Image smoothing using fuzzy morphology

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Abstract

Image smoothing is a key technology of image enhancement, which can remove noise from images. This paper proposes a new approach for smoothing of image objects using fuzzy morphology. With the set operators in fuzzy context, we apply “Open with Closing” morphological processing for smoothing. A modified membership function has been used to fuzzify the image matrix. Experiments are performed using RICE and SURF images. The proposed technique shows improved performance comparison to other nonfuzzy morphological methods.

Keywords: Enhancement, Fuzzy Logic, Fuzzy morphology, open, close.

1 Introduction

Image smoothing is a method of improving the quality of images. The image quality is an important factor for the human vision point of view. The image usually has noise which is not easily eliminated in image processing. The quality of the image is affected by the presence of noise. Many methods are there for removing noise from images. Many image processing algorithms can’t work well in noisy environment, so image filter is adopted as a preprocessing module. However; the capability of conventional filters based on pure numerical computation is broken down rapidly when they are put in heavily noisy environment. Median filter is the most used method [1], but it will not work efficiently when the noise rate is above 0.5. Yang and Toh [2] used heuristic rules for improving the performance of traditional multilevel median filter. Russo and Ramponi [3] applied heuristic knowledge to build fuzzy rule based operators for smoothing, sharpening and edge detection. They can perform smoothing efficiently but not in brightness. Choi and Krishnapuram [4] used a powerful robust approach to image enhancement based on fuzzy logic approach, which can remove impulse noise, smoothing out non-impulse noise, and preserve edge well.

Morphological operators transform the original image into another image through the interaction with the other image of certain shape and size which is known as the structure element. Mathematical morphology provides a systematic approach to analyze the geometric characteristics of signals or images, and has been applied widely too many applications such as edge detection, objection segmentation, noise suppression and so on. Fuzzy Mathematical Morphology aims to extend the binary morphological operators to grey-level images. In order to define the basic morphological operations such as fuzzy erosion, dilation, opening and closing, a general method based upon fuzzy implication and inclusion grade operators is
introduced. Morphological openings and closings are useful for smoothing of grayscale images. But it also takes the thin features along with noise.

In general mathematical morphology operation definitions are similar structures set theory and set operations definitions. For this reason fuzzy set theory is easily applied to the mathematical morphology. Mathematical morphology is a collection of operations which produces useful outcomes in image processing area. It is completely based on set theory. For this reason all of the operations in morphology are defined on the simple set operation rules to apply them on image pixels. By knowing this fact there has been many approaches proposed to the morphology to extend its applications.

In this paper, we propose a new approach for image smoothing based on fuzzy morphology. Our approach gives an image which fuzzified with modified membership function. Basic mathematical morphology operation “Open with Closing” is implemented and inspected via the fuzzy membership functions with (5x5) fuzzy mask.

The organization of the paper is as follows. Mathematical morphological image processing methods are described in Section 2 and Fuzzy image processing methods are introduced in Section 3. The proposed algorithm is described in Section 4 and we have compared the fuzzy smoothing simulation results with that of the non fuzzy methods in Section 5. At the end, conclusions and future prospects of the works are presented in Section 6.

2  Morphological Image Processing

Morphology is a mathematical framework for the analysis of spatial structures and is based on set theory. It is a strong tool for performing many image processing tasks. Mathematical morphology is completely based on set theory. Morphological sets represent important value. By using set operations many useful operators can be defined. The important morphological operations are basically dilation, erosion, open and close operations. Morphological operations make use of a structuring element \( M \); which can be either a set or a function that corresponds to a neighborhood-function related to the image function \( g(x) \) [5]. In general, a dilation (denoted by \( \oplus \)) is every operator that commutes with the supremum operation. On the other hand, erosion (denoted by \( \ominus \)) is every operator that commutes with the infimum operation. There is a homomorphism between the image function \( g \) and the set \( B \) of all pixels with image function value 1. The structuring element \( M(x) \) is a function that assigns a subset of \( N \times N \) to every pixel of the image function. Then dilation, an increasing transformation, is defined as

\[
B \oplus M = \bigcup_{x \in B} M(x).
\]

Whereas, erosion, a decreasing transformation, is defined as

\[
B \ominus M = \{x | M(x) \subseteq B\}.
\]

In the same manner, opening and closing of set \( B \) by structuring element \( M \) are respectively defined as

\[
B \circ M = ((B \ominus M) \oplus M),
\]

And

\[
B \bullet M = ((B \oplus M) \ominus M).
\]
3 Fuzzy Image Processing

Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification. The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. As is evident from Fig 1, the main

![Fuzzy Image Processing Diagram](image)

Fig. 1: Fuzzy Image Processing

Power of fuzzy image processing is in the middle step (membership modification) [6]. After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. In fuzzy sets, the membership is a matter of a degree, i.e., degree of membership of an object in a fuzzy set expresses the degree of compatibility of the object with the concept represented by the fuzzy set [7]. Each fuzzy set, $A$ is defined in terms of a relevant universal set $X$ by a membership function. Membership function assigns each element $x$ of $X$ a number, $A(x)$, in the closed unit interval [0, 1] that characterizes the degree of membership of $x$ in $A$. In defining a membership function, the universal set $X$ is always assumed to be a classical set. A gray value image is considered as a fuzzy set in the sense that it is a fuzzy version of a binary image, or that a gray value represents the degree to which pixel belongs to the image foreground.

4 Proposed Work on Fuzzy Morphological Image Processing

In the present work, we have considered images like rice and surf of 512 x 512 dimensions as an array of fuzzy singletons, each with a value of membership denoting the degree of brightness level $p$, $p = 0, 1, 2 \ldots 255$. In order to get the fuzzified matrix, we have used a modified membership function defined by

$$r = \frac{d - mn}{mx - mn}$$

Where $= \max (\max(image)) : mn = \min (\min(image)); d = \text{double(image)}$.

The fuzzified image is then operated through mathematical morphological operator like “OPEN WITH CLOSING” with the structuring element of 5 x 5 mask filter.

The algorithm for the proposed work comprises of the following steps.

Step1: Read the original image.

Step2: Fuzzify the input image with the membership function $r = \frac{d - mn}{mx - mn}$. 
Step3: Apply 5x5 pixel mask window to the image which are a set of fuzzy logic conditions.

Step4: Perform morphological “OPEN WITH CLOSING” operation on the fuzzified image

5 Experimental Results and Discussion

The proposed algorithm is simulated in MATLAB 6.5 and applied on several test images. The results are compared with the other nonfuzzy morphological methods. First, RICE image is processed. The main image is shown in Fig. 2. The nonfuzzy smoothed image shown in Fig. 3. Finally, the image extracted by the proposed algorithm is shown in Fig 4. As the Figure shown, the proposed algorithm detects much more enhanced, and superiority of the proposed algorithm is clear. The same experiment run over SURF image is shown in Fig. 5. Similarly, extracted image by nonfuzzy morphological method and the proposed method are shown in fig. 6-7. In the present scheme, fuzzy morphology operations are performed with the help of fuzzy membership functions. Then a fuzzy structuring element is traversed on the whole image to process open with closing. Structuring element is selected as a 5x5 mask MATRICES to cover the whole image boundaries. We have used a small odd sized structuring element mask for better performance.

![Fig. 2: Original RICE image](image1)
![Fig. 5: Original SURF image](image2)

![Fig. 3: Rice image using smoothing](image3)
![Fig. 6: Surf image using smoothing](image4)
6 Conclusion

This paper presents a new fuzzy based smoothing technique to reduce the noise. Experimental results show the ability and high performance of proposed algorithm. Fuzzy set and fuzzy logic theory is a new research area for defining new algorithms and solutions in mathematical morphology environment. Fuzzy morphology approach to image smoothing gives better results than various existing nonfuzzy approaches. The output image obtained by the use of fuzzy morphological method are observed to be brighter and enhanced. In future, modified algorithm using fuzzy logic and fuzzy sets may produce better results.

References


