21st ICIFS, 22–23 May 2017, Burgas, Bulgaria
Notes on Intuitionistic Fuzzy Sets
Print ISSN 1310–4926, Online ISSN 2367–8283
Vol. 23, 2017, No. 2, 88–94

Pattern recognition with intuitionistic fuzzy estimations

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Received: 21 February 2017 **Revised:** 8 April 2017 **Accepted:** 15 April 2017

Abstract: An recognition method based on intuitionistic fuzzy estimations is addressed in this paper. The recognition procedure is performed by analysis on an image and comparison between the degrees of membership and non-membership for the pixels in two or more images. In the next step an intuituinistic fuzzy estimation of the whole image is presented.

Keywords: Intuitionistic fuzzy sets, Intuitionistic fuzzy estimations, Pattern recognition, Analysis.

AMS Classification: 03E72.

1 Introduction

Recognition techniques are highly evaluated in areas where the human estimation cannot be applied or it is inefficient. Sample applications are in the area of pattern, data and image analysis. Several color models visualizing the images for different purposes are known. The main are RGB and CMYK. CMYK is applied in the polygraphy for preparation of printed products. It refers to the four inks used in some color printing: cyan, magenta, yellow and black (or key). RGB is used for displaying the images on the monitor or TV. The colors in the computers are represented by combining 3 basic colors: red, green, and blue (RGB). For example black is the combination of (0, 0, 0), white is (255, 255, 255), gray is any (x, x, x) where all the numbers are the same. The first number represents degree of red, second – degree of green and the third present degree of the blue color. The minimum value for each color is 0 and the maximum is 255. Every image is comprised of number of pixels according to the image size. Therefore an image of size *n* by *m* can be represented as a three dimensional array $n_x m_x 3$ where every cell has a certain value.

In the current research work an image will be regarded as a function of intensity and image size. In order to compare two functions it is necessary to obtain their values in terms of numerical values. The definition of function is wide including signals, numerical rows, reading from different biometric sensors including images. For simplification purposes there is a requirement to use monochrome images containing values in the range from 0 to 255 which reduces the size of the array to *n* by *m*. Similar recognition technique using intuitionistic fuzzy estimation of the results obtained by a neural network is presented in [8]. A tool for image filtration is implemented in [7].

The area of application of the proposed method can vary from recognition of biometric parameters to assessment of similarity level of signals (with and without noise), noise level, images and etc.

2 Remark on intuitionistic fuzzy sets

Intuitionistic Fuzzy Sets (IFSs) [1, 5] are defined as extensions of ordinary fuzzy sets [14]. The results valid in fuzzy sets can be transformed in the intuitionistic fuzzy sets (which is not always possible the other way round).

Let a set *E* be fixed. An IFS *A* in *E* is an object of the following form:

$$A = \left\{ \left\langle x, \mu_A(x), \nu_A(x) \right\rangle \middle| x \in E \right\},$$

where the functions $\mu_A : E \to [0,1]$ and $\nu_A : E \to [0,1]$ define the degree of membership and the degree of non-membership of the element $x \in E$:

$$0 \le \mu_A(x) + \nu_A(x) \le 1.$$

For every $x \in E$, let

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x).$$

Therefore, the function π determines the degree of uncertainty. Obviously, for every ordinary fuzzy set $\pi_A(x) = 0$ for each $x \in E$ these sets have the form:

$$A = \left\{ \left\langle x, \mu_A(x), 1 - \mu_A(x) \right\rangle \middle| x \in E \right\}.$$

3 Pattern recognition with intuitionistic fuzzy estimations

In the current research work an investigation of pattern recognition with intuitionistic fuzzy estimations [9, 12] is performed. Intuitionistic fuzzy estimations evaluating each pixel of the images are presented. The received intuitionistic fuzzy estimations of the first image are summarized and compared with the summarized intuitionistic fuzzy estimations from the second image.

3.1 First case: Determination of the intuitionistic fuzzy estimations of pixels

Firstly we observe an image in grayscale. Each pixel in a monochrome image can have a value in the standard scale from 0 to 255. So, let us have the following sets:

- set of pixels $P_o=\{p_1, p_2, .., p_e\}$,
- set of assigned values for color (weights for pixels) $W_s=\{w_1, w_2,..., w_e\}$.

So, let W_{min} be the minimal assigned value for the pixels in an image, and W_{max} be the maximal assigned value of the pixels in an image. According these values we can calculate the intuitionistic fuzzy estimation for each pixel. The degree of membership of the pixel W_i has the following form:

$$\mu_{pixel} = \frac{W_i}{W_{\max}},$$

where W_i is a value of the pixel i in the image and W_{max} is the maximum values for pixel in the selected image. The degree of non-membership of the pixel W_i is presented as:

$$\nu_{pixel} = \begin{cases} \frac{W_{\min} - W_i}{W_{\max}}, & if \ \ W_{\min} \geq W_i \\ 0, & if \ \ W_{\min} < W_i \end{cases},$$

where W_i is a value of the pixel i in the image, W_{max} is the maximum values for pixel in the selected image and W_{min} is the minimum value of the pixel in the selected image. The degree of uncertainty of the pixel W_i has the following form:

$$\pi_{pixel} = \begin{cases} \frac{W_{\max} - W_i}{W_{\max}}, & if \ \ W_{\min} < W_i \\ \\ \frac{W_{\max} - W_{\min}}{W_{\max}}, & if \ \ W_{\min} > W_i \end{cases},$$

where W_i is a value of the pixel i in the image, W_{max} is the maximum values for pixel in the selected image and W_{min} is the minimum value of the pixel in the selected image.

Depending the type of the image, the pixels will be compared using one value for monochrome images or three values for red, green and blue colors in RGB model.

In the second RGB case, for each color the values of the pixel have to be estimated. For example if the selected image is in RGB model, the degrees of membership for the red, green and blue colors will be:

$$\mu_{pixel,R} = \frac{W_{R(i)}}{W_{R(\max)}},$$

representing the degree of membership for the red color in the pixel of the image,

$$\mu_{pixel,G} = \frac{W_{G(i)}}{W_{G(\max)}},$$

representing the degree of membership for the green color in the pixel of the image and

$$\mu_{pixel,B} = \frac{W_{B(i)}}{W_{B(\max)}},$$

representing the degree of membership for the blue color of the pixel in the image.

The degrees of non-membership for the red, green and blue colors will have the following form:

$$\nu_{pixel,G} = \begin{cases} \frac{W_{R(\min)} - W_{R(i)}}{W_{R(\max)}}, if\ W_{R(\min)} \geq W_{R(i)} \\ 0, \quad if\ W_{R(\min)} < W_{R(i)} \end{cases},$$

representing the degree of non-membership for the red color of the pixel in the image,

$$\nu_{pixel,G} = \begin{cases} \frac{W_{G(\min)} - W_{G(i)}}{W_{G(\max)}}, if\ W_{G(\min)} \geq W_{G(i)} \\ 0, \quad if\ W_{G(\min)} < W_{G(i)} \end{cases},$$

representing the degree of non-membership for the green color of the pixel in the image and

$$\nu_{pixel,B} = \begin{cases} \frac{W_{B(\min)} - W_{B(i)}}{W_{B(\max)}}, if\ W_{B(\min)} \geq W_{B(i)} \\ 0, \quad if\ W_{B(\min)} < W_{B(i)} \end{cases},$$

representing the degree of non-membership for the blue color of the pixel in the image.

The degree of uncertainty will be given as:

$$\pi_{pixel,R} = \begin{cases} \frac{W_{R(\max)} - W_{R(i)}}{W_{R(\max)}}, \quad if \quad W_{R(\min)} < W_{R(i)} \\ \frac{W_{R(\max)} - W_{R(\min)}}{W_{R(\max)}}, \quad if \quad W_{R(\min)} > W_{R(i)} \end{cases},$$

representing the degree of uncertainty for the red color of the pixel in the image,

$$\pi_{pixel,G} = \begin{cases} \frac{W_{G(\max)} - W_{G(i)}}{W_{G(\max)}}, \quad if \quad W_{G(\min)} < W_{G(i)} \\ \frac{W_{G(\max)} - W_{G(\min)}}{W_{G(\max)}}, \quad if \quad W_{G(\min)} > W_{G(i)} \end{cases},$$

representing the degree of uncertainty for the green color of the pixel in the image and

$$\pi_{pixel,B} = \begin{cases} \frac{W_{B(\max)} - W_{B(i)}}{W_{B(\max)}}, \quad if \quad W_{B(\min)} < W_{B(i)} \\ \frac{W_{B(\max)} - W_{B(\min)}}{W_{B(\max)}}, \quad if \quad W_{B(\min)} > W_{B(i)} \end{cases},$$

representing the degree of uncertainty for the blue color of the pixel in the image.

The pixels will be the same if they have the same degrees of membership and non-membership for each color.

3.2 Second case: Determination of the intuitionistic fuzzy estimations for images

After comparing the pixels of the images we can construct an intuitionistic fuzzy estimation for whole image. Let a set of images and the following sets of pixels are given:

- set of common pixels (pixels of both images) $K_i = \{k_1, k_2, ..., k_n\}$;
- set of pixels appearing in the first image but not existing in the second $L_j = \{l_1, l_2, ..., l_m\}$;
- set of pixels appearing in the second image but not existing in the first $H_g = \{h_1, h_2, ..., h_f\}$;
- total number of the pixels $P_o = \{p_1, p_2, ..., p_e\}$.

The degree of membership for an image will have the following form :

$$\mu_{image} = \frac{K_i}{P_o},$$

where K_i is a set of the common pixels in the images and P_o is the set of the all pixels in the images (the size of the images).

The degree of non-membership for an image is presented as:

$$\nu_{image} = \frac{L_j}{2P_o},$$

where L_j is a set of the pixels appearing in the first image but not existing in the second and P_o is the set of the all pixels in the images (the size of the images).

The degree of uncertainty for an image is shown as:

$$\pi_{image} = \frac{H_g}{2P_o},$$

where L_j is a set of the pixels appearing in the first image but not existing in the second, H_g is a set of pixels appearing in the second image but not existing in the first and P_o is the set of the all pixels in the images (the size of the images).

The nominators of the formulas for degrees of non-memberships and uncertainty are divided by $2P_o$ because the number of the values for the different pixels in the images is the same (when the images have the same size).

The obtained intuitionistic fuzzy estimations can be further investigated and applied as input data in a procedure of the InterCriteria Analysis (ICA) [3, 4], a method based on the theory of the intuitionistic fuzzy sets [1, 5] and the index matrices [2]. ICA determines the degrees of correlation between several criteria as positive consonance, dissonance or negative consonance. The strong positive consonance present the highest correlation between the criteria, negative consonance – the opposite case and the dissonance shows lack of correlation. ICA is a new procedure used in many applications to estimate the behavior of the selected criteria, and some of these applications [6, 8, 10, 11, 13] are closely related and potentially upgradeable with the research results proposed here.

5 Conclusion

An intuitionistic fuzzy estimation to discover patterns between images has been performed. The recognition estimation is applied by analysis on an image and comparison between the degree of membership and non-membership for each pixel. The method can be modified depending the selected color model. In the current paper intuitionistic fuzzy estimations of pixels for monochrome and RGB images are presented. Depending the degrees of matching the patterns in the images can be recognized. In the next step an intuitionistic fuzzy evaluation of an image is presented. The results can be used in next research for an application of the ICA procedure.

Acknowledgements

The authors are thankful for the support provided by the Bulgarian National Science Fund under Grant Ref. No. DFNI-I-02-5 "InterCriteria Analysis: A New Approach to Decision Making".

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