New Global Motion Compensated De-interlacing Algorithm Based on Horizontal and Vertical Patterns

Min Kyu Park and Moon Gi Kang

Yonsei University
Department of Electrical and Electronic Engineering
120-749, Seoul Korea

ABSTRACT

In this paper, we propose a robust deinterlacing algorithm which combines edge dependent interpolation (EDI) and global motion compensation (GMC). Generally, EDI algorithm shows a visually better performance than any other deinterlacing algorithm using one field. However, due to the restriction of information in one field, a high quality progressive image from interlaced sources cannot be acquired by intrafield methods. Hence, proposed algorithm makes use of mixing process of EDI and GMC. In order to obtain the best result, adaptive thresholding algorithm for detecting the failure of GMC is proposed. Experimental results indicate that the proposed algorithm outperforms conventional approaches with respect to both objective and subjective criteria.

1. INTRODUCTION

Recent advances of HDTV and multimedia personal computers strongly call for the mutual conversion between interlaced images and progressive images. Moreover, as the demand for high quality images increases, advanced deinterlacing techniques with good performance have been recently required and investigated [1]-[14].

A number of deinterlacing techniques have been proposed, which can be roughly classified into intrafield methods [2]-[6] and interfield methods [7]-[14]. Intrafield methods require simple computation and can be easily integrated into hardware. Of the intrafield techniques developed for deinterlacing, EDI algorithms [2]-[6] are the linear directional interpolation method to preserve edge direction. These algorithms make use of the directional correlation to interpolate a missing line linearly between two adjacent lines in the interlaced signal. EDI is the most popular since it exhibits high performance with a small computational load. However, EDI has some problems that the image quality deteriorates in stationary region.

Interfield methods mainly consist of motion adaptive filtering (MAF) [7]-[8] and motion compensation (MC) [9]-[14]. MAF employs different filtering strategies for the motion and motionless case without motion estimation. MC involves estimating motion trajectories and filtering along them. These methods generally yield acceptable results provided that motion information is reliable. However, they are not expected to have good performance in case with unreliable motion information. To achieve better performance in the process of deinterlacing, it is necessary to estimate motion exactly. However, it is not easy to obtain accurate motion due to object deformation, motion blur and so on.

To overcome the problems of both inaccurate motion and the limitation of information in one field, a hybrid-typed deinterlacing algorithm based on EDI and GMC is proposed. In case with inaccurate motion, vertical high-frequency of GMC is increased more than that of EDI while horizontal high-frequency of GMC is not increased. This property is used to determine adaptive threshold for detecting region with inaccurate motion.

The paper is organized as follows. In the next section, the proposed deinterlacing algorithm is presented. Experimental results are explained in Section 3. Finally, our conclusions are given in Section 4.

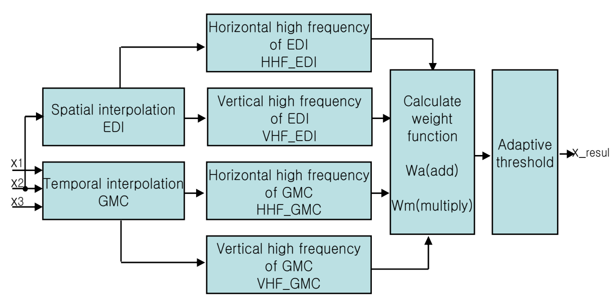


Fig. 1. The block diagram of the proposed algorithm.

2. THE PROPOSED DEINTERLACING ALGORITHM

The proposed algorithm is composed of the following steps: ① EDI, ② GMC, and ③ adaptive thresholding. A brief block diagram of the proposed algorithm is shown in Fig. 1.

2.1. EDI

$x(h,v,t)$ denotes an estimate of the intensity of the pixel at location (h,v) and time t . The key to the success of EDI is an accurate estimation of edge direction. However, pixel approach produces unpleasant results due to noise, variation of intensity, and weak edge. To increase the probability of detecting a reliable edge, EDI between two vectors in a small window has been widely used [2]. Let us define the 3-long vectors upper vector $\mathbf{u}(d,l)$ and lower vector $\mathbf{v}(d,m)$, respectively as

$$\mathbf{u}(d,l)=\begin{bmatrix} x(h+d+l-1,v-1) \\ x(h+d+l,v-1) \\ x(h+d+l+1,v-1) \end{bmatrix}, \quad (1)$$

and

$$\mathbf{v}(d,m)=\begin{bmatrix} x(h-d+m-1,v+1) \\ x(h-d+m,v+1) \\ x(h-d+m+1,v+1) \end{bmatrix}, \quad (2)$$

where l and m respectively represent the positions of those vectors in the horizontal axis with respect to the interpolation point (h,v) . Based on these vectors, let us define the weighted absolute difference between them as

$$diff(d,l,m)=\|\mathbf{u}(d,l)-\mathbf{v}(d,m)\|_1 \times w(d,l,m), \quad (3)$$

where $\| \|_1$ is l_1-norm and $w(d,l,m)$ is a simple normalized weight. Let us define (d',l',m') as

$$(d',l',m') = \arg \min_{\substack{-1\le l,m\le 1 \\ -3d\le 3}} diff(d,l,m). \quad (4)$$

Then, $x(h,v)$ is estimated as

$$x(h,v)=\frac{x(h+a,v-1)+x(h+b,v-1)+x(h+c,v+1)+x(h+e,v+1)}{4}, \quad (5)$$

where

$$(a,b,c,e)=\begin{cases} (d',d',-d',-d') & if \quad (l',m')=(-1,-1),(0,0),(1,1) \\ (d'-1,d',-d',-d'+1) & if \quad (l',m')=(0,-1),(1,0) \\ (d'-1,d'-1,-d'+1,-d'+1) & if \quad (l',m')=(1,-1) \\ (d',d'+1,-d'-1,-d') & if \quad (l',m')=(-1,0),(0,1) \\ (d'+1,d'+1,-d'-1,-d'-1) & if \quad (l',m')=(-1,1) \end{cases}. \quad (6)$$

2.2. GMC

GMC begins by taking three input fields x_1 , x_2 , and x_3 . To estimate integer global motion, motion between x_1 and x_3 with same parity is estimated by using block matching algorithm. Let x_{1_I} and x_{3_I} denote integer global motion shifted pre-field and post-field, respectively. Then, sub-pixel motion between x_2 and x_{1_I} (or x_{3_I}) is estimated by using a gradient-based method. Let sub-pixel motion vector of ith field be denoted by (Δh_i , Δv_i). The result frame of GMC, x_{2_GMC} , is determined by

$$x_{2\_GMC}(h,v)=x_{i\_I}(h,v)\times w_1+x_2(h,v)\times w_2+x_{3\_I}(h,v)\times w_3, \quad (7)$$

where

$$\begin{cases} w_i=k_i/\Sigma k_i \\ k_i=1/\sqrt{(\Delta h_i)^2+(\Delta v_i)^2} \end{cases} \quad for\ i=1,2,3. \quad (8)$$

2.3. Adaptive thresholding

Generally, in the simple motion detection, the pixel difference between two fields with same parity is used. The difference $D(h,v,t)$ is defined as

$$D(h,v,t)=|x(h,v,t-1)-x(h,v,t+1)|, \quad (9)$$

The motion detection $MD(h,v,t)$ is determined according to the difference $D(h,v,t)$ as follows:

$$MD(h,v,t)=\begin{cases} 0\ (stationary) & if\ D(h,v,t)<th \\ 1\ (moving) & otherwise \end{cases}, \quad (10)$$

where th is a threshold value. This method has two problems: ①In region where spatial intensity variation is small, motion error cannot be detected. While, ②in region with high frequency (HF), such as edge region, it is not easy to divide exactly an image into moving and stationary. The larger the threshold value is, the more the failure of the GMC occurs. On the other hand, the smaller the threshold value is, the less new information from GMC is incorporated to results.

As the failure of GMC increases, the value of $|x_{1\_I}-x_{3\_I}|$ and the energy of the vertical HF (VHF) of x_{2_GMC} increase. This property is used in the proposed algorithm. x_{2_HEDI} (Horizontal HF (HHF) of EDI), x_{2_VEDI} (VHF of EDI), x_{2_HGMC} (HHF of GMC), and x_{2_VGMC} (VHF of GMC) are obtained by differentiating

x_{2_EDI} and x_{2_GMC} horizontally and vertically, respectively. Then, x_{2_VD} and x_{2_HD} are defined as

$$x_{2\_VD} = \begin{cases} 1 & if\ |x_{2\_VGMC}| > th_{HF}\ and\ |x_{2\_VEDI}| < th_{HF} \\ 0 & otherwise \end{cases}, \quad (11)$$

$$x_{2\_HD} = \begin{cases} 1 & if\ |x_{2\_HGMC}| > th_{HF}\ and\ |x_{2\_HEDI}| < th_{HF} \\ 0 & otherwise \end{cases}, \quad (12)$$

where th_{HF} is a threshold value for detecting HF. The weight must satisfy three properties: ①As the density of $x_{2\_VD} = 1$ increases, the weight must increase. ②As both the densities of $x_{2\_VD} = 1$ and $x_{2\_HD} = 1$ decrease, the weight must decrease. ③As both the densities of $x_{2\_VD} = 1$ and $x_{2\_HD} = 1$ increase, weight must increase. In case where both the densities of $x_{2\_VD} = 1$ and $x_{2\_HD} = 1$ increase, new information from different fields is used to make a frame. Let C_{HD} and C_{VD} denote the count of $x_{2\_HD} = 1$ and $x_{2\_VD} = 1$ in block with size $B_h \times B_v$. The weights $W_a(h,v,t)$ and $W_m(h,v,t)$ are defined as

$$\begin{aligned} & if\ ((C_{VD} - C_{HD}) > block\,50) \\ & \qquad \{W_a(h,v,t) = w_{ah}, W_m(h,v,t) = w_{mh}\} \\ & else\ if\ (C_{VD} > block\,50) \\ & \qquad \{W_a(h,v,t) = w_{ah}, W_m(h,v,t) = w_{mh}\} \\ & else\ if\ ((C_{VD} < block\,20)\ and\ (C_{HD} < block\,20)) \\ & \qquad \{W_a(h,v,t) = w_{al}, W_m(h,v,t) = w_{ml}\} \\ & else \\ & \qquad \{W_a(h,v,t) = w_{am}, W_m(h,v,t) = w_{mm}\} \end{aligned}, \quad (13)$$

where w_{ah}, w_{am}, w_{al}, w_{mh}, w_{mm}, and w_{ml} are constant values. $block50$ and $block20$ are 50% and 20% of the number of pixel in the block, respectively. Based on the weights, let us define the weighted absolute difference $WD(h,v,t)$ as

$$WD(h,v,t) = W_a(h,v,t) + W_m(h,v,t) \times |x_{2\_EDI}(h,v,t) - x_{2\_GMC}(h,v,t)|. \quad (14)$$

Finally, the result $x_2(h,v,t)$ is acquired as

$$\begin{aligned} & if\ (WD(h,v,t) > th_H) \\ & \quad \{x_2(h,v,t) = x_{2\_EDI}(h,v,t)\} \\ & else\ if\ (WD(h,v,t) < th_L) \\ & \quad \{x_2(h,v,t) = x_{2\_GMC}(h,v,t)\} \\ & else \\ & \quad \{x_2(h,v,t) = \alpha \times x_{2\_EDI}(h,v,t) + (1-\alpha) \times x_{2\_GMC}(h,v,t)\} \end{aligned}, \quad (15)$$

where

$$\alpha = \frac{(WD(h,v,t) - th_L)}{(th_H - th_L)}. \quad (16)$$

3. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed algorithm, we present some simulation results in this section. For a quantitative comparison, "mobile" sequence of which we know the original progressive sequence is used. Partially-magnified results of a conventional method (CM) with constant threshold of 10 and 40, and the proposed algorithm on 2nd frame of "mobile" sequence are shown in Fig. 2. The result of CM with small threshold value in Fig. 2 (a) is not improved where dates, such as "13" and "16", are written. The result of CM with large threshold value in Fig. 2 (b) has artifacts caused by the failure of GMC. The proposed algorithm provides a visually satisfactory result without artifacts. These results are also reflected in PSNR in Fig. 3. It is easily understood that the proposed algorithm outperforms CM.

4. CONCLUSION

We proposed a new deinterlacing algorithm which combines EDI and GMC using adaptive thresholding based on VHF and HHF. In region where GMC is not correct, the fidelity of the result increases by using not only the difference between fields but also the pattern of VHF and HHF.

ACKNOWLEDGEMENT

This work was supported by Samsung Electronics Co. Ltd.

5. REFERENCES

[1] G. de Haan and E. B. Bellers, "Deinterlacing - an overview," *Proceedings of the IEEE*, vol. 86, Issue 9, pp.1839 -1857, Sep. 1998.

[2] Y. Kim, "Deinterlacing algorithm based on sparse wide vector correlations," *SPIE Optical Engineering*, vol. 2727, pp.89-99, 1996.

[3] T. Doyle and M. Looymans, "Progressive scan conversion using edge information," *Signal processing of HDTV, II*, pp. 711-721, 1990.

[4] H. S. Oh, Y. Kim, Y. Y. Jung, A. W. Morales, and S. J. Ko, "Spatio-temporal edge–based median filtering for deinterlacing," in *Digest of the Int. Conference on Consumer Electronics*, pp. 52-53, June 2000.

[5] Hoon Yoo and Jechang Jeong, “Direction-oriented interpolation and its application to de-interlacing,” *IEEE Trans. Consumer Electronics*, vol. 48, Issue 4, pp. 954-962, Nov. 2003.

[6] Min Kyu Park and Moon Gi Kang, “New Edge Dependent Deinterlacing Algorithm Based on Horizontal Edge Pattern,” submitted in *IEEE Trans. Consumer Electronics*.

[7] N. Seth-Smith and G. Walker, “Flexible up-conversion for high quality TV and multimedia displays,” in *Proc. of the ICCE*, pp.338-339, June 1996.

[8] M. Lee, J. Kim,J. Lee, K. Ryu, and D. Song, “A new algorithm for interlaced to progressive scan conversion based on directional correlations and its IC design,” *IEEE Trans. Consumer Electronics*, vol. 40, pp. 119-129, May 1994.

[9] Li Renxiang, Zheng Bing, and M. L. Liou, “Reliable motion detection/compensation for interlaced sequences and its applications to deinterlacing,” *IEEE Trans. Circuits and Systems for Video Technology*, vol.10, Issue 1, pp. 23-29, Feb. 2000.

[10] J. Kovacevic, R. J. Safranek, and E. M. Yeh, “Deinterlacing by successive approximation,” *IEEE Trans. Image Processing*, vol. 6, Issue 2, pp. 339-344, Feb. 1997.

[11] D. Han, C. Shin, S. Choi, and J. Park, “A motion adaptive 3-D de-interlacing algorithm based on the brightness profile pattern difference,” *IEEE Trans. Consumer Electronics*, vol. 45, no. 3, pp. 690-697, Aug. 1999.

[12] P. Delogne, L. Cuvelier, B. Maison, B. van Caillie, and L. vandendorpe, “Improved interpolation, motion estimation and compensation for interlaced pictures,” *IEEE Trans. Image Processing*, vol. 3, pp. 482-491, Sep. 1994.

[13] Y. Kim, S. Kim, and S. Park, “Motion Decision Feedback Deinterlacing Algorithms,” *IEEE ICIP2002*, vol. 3, pp. 24-28, June, 2002.

[14] Y. Jung, S Yang, and P. Yu, “An Effective De-interlacing Technique Using Two Types of Motion Information,” *IEEE Trans. Consumer Electronics*, vol. 49, pp. 493-498, Aug., 2003.

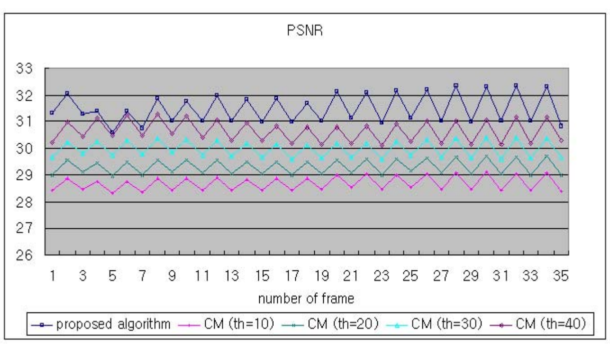
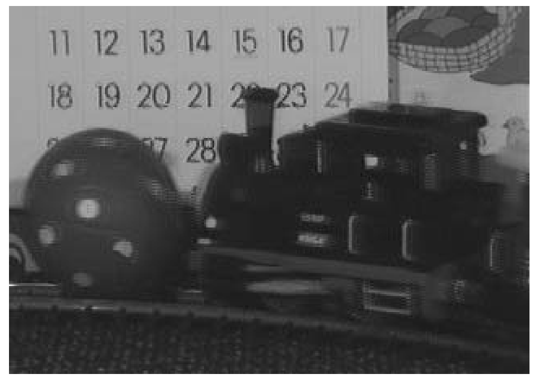
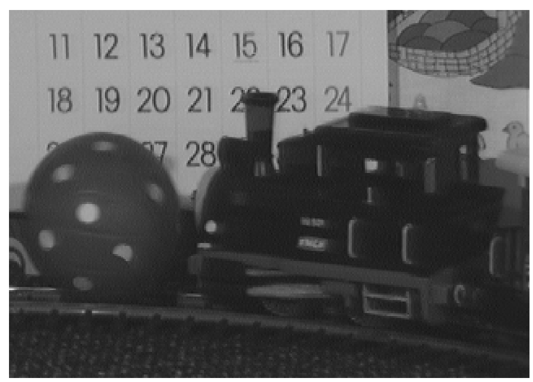


Fig. 3. The PSNR performance of the three methods on the “mobile” sequence.

(a) the result of CM(th=10)



(b) the result of CM(th=40)



(c) the result of proposed algorithm

Fig. 2. Partially-magnified result of (a) CM (th=10) (b) CM(th=40) (c) Proposed algorithm on a 2nd frame of “mobile” sequence.