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Role of fuzzy and intuitionistic fuzzy contrast intensification operators in enhancing images

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Abstract

Quality of an image should be improved to support the human perception in image processing applications. The aim of contrast enhancement is to process a given image so that the result is more suitable than the original for pattern recognition. In this paper, a method for image enhancement based on the contrast intensification operator on first and second type Intuitionistic Fuzzy Sets (IFSs) is established.

Key words

Image enhancement, contrast intensification, first and second type IFSs.

1 Introduction

Image enhancement plays a fundamental role in image processing applications where human beings (the experts) make decisions depended on the image information. Types of image enhancement include noise reduction, edge enhancement and contrast enhancement. Enhancement may be used to restore an image that has suffered some kind of deterioration or to enhance certain features of an image.

In image processing applications, one has to use expert knowledge to overcome the difficulties (e.g. object recognition, scene analysis). Fuzzy set theory and fuzzy logic are powerful tools to represent and process human knowledge in the form of fuzzy if-then rules. The difficulties in image processing arise because the data/tasks/results are uncertain. This uncertainty, however, is not always due to the randomness but to the ambiguity and vagueness.

The three kinds of imperfection in the image processing namely, grayness ambiguity, geometrical fuzziness and vague (complex/ill-defined) knowledge are shown in Figure1 [1].

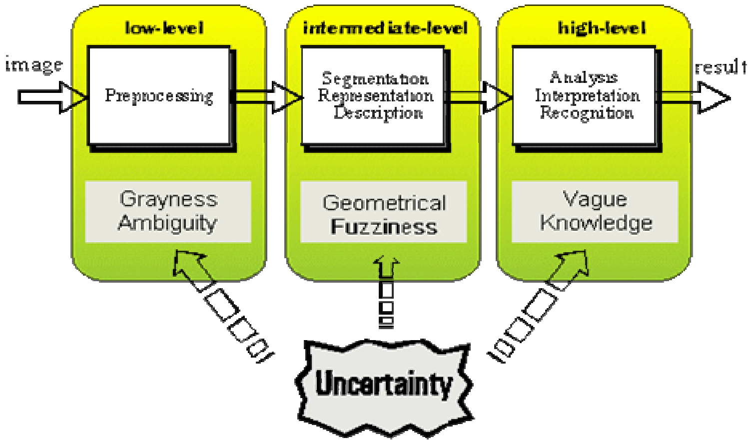

Figure 1. Uncertainty/imperfect knowledge in image processing

These problems are fuzzy in nature. Hence, fuzzy approach can be the more suitable way to manage the imperfection**.**

Contrast within an image is the measure of difference between the gray levels in an image. The greater the contrast, the greater is the distinction between gray levels in the image. Images of high contrast have either all black or all white regions. There is only very little gray in the image. Low contrast images have lots of similar gray levels in the image and very few black or white regions. High-contrast images can be thought of as crisp, and low-contrast ones are completely fuzzy. Images with good gradation of grays between black and white are usually the best images for purposes of recognition by humans [7,8,9]. In [5], the authors used grayscale morphological operators to erode and dilate an image.

As fuzzy set theory deals with linguistic variables like grayness, in [1], H.R.Tizhoosh proposed a fuzzy approach to image enhancement using contrast intensification operator. In this paper, a method based on Intuitionistic Fuzzy (IF) approach for image enhancement using contrast intensification operator is established.

The paper is organized as follows. Section 2 deals with the IFS operators involved in this work. Section 3 describes the role of contrast intensification operator on first and second type IFS image processing. The results are discussed in Section 4. Section 5 concludes the paper.

2 IFS operators

A large part of mathematical models are based on a recent extension of the ordinary set theory, namely, the so-called Fuzzy Sets (FSs). FSs were introduced by Lotfi A Zadeh in 1965. Later on, fuzzy linguistic variables find very important place in the area of real life applications. The advantage is crisp variables can be made into fuzzy variables, meaning that problems that are dominated by uncertainty and impreciseness could also be completed using this FSs. Starting from 1985, this theory was further generalized into many-valued logic with the efforts of Lukaiwicz, Gottwald, Post, Godel and so on.

There is another way of generalization. Generalizing sets into intuitionistic sets by way of taking the non-membership values also into consideration. The same idea is extended to fuzzy sets by Krassimir T Atanassov and George Gargov recently to define Intuitionistic Fuzzy Sets (namely first type IFSs). These new sets allow the definitions of operators such as concentration, dilation, normalisation, contrast intensification and so on [2]. Further Krassimir T Atanassov extended these sets into second type IFS. The above-mentioned operators are meaningful on these sets also.

The operator contrast intensification, as its name implies, reduces the fuzziness of a fuzzy set A by increasing those of $\mu_A(x)$ which are above 0.5, and deceasing those which are below it. Its definitions on FSs, first and second type IFSs are given in this section. Their applications in image processing problems are also discussed.

Definition 2.1 [3]

Let X be a non empty set. A fuzzy set A in X is characterized by its membership function μ_A : $X \rightarrow [0, 1]$ and $\mu_A(x)$ is interpreted as the degree of membership of element x in fuzzy set A for each $x \in X$. That is, A = $\{(x, \mu_A(x)) | x \in X\}$.

Definition 2.2 [2]

Let X be a nonempty set. An IFS A in X is defined as an object of the form $A=\{(x, \mu_A(x), \gamma_A(x)) : x \in X\}$ where the fuzzy sets $\mu_A : X \rightarrow [0,1]$ and $\gamma_A : X \rightarrow [0,1]$ denote the membership and non-membership functions of A respectively, and $0 \leq \mu_A(x) + \gamma_A(x) \leq 1$ for each $x \in X$.

Definition 2.3[2]

Let X be a nonempty set. A second type IFS A in X is defined as an object of the form $A = \{ \langle x, \mu_A(x), \gamma_A(x) \rangle : x \in X \}$ where the fuzzy sets μ_A : X → [0,1] and γ_A : X → [0,1] denote the membership and non-membership functions of A respectively, and $0 \leq \mu_A(x)^2 + \gamma_A(x)^2 \leq 1$ for each $x \in X$.

Definition 2.4 [4]

The contrast intensification operator on a first type IFS A of the Universe X, denoted by *INTEN(A)*, is defined as *INTEN(A)* = $\{\langle x, \mu_{INTEN}(x), \gamma_{INTEN}(x) \rangle : x \in X\}$ where $\mu_{INTEN}(x) = 1 - (1 - \mu_A(x)^2)^2$ and $\gamma_{INTEN}(x) = [1 - (1 - \gamma_A(x))^2]^2$.

Definition 2.5 [4]

The contrast intensification operator on a second type IFS A of the Universe X, denoted by *INTEN(A)*, is defined as *INTEN(A)* = $\{\langle x, \mu_{INTEN}(x), \gamma_{INTEN}(x) \rangle : x \in X\}$ where $\mu_{INTEN}(x) = 1 - (1 - \mu_A(x)^8)^2$ and $\gamma_{INTEN}(x) = [1 - (1 - \gamma_A(x)^2)^2]^4$.

3 Enhancement Algorithm

Image enhancement suppresses the disturbances such as noise, blurring, geometrical distortions, and illumination corrections. It may be the final goal of the image processing operation to produce an image, with a higher contrast. Whenever the properties of an image cannot be numerically quantified, fuzzy image enhancement techniques take a major role. Fuzzy image enhancement is based on gray level mapping into a fuzzy plane, using a membership transformation function. The aim is to generate an image of higher contrast than the original image by giving a larger weight to the gray levels that are closer to the mean gray level of the image than to those that are farther from the mean.

3.1 Image Representation

An image G of size M x N and L gray levels can be considered as an array of fuzzy singletons, each having a value of membership denoting its degree of brightness relative to some brightness levels. For an image G, we can write in the notation of fuzzy sets as

$$G = \bigcup_{m=1}^{M} \bigcup_{n=1}^{N} \mu_{mn} / x_{mn}$$

where μ_{mn} is its membership value of each image point $x_{mn}{}^{th}$ pixel. The membership function characterizes a suitable property of image (e.g. edginess, darkness, brightness, homogeneity, textural property) and can be defined globally for the whole image or locally for its segments.

3.2 Contrast Improvement using Intensification Operator

This method uses the intensification operator to reduce the fuzziness of the image that results in an increase of image contrast. The algorithm is formulated as follows:

- Set the parameters F_e , F_d and calculate $X_{\max}$.

$$F_e = 2; \quad F_d = \frac{X_{\max} - X_{mn}}{(0.5)^{-1/F_e} - 1}$$

- Define the membership function

$$\mu_{mn} = G(X_{mn}) = \left[1 + \frac{X_{\max} - X_{mn}}{F_d}\right]^{-F_e}$$

- Modify the membership values using contrast intensification operator on fuzzy sets [9]

$$\mu_{mn}{}' = \begin{cases} 2[\mu_{mn}]^2 & 0 \le \mu_{mn} \le 0.5 \\ 1 - 2[1 - \mu_{mn}]^2 & 0.5 \le \mu_{mn} \le 1. \end{cases}$$

- Generate new gray levels

$$g_{mn}{}' = G^{-1}(\mu_{mn}{}') = X_{\max} - F_d * ((\mu_{mn}{}')^{-\frac{1}{F_e}}) + F_d$$

- Fuzzy contrast intensified image is obtained.

- Calculate the non-membership values in terms of membership values.

$$\gamma_{mn} = \frac{1}{2} \max[|1 - \mu_{mn}|, |0 - \mu_{mn}|] \quad \text{if } 0 \le \mu_{mn} \le 0.5$$

$$= \frac{1}{2} \min[|1 - \mu_{mn}|, |0 - \mu_{mn}|] \quad \text{if } 0.5 \le \mu_{mn} \le 1$$

such that $0 \le \mu_{mn} + \gamma_{mn} \le 1$.

- Modify membership and non-membership values using contrast intensification on first type IFS.

$$\mu_{mn}' = 1 - (1 - \mu_{mn}^2)^2 \qquad 0 \le \mu_{mn} \le 1$$

$$\gamma_{mn}' = (1 - (1 - \gamma_{mn})^2)^2 \qquad 0 \le \gamma_{mn} \le 1$$

- Calculate the new gray level using the modified membership and non-membership values.

$$g_{mn}' = \mathrm{G}^{-1}(\mu_{mn}') = \mathrm{g}_{\max} - \mathrm{F_d} * ((\sqrt{\mu_{mn}' * (c_1 - \gamma_{mn}')})^{-\frac{1}{C_2 * F_e}}) + F_d$$

where c_1 and c_2 are arbitrary constants.

- First type intuitionistic fuzzy contrast intensified image is obtained.
- Modify membership and non-membership values using contrast intensification on second type IFS.

$$\mu_{mn}' = 1 - (1 - \mu_{mn}^8)^2 \qquad 0 \le \mu_{mn} \le 1$$

$$\gamma_{mn}' = (1 - (1 - \gamma_{mn}^2)^2)^4 \qquad 0 \le \gamma_{mn} \le 1$$

- Calculate the new gray level using the modified membership and non- membership values.

$$g_{mn}' = \mathrm{G}^{-1}(\mu_{mn}') = \mathrm{g}_{\max} - \mathrm{F_d} * ((\sqrt{\mu_{mn}' * (c_3 - \gamma_{mn}')})^{-\frac{1}{C_4 * F_e}}) + F_d$$

where c_3 and c_4 are arbitrary constants.

- Second type intuitionistic fuzzy contrast intensified image is obtained.
- Analysis is made on all the images and the same is displayed.

4 Results and Discussion

Enhancement algorithms are used to reduce image noise and increase the contrast of structures of interest in image. Enhancement improves the quality of the image and facilitates diagnosis enhancement techniques and generally provides a clearer image for a human observer but it can also form a preprocessing step for subsequent automated analysis. The system is developed using MATLAB. The original image taken for analysis is shown in Figure 2.

Figure 2. Original image

Figure 3 displays the enhanced image using fuzzy contrast intensification operator.

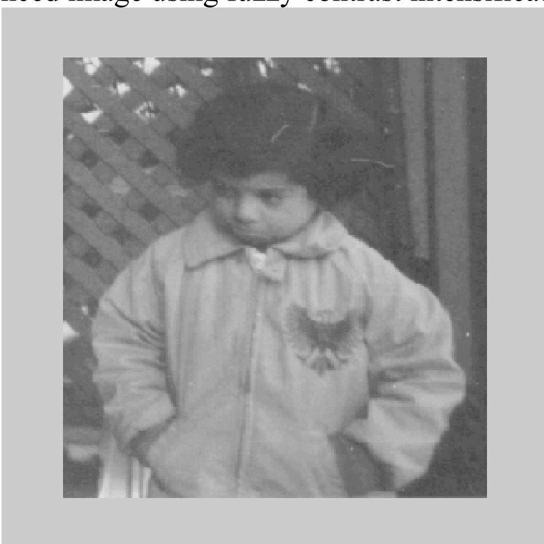

Figure 3. Enhanced Image (Fuzzy contrast intensification operator)

Figure. 4 shows the enhanced image using contrast intensification operator on first type IFS.

Figure 4. Enhanced image (contrast intensification operator on first type IFS)

Figure.5 depicts the role of contrast intensification operator on second type IFS in enhancing the same image.

Figure 5. Enhanced image (contrast intensification operator on second type IFS)

A comparative study is made on these output images obtained using contrast intensification operator on fuzzy, first and second type IFSs. It is customary that the modified membership function is defined in two different intervals as [0,0.5] and [0.5,1]. But, this system has been developed by merging both the intervals into an interval [0,1]. Figure. 6 shows the overall view of the resultant images for assessing the quality in an easy manner to any observer.

Figure. 6 Comparative study on the results

5 Conclusion and further scope

In this paper, it is proved that the contrast intensification operator plays an important role in improving the quality of an image. The following are the ways by which this system is different from the existing fuzzy contrast enhancement system.

- the non-membership values have also got as much importance as membership values in contrast enhancement
- Geometric mean of membership and non-membership value is taken into consideration while calculating the new gray level
- the range for modified membership and non-membership values is in the interval [0, 1] instead of the split at 0.5.

The system may further be extended to other types of intuitionistic fuzzy sets.

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