Improvement of the DOI Technique for De-Interlacing

Kyeong Ran Kim
Dongseo University
San 69-1, Jurye 2-Dong
Sasang-gu
617-716, Busan, S.Korea
d0076040@dongseo.ac.kr

Byung Gook Lee
Dongseo University
San 69-1, Jurye 2-Dong
Sasang-gu
617-716, Busan, S.Korea
lbg@dongseo.ac.kr

Hoon Yoo
Sangmyung University
Hongji 7-Dong,
Jongno-gu
110-743, Seoul, S.Korea
hunie@smu.ac.kr

ABSTRACT

This paper presents an improved method for the direction-oriented interpolation (DOI) method. The technique of DOI is considered to be a very strong tool for intraframe-based deinterlacing in the literature. However, the DOI still have a problem to use wrong edge direction. To remedy this problem, we embed three steps in the DOI method to interpolate missing lines more efficiently and robustly than existing methods. In the proposed method, the spatial direction vector (SDV) data are reused and processed to prevent them utilizing in next interpolation step, resulting in the more accurate de-interlacing method. We carry out experiments to compare the proposed method with the existing methods including the edge-based line averaging (ELA) and DOI. Experimental results show that the proposed method gives better performance in objective and subjective quality than the existing de-interlacing methods.

Keywords
Direction-oriented interpolation, direction vectors, ELA, de-interlacing.

1. Introduction

In order to reduce bandwidth for broadcasting, television system decides to adopt interlaced video signal. The interlaced video signal means delete odd lines in one frame and delete even lines in the next frame alternatively. We call frame without odd lines or even lines as field. It means capacitor of interlaced signal will become half of the original signal. Moreover the technique of CRT can display interlaced signal directly in alternative scanning lines. It will not exhibit flicker obviously. However, flat display can't show interlaced signal instantly. Interlaced signal must be recovered the original progressive signal before displayed. Therefore the technique of recovery is called de-interlacing.

De-interlacing methods have been proposed ever since the introduction of interlacing. With the advancement of technology, progressive displays have become feasible and that the importance of de-interlacing has increased. The methods have been suggested vary greatly in complexity and performance, but they can be segmented into two categories: intraframe and interframe. Intraframe methods only use the current field for reconstruction, while interframe methods make use of the previous or subsequent frames as well. Note that, all the methods attempt to reconstruct the missing scan lines without the knowledge of the original progressive source.

One well-known special domain interpolation method is the edge-based line-averaging (ELA) algorithm [10]. The algorithm utilizes directional correlation to interpolate a missing line between two adjacent lines of the even or odd filed. The ELA method provides a good result in regions where the edge can be estimated correctly. Introducing several methods in this paper is based on ELA.

In this paper, we proposed improved DOI method that added 3 steps. Expand the edge because after that the edge will be stronger and clearer. The method used SDV. Then, added the direction that can't be found and removed the noise produced after interpolation. In the section 2, will explained ELA and Directional Oriented Interpolation (DOI). In the section 3, we will explain our proposed method and next section we will explain the comparison our propose method with the previous method. In the last section, we will explain the conclusion.

.

2. Conventional De-interlacing Methods

2.1 Edge-based Line Averaging

The ELA method which utilizes directional correlations among the neighboring pixels interpolates the missing pixels linearly. A 3x3 window is used as shown in Fig.1.

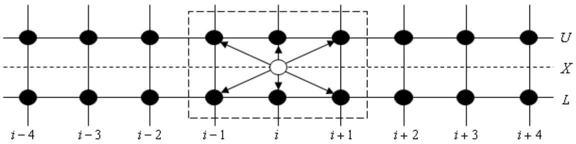

Figure 1 3×3 window for ELA method

According to Fig.1, the ELA method can be described in the equation (1), (2) and (3). The $C(k)$ denote a directional correlation measurement,

$$C(k) = \left|U(i+k) - L(i-k)\right|,\ k = -n, ..., -1, 0, 1, ..., n \quad (1)$$

The $C(k)$ is then used to determine the direction of the highest spatial correlation. The edge direction θ is determined as:

$$\theta = \arg\ \min\{C(k)\}, -n \le k \le n \quad (2)$$

The current pixel $x(i)$ is then interpolated by:

$$x(i) = \frac{U(i+\theta) + L(i-\theta)}{2} \quad (3)$$

The ELA method provides good performance in the most cases, however, due to misleading edge directions, interpolation errors often become larger in the areas of high frequency components. These unwanted artifacts significantly deteriorate visual quality.

2.2 Directional Oriented Interpolation

The DOI method interpolated the missing pixels using spatial direction vectors (SDVs) [13]. A spatial direction vector (SDV) is introduced so that finer resolution and higher accuracy of the edge-direction can be obtained. In figure 2, the center block of size 3-by-2 slides on the two upper reference lines or on the two lower reference lines for block-matching purpose.

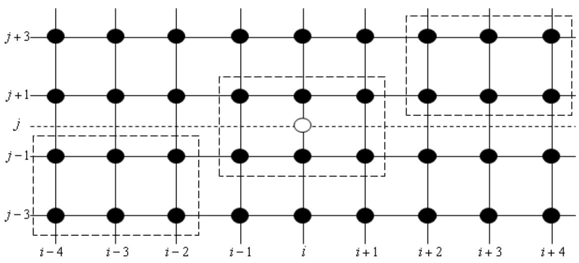

Figure 2 Illustration of the DOI

The USDV and the LSDV are determined as:

$$S_u(k) = \sum_{j=-1}^{1} \left(\left|U_0(i+j) - U_1(i+j+k)\right|^2 + \left|L_0(i+j) - U_0(i+j+k)\right|^2\right) \quad (4)$$

$$S_L(k) = \sum_{j=-1}^{1} \left(\left|U_0(i+j) - L_0(i+j+k)\right|^2 + \left|L_0(i+j) - L_1(i+j+k)\right|^2\right) \quad (5)$$

Using (4) and (5), the horizontal components of the USDV and the LSDV are obtained from:

$$sdv_u = \arg\ \min\{S_u(k)\}, -R \le k \le R \quad (6)$$

$$sdv_L = \arg\ \min\{S_L(k)\}, -R \le k \le R \quad (7)$$

The current pixel $x(i)$ is then interpolated by:

$$X(i) = \frac{U_0(i+i_u) + L_0(i+i_L)}{2} \quad (8)$$

$$\begin{aligned} i_u &= sdv_u / 2,\ i + i_u \\ i_L &= sdv_L / 2,\ i + i_L \end{aligned} \quad (9)$$

If the two index of the reference pixel i_U and i_L are not integer, the reference pixel can be obtained using interpolation in the horizontal direction. Detailed explain this method, give the current line and 4 reference lines, the magnitude of the difference between $U_0(i)$ and $L_0(i)$ is compared with a threshold T. If the magnitude of the summation of the two SDVs is larger than one, $X(i)$ is interpolated using linear interpolation in the vertical direction. Otherwise, the reference pixels are founds and $X(i)$ is interpolated using (12).

This de-interlacing method gives better performance in objective and subjective quality than ELA, Line Doubling, Line Averaging, A-ELA and E-ELA. However, even though DOI is more robust than the above methods, but DOI may produce annoying artifacts in periodic structures.

3. Proposed method

In this paper, we propose an improved approach to intra-frame de-interlacing which is based on direction-oriented interpolation (DOI) method as figure 3. We proposed method find the SDV, and then extend the SDV boundary within edge. Next, fill up the SDVs space in edge. Finally, we delete the wrong direction.

3.1 Calculate the intensity value

This step is previous step, we need the intensity value of edge in order to interpolate edge of correct direction. Intensity value of edge can estimate whether the direction edge is correct or not. Intensity value of edge is shown in the following:

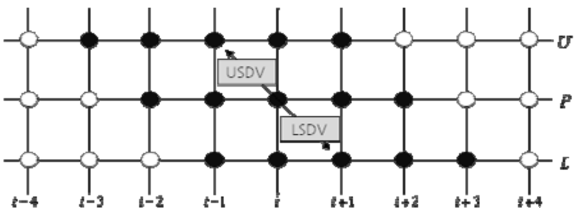

Figure 3 Calculate the intensity value

 ISBN 978-80-86943-94-7

If the blank points are edges, current pixel calculates the intensity edge of value which is using SDV. And if the difference of USDV and LSDV is small, the edge has high possibility. So, intensity value of edge is large. Otherwise, if the difference is large, and the intensity value of edge is small. The equation of intensity edge of value is in the following:

$$\begin{aligned}
&Case\ 1: |U_0[i] - L_0[i]| \geq T \\
&\quad Case\ 1.1: |P_{USDV}[i] + P_{LSDV}[i]| \leq 1 \\
&\qquad \rightarrow \text{ robust edge direction} \\
&\quad Case\ 1.2: |P_{USDV}[i] + P_{LSDV}[i]| > 1 \\
&\qquad \rightarrow \text{ weak edge direction} \\
&Case\ 2: |U_0[i] - L_0[i]| < T \\
&\qquad \rightarrow \text{nondirection}
\end{aligned} \tag{10}$$

3.2 Extension of edge area

The first step is how to extend the edge area which used SDV. Extension of edge area is showing in the figure:

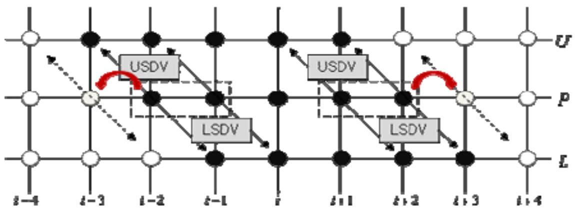

Figure 4 Extension of edge area

If black points are edges, we should compare SDVs of left and right pixels. The SDV in comparison, if there is no difference and similar, the SDV value is inserted at side pixel. The extension of edge area is determined as:

$$\begin{aligned}
&CASE\ 1: D[i+1] = 2 \text{ and } D[i+2] = 2 \text{ or} \\
&\qquad D[i-1] = 2 \text{ and } D[i-2] = 2 \\
&\quad CASE\ 1.1: |P_{SDV}[i+1] - P_{SDV}[i+2]| = 0 \text{ and} \\
&\qquad |P_{USDV}[i+1] + P_{LSDV}[i+1]| = 0 \\
&\qquad \rightarrow \text{extend the left SDVs} \\
&\quad CASE\ 1.2: |P_{SDV}[i-1] - P_{SDV}[i-2]| = 0 \text{ and} \\
&\qquad |P_{USDV}[i-1] + P_{LSDV}[i-1]| = 0 \\
&\qquad \rightarrow \text{extend the right SDVs} \\
&CASE\ 2: D[i-1] < 2 \text{ and } D[i-2] < 2 \\
&\qquad \rightarrow \text{maintain the SDVs}
\end{aligned} \tag{11}$$

Through this step, the edge is robust and sharp.

3.3 Elimination of edge hole area

The result of previous step, we can get higher quality image than using the general SDV method. But it still can't find SDV. In this step, we can find the direction and add the direction of the edge using the near SDV, and we also can find direction using USDV, LSDV.

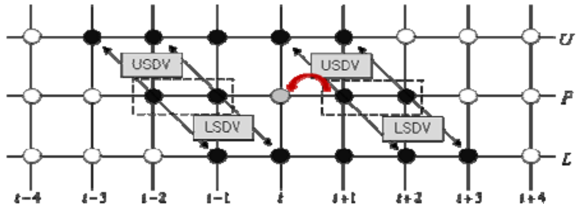

Figure 5 Elimination of edge hole area

For elimination of edge hole area, we use the neighborhood pixel of hole area. If intensity values of side pixels are large and SDVs(LSDV, USDV) of side pixels are similar, we can consider that the neighborhood pixels are in the same direction. So SDV of hole area pixel inserts SDV of next pixel, and then we can eliminate the edge hole area. The equation of elimination of edge hole area is as following:

$$\begin{aligned}
&CASE\ 1: D[i+1] = 2 \text{ and } D[i+2] = 2 \text{ or} \\
&\qquad D[i-1] = 2 \text{ and } D[i-2] = 2 \\
&\quad CASE\ 1.1: |P_{SDV}[i-1] - P_{SDV}[i-2]| = 0 \text{ and} \\
&\qquad |P_{USDV}[i-1] + P_{LSDV}[i-1]| = 0 \text{ and} \\
&\qquad |P_{SDV}[i+1] - P_{SDV}[i+2]| = 0 \text{ and} \\
&\qquad |P_{USDV}[i+1] + P_{LSDV}[i+1]| = 0 \\
&\qquad \rightarrow \text{fill up the SDVs} \\
&CASE\ 2: D[i-1] < 2 \text{ and } D[i-2] < 2 \text{ or} \\
&\qquad D[i-1] < 2 \text{ and } D[i-2] < 2 \\
&\qquad \rightarrow \text{maintain the SDVs}
\end{aligned} \tag{12}$$

3.3 Correction of misdirection

The image of the last step which we calculated usually is wrong. Because it has the hopeless image, so in this step, we can get the improved quality of image when the information of SDV is wrong. How to remove the wrong SDV, the method is following:

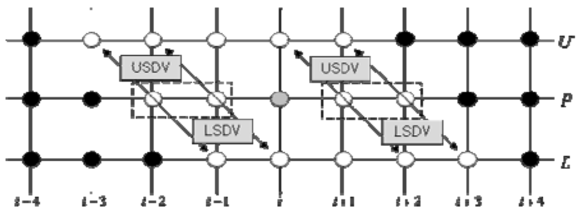

Figure 6 Correction of misdirection

To correct misdirection, we use the neighborhood pixels. If intensity value of neighborhood pixels is lowly and SDV of neighborhood pixels are similar.

 ISBN 978-80-86943-94-7

So we consider that current pixel is the misdirection. We need modify SDV of current pixel. The correction of misdirection is shown in following equation 13:

$$
\begin{aligned}
&CASE\ 1: D[i+1] \le 1 \text{ and } D[i-1] \le 1 \\
&\quad CASE\ 1.1: \left|P_{SDV}[i-1] - P_{SDV}[i-2]\right| \le 1 \text{ and} \\
&\qquad \left|P_{USDV}[i-1] + P_{LSDV}[i-1]\right| \le 1 \text{ and} \\
&\qquad \left|P_{SDV}[i+1] - P_{SDV}[i+2]\right| \le 1 \text{ and} \\
&\qquad \left|P_{USDV}[i+1] + P_{LSDV}[i+1]\right| \le 1 \\
&\qquad \rightarrow \text{delete the wrong direction SDVs} \\
&CASE\ 2: D[i+1] > 1 \text{ and } D[i-1] > 1 \\
&\qquad \rightarrow \text{maintain the SDVs}
\end{aligned}
\tag{13}
$$

Through these steps, we can use the correction of misdirection to decrease the noise of image and improve the quality of image.

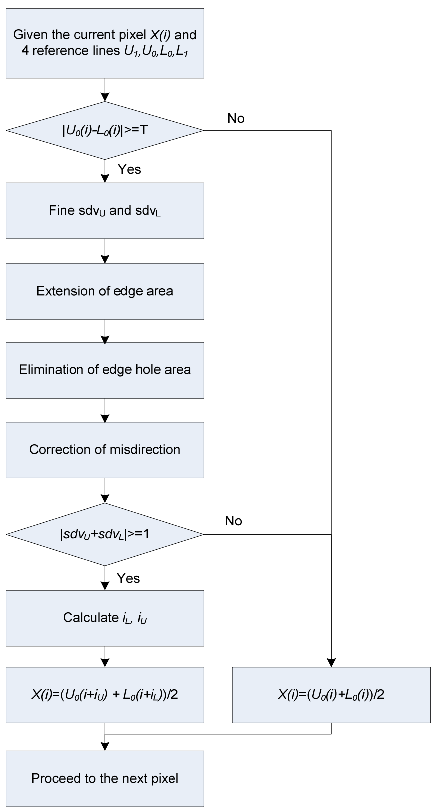

Figure 7 Flow diagram of the proposed method

4. Experimental Results

In order to obtain fair empirical evaluation of intraframe de-interlacing methods, it is important to use a set of well-known images for experiments. In this paper, seven intraframe-based de-interlacing methods are chosen to evaluate their performance. Here we set the threshold t to 10, and we set the search rage R to 16 as DOI.

Table 1 shows the performance of these methods for various images. We compare the proposed method with ELA, Block-Based Directional, Edge Interpolation (BDEI), Edge-Based Median Filtering (EMF), Anti-aliasing Interpolation filter (AAIF), Modified ELA (MELA) and Directional Oriented Interpolation (DOI). Compare to proposed method with other method, the propose method most performance is good. PSNR results show a higher value of 0.03dB to 0.47dB. Subjectively, the quality of result image is similar to the DOI, and the result images are good as shown figure 8 and figure 9.

5. Conclusion

In this paper, we proposed an improved directional oriented interpolation algorithm. We proposed method is based on DOI. We apply the three steps in DOI algorithm. We obtain the more sharp result image using extend SDVs step. And proposed method improves image quality for the SDV of wrong direction modified. Using the SDV method, the edge's boundary will be expanded. So, we can get the clearer image. And also we get the high quality image because of reducing noise when modify the wrong direction. The result of our experiment showed objectivity using PSNR. The value is almost same with the other methods and even better in some cases. Experimental results show that the proposed method gives better performance in objective and subjective quality than the existing de-interlacing methods.

6. References

[1] J.Kovacevic, Reobert J. Safranek, and Edmund M.Yeh. Deinterlacing by Successive Approximation. *IEEE Transactions on Image Processing*, Vol. 6, No. 2, pages 339-344, February 1997

[2] O.J.Kwon, Kwanghoon Sohn, and Chulhee Lee. Deinterlacing using Directional Interpolation and Motion Compensation. *IEEE Transactions on Consumer Electronics*, Vol. 49, No. 1, pages 198-203, February 2003

[3] S.F.Lin, Yu-Ling Chang, and Liang-Gee Chen. Motion Adaptive Interpolation with Horizontal Motion Detection for Deinterlacing. *IEEE Transactions on Consumer Electronics*, Vol. 49, No. 4, pages 1256-1265, November 2003

[4] M.K.Park, Moon Gi Kang, Kichul Nam, and Sang Gun Oh. New Edge Deinterlacing Algorithm Based on Horizontal Edge Pattern. *IEEE Transactions on Consumer Electronics*, Vol. 49, No. 4, pages 1508-1512, November 2003

[5] Y.L.Chang, Shyh-Feng Lin, Ching-Yeh Chen, and Liang-Gee Chen. Video De-Interlacing by Adaptive 4-Field Global/Local Motion Compensated Approach. *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 15, No. 12, pages 1569-1582, December 2005

[6] Q.Huang, Wen Gao, Debin Zhao, and Huifang Sun. An Efficient and Robust Adaptive Deinterlacing Method. *IEEE Transactions on Consumer Electronics*, Vol. 52, No. 3, pages 888-895, August 2006

[7] L.Yu, Jintao Li, Yongdong Zhang, and Yanfei Shen. Motion Adaptive Deinterlacing with Accurate Motion Detection and Anti-Aliasing Interpolation Filter. *IEEE Transactions on Consumer Electronics*, Vol. 52, No. 2, pages 712-717, May 2006

[8] Y.Shen, Dongming Zhang, Yongodng Zhang, and Jintao Li. Motion Adaptive Deinterlacing of Video Data with Texture Detection. *IEEE Transactions on Consumer Electronics*, Vol. 52, No. 4, pages 1403-1408, November 2006.

[9] W.Kim, S Jin, J Jeong, "Novel Intra Deinterlacing Algorithm Using Content Adaptive Interpolation", *IEEE Transactions on Consumer Electronics*, Vol. 53, No. 3, pages 1036-1043, AUGUST 2007.

[10] T.Doyle and M.Looymans, Progressive scan conversion using edge information, *Signal Processing of HDTV II*, L. Chairiglione, ED. Amsterdam, The Netherlands: Elsevier, pages 711-721, 1990

[11] Y.Kim, Deinterlacing Algorithm based on sparse wide vector correlations, SPIE Optical Engineering, vol.2727, pages 88-99, 1996

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

[13] H.Yoo and Jechang Jeong. Directional-oriented interpolation and its application to de-interlacing. *IEEE Trans. Consumer Electronics*, Vol. 48, Issue 4, pages 954-962, November 2002

[14] G. de Haan and E. B. Bellers. Deinterlacing of video data. *IEEE Transactions on Consumer Electronics.* Vol.43, No. 3, pages 819-825, August 1997

[15] R.Li, B.Zeng, and M. Liou. Reliable motion detection/compensation for interlaced sequences and its applications to deinterlacing. *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 10, No. 1, pages 23-29, February 2000

[16] C.Ballester, Marcelo Betralmio, Vicent Caselles, Luis Garrido, Adrian Marques, and Florent Ranchin. An Inpainting-based Deinterlacing Method. *IEEE Transactions on Image Processing*, Vol. 16, No. 10, pages 2476-2491, October 2007

[17] T.Chen, Hong Ren Wu, and Zheng Hua Yu, "Efficient Deinterlacing algorithm using edge-based line average interpolation," *Optical Engineering*, Vol. 39, No. 8, pp. 2101-2105, Aug. 2000.

[18] http://sipi.usc.edu/database/index.html

Table 1 PSNR result of different intraframe de-interlacing methods for various images

Image	LA	ELA	MELA	BDEI	EMF	AAIF	DOI	Proposed method
Lena (512×512)	36.82	35.99	36.07	37.09	36.81	38.05	37.32	37.35
Airplane (512×512)	31.82	31.12	30.41	31.59	31.55	32.22	31.69	31.72
Baboon (512×512)	23.50	22.97	23.00	23.49	23.71	23.07	23.43	23.47
Bike (400×500)	24.40	23.60	22.92	24.26	24.51	24.19	25.36	25.59
Gold (720×576)	33.30	32.73	32.94	33.44	33.57	33.73	33.73	33.80
Hotel (720×576)	32.88	32.15	31.75	32.42	32.37	33.39	32.94	33.07
Target (512×512)	17.13	18.98	17.35	16.46	17.16	16.54	18.60	18.75
Table Tennis (352×240)	26.83	27.05	27.27	26.90	26.98	25.19	29.53	30.10
Light House (512×768)	30.27	29.38	30.30	29.87	29.69	24.01	30.40	30.86
House (256×256)	31.83	31.88	31.79	31.73	31.68	22.59	32.55	32.62
Couple (512×512)	27.93	27.43	27.42	27.75	27.88	22.28	27.91	27.94
Average	28.79	28.48	28.29	28.64	28.72	26.84	29.41	29.57

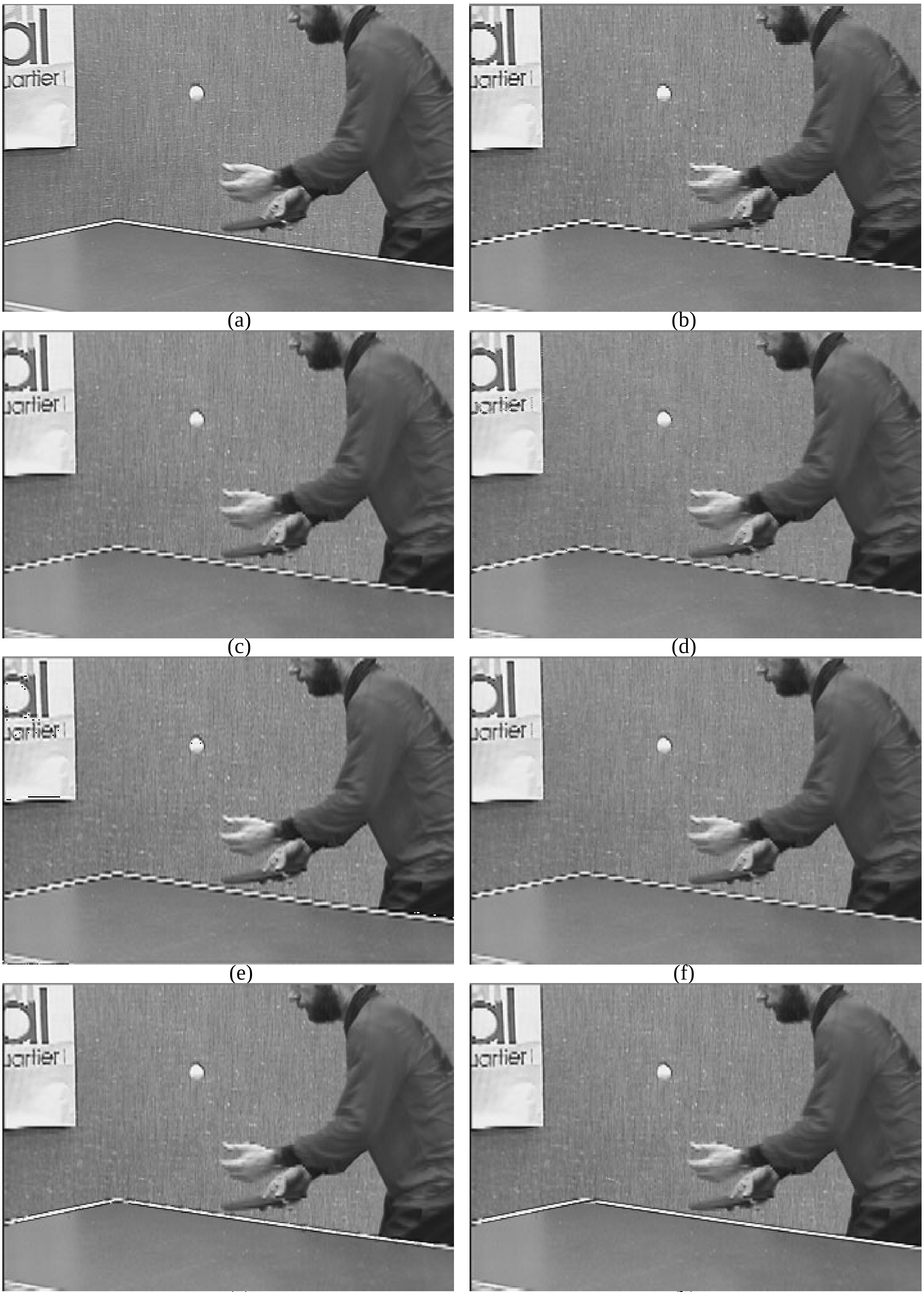

Figure 8 (a) Result of Table Tennis image, (b)-(h) Interpolated: (b) line-doubling (c) line-averaging (d) ELA (e) AAIF (f) MELA-2 (g) DOI (h) proposed method

 ISBN 978-80-86943-94-7

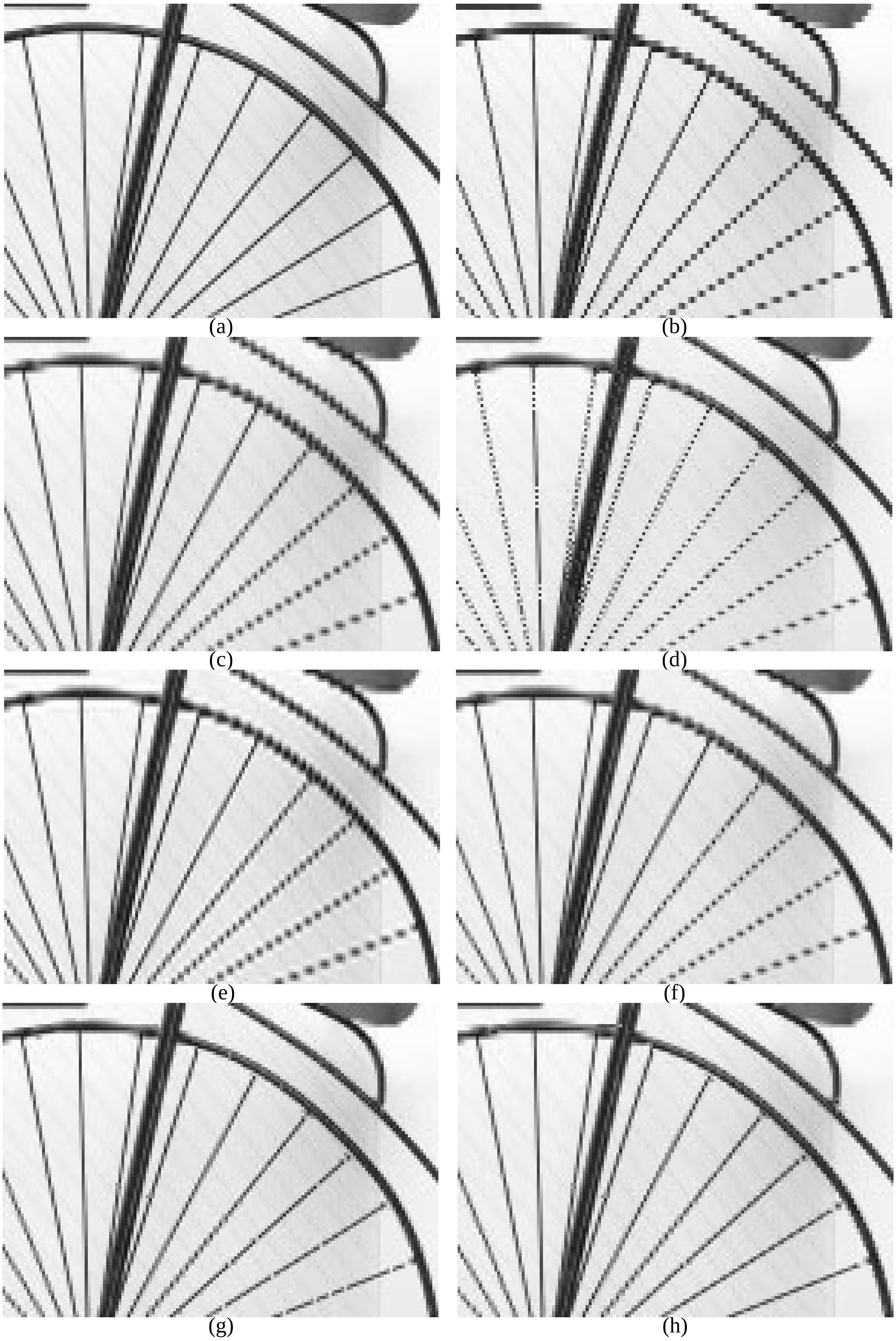

Figure 9 (a) Zoomed results of Bike image, (b)-(h) Interpolated: (b) line-doubling (c) line-averaging (d) ELA (e) AAIF (f) MELA-2 (g) DOI (h) proposed method

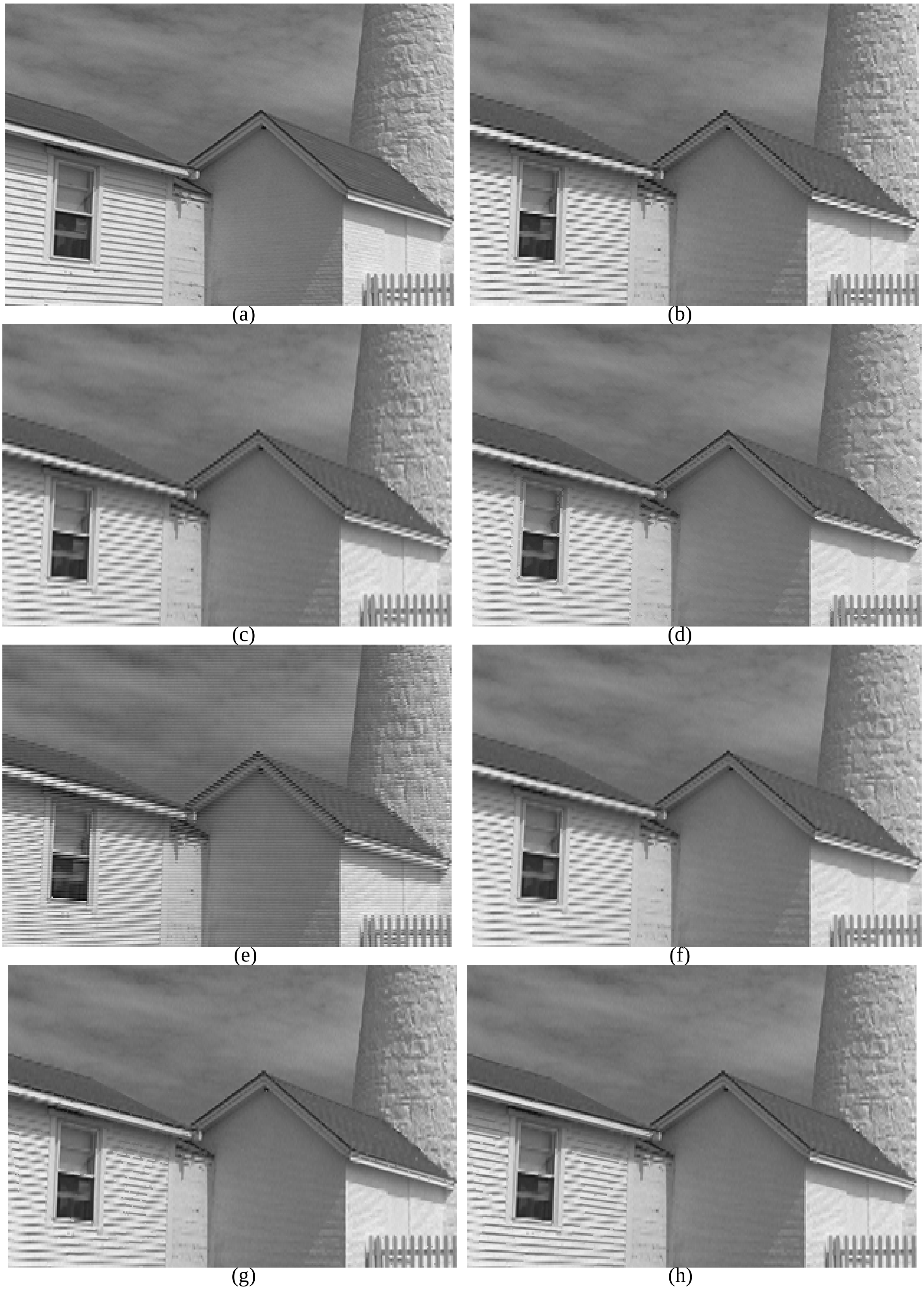

Figure 8 (a) Result of Light house image, (b)-(h) Interpolated: (b) line-doubling (c) line-averaging (d) ELA (e) AAIF (f) MELA-2 (g) DOI (h) proposed method

 ISBN 978-80-86943-94-7