International Journal of Hybrid Information Technology
Vol. 9, No.10 (2016), pp. 219-228
http://dx.doi.org/10.14257/ijhit.2016.9.10.22

An Expert System using Conditional Rules

Gwanggil Jeon

Department of Embedded Systems Engineering, Incheon National University
119 Academy-ro, Yeonsu-gu, Incheon 406-772, Korea
gjeon@inu.ac.kr

Abstract

In this paper, fuzzy condition rules are studied to improve video format conversion. The propose method consists of three parts: (1) system consideration, (2) image quality assessment, and (3) adjusting parameters. By adopting hedges in membership function, we apply additional effects for fuzzy operations. In addition, by providing condition rules for four fuzzy sets 'fast', 'slow', 'homogeneity', and 'heterogeneity', we could improve restored images. The hedges are applied in each fuzzy set depending on the input values, which provides additional effect. Experimental results show that the proposed method outperforms two benchmark methods.

Keywords*: Image processing, fuzzy rule-based approach, Gaussian filter, membership hedge*

1. Introduction

The expert system is based on common sense although common sense is normally vague [1-3]. Thus this vague concept cannot be directly used as engineer knowledge, and is processed by pre-processing step. Then, this knowledge becomes meaningful one and engineer will use it in computer as the same level of understanding [4]. Here, the question is how to manage expert knowledge which is vague and ambiguous in a tangible concept for computer [5]. To solve this issue, some researchers studied artificial intelligence including fuzzy sets theory.

The fuzzy sets theory is used to manage degree of fuzziness and vagueness (FV). This FV can be applied in many topics such as degree of room temperature, degree of person's height, degree of car speed, degree of school distance, and degree of lady's beauty [6-9]. This all information can be stated as scale. In general, this scale is hard to differentiate either 'yes' or 'no' category. In 1937, a philosopher M. Black published a paper known as "*Vagueness: an exercise in logical analysis*." After that, in 1965, L. Zadeh published "*Fuzzy sets*." In this paper, Zadeh used fuzzy possibility theory into a formal system of mathematical logic [10]. In addition, he proposed a new concept for applying natural language terms into fuzzy sets. The natural language is concrete, immediate and descriptive. Zadeh represented crisp binary logic into degree of membership. Therefore, classical two-valued boolean logic became multi-valued fuzzy logic. In addition, the fuzzy logic can represent the logical value between zero and one, where zero and one are totally false and totally true [11-14].

In image processing, denoising is an important issue to solve [15-21]. There are two types of noises, one is impulse noise and the other is random noise [22-23]. In general, the impulse noise is called as salt-and-pepper noise and the random noise is called as Gaussian noise. The Gaussian noise is represented with two parameters, mean (μ) and the variance (σ^2) values. The noise is generated during image/video capture, transmission, and storage. Therefore, during the TV communication, information can be changed due to the noise.

ISSN: 1738-9968 IJHIT

The fuzzy logic is a process of the multi-valued calculation where the truth values of variables can be any value between 0 and 1. The crisp logic is the opposite concept of fuzzy logic, which is also called as boolean logic and only two values are used: ‘0’ and ‘1’.

In this paper, an efficient fuzzy rule based deinterlacing algorithm is proposed. Most of the traditional edge-based single field deinterlacing methods adopt average filters with small number taps, thus the accuracy of restoration is low quality due to the frequency response of the average filter looks like a dome. The rest of the manuscript is organized as follows. In Section 2, we introduce the fuzzy logic concept and describe the proposed method. Section 3 shows simulation results and their corresponding performance analysis. Finally, conclusion remarks are shown in Section 4.

2. Proposed Method

In general, there are three main topics in image processing, and they can be stated as follows:

(1) System consideration,
(2) Image quality assessment,
(3) Adjusting parameters.

The ‘system consideration’ issue means that there is no systematic consideration of subjectivity. The ‘image quality assessment’ issue deals with how to assess concurred image qualities. Finally, the ‘adjusting parameters’ issue means how adjust parameters for algorithms. This concept is shown in Figure 1.

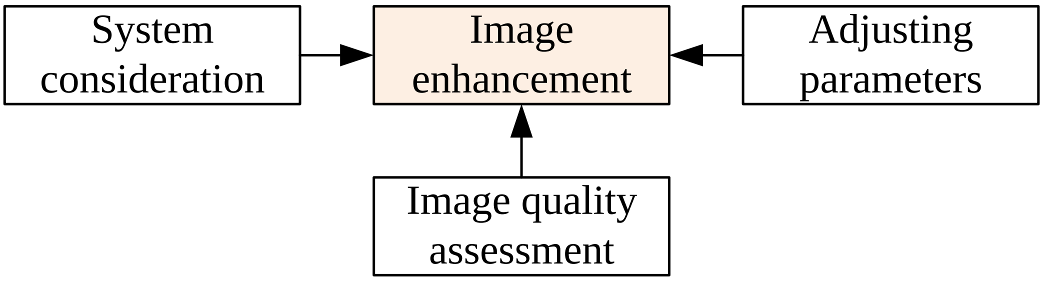


Figure 1. Three Topics to Be Considered In Image Enhancement

The fuzzy variable can be explained with linguistic variable. The fuzzy expert system is based on linguistic variables and its form is,

$$\begin{array}{l} \text{IF } \mathbf{A}_1 \text{ is } \mathbf{B}_1, \text{ THEN } \mathbf{C}_1 \text{ is } \mathbf{D}_1 \\ \text{IF } \mathbf{A}_2 \text{ is } \mathbf{B}_2, \text{ THEN } \mathbf{C}_2 \text{ is } \mathbf{D}_2 \\ \dots \\ \text{IF } \mathbf{A}_N \text{ is } \mathbf{B}_N, \text{ THEN } \mathbf{C}_N \text{ is } \mathbf{D}_N \end{array} \quad (1)$$

The possible range of fuzzy variable is the universe of discourse. The linguistic variable contains the concept of several hedges (or modifiers) such as very, quite or extremely. The hedges work as operations themselves. Here are some examples: a hedge ‘very’ works concentration and generates a new subset, and eventually emphasis the meaning. Another example is ‘extremely’ which gives even stronger meaning of ‘very’. Normally hedges work as operations, which are found to be effective. In addition, the hedges help to reflect human mind, as human generally cannot differentiate between ‘very’ and ‘extremely’.

Figures 2(a) and 2(b) display two membership functions, SMALL (μ_{SMALL}) and LARGE (μ_{LARGE}). Two Figures Figures 2(c) and 2(d) display ‘*prodor*’ and ‘*max*’ operations, while Figures 2(e) and 2(f) display ‘*product*’ and ‘*min*’ operations.

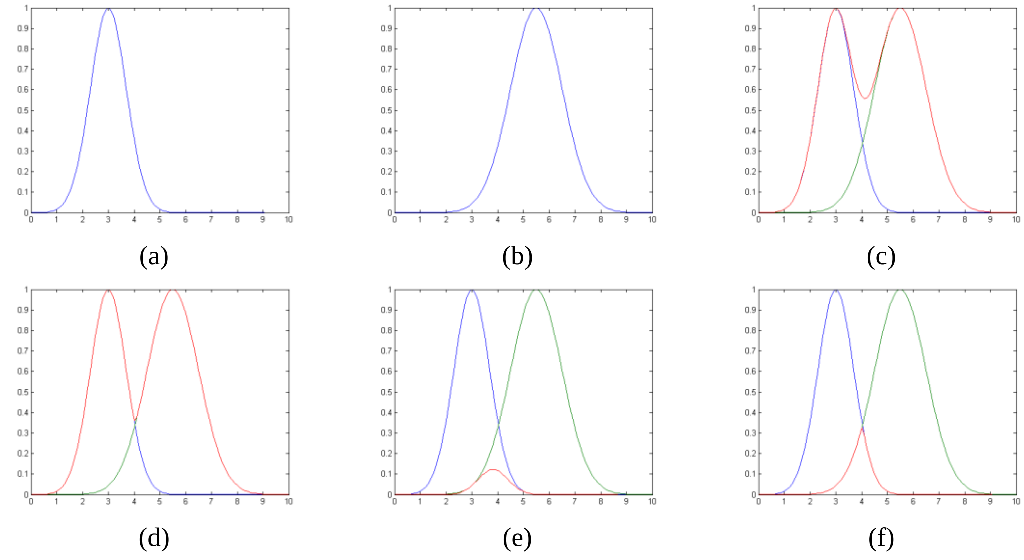


Figure 2. Examples of Fuzzy Operations: (A) *SMALL*, (A) Original *LARGE*, (C) *Prodor* Command Operation, (D) *Max* Command Operation, (E) *Product* Command Operation and (F) *Min* Command Operation

The hedges can be applied in a given operation, and their equations can be represented as

$$\mu_{HM}^{very}\left(x\right)=\left[\mu_{HM}\left(x\right)\right]^{2} \tag{2}$$

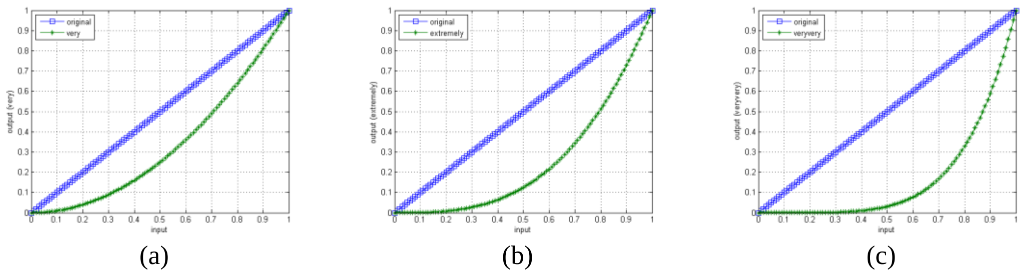
$$\mu_{HM}^{extremely}\left(x\right)=\left[\mu_{HM}\left(x\right)\right]^{3} \tag{3}$$

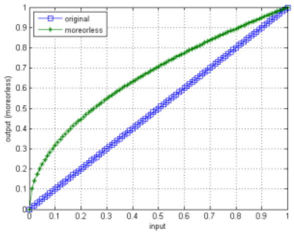
$$\mu_{HM}^{very-very}\left(x\right)=\left[\mu_{HM}^{very}\left(x\right)\right]^{2}=\left[\mu_{HM}\left(x\right)\right]^{4} \tag{4}$$

$$\mu_{HM}^{more-or-less}\left(x\right)=\left[\mu_{HM}\left(x\right)\right]^{1/2} \tag{5}$$

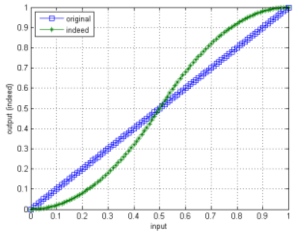
$$\begin{aligned}&\text{For } \mu_{HM}<5,\ \ \mu_{HM}^{indeed}\left(x\right)=2\left[\mu_{HM}\left(x\right)\right]^{2}\\&\text{otherwise, } \mu_{HM}^{indeed}\left(x\right)=1-2\left[1-\mu_{HM}\left(x\right)\right]^{2}\end{aligned} \tag{6}$$

where HM is height of mountain. For example, if $\mu_{HM}(x)$ is 0.5, then very, extremely, very-very, more-or-less, and indeed are 0.5, 0.125, 0.0625, 0.7071, and 0.5. Figure 3 shows Graphical representation of give hedges for ‘very’, ‘extremely’, ‘very-very’, ‘more-or-less’, and ‘indeed’.





(d)



(e)

Figure 3. Graphical Representation of Give Hedges: (A) Very, (B) Extremely, (C) Very-Very, (D) More-Or-Less and (E) Indeed

The proposed expert system is based on fuzzy *if-then* rules which is designed for video deinterlacing. The proposed method is fuzzy inference ruled by else action. The proposed fuzzy inference ruled by else action is written as:

IF **video motion** is **fast**, THEN **intra method is selected**
Else IF **video motion** is **slow**, THEN **inter method is selected** (7)

IF **$x(i,j)$ is located in homogeneity region**, THEN **larger window is used**
Else IF **$x(i,j)$ is located in heterogeneity region**, THEN **smaller window is used** (8)

IF **$x(i,j)$ is located in homogeneity region**, THEN **inter method is selected**
Else IF **$x(i,j)$ is located in heterogeneity region**, THEN **LA method is used** (9)

By applying hedge property, we obtain,

IF $\mathbf{D_{VM}} < v_1$, THEN $\omega = \mu_{Gaussian}^{more-or-less}$
Else IF $v_1 < \mathbf{D_{VM}} < v_2$, THEN $\omega = \mu_{Gaussian}$
Else IF $v_2 < \mathbf{D_{VM}} < v_3$, THEN $\omega = \mu_{Gaussian}^{very}$ (10)
Else IF $v_3 < \mathbf{D_{VM}} < v_4$, THEN $\omega = \mu_{Gaussian}^{extremely}$
Else IF $v_4 < \mathbf{D_{VM}}$, THEN $\omega = \mu_{Gaussian}^{veryvery}$

where D_{VM} is difference of video motion. Parameters v_1, v_2, v_3, v_4, and v_5 are empirically obtained, which are assigned as 3, 5, 8, 11, and 15, respectively. For above equation, we used Gaussian fuzzy membership function which is defined as

$$\mu_{Gaussian}(x) = e^{\left(-\frac{(c_{Gaussian}-x)^2}{2\sigma^2}\right)}. \quad (11)$$

Here, $c_{Gaussian}$ is the center of fuzzy set (*Gaussian*). Parameter σ is the width of the fuzzy set *Gaussian*, and x is the input variable. Parameter value σ is determined empirically, and we selected σ=1.5 in our simulation. Fuzzy sets 'fast', 'slow', 'homogeneity', and 'heterogeneity' are also chosen.

In the similar way, we compute homogeneity and heterogeneity regions,

IF $D_{HOR} < D_{HER} + 10$, THEN the region is strong homogeneity region
Else IF $D_{HOR} < D_{HER}$, THEN the region is weak homogeneity region (12)

Else IF $D_{HER} < D_{HOR}$, THEN the region is weak heterogeneity region

Else IF $D_{HER} < D_{HOR} + 10$, THEN the region is strong heterogeneity region

Here, parameters D_{HOR} and D_{HER} are difference of homogeneity and heterogeneity regions.

Finally, the output pixel is calculated as follows:

$$output\left(i,j\right)=\frac{\sum_{k=-1}^{1}\sum_{l=-1}^{1}\omega\left(i+k,j+l\right)\times input\left(i+k,j+l\right)}{\sum_{k=-1}^{1}\sum_{l=-1}^{1}\omega\left(i+k,j+l\right)}, \tag{13}$$

3. Simulation Results

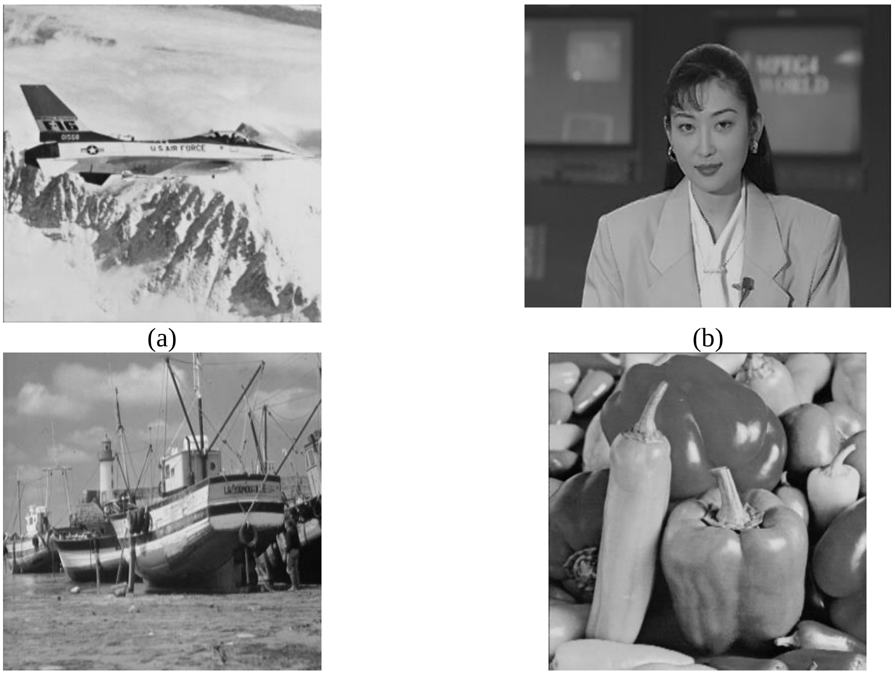


Figure 4. Four Test Images: Airplane (512×512), Akiyo (512×512), Pepper (512×512) and Boat (352×288)

In this Section, we present visual performance comparison for four images. They are Airplane (512×512), Akiyo (512×512), Pepper (512×512), and Boat (352×288), which are shown in Figure 4. Two methods were adopted in this paper, the LA method ($benchmark_1$) and the edge based line average (ELA, $benchmark_2$) method. For visual performance comparison, we only consider $benchmark_2$ for primary benchmark. For objective performance comparison, we consider both of $benchmark_1$ and $benchmark_2$ methods. The simulations were conducted on the Intel Core 2 Duo CPU E8500 @ 3.16 GHz.

To measure the performance of objective visual quality, a peak signal-to-noise ratio (PSNR) is applied and the PSNR is obtained by

$$PSNR=10\times\log_{10}\left(\frac{255^2}{MSE}\right) \tag{14}$$

where MSE denotes the mean squared error.

The restored figures are displayed in Figure 5-8. Each image noted in (a) show original images. Images (b) and (c) are benchmark results and the proposed method results. As one can see, the proposed method visually outperforms the benchmarks. The staircase artifacts were removed from the roof, edges, and details. In addition, the blurred results in (b) has been solved.

(a) (b) (c)

Figure 5. Cropped and Zoomed Airplane Image: (A) Original, (B) Benchmark and (C) Proposed Method

(a) (b) (c)

Figure 6. Cropped and Zoomed Akiyo Image: (A) Original, (B) Benchmark and (C) Proposed Method

(a) (b) (c)

Figure 7. Cropped and Zoomed Boat Image: (A) Original, (B) Benchmark, and (C) Proposed Method

(a) (b) (c)

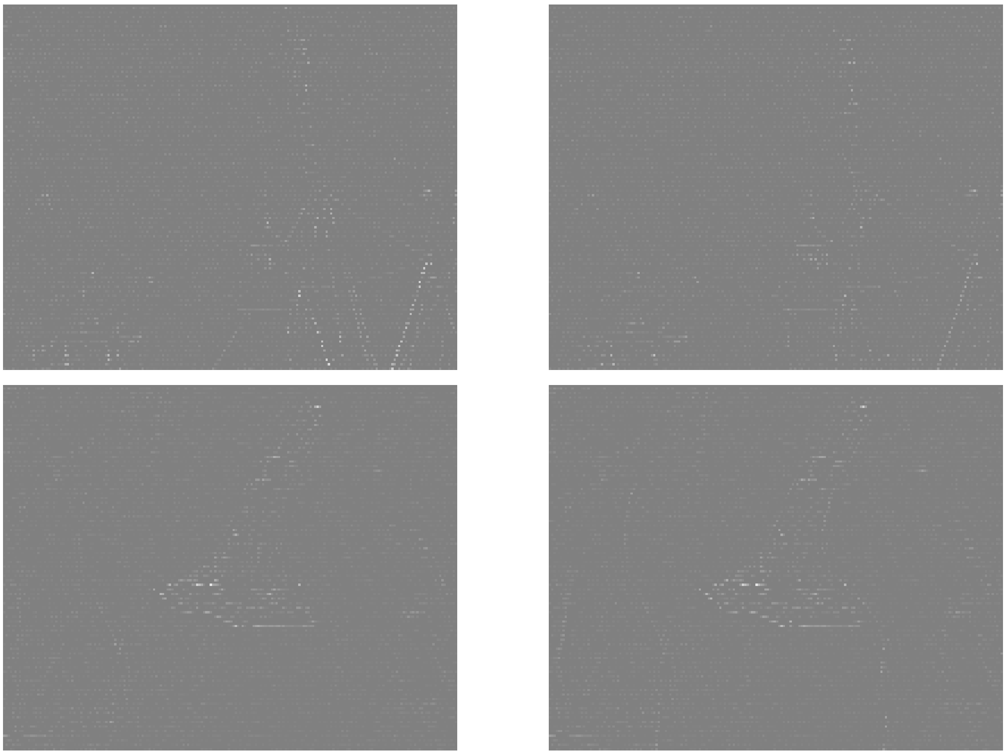
Figure 8. Cropped and Zoomed Pepper Image: (A) Original, (B) Benchmark and (C) Proposed Method

Figures in Figure 9 show difference images between (a) original and benchmark and (b) original and the proposed method. As one can see, images in (b) show less edges and this means the proposed method outperforms the benchmark method. Figure 10 shows visual performance comparison with Milk image.

Table 1 shows PSNR and MSE results for four images.

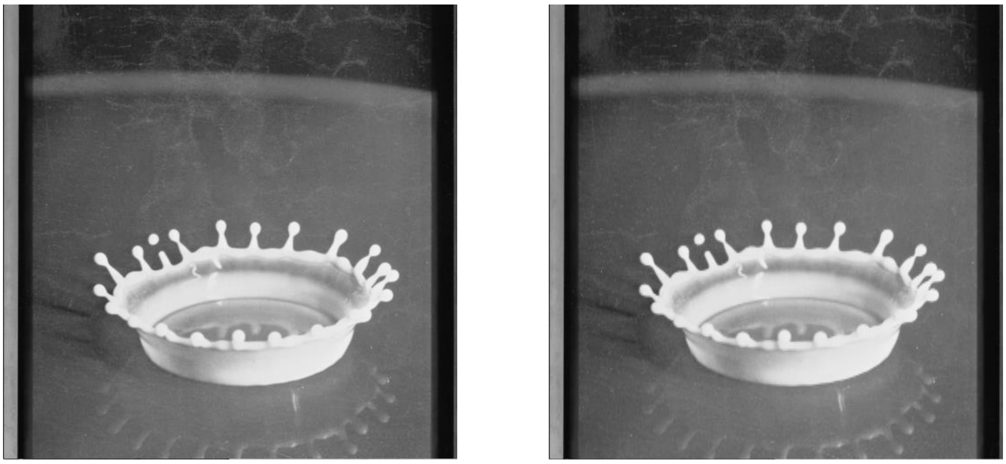
Table 1. PSNR and MSE Results Comparison

		Airplane	Akiyo	Boat	Peppers
$Benchmark_1$	PSNR	38.1178	36.7294	37.2622	35.0889
	MSE	10.0301	13.8082	12.2141	20.1459
$Benchmark_2$	PSNR	37.7045	34.4300	34.1691	35.0855
	MSE	11.0314	23.4465	24.8984	20.1619
Proposed	PSNR	37.5874	35.1365	35.4897	34.9200
	MSE	11.3330	19.9265	18.3699	20.9448

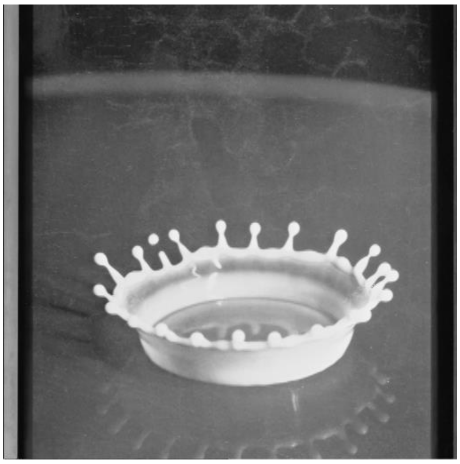


(a) (b)

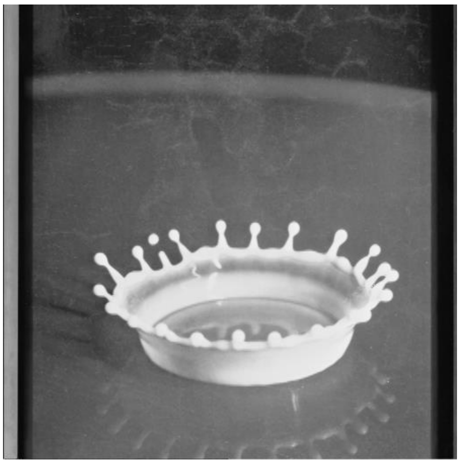
Figure 9. Difference Images (A) Between Original and Benchmark and (B) Between Original and the Proposed Method



(a) (b)



(c)



(d)

Figure 10. Visual Performance Comparison on Milk Image, (A) Original Image, (B) Benchmark 1, (C) Benchmark 2 and (D) Proposed Method

4. Conclusions

To improve image quality, we used fuzzy condition rules for format conversion. By using membership hedges, we applied additional effects in each membership function. In this paper, we used tour fuzzy sets, which are “fast”, “slow”, “homogeneity”, and “heterogeneity”. By applying hedges, we could improve the visual and objective performance. Simulation results indicate that the presented fuzzy rule based method outperforms two traditional benchmark methods.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (2015R1D1A1A01058171). This paper is a revised and expanded version of a paper entitled “A Rule-based Expert System for Image Processing” presented at UCMA2016.

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Author

Gwanggil Jeon, he received the BS, MS, and PhD (summa cum laude) degrees in Department of Electronics and Computer Engineering from Hanyang University, Seoul, Korea, in 2003, 2005, and 2008, respectively. From 2008 to 2009, he was with the Department of Electronics and Computer Engineering, Hanyang University, from 2009 to 2011, he was with the School of Information Technology and Engineering (SITE), University of Ottawa, as a postdoctoral fellow, and from 2011 to 2012, he was with the Graduate School of Science & Technology, Niigata University, as an assistant professor. He is currently an associate professor with the Department of Embedded Systems Engineering, Incheon National University, Incheon, Korea. His research interests fall under the umbrella of image processing, particularly image compression, motion estimation, demosaicking, and image enhancement as well as computational intelligence such as fuzzy and rough sets theories. He was the recipient of the IEEE Chester Sall Award in 2007 and the 2008 ETRI Journal Paper Award.

