LETTER

Weighted Interpolation Scheme for Robust Video Deinterlacing

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SUMMARY   In this letter, a low-cost weighted interpolation scheme (WIS) for deinterlacing within a single frame is discussed. Three useful weights measurements are introduced within the operation window to reduce false decisions on the basis of the LCID algorithm. The WIS algorithm has a simple weight-evaluating structure with low complexity, which therefore makes it easy to implement in hardware. Experimental results demonstrated that the WIS algorithm performs better than previous techniques.
key words: *video deinterlacing, low-complexity, weight*

1. Introduction

Image communication is a quickly developing multi-disciplinary area that involves the evaluation and establishment of successful means for acquisition, storage, transmission, representation, manipulation, and understating of visual information. However, in practical cases, muted noise and high quality original images are not often found. Therefore, post-processing such as deinterlacing is the last step to improve the perceptual quality of the content [1].

The interlaced scanning format is used broadly in TV manufacturing and within consumer electronic video cameras including NTSC, PAL, and SECAM. The merit of the interlaced scanning format is that the refreshing rate is doubled without widening the bandwidth. However, an interlaced TV signal in the vertical direction does not satisfy the demands of the Nyquist sampling theory [2]. There is a trade-off between the video signal's bandwidth requirements and an optimal frame rate. Because of the intrinsic nature of the interlaced scanning process, bothersome visual artifacts like edge flickering, interline flickering, and line crawling will appear when displaying interlaced content on a progressive device such as a PC monitor [3]. Therefore,

to assure compatibility with existing TV broadcasting standards, deinterlacing is required to convert interlaced video to progressive video.

Many researchers have attempted to solve the above issues by exploring deinterlacing. Various algorithms have been presented with different degrees of complexity and reconstruction quality. In particular, many spatial interpolation techniques have been proposed to improve the quality of the interpolated images by enhancing the edges and the overall image sharpness. Among them are the classical edge direction-based linear filters, including ELA [4], EELA [5], DOI [6], NEDD [7], FDED [8], MADLSCD [9], LABI [10], and LCID [11]. An alternative is to employ a non-linear and soft computing-based approach which includes fuzzy logic for image interpolation, namely FDOI [12].

In this letter, we attempt to increase the interpolation accuracy of the LCID algorithm by considering three useful weight measurements. By a simple rule, the three weights are incorporated to lessen errors for the subsequent directionally dependent interpolation. The rest of this letter is organized as follows. The LCID algorithm is described briefly in Sect. 2. In Sect. 3, we present the proposed WIS algorithm. Simulation results for a variety of video sequences are provided in Sect. 4. Finally, conclusions are given in Sect. 5.

2. The LCID Algorithm

Let $x(i, j)$ denote the signal to be interpolated where i refers to the column number and j to the line number. A 2D localized window is used to calculate directional correlations and to interpolate the current pixel, as shown in Fig. 1, where u, d, l, m, and r represent *up*, *down*, *left*, *mid*, and *right*, respectively. For the purpose of the checking edges existing in the diagonal, vertical and horizontal directions respectively, four directional differences, denoted as α, β, γ, and δ, are defined and calculated as follows:
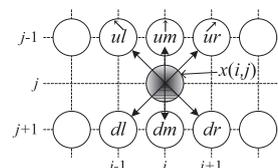
Fig. 1   Window for direction-based deinterlacing.

$$\alpha = |ul - dm| + |um - dr|, \ \beta = |um - dl| + |ur - dm|$$
$$\gamma = |um - dm| \times 2, \ \delta = |um - ul| + |dm - dl| \qquad (1)$$

The interpolated pixel can be estimated as (2):

$$x_{LCID}(i, j) = \begin{cases} x(i-1, j), & \text{if } \delta = 0 \\ \dfrac{ul + dr + um + dm}{4}, & \text{if } \min(\alpha, \beta, \gamma) = \alpha \\ \dfrac{ur + dl + um + dm}{4}, & \text{if } \min(\alpha, \beta, \gamma) = \beta \\ \dfrac{um + dm}{2}, & \text{if } \min(\alpha, \beta, \gamma) = \gamma \end{cases}$$
$$(2)$$

However, the LCID algorithm is affected by previously encoded results when $\delta = 0$. Such results make the system fragile when the image contains noise, and the information tends to cause, or exaggerate, error propagation. To address the above issue, we propose the WIS algorithm which is not a time-recursive scheme in the sense that the deinterlaced previous pixel is not used as the reference for the pixel to be interpolated, which helps to stop error propagation of the LCID.

3. Proposed Method

The WIS algorithm is an extension of the LCID algorithm that was explained in the preceding section. The main idea is to launch additional weight-evaluating measurements for calculating the directional correlation more effectively. The simple and computationally low-cost structure of the WIS algorithm was designed for easy realization.

The measurements LD_θ are the *luminance different* in the edge direction represented by θ (45°: ↗, 90°: ↑, 135°: ↖), and are defined as follows:

$$LD_\nwarrow = |ul - dr|, \ LD_\uparrow = |um - dm|, \ LD_\nearrow = |ur - dl| \qquad (3)$$

Then, three weights ($\omega_\nearrow$, $\omega_\nwarrow$, and $\omega_\uparrow$) are calculated as (4), and the interpolated pixel can be estimated as (5).

$$\begin{aligned} &\text{if } (LD_\uparrow = 0) \ \omega_\uparrow = \omega_\nwarrow = \omega_\nearrow = 1, \\ &\text{else if } \{\min(\alpha, \beta, \gamma) = \alpha\}, \ \omega_\uparrow = 1/\omega = LD_\nwarrow /LD_\uparrow, \\ &\text{else if } \{\min(\alpha, \beta, \gamma) = \beta\}, \ \omega_\uparrow = 1/\omega_\nearrow = LD_\nearrow /LD_\uparrow \end{aligned} \qquad (4)$$

$$x_{WIS}(i, j) =$$
$$\begin{cases} \dfrac{um + dm}{2}, & \text{if } \{\delta = 0\} \text{ or } \{\min(\alpha, \beta, \gamma) = \gamma\} \\ \dfrac{(\omega_\nwarrow)^2 \cdot (ul + dr) + (um + dm)}{2 \cdot \{(\omega_\nwarrow)^2 + 1\}}, & \text{if } \min(\alpha, \beta, \gamma) = \alpha \\ \dfrac{(\omega_\nearrow)^2 \cdot (ur + dl) + (um + dm)}{2 \cdot \{(\omega_\nearrow)^2 + 1\}}, & \text{if } \min(\alpha, \beta, \gamma) = \beta \end{cases}$$
$$(5)$$

The idea behind our work is to assign bigger weights to the directions that have a smaller LD_θ as the center. For instance, if $[\{\delta \neq 0\}$ and $\{\min(\alpha, \beta, \gamma) = \beta\}]$, then the output pixel, $x_{WIS}(i, j)$, is calculated as (6).

$$x_{WIS}(i, j) = \frac{(\omega_\nearrow) \cdot (ur + dl) + (\omega_\uparrow) \cdot (um + dm)}{2 \cdot (\omega_\nearrow + \omega_\uparrow)} \qquad (6)$$

4. Experimental Results

The performance of the intra-field deinterlacing algorithm was evaluated on seven test sequences of CIF size: Akiyo, Flower, Foreman, Mobile, News, Stefan, and Table Tennis. To compare the WIS algorithm with conventional techniques, the peak signal-to-noise ratio (PSNR) was used as

| (a) original | (b) ELA | (c) DOI | (d) NEDD | (e) FDED |

| (f) MADLSCD | (g) LABI | (h) LCID | (i) FDOI | (j) WIS |

Fig. 2 Comparison of subjective qualities in the 41st Foreman sequence.

Table 1   PSNR comparison for CIF sequences (dB/frame).

	Aki.	Flo.	For.	Mob.	New.	Ste.	Ten.	Avg.
ELA	37.68	21.93	31.40	23.34	31.53	25.97	31.24	29.01
EELA	36.76	21.96	30.40	23.27	31.92	26.36	30.88	28.79
DOI	39.61	22.25	30.22	24.91	33.38	26.69	31.55	29.80
NEDD	38.69	22.34	30.64	24.76	32.69	27.00	31.64	29.68
FDED	39.93	22.27	31.14	25.16	33.55	27.28	31.88	30.17
MADL.	38.62	22.37	30.42	24.55	32.59	26.46	31.17	29.46
LABI	33.89	20.50	28.03	21.38	28.41	23.08	27.60	26.12
LCID	39.74	22.44	31.20	25.31	33.19	27.09	32.06	30.15
FDOI	37.73	22.06	30.86	24.32	32.62	26.14	30.77	29.22
WIS	39.81	22.44	31.21	25.32	33.22	27.11	32.07	30.17

Table 2   Average CPU time for CIF sequences (ms/frame).

	Aki.	Flo.	For.	Mob.	New.	Ste.	Ten.	Avg.
ELA	23.3	23.3	31.0	19.3	27.3	23.8	23.5	24.5
EELA	22.7	18.2	36.8	32.1	22.9	27.4	23.2	26.2
DOI	172.0	539.0	312.5	648.5	363.3	664.0	812.5	501.7
NEDD	39.3	35.5	50.8	35.0	42.8	50.5	51.3	43.6
FDED	94.0	93.5	93.0	109.3	148.8	132.8	175.8	121.0
MADL.	136.8	148.3	140.5	148.5	187.8	191.0	257.8	173.0
LABI	15.8	15.5	15.8	20.0	19.3	27.5	39.0	21.8
LCID	31.3	19.8	31.3	15.3	23.3	31.0	31.3	26.2
FDOI	97.8	109.5	97.8	125.0	109.5	168.3	175.5	126.2
WIS	23.3	31.3	27.3	23.3	35.3	35.5	46.8	31.8

an objective measure. We compare the WIS with the following recently published well-known deinterlacing algorithms: ELA [4], EELA [5], DOI [6], NEDD [7], FDED [8], MADLSCD [9], LABI [10], LCID [11], and FDOI [12].

Tables 1 and 2 include the average PSNR results and computational CPU time for various test sequences, respectively. The WIS algorithm showed almost the same (30.17 dB) objective performance as the FDED method in terms of PSNR with only approximately 26.28 % of the computational CPU time required. Moreover, WIS showed an average reduction in computational CPU time of 93.7 % and 74.8 % for test sequences relative to the DOI and FDOI with 0.37 dB and 0.95 dB improvements, respectively. The WIS has about 45.8 % more computational CPU time than the LCID method while achieving an average PSNR improvement up to 0.02 dB.

However, objective performance measures are not always a reasonable standard for image quality because objective quality measures only calculate LD values between the original image and the reconstructed one, and there are no direct and logical connections between such objective measures and the subjective impression of the human observer. Figure 2 shows the simulation results for the 41st Foreman sequence. From Fig. 2 (i), it is apparent that FDOI provides the best subjective quality among all traditional methods. However, it requires huge computational CPU time while providing relatively worse PSNR results. In contrast, the WIS method shows outstanding performance by reproducing an image very close to the original one, compared to conventional methods. Furthermore, the WIS algorithm improves natural images with less staircase artifacts for all edge areas including gentle slope edge, compared to tradi-

tional algorithms.

5.   Conclusion

This letter describes a low-cost directional deinterlacing algorithm using a single frame. The proposed algorithm has a simple weight-evaluating structure that makes it easy to realize in hardware environments. The performance of this algorithm for gentle slope edge areas as well as complex edge areas is excellent compared to traditional methods.

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