Novel Adaptive De-interlacing Algorithm using Temporal Correlation

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ABSTRACT

This paper proposes a novel adaptive algorithm for de-interlacing. In the proposed algorithm, the previously developed Enhanced ELA [6], Chen [9] and Li [10] algorithms were used as a basis. The fundamental mechanism was the selection and application of the appropriate algorithm according to the correlation with the previous and next field using temporal information. Extensive simulations were conducted for video sequences and showed good performance in terms of peak signal-to-ratio (PSNR) and subjective quality.

Keywords: De-interlacing,, Interpolation, Temporal Correlation, Image Processing

1. Introduction

Interlaced scanning processes are applied in current TV systems but uncomfortable visual artefacts are often produced, including edge flickers, interline flickers, and line crawling. In order to reduce interlaced artefacts in a display, and also operate as a pre- or post-processing for efficient video coding, de-interlacing of interlaced video signals is becoming an essential step.

Various de-interlacing techniques have been proposed [1-11]. They can be classified into two categories, spatial domain methods, [2-7] which use only one field, and spatio-temporal domain methods, [8-11] which use multiple fields. The enhanced ELA [6], which is based on the ELA algorithm uses the direction correlation between adjacent lines to interpolate the missing pixels. Chen's algorithm [9], which is based on a 2D-ELA [8] algorithm, references the previous and next field while using spatio-temporal information to interpolate the missing pixels. Li's algorithm [10] references only the previous field and uses spatio-temporal information.

This paper proposes a method that uses the above three algorithms as a basis. The key point of this proposed paper is a correlation between the previous and next fields. A Correlation Detector took the missing pixels of the current field into consideration for a correlation between the previous and next fields. Then, the proper algorithm was chosen according to the Correlation Detector information.

In Section 2, the previous algorithms that served as a basis in this paper are briefly reviewed. In Section 3, the proposed algorithm is described in detail. The experimental results and analysis detailed in Section 4 showed that the proposed algorithm was very effective. Finally, conclusions are given in Section 5.

2. Previous Algorithms

In this section, we will examine three existing algorithms as a basis of this paper: the Enhanced ELA and the Chen [9] and Li [10] algorithms.

2.1 The E-ELA(Enhanced Edge-based Line Average) algorithms

When both fields are not correlated, we adopted the E-ELA algorithm [6]. This algorithm uses directional correlation among pixels to interpolate a missing line between two adjacent lines in a spatial domain. If the edge direction is properly estimated, the method produces a good result. Otherwise, it produces undesirable artefacts.

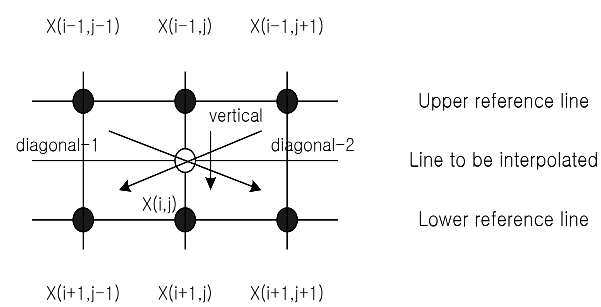

Figure 1. 3x3 window for the E-ELA algorithms

$$\begin{cases} a = \left| X(i-1, j-1) - X(i+1, j+1) \right| \\ b = \left| X(i-1, j) - X(i+1, j) \right| \\ c = \left| X(i-1, j+1) - X(i+1, j-1) \right| \end{cases} \quad (1)$$

In (1), a is the edge direction from left to right (diagonal-1), c is the edge direction from right to left (diagonal-2), and b is the vertical direction.

$$\begin{cases} p = \left|X(i-1, j-1) - X(i+1, j)\right| + \left|X(i-1, j) - X(i+1, j+1)\right| \\ q = \left|X(i-1, j+1) - X(i+1, j)\right| + \left|X(i-1, j) - X(i+1, j-1)\right| \end{cases} \quad (2)$$

In (2), p is the edge direction from left to right (diagonal-1 direction), and q refers to the edge direction from right and left (diagonal-2 direction). The E-ELA algorithm can be defined by the following:

$$X(i,j) = \begin{cases} (X(i-1, j-1) + X(i+1, j+1))/2, & \begin{cases} \text{if p<q and min(a,b)=a} \\ \text{if p=q and min(a,b,c)=a} \end{cases} \\ (X(i-1, j) + X(i+1, j))/2, & \begin{cases} \text{if p<q and min(a,b)=b} \\ \text{if p=q and min(a,b,c)=b} \\ \text{if p>q and min(b,c)=b} \end{cases} \\ (X(i-1, j+1) + X(i+1, j-1))/2, & \begin{cases} \text{if p>q and min(b,c)=c} \\ \text{if p=q and min(a,b,c)=c} \end{cases} \end{cases} \quad (3)$$

The equation in (3) is very similar to the ELA method, but just p and q are added, enabling the E-ELA method to locate edge directions with more accuracy than the ELA method.

2.2 Chen's algorithm

When both fields are highly correlated, we adopted Chen's algorithm. First, the input fields are classified as either foreground or background. The difference fields are defined as follows:

$$DF_n(p,n) = \begin{cases} 1, & if \quad X(p,n) - X(p,n-2) > T \\ 0, & otherwise \end{cases} \quad (4)$$
$$DF_{or}(p,n) = DF_n(p,n) \ OR \ DF_{n-1}(p,n-1)$$

where $p = (i,j)$ designates the spatial position and n is the current field number. $DF_{or}(p,n)$ is applied to classify the interpolated pixels to the foreground or background.
The Chen's algorithm is defined as follows:

$$X_o(p,n) = \begin{cases} X(p,n), & y \bmod 2 = n \bmod 2 \\ X(p,n-1), & DF_{or}(p,n) = 0 \\ median(A,b,e,h,k), & otherwise \end{cases} \quad (5)$$

$X(p,n)$ is the input field defined for $y \bmod 2 = n \bmod 2$. And $X_o(p,n)$ is the output frame defined as in equation (5). The pixels of the background are filled by the pixels of the previous field, and the pixels of the foreground were interpolated using a 2D-ELA algorithm.
Where a, b, c, d, e, f, g, h, i, j, k and l represent values indicated in Fig.2

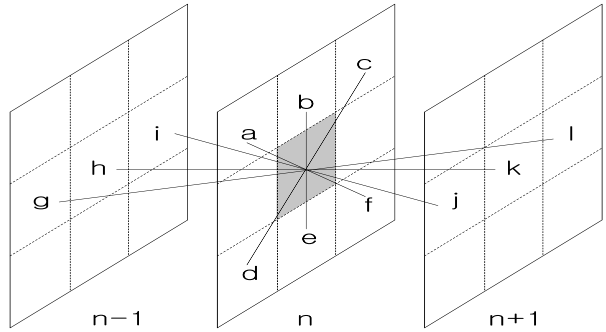

Figure 2. Spatial-temporal window for the pixels in foreground region

A represents a minimum difference value among the six directional changes as follows:

$$A = min(|a\text{-}f|, |b\text{-}e|, |c\text{-}d|, |g\text{-}l|, |h\text{-}k|, |i\text{-}j|) \quad (6)$$

2.3 Li's algorithm

When only the previous fields are highly correlated, we adopted Li's algorithm.

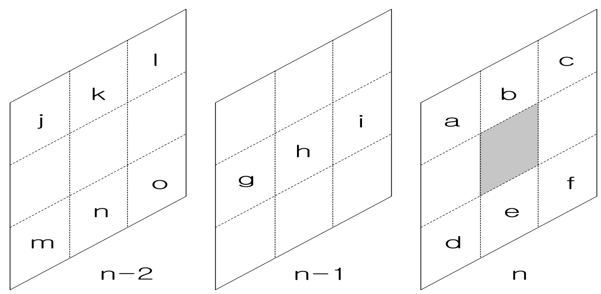

Figure 3. Spatial-temporal window for description of Li's algorithm

First, the input fields are classified to either the foreground or background using a different method with Chen's algorithm.

$$DF_n(p,n) = \begin{cases} 1, & if \ \frac{1}{7}(|a-j|+|b-k|+|c-l|+|d-m|+|e-n|+|f-o|+|g-i|) > T \\ 0, & otherwise \end{cases} \quad (7)$$

If the $DF_n(p,n)$ is 1, the interpolated pixel belongs to the foreground: otherwise, the interpolated pixel belongs to the background.

$$X_o(p,n) = \begin{cases} X(p,n), & y \bmod 2 = n \bmod 2 \\ X(p,n-1), & DF_n(p,n) = 0 \\ median(a,b,c,d,e,f,g,h,i), & otherwise \end{cases} \quad (8)$$

The pixels of the background are filled by the pixels of a previous field as with Chen's algorithm. However, the pixels of the foreground are interpolated using the current and previous fields, unlike the Chen's algorithm.

3. Proposed Algorithm

There are various de-interlacing techniques available to interpolate missing pixels. ELA and E-ELA are popular techniques of spatial domain interpolation. 2D-ELA, Chen’s, and Li’s algorithms are spatio-temporal interpolation methods. As mentioned above, when both fields are only slightly correlated, the proposed method adopted the E-ELA algorithm, which uses spatial domain interpolation. When both fields are highly correlated, the proposed method adopted Chen’s algorithm. When there is a low correlation with the next field, but a high correlation with the previous field, the case adopted Li’s algorithm. However, in the case where there was a low correlation with previous fields, but a high correlation with the next field, an inverse of Li’s algorithm was adopted, which was a part of our proposed method. Li’s algorithm uses the current, *n-1*, and *n-2* fields. On the contrary, the inverse of Li’s algorithm uses the current, *n+1* and *n+2* fields, but the interpolation process is the same as with Li’s algorithm.

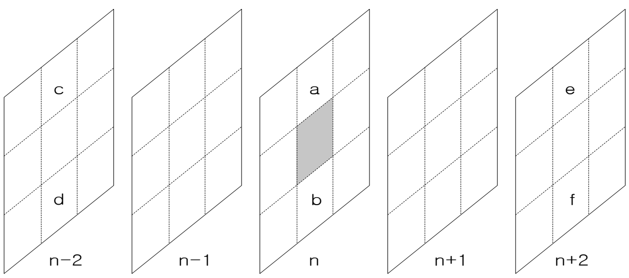

Figure 4. Temporal window for description of proposed algorithm

First, the proposed algorithm takes the correlation with the previous and next fields into consideration.

$$CDP = \begin{cases} 1, & if \ \ |a-c|+|b-d| < T \\ 0, & otherwise \end{cases} \qquad (9)$$

$$CDN = \begin{cases} 1, & if \ \ |a-e|+|b-f| < T \\ 0, & otherwise \end{cases}$$

If the Correlation Detector with the Previous field (CDP) is 1, the interpolated pixel is highly correlated with the previous fields: otherwise, the interpolated pixel is slightly correlated with previous fields. In the same way, if the Correlation Detector with the Next field (CDN) is 1, the interpolated pixel is highly correlated with the next fields: otherwise, the interpolated pixel is slightly correlated with the next fields.

$$X_o(p,n) = \begin{cases} E-ELA, & if \ CDP=0 \ and \ CDN=0 \\ Li's \ algorithm, & if \ CDP=1 \ and \ CDN=0 \\ Inverse \ Li's \ algorithm, & if \ CDP=0 \ and \ CDN=1 \\ Chen's \ algorithm, & if \ CDP=1 \ and \ CDN=1 \end{cases} \qquad (10)$$

The proposed algorithm was adaptively selected to interpolate the missing pixels using the appropriate algorithm according to the Correlation Detector.

4. Experimental Results

In this section, the proposed algorithm was compared with the conventional algorithms with respect to objective performance and subjective quality.

Table 1. PSNR(dB) results of different methods for various sequences

Method / Sequence	LD	E-ELA	Li's	Chen's	Proposed
Stefan	23.22	26.28	25.56	25.81	26.38
Bus	23.74	26.51	25.40	26.15	26.59
Football2	25.94	29.21	27.31	27.96	29.40
Football	32.71	36.98	32.24	31.12	35.13
Dancer	33.76	37.47	34.81	36.29	37.11
Foreman	27.91	30.86	32.53	34.66	33.80
Table	24.45	27.39	29.24	34.29	32.40
Mother-daughter	33.10	36.23	42.16	44.66	43.25

Table 1 compares the results of using various de-interlacing methods in a variety of test sequences. The proposed algorithm showed good performance in the Stefan, Bus, and Football sequences. The Football and Dancer sequences had a low correlation in the temporal domain, and thus E-ELA, which uses only spatial information, shows an enhanced performance over Li’s and Chen’s algorithms, which use spatio-temporal information. The proposed algorithm’s performance follows up E-ELA in this case. On the contrary, the Foreman, Table, and Mother-daughter sequences were highly correlated in the temporal domain, so Chen’s and Li’s algorithm showed better performance than that of E-ELA. In this case, the proposed algorithm follows up Chen’s.

(a) (b)

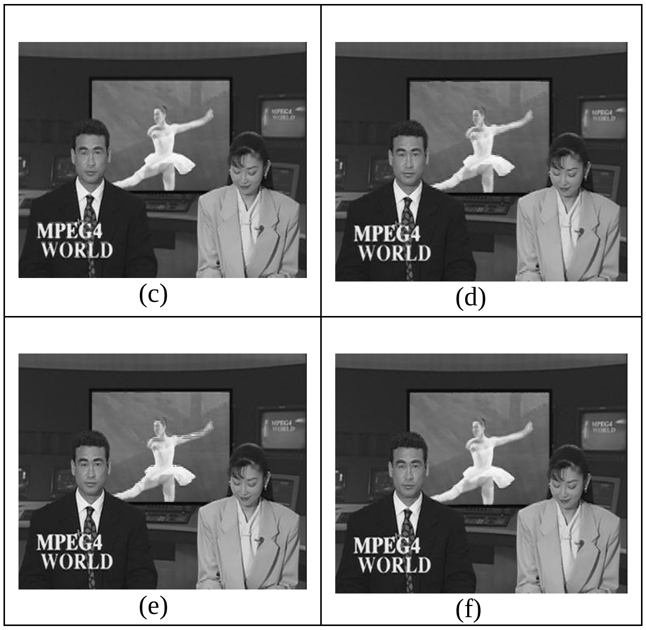

Figure 5. Portion of progressive source image and de-interlacing results of the corresponding interlaced image (a) Source image (b) LD (c) E-ELA (d) Li's (e) Chen's (f) Proposed

Figure 5 shows the interpolated images resulting from the application of various methods. The proposed method was more effective than other methods in terms of visual quality.

5. Conclusions

In this paper, an efficient de-interlacing technique that considers temporal correlation was proposed. According to the correlation with previous and next fields, the proper algorithm was selected to interpolate the missing pixels. The experimental results demonstrated that the proposed method shows good performance in terms of objective (PSNR) and subjective.

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