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Fuzzy Entropy Interpretation and Its Application in Deinterlacing

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Abstract

This paper proposes a new deinterlacing method using fuzzy entropy-based cost function to select possible image deinterlacing methods. The classical entropy was presented by Shannon, which is widely used in information and communication theory. Apart from Shannon's entropy, fuzzy entropy deals with vagueness and ambiguous uncertainties. The obtained fuzzy entropy map becomes criteria to select the best method to interpolate missing pixel and upsample the low-resolution image. The experimental results describe that our proposed method is superior to conventional methods.

Keywords: *fuzzy entropy, deinterlacing, image upscaling, upsampling*

1. Introduction

Nowadays, there are two different kinds of video format, i.e. interlaced scanning format video and progressive scanning format video [1]. A deinterlacing method is a process of converting interlaced scanning format signal to progressive scanning format one. After deinterlacing procedure, a half-pictured image is converted to full-pictured image. Conventional TV does not present full-frame at once; rather they could alternately display odd and even lines in every 1/60 second. This was caused by insufficient bandwidth issue. However, due to develop of technology, current TV displays full pictures at once, interlace scanning format signals must be converted to progressive one. Fine quality deinterlacing topic becomes a decisive topic, which converts original interlaced scanning format video fields into progressive scanning format frames with less visual artifacts.

There have been many deinterlacing methods to improve video format conversion. These methods are approximately divided into two categories: motion compensated (temporal) and no-motion compensated (spatial) methods. Since the proposed method uses only a field to obtain a frame, our method is spatial method. The edge-based line average (ELA) method is a spatial method which is widely known as it demonstrates good performance with less complexity [2].

Information theory is used in computer science, electrical engineering, and applied mathematics, which quantify effect of information. Information theory was studied and matured by Shannon to obtain essential bound on signal and image processing works such as coding efficiency and data compression with reliability [3]. The fuzzy sets were firstly introduced by Zadeh with a goal to tackling problems where indefiniteness resulting from a inherent ambiguity plays a essential function [4-6]. In this paper, we study fuzzy information calculation with fuzzy entropy, which is used to select the candidate method [7-10]. The main difference between information theory and fuzzy entropy is that the previous one handles stochastic uncertainties and the later deals with unclarity and ambiguous uncertainties.

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In this paper we proposed fuzzy entropy-based deinterlacing approach. In Section 2, we compare traditional entropy by Shannon and fuzzy entropy. In Section 3, we show some example of fuzzy entropy-based deinterlacing strategy determination. Section 4 shows the simulation results and objective and subjective comparison with conventional methods. Section 5 draws the concluding remarks.

2. Fuzzy Entropy and Information Theory

Information entropy is a degree of the uncertainty in a random variable. Typically, this is called Shannon entropy. We assume $\Delta_n=\{L=l_1,...,l_n\}$: $i_i \geq 0$, and $n \geq 2$ be a set of n-complete likelihood distributions. For any probability distribution $L=(l_1,...,l_n) \in A_n$. Shannon's entropy is defined as

(1)

Several applied information entropies have been proposed with different purposes by many authors and all entropies have been modification of Shannon's entropy. The applications have been reached to statistics, information processing, economics, medical image, and computer science. In particular, De Luca and Termini proposed a set of four basic assumptions and these assumptions are broadly adopted as a measurement for obtaining fuzzy entropy [11, 12]. Meanwhile, the fuzzy entropy is a criterion of fuzziness which declares the quantity of vagueness or hardness in determining in a decision making. A criterion of vagueness in a fuzzy set must have following assumptions:

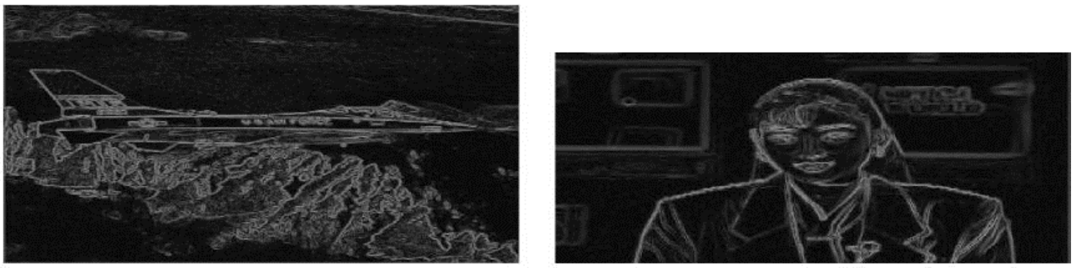
Assumption1. *Sharpness*:	$H(A)$ is minimum if an only if A is a crisp set.
Assumption2. *Maximality*:	$H(A)$ is maximum if an only if A is a most fuzzy set.
Assumption3. *Resolution*:	$H(A^*) \leq H(A)$, where A^* is a sharpened version of A.
Assumption4. *Symmetry*:	$H(A) \leq H(A^C)$, where A^C is a complement set of A.

De Luca and Termini defined fuzzy entropy for a fuzzy set A as,

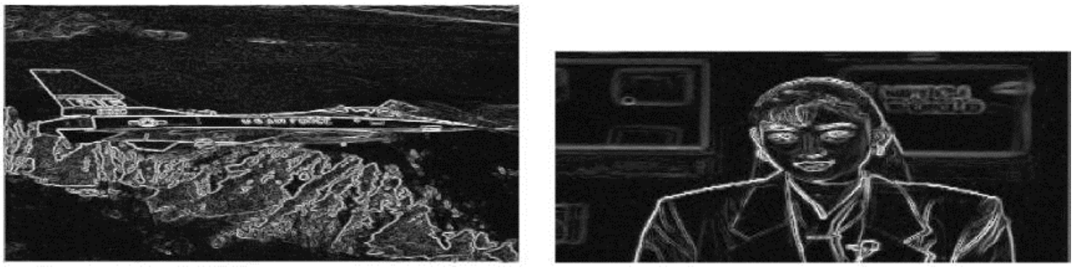
(1)

1

This paper is based on De Luca and Termini's fuzzy entropy to determine the candidate method. De Luca and Termini proposed fuzzy entropy as a criterion of fuzziness. They used Shannon's function, and explained a measure that became largest at the degree of membership of 0.5. Figure 1 shows examples of traditional Shannon's entropy and fuzzy entropy map on two images (Airplane and Akiyo).



(a)



(b)

Figure 1. (a) Shannon's Traditional Entropy Map and (b) Our Fuzzy Entropy Map. Images in Left Side are Interlaced 512×256 Airplane Image. Images in Right Side are Interlaced 352×144 Akiyo Image

3. Method Determination Using Fuzzy Entropy

This section shows an example of fuzzy entropy values with different input. Let us assume *a*, *b*, *c*, and *m* as follows. Note that linspace is a Matlab command, which produces linearly spaced vectors. For instance, y=linspace(a,b,n) creates a row vector y of *n* points linearly spaced between and including *a* and *b*.

a = linspace(0,1,9)

0	0.1250	0.2500	0.3750	0.5000	0.6250	0.7500	0.8750	1.0000

b = linspace(0,1,9)

0	0.1250	0.2500	0.3750	0.5000	0.6250	0.7500	0.8750	1.0000

c = linspace(1,0,9)

1.0000	0.8750	0.7500	0.6250	0.5000	0.3750	0.2500	0.1250	0

m = linspace(0.25,0.25,9)

0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500

The obtained fuzzy entropy values are shown in Figure 2. As we can see, as two input values are close to 0.5, output fuzzy entropy value grows toward 1. Moreover, since $\mu_A(x)$ and $(1-\mu_A(x))$ yield the same degree of fuzziness, fuzzy entropy results are the same.

[a' b' res1]   [a' c' res2]   [m' a' res3]

0	0	NaN
0.1250	0.1250	0.5436
0.2500	0.2500	0.8113
0.3750	0.3750	0.9544
0.5000	0.5000	1.0000
0.6250	0.6250	0.9544
0.7500	0.7500	0.8113
0.8750	0.8750	0.5436
1.0000	1.0000	NaN

(a)

0	1.0000	NaN
0.1250	0.8750	0.5436
0.2500	0.7500	0.8113
0.3750	0.6250	0.9544
0.5000	0.5000	1.0000
0.6250	0.3750	0.9544
0.7500	0.2500	0.8113
0.8750	0.1250	0.5436
1.0000	0	NaN

(b)

0.2500	0	NaN
0.2500	0.1250	0.5436
0.2500	0.2500	0.8113
0.2500	0.3750	0.9544
0.2500	0.5000	1.0000
0.2500	0.6250	0.9544
0.2500	0.7500	0.8113
0.2500	0.8750	0.5436
0.2500	1.0000	NaN

(c)

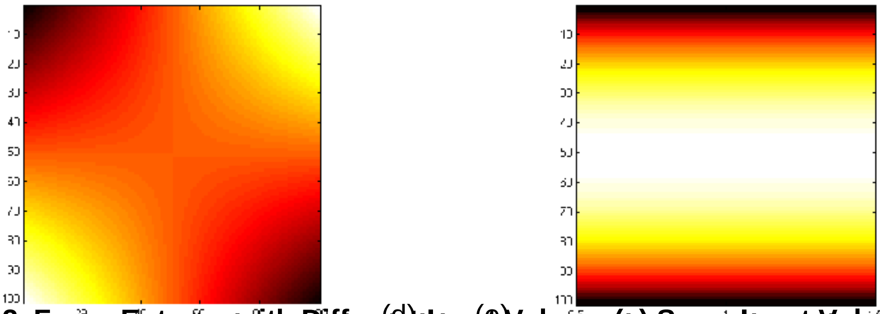


Figure 2. Fuzzy Entropy with Different Input Values: (a) Same Input Values (a=b, … Equally Generated Numbers between 0 to 1, and (e) Fuzzy Entropy Values of (d)

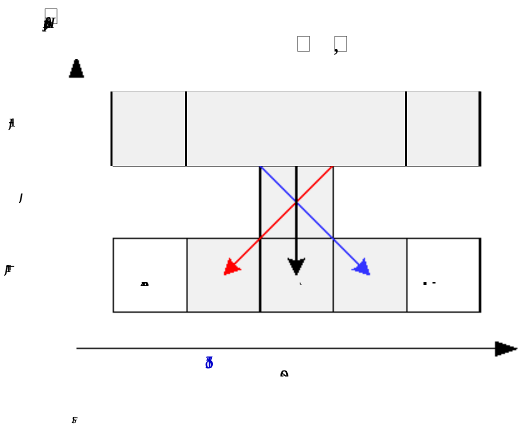


Figure 3. Differences in Three Edge Directions: δ_{45}, δ_{90}, and δ_{135}

Figure 3 shows the method how we obtain suitable edge direction. We assume input values A of fuzzy entropy are $A=[\delta_{45}, \delta_{90}, \delta_{135}]$. By applying Eq. (2), we obtain H_{FS}.

$$A = \delta_{45}, \delta_{90}, \delta_{135} \quad (3)$$

where

(4)

Now, obtained H_{FS} is compared with pre-determined threshold value *th* to select suitable method between ELA [2] and LA, as shown in Eq. (5). Note that we assume there are two conventional methods ELA and LA. The fuzzy entropy H_{FS} is used to determined the methods to be used,

$$\text{if } H_{FS} \; th , \qquad (5)$$

The threshold is obtained empirically, which is presented in Section 4.

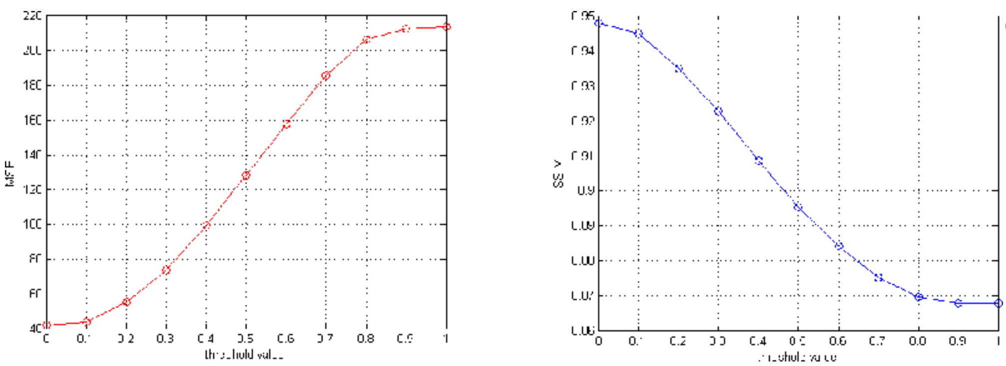


Figure 4. Performance Comparison with Varying Threshold Value: (a) MSE, (b) SSIM

4. Experimental Results

We used 24 images and video sequences to evaluate the objective and visual performance of the proposed method. The threshold value *th* is determined empirically, which is *th*=0.3. Figure 4 shows MSE and structural similarity (SSIM) results with different *th* values [13]. As we can see, the performance is getting better as *th* decreases, while visual performance is getter worse. Therefore, we have to compromise on selecting the *th* value, and 0.3 was selected. Figure 5 shows SSIM results with varying *th* values between 0 and 1. Note that SSIM is an assessment method for evaluating the similarity between two signals as shown in Eq. (6). SSIM takes into account image degradation as noticed alter in structural information.

(6)

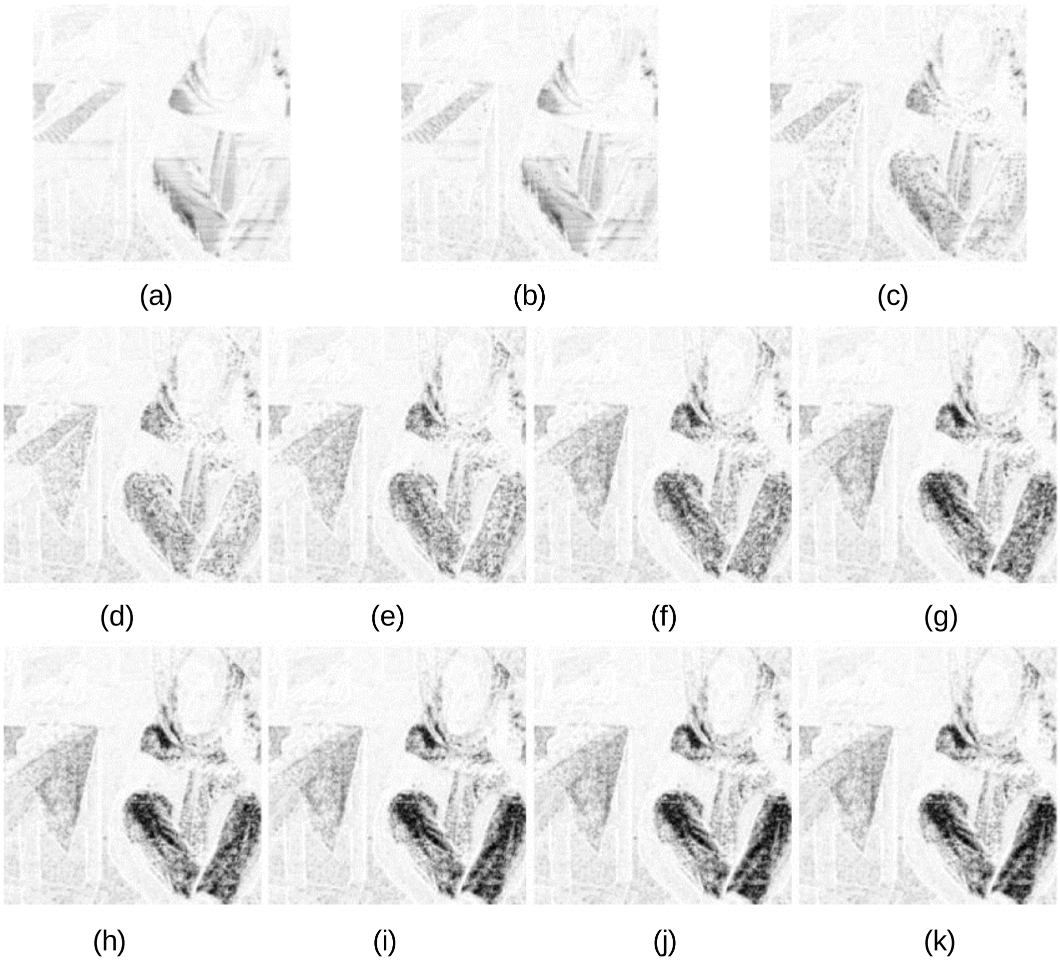
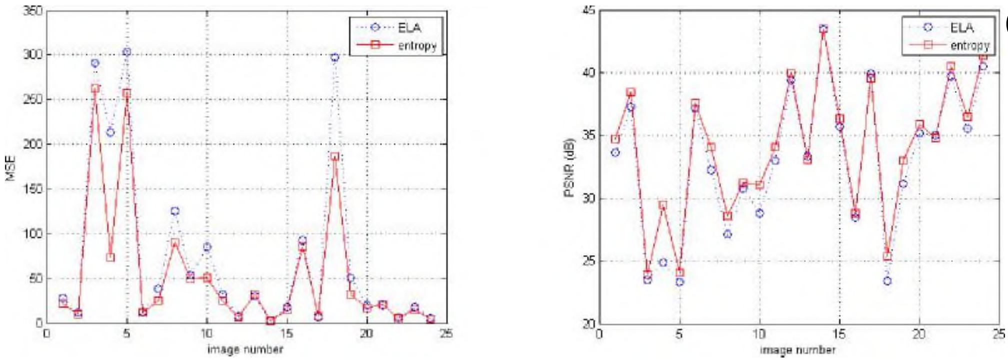


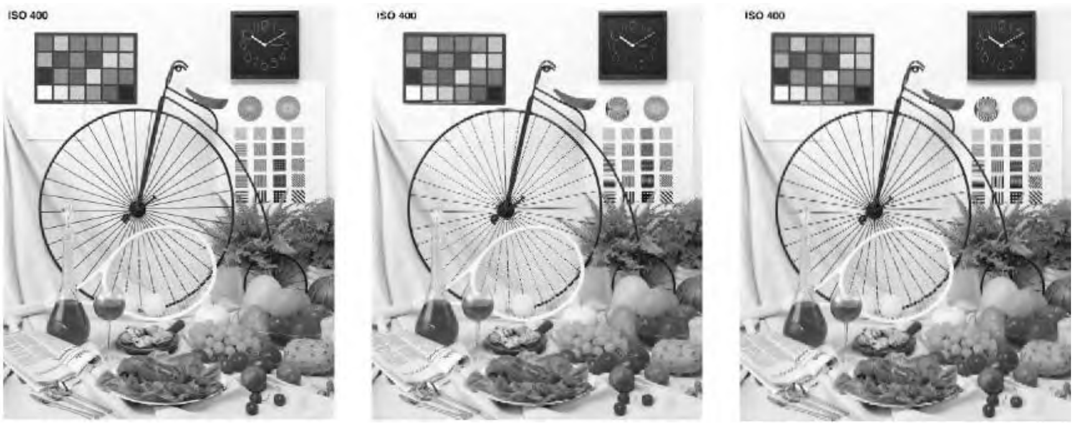
Figure 5. SSIM Images with Varying Threshold Values: (a) *th*=0, (b) *th*=0.1, (c) *th*=0.2, (d) *th*=0.3, (e) *th*=0.4, (f) *th*=0.5, (g) *th*=0.6, (h) *th*=0.7, (i) *th*=0.8, (j) *th*=0.9, and (k) *th*=1.0

Figure 6 shows the PSNR and MSE results of the proposed method (entropy) and its corresponding ELA method. As we can see, the proposed method always yields better objective performance than ELA method. As PSNR is not the only criteria for assess the performance of interpolation quality, we provide visual performance. Figures 7 and 8 show visual quality comparisons between the proposed method and the ELA method. The defect of ELA obtained results is that it deteriorate the image quality in motionless region and are sensitive to the high frequency region.



(a)

Figure 6. (a) MSE and (b) PSNR (dB) Performance Comparison for 24 Test Images



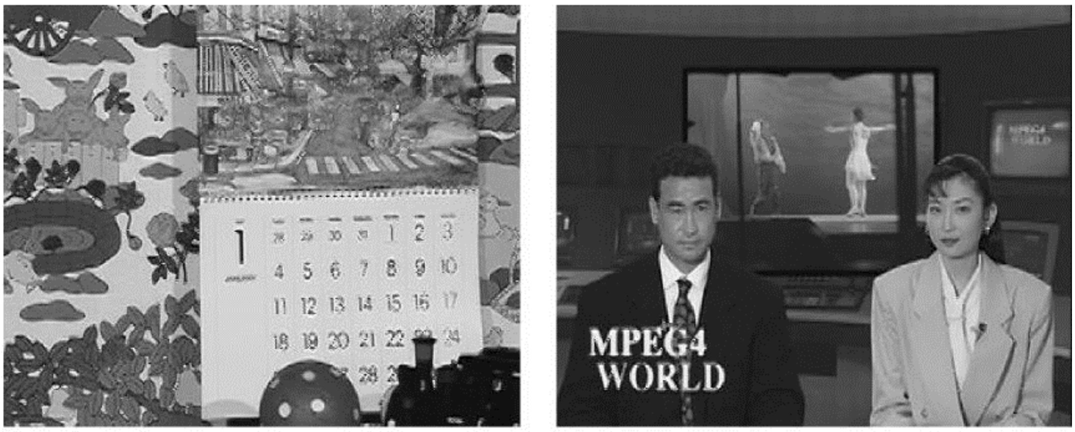
(a) (b) (c)

Figure 7. Visual Performance Comparison: (a) Original Bike Image, (b) ELA Method, and (c) Proposed Fuzzy Entropy-Based Method

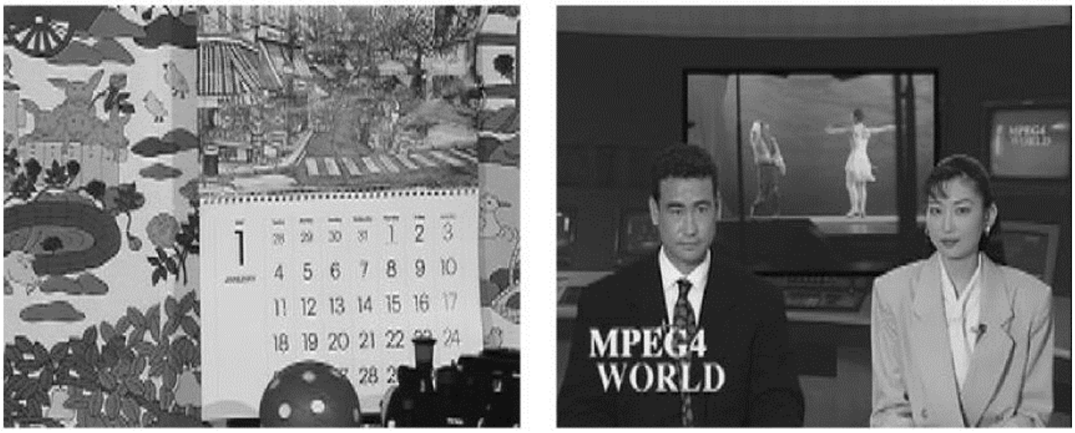
5. Conclusions

In this paper, a new video format conversion method was proposed. The proposed method is based on fuzzy entropy that was proposed by De Luca and Termini. We compared fuzzy entropy map with Shannon's entropy map. The simulation results prove that the proposed method gives better performance than conventional ELA method.

(a)



(b)



(a)

Figure 8. Visual Performance Comparison: (a) Original Mobile and News Image, (b) ELA Method, and (c) Proposed Fuzzy Entropy-Based Method

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