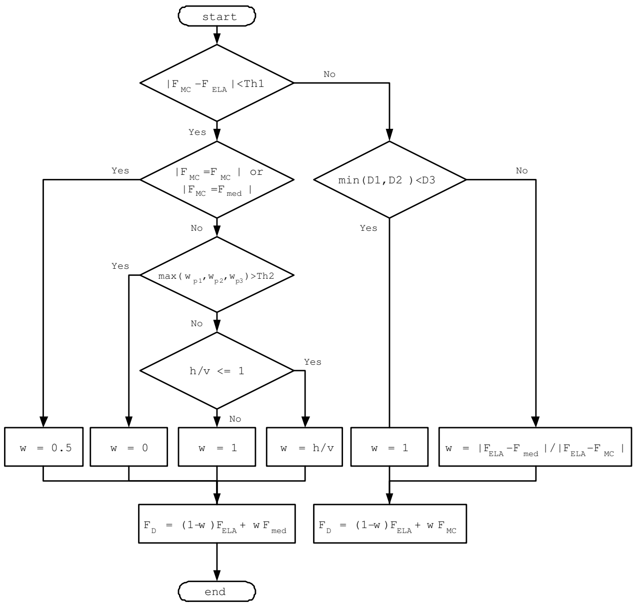


Fig. 3. Flowchart of the proposed de-interlacing algorithm

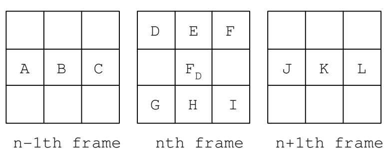


Fig. 4. Pixel positions used in the median filter

and the MC method to overcome the shortcoming of the bi-directional BMA and to reduce propagation error that can be observed in recursive processing [8].

The flowchart of the proposed algorithm is illustrated in Fig. 3. F_{MC} is the MC value determined by the bi-directional BMA, F_{ELA} is the non-MC values by the weighted ELA algorithm in $n-th$ frame, and F_{med} is the pixel value by median filter defined in Eq. (5) and shown in Fig. 4. In Eq. (5), B is involved in backward estimation, and K is involved in the forward estimation.

$$F_{med} = median(D, E, F, G, H, I, F_{MC}, F_{ELA}, B(\text{or}K)) \quad (5)$$

If the difference between F_{ELA} and F_{MC} is less than a threshold value, the proposed de-interlacing algorithm is performed by applying the weighted summation of F_{ELA} and F_{med} which is adjusted by h and v. h is the sum of difference in 3×3 mask between horizontal projections in a current frame and a neighbor frame on the motion trajectory, and v is the sum of difference in 3×3 mask between vertical projections. When v is larger than h, F_{ELA} will have more weight, because there probably is the incorrect motion estimation. When the difference between F_{ELA} and

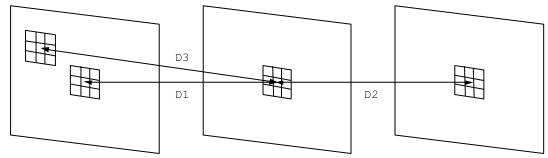


Fig. 5. Verification of motion estimation

F_{MC} is bigger than a threshold value, the weighted summation of F_{ELA} and F_{MC} will be applied in our approach, after the verification of motion estimation by Eq. (6).

$$\begin{aligned} D1 &= \textstyle\sum_{3\times 3mask} |F(n-1) - F(n)| \\ D2 &= \textstyle\sum_{3\times 3mask} |F(n) - F(n+1)| \\ D3 &= \textstyle\sum_{3\times 3mask} |F(n) - F(n \pm 1)| \end{aligned} \quad (6)$$

$D1$, and $D2$ is the sum of difference in 3×3 mask between current frame and neighbor frame, and $D3$ is one between $n-th$ frame and $(n-1)$-th or $(n+1)$-th frame determined by the direction of motion estimation, as shown in Fig. 5. Because the weighed ELA can maintain good quality of image even with poor conditions, the weight parameter is adjusted by comparing F_{ELA} and F_{med} .

3. EXPERIMENTAL RESULTS

For performance evaluation purpose, we convert progressive sequences into interlaced sequences by elimination of even or odd lines alternatively, and measure the performance of the proposed algorithm by calculating MSE(mean square error), as defined in Eq. (7).

$$MSE = \frac{1}{NM} \sum_{i=1}^{N} \sum_{j=1}^{M} (F_{orig}(i,j) - F_D(i,j))^2 \quad (7)$$

where, N and M is for defining frame size, F_{orig} represents the original frame image, and F_D represents the de-interlaced frame image.

We have used four test image sequences, 'mom', 'foreman', 'cops', and 'kitty'. 'mom' is with fixed background and 'foreman' is with moving object and moving background. And 'cops' and 'kitty' include scene changes as well as moving objects on a moving camera.

The effectiveness of the proposed approach has been evaluated by observing the de-interlaced result images. MSE comparison of the test images is listed in Table 1. In the table, ELA represents the weighted ELA method, MED represents the temporal median filter method, MA-ELA represents the motion adaptive weighed ELA, and MC represents the MC method using bi-directional BMA. This table shows the effectiveness of the proposed algorithm. Especially if there are motions in whole image like a foreman this algorithm executes de-interlacing effectively. Among

Table 1. MSE comparison

Image	ELA	MED	MA-ELA	MC	Proposed
mom	27.125	13.670	6.968	10.565	6.802
foreman	23.651	32.150	25.108	28.381	15.877
cops	44.173	34.656	29.529	38.783	25.927
kitty	36.843	26.624	17.044	36.839	15.313

(a)

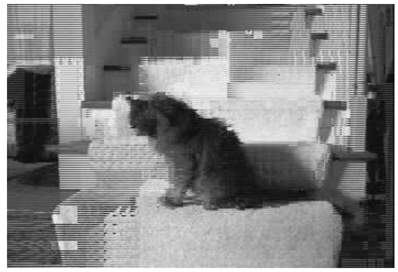
(b)

Fig. 6. Foreman: de-interlaced by (a) MA-ELA and (b)proposed

the images, Fig. 6 and Fig. 7 show how the algorithm works effectively. No blocking effect by block based motion estimation and no error propagation by recursive processing are observed. In addition, the approach is working properly for the video sequences with scene changes and abrupt brightness changes, as the spatial information is involved.

4. CONCLUSION

In this paper, we propose an approach for de-interlacing by incorporation of not only spatial information but temporal information. The approach aims to minimize the problem which is frequently observed when the block based motion estimation and recursive processing are involved. The simplicity of the approach, regardless of various image conditions, supports easy hardware realization using parallel processing and implementation of a real-time system. Effectiveness of the approach has been evaluated using a set of



(a)

(b)

Fig. 7. Kitty: de-interlaced by (a) MC and (b)proposed algorithm

images.

5. REFERENCES

[1] G. De Haan and E. B. Bellers, "Deinterlacing-an overview," *Proceedings of the IEEE*, vol. 86, no. 9, pp. 1839–1857, 1998.

[2] A. Nguyen and E. Dubois, "Spatio-temporal adaptive interlaced-to-progressive conversion," in *Signal processing of HDTV, iv*, E. Dubois and L. Chiariglione, Eds., pp. 749–756. Elsevier Science Publisher, Amsterdam, The Netherlands, 1993.

[3] M. Achiha, K. Ishikura, and T. Fukinuki, "A motion-adaptive high-definition converter for NTSC color TV signals," *SMPTE Journal*, vol. 93, no. 5, pp. 470–476, 1984.

[4] T. Koivunen, "Motion detection of an interlaced video signal," *IEEE Transactions on Consumer Electronics*, vol. 40, no. 3, pp. 753–760, 1994.

[5] T. Doyle and M. Looymans, "Progressive scan conversion using edge information," in *Signal processing of HDTV, II*, L. Chiariglione, Ed., pp. 711–715. Elsevier Science Publisher, Amsterdam, The Netherlands, 1990.

[6] J. Salonen, "Edge and motion controlled spatial upconversion," *IEEE Transactions on Consumer Electronics*, vol. 40, no. 3, pp. 225–233, 1994.

[7] D. J. Wang and J. J. Leou, "A new approach to video format conversion using bidirectional motion estimation and hybrid error concealment," *Journal of Information Science and Engineering*, vol. 17, no. 5, pp. 763–777, 2001.

[8] F.-M. Wang, D. Anastassiou, and A. N. Netravali, "Time-recursive deinterlacing for IDTV and pyramid coding," *Signal Processing: Image Communication*, vol. 2, no. 3, pp. 365–374, 1990.