New Developments in Fuzzy Sets, Intuitionistic Fuzzy Sets, Generalized Nets and Related Topics Volume II: Applications

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Interval type-2 fuzzy logic for enhancing image processing and recognition

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Abstract

Interval type-2 fuzzy logic can be applied to perform image processing and pattern recognition. In this work a new type-2 fuzzy logic method is applied for edge detection in images and the results are compared with traditional techniques for the same goal with the type-2 edge detection outperforming the other techniques. We also describe a method for pattern recognition that is based on interval type-2 fuzzy systems that is also shown to outperform type-1 fuzzy systems and other methods.

Keywords: interval type-2 fuzzy logic, image processing, pattern recognition.

1 Introduction

In the area of digital signal processing, methods have been used that solve the problem of image recognition. Some of them include techniques like binarization, bi-dimensional filtering, edge detection and compression using banks of filters and trees [11], among others.

Specifically in edge detection we can find comparative studies of methods like: Canny, Narwa, Iverson, Bergholm y Rothwell [5]. Others methods can be grouped into two categories: Gradient and Laplacian.

The gradient methods like Roberts, Prewitt and Sobel detect edges, looking for maximum and minimum in first derivative from the image. The Laplacian methods like Marrs-Hildreth do it by finding the zeros of second derivative from the image [2].

This work describes the efforts in the design of new pre-processing images techniques, using Fuzzy Inference Systems (FIS), which allows feature extraction and construction of input vectors for neural networks with aims of image recognition.

Artificial neural networks are one of the most used objective techniques in the automatic recognition of patterns, here some reasons:

- Theoretically any function can be determined.
- Except the input patterns, it is not necessary to provide additional information.
- They can be applied to any type of patterns and to any data type [7].

The idea to apply artificial neural networks for images recognition, tries to obtain results without providing another data that the original images, of this form the process is more similar to the form in which the biological brain learns to recognize patterns, only knowing experiences of past. Models with modular neural networks have been designed, that allow to recognize images divided in four or six parts, which is necessary by the great amount of input data, since an image without processing of 100x100 pixels, needs a vector 10000 elements, where each one corresponds to pixel with variations of gray tones between 0 and 255 [8].

2 Sobel operators

Another Section is written the same way as the previous one. The width of the page and the margins should be followed as in this document. The Sobel operator applied to a digital image in gray-scale, calculates the gradient of the intensity of brightness of each pixel, giving the direction of the greater possible increase of black to white, in addition calculates the amount of change of that direction.

The Sobel operator performs a 2-D spatial gradient measurement on an image. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image.

The Sobel edges detector uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows).

A convolution mask is usually much smaller than the actual image. As a result, the mask is slid over the image, manipulating a square of pixels at a time.

The Sobel masks are shown in (1) [4]:

$$Sobel_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} Sobel_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \tag{1}$$

where $Sobely_x$, $Sobely_y$ are the Sobel Operators throughout x-axis and y-axis.

If we define I as the source image, g_x and g_y are two images which at each point contain the horizontal and vertical derivative approximations, the latter are computed as (2) and (3):

$$g_x = \sum_{i=1}^{i=3} \sum_{j=1}^{j=3} Sobel_{x,i,j} * I_{r+i-2,c+j-2} \tag{2}$$

$$g_y = \sum_{i=1}^{i=3} \sum_{j=1}^{j=3} Sobel_{y,i,j} * I_{r+i-2,c+j-2} \tag{3}$$

where gx and gy are the gradients along axis-x and axis-y, and * represents the convolution operator.

The gradient magnitude g calculates with (4) [3]:

$$g = \sqrt{g_x^2 + g_y^2} \tag{4}$$

3 Edge detection by gradient magnitude

Although the goal of this work, is to verify the efficiency of a FIS for edges detection in digital images, from the approaches given by the Sobel operator, it is necessary to display first the obtained results using only the gradient magnitude. An example will be used with the first image of the subject number one of the ORL (Figure 1) [12]. The gray tone of each pixel of this image is a value of between 0 and 255.

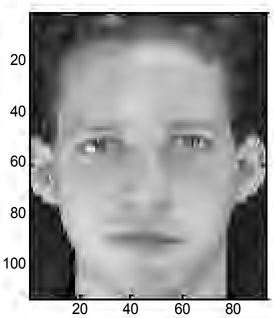


Figure 1: Original Image 1.pgm

In Figure 2 we show the image generated by *gx*, and Figure 3 presents the image generated by *gy*. An example of maximum and minimum values of the matrix given by *gx*, *gy* and *g* from the image 1.pgm is shown in Table 1.

After applying (4), g is obtained as it is shown in Figure 4.

Table 1: Maximum and Minimum values from 1.pgm, gx, gy and g

Tone	1.pgm	gx	gy	g
Minimum	11	-725	-778	0
Maximum	234	738	494	792

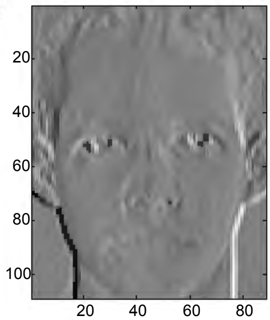


Figure 2: Image given by *gx*

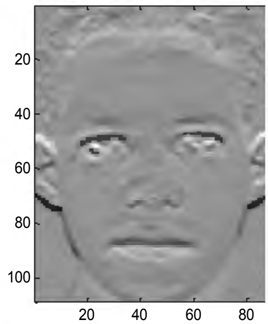


Figure 3: Image given by *gy*

Figure 4: Edges image given by g

4 Edge detection with type-1 fuzzy logic

A Mamdani FIS was implemented using Type-1 Fuzzy Logic, with four inputs, one output and 7 rules, using the Matlab Fuzzy Logic Tool Box [13].

4.1 Inputs for type-1 FIS

For the Fuzzy Inference System Type-1, 4 inputs are required, 2 of them are the gradients with respect to x-axis and y-axis, calculated with (2) and (3), to which we will call DH and DV respectively. The other two inputs are filters that calculate when applying two masks by convolution to the original image. One is a high-pass filter, given by the mask of the equation (5), and the other a low-pass filter given by the mask of equation (6).

The high-pass filter hHP detects the contrast of the image to guarantee the border detection in relative low contrast regions. The low-pass filter hMF allow to detects image pixels belonging to regions of the input were the mean gray level is lower. These regions are proportionally more affected by noise, supposed it is uniformly distributed over the whole image. The goal here is to design a system which makes it easier to include edges in low contrast regions, but which does not favor false edges by effect of noise [10].

$$hHP = \begin{bmatrix} -\frac{1}{16} & -\frac{1}{8} & -\frac{1}{16} \\ -\frac{1}{8} & \frac{3}{4} & -\frac{1}{8} \\ -\frac{1}{16} & -\frac{1}{8} & -\frac{1}{16} \end{bmatrix} \qquad (5)$$

$$hMF = \frac{1}{25} * \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \qquad (6)$$

Then the inputs for FIS type 1 are: DH=g_x DV=g_y HP= $hHP*I$ M= $hMF*I$ where * is the convolution operator.

4.2 Fuzzy variables

For all the fuzzy variables, the membership functions are Gaussian. According to the executed tests, the values in DH and DV, go from -800 to 800, then the ranks in x-axis adjusted as it is in figures 5, 6 and 7, in where the membership functions are:

LOW: gaussmf(43,0), MEDIUM: gaussmf(43,127), HIGH: gaussmf(43,255).

In the case of variable M, the tests threw values in the rank from 0 to 255, and thus the rank in x-axis is adjusted, as it is appreciated in Figure 8.

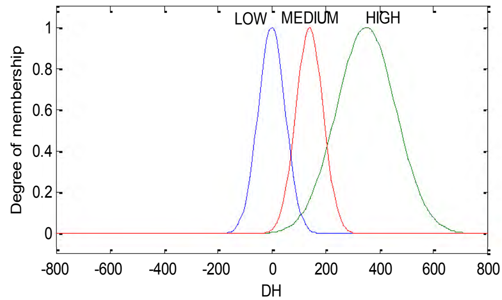


Figure 5: Input variable DH

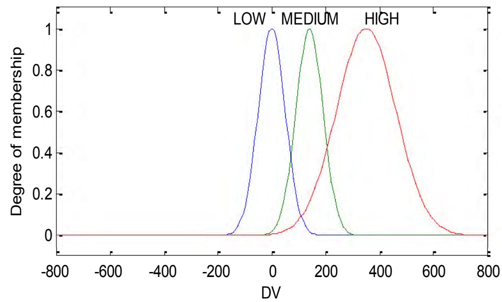


Figure 6: Input variable DV

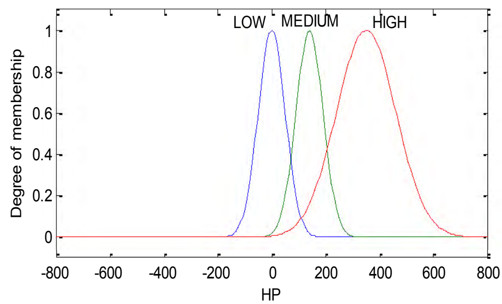


Figure 7: Input variable HP

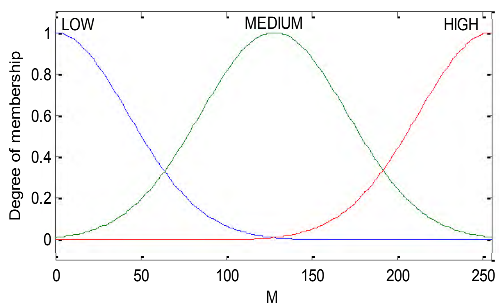


Figure 8: Input variable M

In Figure 9 is the output variable EDGES that also adjusted the ranks between 0 and 255, since it is the range of values required to display the edges of an image.

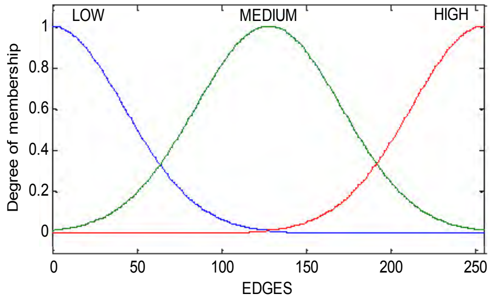


Figure 9: Output variable EDGES

4.3 Fuzzy inference rules

The seven fuzzy rules that allow to evaluate the input variables, so that the exit image displays the edges of the image in color near white (HIGH tone), whereas the background was in tones near black (tone LOW).

1. If (DH is LOW) and (DV is LOW) then (EDGES is LOW)
2. If (DH is MEDIUM) and (DV is MEDIUM) then (EDGES is HIGH)
3. If (DH is HIGH) and (DV is HIGH) then (EDGES is HIGH)
4. If (DH is MEDIUM) and (HP is LOW) then (EDGES is HIGH)
5. If (DV is MEDIUM) and (HP is LOW) then (EDGES is HIGH)
6. If (M is LOW) and (DV is MEDIUM) then (EDGES is LOW)
7. If (M is LOW) and (DH is MEDIUM) then (EDGES is LOW)

4.4 FIS type 1 results

The result obtained for image of Figure 1 is remarkably better than the one than it was obtained with the method of gradients, as it is in Figure 10.

Figure 10: EDGES Image by FIS Type 1

Reviewing the values of each pixel, we see that all fall in the rank from 0 to 255, which is not obtained with the method of gradient magnitude.

5 Edge detection with type-2 fuzzy logic

For the Type-2 FIS, the same method was followed as in Type-1 FIS, indeed to be able to make a comparison of both results. The tests with the type-2 FIS were executed using a program, which creates an Interval Type-2 Inference System (Mamdani) [6] [9]. This program creates the type 2 fuzzy variables as can be seen in Figure 11. The wide of the FOU area chosen for each membership function was the one that had better results after several experiments. The result of each evaluation gives a vector with gray tones for each part of the image, in the end is the complete image with the edges (see Figure 12).

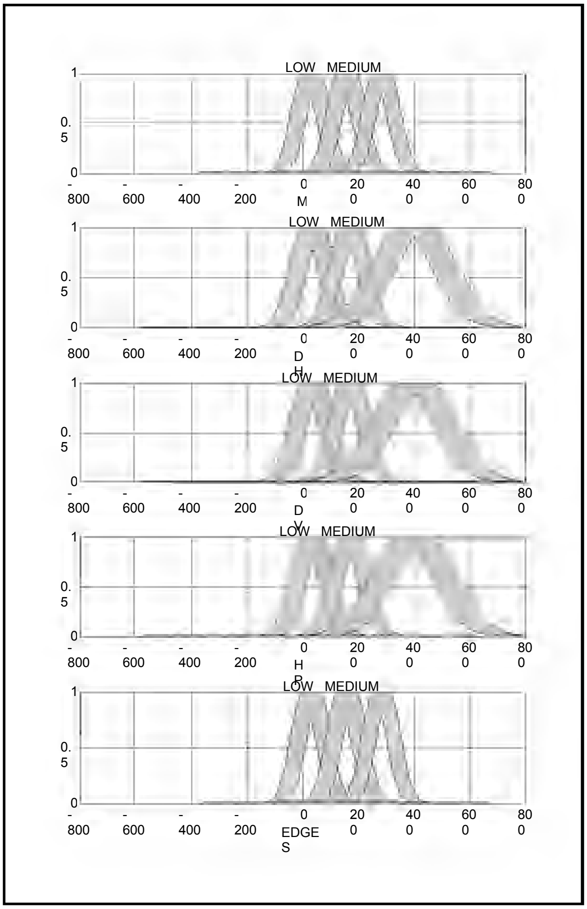


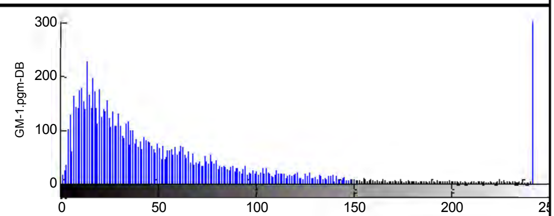
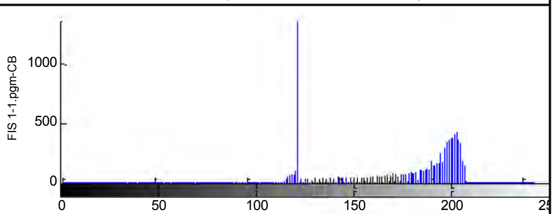
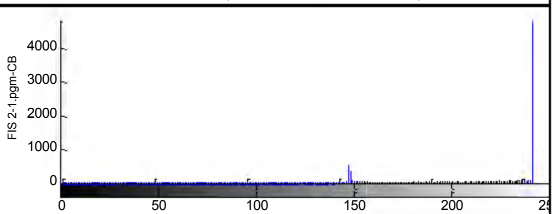
Figure 11: Type 2 fuzzy variables

Figure 12: EDGES Image by FIS Type 2

6 Comparison of edge detection results

In order to obtain an objective comparison of the images, histograms were elaborated respectively [1] corresponding to the resulting matrices of edges of the FIS 1 and FIS 2, which are in Table 2. The histograms show in the y-axis the range of tones of gray corresponding to each image and in x-axis the frequency in which he appears pixel with each tone.

Table 2: Histograms of the Resulting Images of the Edges by Gradient Magnitude, FIS 1 and FIS 2 methods

IMAGE: 1.PGM
METHOD: GRADIENT MAGNITUDE

METHOD: FIS 1 (CLEAR BACKGROUND)

METHOD: FIS 2 (CLEAR BACKGROUND)


7 Results of pattern recognition

We have designed fuzzy systems for estimating the fuzzy densities in the Sugeno integral, which is used to combine the recognition of the modules in a modular neural network [7, 8].

If some of the images don't reach a sufficient value in the simulation of the three modules, in these cases, there isn't enough information to select an image at the modules combination, and the image is wrongly selected. In Tables 3 and 4 we show the recognition rates for type-1 and type-2, respectively.

Table 3: Recognition rates with type-1 fuzzy logic

P	Image Recognition (%)				
	Train 1	Train 2	Train 3	Avg	Max
1	94.00	95.75	94.50	94.75	95.75
2	94.25	94.75	94.25	94.41	94.75
3	94.25	94.25	95.25	94.58	95.25
4	94.00	93.25	93.50	93.58	94.00
5	94.75	94.75	94.00	94.36	94.75
				94.36	**95.75**

Table 4: Recognition rates with type-2 fuzzy logic

P	Image Recognition (%)				
	Train 1	Train 2	Train 3	Avg	Max
1	97.25	96.25	95.00	96.17	97.25
2	94.75	95.25	95.75	95.25	95.75
3	95.50	97.50	96.00	96.33	97.50
4	95.25	95.00	95.50	95.25	95.50
5	96.50	97.00	96.00	96.50	97.00
				95.90	**97.50**

In Figure 13 we show the best recognition rates for both systems. As we can see in this test, the recognition rates using the Type-2 Fuzzy System are always better than with the Type-1 Fuzzy System.

8 Conclusions

The application of Sobel filters was very useful to define the input vectors for the Type-1 FIS and Type-2 FIS, although in future works we will try to design Neuro-Fuzzy techniques able to extract image patterns without another data that the original image and to compare the results with traditional techniques of digital signal processing. Thanks to the histograms of the images it was possible

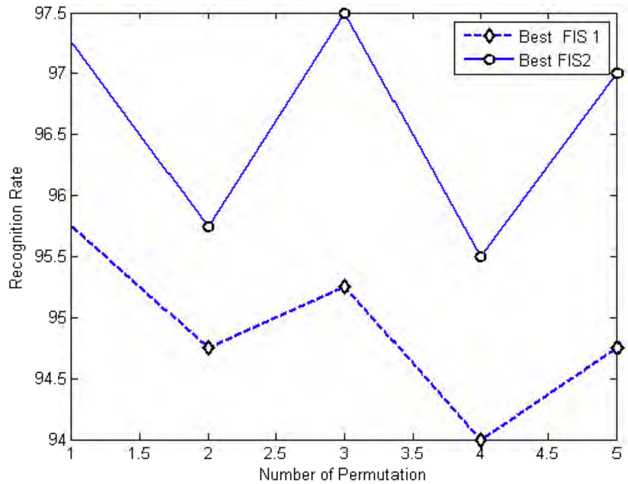


Figure 13: The best Recognition Rates forFIS 1 and FIS 2 fuzzy densities estimation

to verify the improvement of results of the Type-1 FIS with respect to the Type-2 FIS, since with only the appreciation of the human eye was very difficult to see an objective difference. The best result was obtained by the Type-2 Fuzzy Inference System, because it was possible to clear more than half of the pixels without depreciating the image, which will reduce in drastic form the cost of training in a neuronal network. The simulation results in pattern recognition also show that interval type-2 fuzzy logic is able to outperform type-1 fuzzy logic when used in conjunction with modular networks, in this case for face recognition (ORL face database).

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The papers presented in this Volume 2 constitute a collection of contributions, both of a foundational and applied type, by both well-known experts and young researchers in various fields of broadly perceived intelligent systems.
It may be viewed as a result of fruitful discussions held during the Tenth International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets (IWIFSGN-2011) organized in Warsaw on September 30, 2011 by the Systems Research Institute, Polish Academy of Sciences, in Warsaw, Poland, Institute of Biophysics and Biomedical Engineering, Bulgarian Academy of Sciences in Sofia, Bulgaria, and WIT - Warsaw School of Information Technology in Warsaw, Poland, and co-organized by: the Matej Bel University, Banska Bystrica, Slovakia, Universidad Publica de Navarra, Pamplona, Spain, Universidade de Tras-Os-Montes e Alto Douro, Vila Real, Portugal, and the University of Westminster, Harrow, UK:

Http://www.ibspan.waw.pl/ifs2011

The consecutive International Workshops on Intuitionistic Fuzzy Sets and Generalized Nets (IWIFSGNs) have been meant to provide a forum for the presentation of new results and for scientific discussion on new developments in foundations and applications of intuitionistic fuzzy sets and generalized nets pioneered by Professor Krassimir T. Atanassov. Other topics related to broadly perceived representation and processing of uncertain and imprecise information and intelligent systems have also been included. The Tenth International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets (IWIFSGN-2011) is a continuation of this undertaking, and provides many new ideas and results in the areas concerned.

We hope that a collection of main contributions presented at the Workshop, completed with many papers by leading experts who have not been able to participate, will provide a source of much needed information on recent trends in the topics considered.

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