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Image Sharpening Using Fuzzy Logic Based Edge Detection

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ABSTRACT

In this study, enhancement of digital images, specifically sharpening of satellite images is presented. A technique called unsharp masking is modified for this task. In unsharp masking, high frequency data is emphasized in an image. In the present investigation, modifiedmethod to extract the high frequency data from the image is used; based on Fuzzy logic based system is used for this task. As soon as the high frequency data is available, it can be engraved over the image to sharpen the edges. A comparative analysis is also provided with conventional operator based edge detection techniques.

Keywords : Edge Detection, Image Sharpening, Fuzzy Logic, Satellite Image Enhancement

I. INTRODUCTION

Satellite image play a vital role in digital era. Penetration of computers in the field of aerotech which forced the designers to add the capability to see and analyse and to innovate more and more into the domain of electronic vision or image processing. At the level of computational intelligence for electronic vision, many of the algorithms have been developed to extract different types of features from the image such as edges, segments and lot many other types of image features. In order to perceive images correctly, visual enhancement specifically sharpening of digital images is crucial.Various researchers have proposed different algorithms for sharpening of edges in a digital image.

II. METHODS AND MATERIAL

A. Related Work

In this section a brief overview of work related to present investigation is discussed. The review of literature is presented under four different domains as depicted in Table 1.

Table 1 : Overview of Literature Review

S. No.	Parameters	Authors
1.	Edge Detection in Images	A. Rosenfeld [1970]; A. K. Griffith [1973]; X. Z. Sun[1986] and A. N. Venetsanopoulos [1986]; V. J. Stanger [1991]; H. B. Mitchell [1992]; GongyuanQu and S. Wood [1998]; Da-Shun Qu*et al.*[1998]; W.BoonchiengandR.Kanjanavanit[2004];LingFeiLiangandZiLiangPing[2008; ZhongshuiQu and Jianwei Wang[2010]; Zhang Rongxue*et al.* [2012]; GirishChaple and R. D. Daruwala[2014]; Liying Yuan and XueXu [2015]; Vishal Paika*et al.* [2013]; FarnazHoseini*et al.*[2015];Kuo Y. *et al.*[2001].

S. No.	Parameters	Authors
2.	Image Sharpening	K. Hedengren [1992]; Y. H. Lee andSoonYoungPark[1990]; S.Guillon*et al*.[1996]; G. Ramponi [1998]; M. Huang *et al*. [2002] ; Liu Ying *et al*. [2008]; BadreddineBouledjfane*et al.* [2013]; Shailendra Singh Negie*et al*. [2014]; Ali Alsam*et al*. [2015];S.S Bedi*et al.* [2013].
3.	Satellite Image Enhancement	R.Vorobel [1996]; JyotiSinghai and PareshRawat [2007]; BoonwatAttachoo and PetcharatPattanasethanon [2009]; HaciTaşmaz*et al*. [2012]; Saeed Al Nuaimi*et al.* [2014]; R. Thriveni and Ramashri [2015].
4.	Fuzzy Logic Based System Modelling	A.Bala[2010]; A. L. Choodarathnakara*et al*.[2012];R.Shenbagavalli and K.Ramar [2013]; DiwakarShrivastava and VineetRichhariya[2014];P.D Patel *et al*.[2014]; P.Mishra and K.L Sinha[2014],C.Bansal[2014]; A.Dara[2014];S.Sharma and A.Bhatiya[2015]; K.Bhargavi and S.Jyoth[2016].

B. Edge Detection Using Fuzzy LOGIC

Edge is defined as object border, and extracted by features such as graycolor or texture discontinuities. Luminance and geometrical features, lightening condition and noise volume has a great impact on shaping the edge. Edge contains important information of image and provides object's location. Edge is considered an important feature in a digital image and is used for image enhancement, restoration and segmentation [Vishal Paikaet al., 2013]

A. Basics of Edge Detection

Edge detection is a fundamental tool in image processing and computer vision, particularly in the areas of feature detection and feature extraction, which aim at identifying points in a digital image at which the image brightness changes sharply or more formally has discontinuities. The contrast is improved by increasing the difference across discontinuities of the image components. In order to improve the differences, they have to be detected. The edge detection algorithm is designed to detect and highlight these discontinuities.

The goal of edge detection is to identify pixels in an image which represent edges of the objects present in the image. The usual operation which is used to identify these edges is a first and/or a second derivative measurement. This operation is followed by a thresholding operation which either marks the pixel as an edge pixel or not.

C. Edge detection algorithms

Since the last two decades various edge detection algorithms have been developed and implemented. Primarily, operator based techniques may be grouped into two specific classes [Zhang Ronguxeet al., 2012]

1) Gradient based operators: In these operators, an estimate of the gradient magnitude is obtained using the averaging filter and then, the positions of the edges are estimated. Thus, the maximum and the minimum in the first derivative of the image are analysed to detect the edges. Magnitude of the gradient of image is given using eq. (1).

$$\left|grad\ f(x,y)\right| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2} \quad (1)$$

The implementation of gradient is done via convolution masks. Various operators which approximate first derivatives have been established which contain separate masks for each direction. These operators are, for example, Canny Operator, Roberts operator, Prewitt operator, Sobel operator etc.

2)Laplacian (zero-crossing) based operators: In this method, second derivative of the image is obtained. This method searches for zero crossings in the second derivative of the image to find edges. The expression for laplacian operator is given using eq. (2).

$$\left|lap\ f(x,y)\right| = \nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2} \quad (2)$$

D. Characteristics of an edge detector

A good edge detection algorithm should possess following characteristics:

1) It checks less number of false edges and detection of real edges should be maximum.
2) The marked pixels should be closer to the true edge.
3) Error of detecting more than one response to single edge (double edges) should be less.
4) To design one edge detector that performs well in several contexts (satellite images, face recognition, medical images, natural images etc.)

E. Fuzzy Logic Based Edge Detection

Fuzzy set theory is powerful mathematical tool for handling imprecision or vagueness. A particular problem that is to be solved is represented in the form of human language can be solved easily with the help of fuzzy sets. So, the extension of classical set theory-'Fuzzy set' becomes robust and flexible. Fuzzy logic is a version of first-order logic which allows the truth of a statement to be represented as a value between 0 and 1, rather than simply True (1) or False (0). This varying degree of values shows the degree of possessiveness of elements to its fuzzy set or simply it shows the fuzziness and is known as membership function. Depending on the values, these functions are classified as Gaussian, triangular, exponential, polynomial etc. Selection of particular function is user defined [FarnazHoseiniet al., 2015].

The edge detection algorithm using fuzzy logic is explained as follows:

1) Image fuzzification

The image that read is gray scale image and data might range from 0 to 255. The data 0 belongs to black pixel of the image and data 255 belongs to while pixel of the image. In order to apply the fuzzy algorithm, data should be in the range of 0 to 1 only. The image data are converted to this range that is known as membership plane, after the image data are transformed from gray-level plane to the membership plane (fuzzification); appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach and a fuzzy integration approach.The gradient is computed both in horizontal (X) direction and in vertical (Y) direction.

2) Fuzzy Inference system

The system implementation was carried out considering that the input image and the output image obtained after defuzzification are both 8-bit quantized; this way, their gray levels are always between 0 and 255. The fuzzy sets were created to represent each variable's intensities; these sets were associated to the linguistic variables "Black" as background and "White" as Edge. After computing the gradient of the image, the higher value represent edge and lower values, the background. The adopted membership functions for the fuzzy sets associated to the input and to the output are as shown in Fig. 1and 2 respectively.

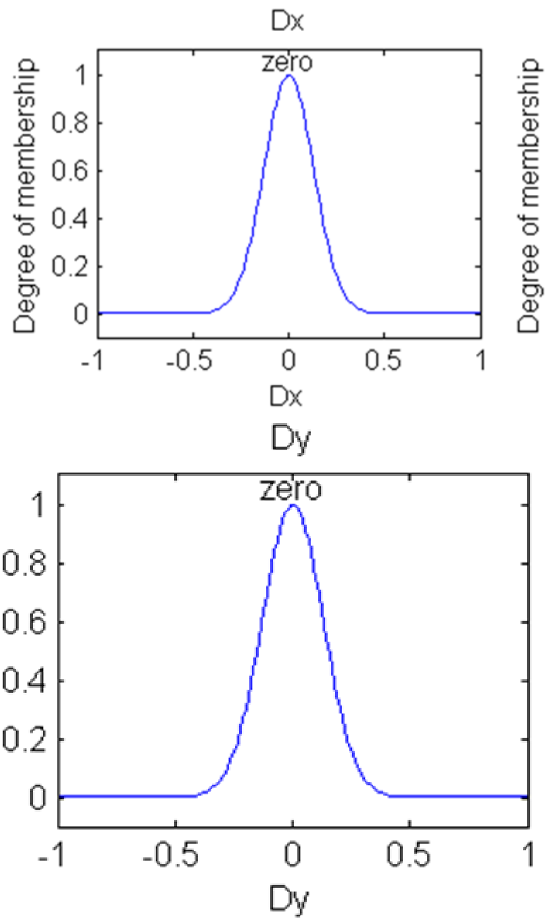


Figure 1. Input Membership functions (MATLAB)

The functions adopted to implement the "and" and "or" operations were the minimum and maximum functions respectively. The Mamdani method was chosen as the defuzzification procedure, which means that the fuzzy sets obtained by applying each inference rule to the input data were joined through the add function; the output of the system was then computed as the low of the resulting membership function. The values of the three membership's function of the output are designed to separate the values of the blacks and whites and edges of the image. In many image processing applications, expert knowledge is often used to work out the problems. Expert knowledge, in the form of fuzzy if-then rules, is used to deal with imprecise data in fuzzy set theory and fuzzy logic.

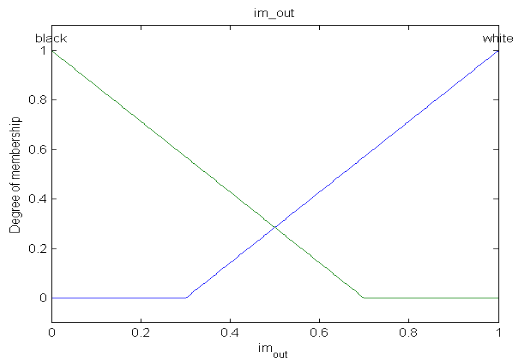


Figure 1. Output Membership functions(MATLAB)

3) Fuzzy inference rule

The Inference rule depends on value of the gray level pixels of the fuzzified data set; in this case fuzzified gradient images. Two rules are used based on and-or conditions. In both, gradients are low, the pixel is background. If any of the pixels is high, data is edge data. The powerful feature of these rules is the ability of extract all edges in the processed image directly.

4) Defuzzification

From the side of the fuzzy construction, the input grays is ranged from 0-255 gray intensity, and according to the desired rules the gray level is converted to the values of the membership functions . The Mamdani method was chosen as the defuzzification procedure.

F. Unsharp Masking

Image sharpening using unsharp mask is by far the most popular technique. It has its roots in analog photography where the blurred version of the photo used to be printed together with the negative in the form of registered sandwich. This would increase edge sharpness as well as suppress the noise caused by the film grain which is random for both versions. The name of the procedure comes from the fact that the unsharp version is used as a mask. But the massive popularity of unsharp mask came with the digital photography.

The principle of it is to extract the high frequency components by subtracting the blurred version from the original (**X**). This may also be achieved by directly computing the high frequency components using edge detection process. Let us denote it by $\mathbf{X_{high}}$. Once the high frequency components are available, the sharpened image can be computed using equation (3).

$$\mathbf{X_{sharp} = X + a\, X_{high}} \quad \text{.....(3)}$$

Steps involved in unsharp masking:
The steps are as follows:

Step 1: Extract the high frequency components. Two primary methods are available for this:

a. Subtracting the blurred version of the image (low frequency components) from the original image.
b. Using high pass filter/edge detectors

Step 2: Adding the extracted high frequency components to original image.

A modified version of the unsharpmasking process is proposed by changing the method to extract the high frequency components. Instead of subtracting the blurred version of the image (low frequency components) from the original image or using conventional high pass filter/edge detectors, the high frequency components are extracted using Fuzzy Inference System.

III. RESULTS AND DISCUSSION

The satellite image used for sharpening algorithm is shown in Fig. 3

Figure 3. Satellite Image [Source:http://www.satimagingcorp.com/gallery/geoeye-1/geoeye-1-pantheon-rome-italy/]

It is normalized (divide by 255, so range from 0 to 1) and then 4 gradient images are computed (2 in each direction) as shown in Fig. 4. Next, a fuzzy inference system is designed whereby inputs are defined as gradient images. Membership function have to be defined for input and output as shown in Fig. 5. Also fuzzy inference rules are created. Let Dx and Dx2 be the gradient images in horizontal direction while Dy and Dy2 be the gradient images in vertical direction.

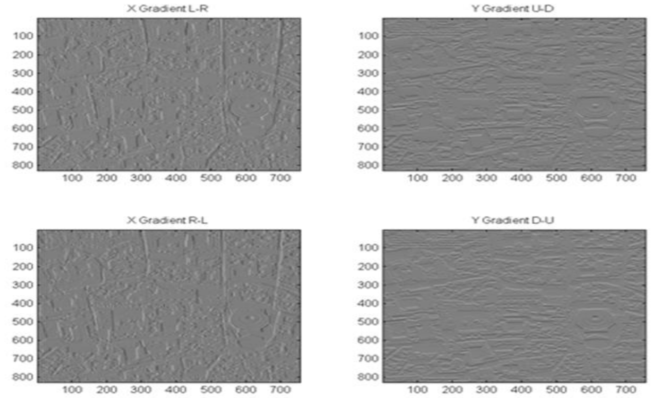
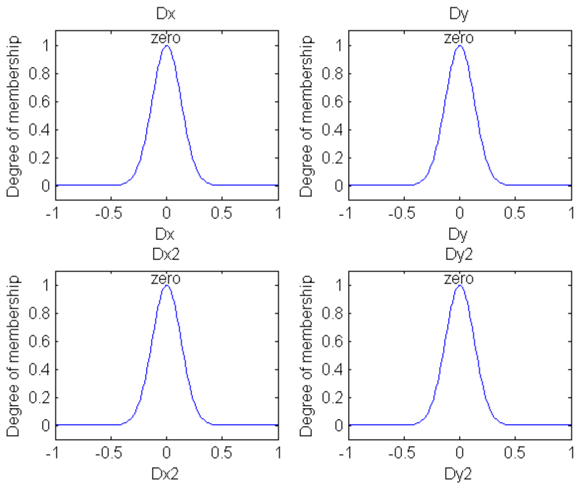


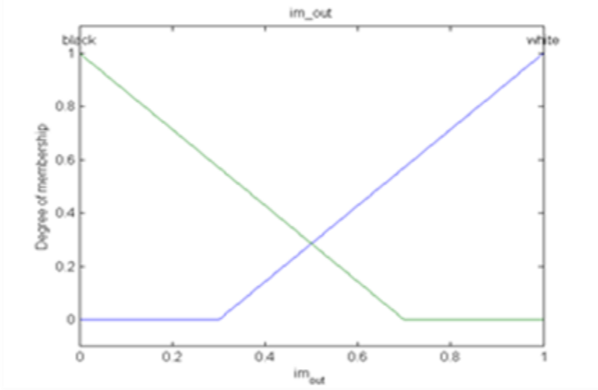
Figure 4. Gradient Images obtained for the image shown in Figure 3

The inference rules used are:

1. If (Dx is zero) and (Dy is zero) and (Dx2 is zero) and (Dy2 is zero) then (im_out is black)
2. If (Dx is not zero) or (Dy is not zero) or (Dx2 is not zero) or (Dy2 is not zero) then(im_out iswhite).



(a)



(b)

Figure 5. Membership functions (a) for Inputs (b) for Outputs [MATLAB]

The result of edge detection is shown in Fig. 6. Also, the results are compared with other edge detection techniques as shown in Fig. 7. The detected edges are embossed onto the original image and the results of sharpening are shown in Fig8. Finally, the results are compared with the algorithms in Fig. 9.

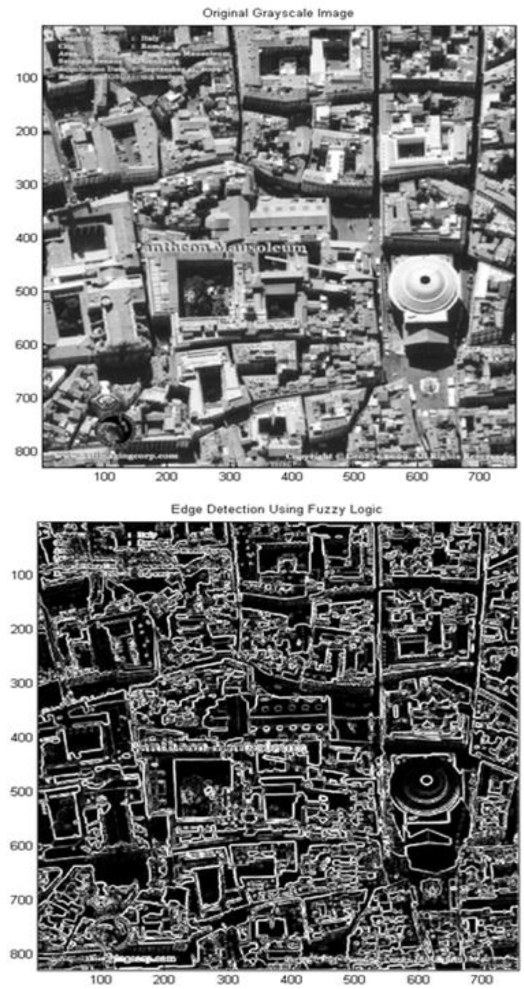


Figure 6. Result of edge detection of Fig (3)

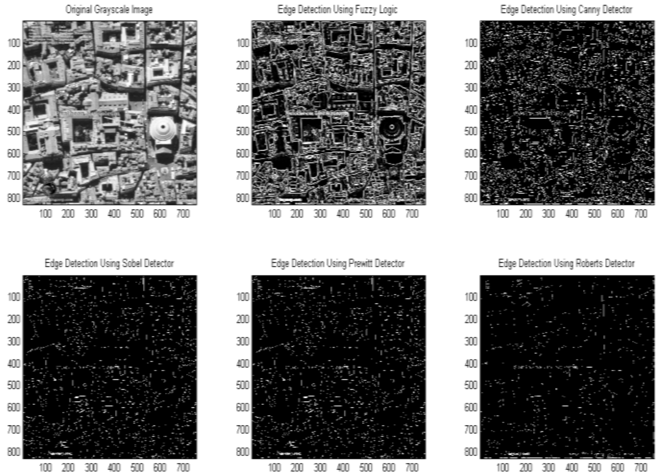


Figure 7. Comparison of edge detection techniques

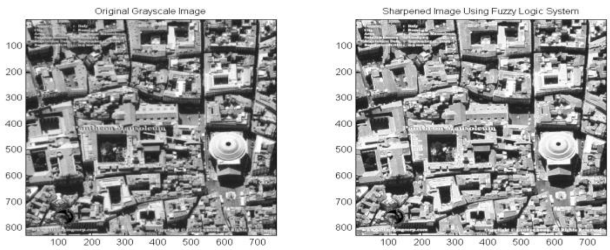


Figure 8. Result of sharpening

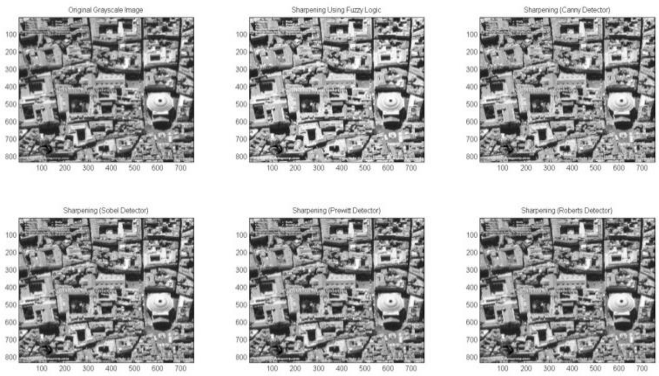


Figure 9. Comparison of sharpening techniques

IV. CONCLUSION

In this paper, a new technique for sharpening of satellite images is presented. First, various concepts related to edge detection in digital images are studied. Then, a comprehensive discussion of fuzzy based edge detection and unsharp masking is provided. Finally, a comparative analysis of proposed technique with other techniques is provided. From various results shown in Fig. 12 and 13, it can be concluded that the proposed technique provides sharpening results far better than the other techniques compared.

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