Interval-Valued Intuitionistic Fuzzy Estimations of an Ultrasonic Image for Recognition Purposes

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Abstract. In the current research work the authors investigate the process of pattern recognition in terms of an object of interest, obtained by a radar image technique by applying the tools of Interval-Valued Intuitionistic Fuzzy Sets (IVIFS). The process of image acquisition by using the remote sensing approach is usually performed by a fast Fourier transform of the reflected signal. Due to the nature of waves, the reflection signal is comprised of direct and reflected signals, causing image blurring and smudging. The approach presented in this research work aims to propose an analytical evaluation of the processed image in comparison to preliminary defined images such as images of internal organs, tissues or bones. By applying the technique in question, it is possible to apply the method for recognition of any king of objects, and in particular – difference between organs with normal structure and organs with anomalies. The algorithm itself uses an interval-valued intuitionistic fuzzy estimations (IVIF-estimations) representing the dependencies between the target image and the selected image. The resulted IVIF-estimations represent the similarities between the selected images. According to the quantity of the processed key pixels in the images, there is a tradeoff between performance and quality of recognition. In order to verify the algorithm correctness, a numerical experiment on liver images with a different structure has been carried out.

Keywords: Interval-valued intuitionistic fuzzy estimation · Pattern recognition · Ultrasonic image · Internal organs

1 Image Acquisition

In the recent years different pattern recognition approaches are discussed in the literature [6–8, 11, 12, 14, 15]. In the current investigation the authors present an imaging technique called bistatic forward scattering inverse synthetic aperture radar (BFISAR) which is used to depict the object of interest. It uses the movement of the transmitter in order to observe objects of interest represented in the current case as a healthy human liver and one with cirrhosis. The geometry depicted in Fig. 1 is comprised of moving transmitter and stationary receiving station, situated in a Cartesian coordinate system, as depicted in the figure below.

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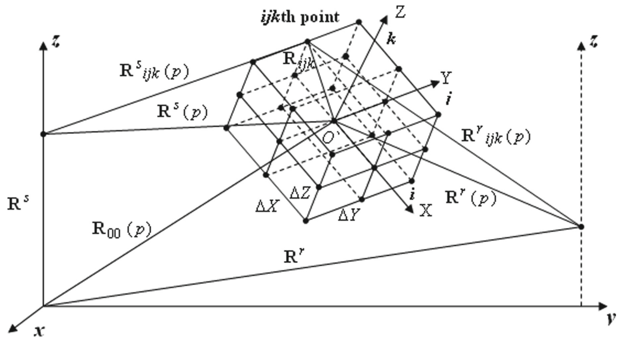


Fig. 1. BFISAR kinematics

where

$$\mathbf{R}^{s}(p) = \mathbf{R}^{s} - \mathbf{R}_{00}(p) = \mathbf{R}^{s} - \mathbf{R}_{00}(0) - \mathbf{V}\left(\frac{N}{2} - p\right)T_{p} \tag{1}$$

Is the range distance from the transmitter to the mass center of the object,

$$\mathbf{R}^{r}(p) = \mathbf{R}^{r} - \mathbf{R}_{00}(p) = \mathbf{R}^{r} - R_{00}(0) - \mathbf{V}\left(\frac{N}{2} - p\right)T_{p} \tag{2}$$

Is the Range distance vector from the transmitter to the ijk-th point of interest.

This imaging approach represents the object of observation as an assembly of point scatterers, observed by a bistatic system. Every point scatterer can be interpreted as a pixel of the object image, corresponding to the module of the range distance transmitter-object-receiver. The BFISAR technique can be regarded as a reception of broadband signal reflected by each point scatterer of the object which in this case is consisted of a series of linear frequency modulated pulses, and the signal is a superposition of the reflected pulses:

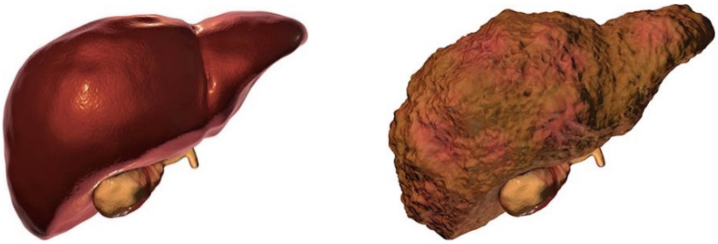
$$\begin{aligned} \dot{S}(p,t) &= \sum_{ijk} \dot{S}_{ijk}(p,t) \\ &= \sum_{ijk} a_{ijk}\, \mathbf{rect}\frac{t - t_{ijk}(p)}{T} \mathbf{exp}\left\{-j\begin{bmatrix} \omega\left(t - t_{ijk}(p)\right) + \\ +b\left(t - t_{ijk}(p)\right)^{2} \end{bmatrix}\right\} \end{aligned} \tag{3}$$

The range resolution of the image is resulted by the displacement of the observed object, as the azimuth resolution is achieved by the resolution properties of the signal, depending on the bandwidth.

The images acquisition is a result of a process called image reconstruction. In the complex signal, the time delays of the signals reflected by the object point scatterers, referred as range dimension is extracted by inverse Fourier transform known as range compression. The Doppler frequencies of the signals received, referred as azimuth dimension can also be extracted by inverse Fourier transform

$$\hat{I}(\hat{p},\hat{k}) = \sum_{p=1}^{N}\left[\sum_{k=1}^{K}\hat{S}(k,p).\exp\left(j2\pi\frac{k\hat{k}}{K}\right)\right]\exp\left(j2\pi\frac{p\hat{p}}{N}\right). \tag{4}$$

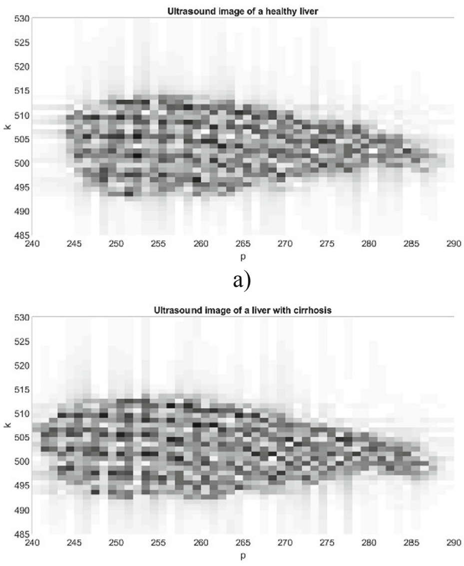
The objects in question – a human liver with normal structure a size and a human liver with cirrhosis are depicted in Fig. 2(a) and (b).



a) b)

Fig. 2. Objects, aim of imaging

After the remote imaging technique has been applied to the objects, the resulting images are represented in Fig. 3(a) and (b) respectively:



a)

b)

Fig. 3. Objects images – healthy liver with normal structure (a) and liver with cirrhosis (b)

2 Interval-Valued Intuitionistic Fuzzy Estimations

The theory of intuitionistic fuzzy sets is presented in [1, 3, 4]. The intuitionistic fuzzy evaluations are used for assessment of objects based on several criteria. The intutionistic fuzzy evaluation has the form of intuitionistic fuzzy pair $\langle a, b\rangle$ where $a, b \in [0, 1]$ and $a + b \leq 1$. The investigations using intuitionstic fuzzy evaluations are presented [2, 5, 9, 10]. In the current paper a method for image classification using interval-valued intuitionistic fuzzy estimations is proposed [8, 13]. The images are obtained by the BFISAR technique using ultrasonic waves. The interval-valued intuitionistic fuzzy estimations (IVIF-estimations) representing the similarities between the target image and the selected images in the comparison procedure. According to the quantity of the processed key pixels in the images, there is a tradeoff between performance and quality of recognition. In the current paper the IVIF-estimations are defined to evaluate the similarity between the images. The procedure has the following form:

1. Target image is juxtaposed to the second image. The original pattern *ABCD* and the other pattern *AGHI* are given.
2. Sections *BC* and *HI* are fuzzified so that they are modified to the regions *BCEF* and *HIKJ*.

   The following regions are determined (Fig. 4):

   $s = \#AGHOCD$, $a = \#AELK$, $b = \#EBML$, $c = \#BGJM$, $d = \#MJHO$, $e = \#KLNI$, $f = \#INFD$, $g = \#NOCF$ and $h = \#LMON$.

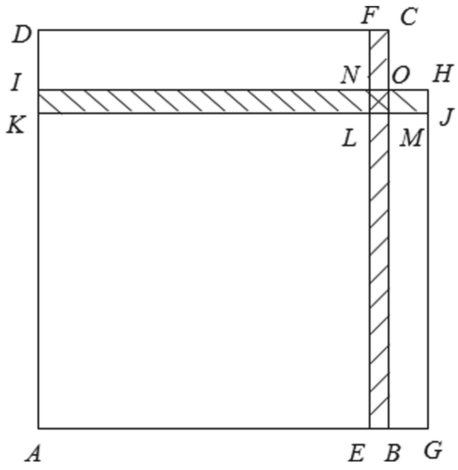


Fig. 4. Example

   Thereafter $s = a + b + c + d + e + f + g + h$ (Fig. 4).
3. The IVIF-degree of coincidence of the second pattern with the original are defined:

$$\langle M, N\rangle = \left\langle \left[\frac{a}{s}, \frac{a+b+e+h}{s}\right], \left[\frac{c}{s}, \frac{c+d}{s}\right]\right\rangle \quad (5)$$

   The degree of uncertainty is determined as the interval $\left[0, \frac{f+g}{s}\right]$.

For the purposes of images classification, an intuitionistic fuzzy estimation has been used. In order to assess the resulted images, an approach using the number of correlating and non-correlating image pixels is used. The number of pixels common for the both images (correlating pixels) is at a total of 628 pixels. The number of pixels (non-correlating) of the image from Fig. 3(a) is 87 at total and the number of pixels (non-correlating) of the image from Fig. 3(b) is 136. The total number of pixels for the image of the healthy liver – Fig. 3(a) is 715 and for the liver with cirrhosis is 764. The border pixels are 223.The Interval-Valued Intuitionistic Fuzzy Estimation for the images from Figs. 2 and 3 is:

$$M = \langle 0.74;\ 0.80\rangle,\quad N = \langle 0.16;\ 0.20\rangle.$$

The degree of uncertainty is in the interval $\langle 0;\ 0.13\rangle$.

The result presents the not enough similarity between the images. The pictures can not to be considered as the exactly the same. They can have close relationships and they can be considered to be in one group in the classification problem.

3 Conclusion

The presented image acquisition technique and interval-valued intuitionistic fuzzy estimations method can be successfully applied in the fields of image classification and pattern recognition. The proposed approach will be extended in the future research work: the algorithm will be applied to the set of images. The resulting interval-valued intuitionistic fuzzy estimations will be used to apply InterCriteria analysis to detect the correlations.

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References

1. Atanassov, K., Szmidt, E., Kacprzyk, J.: On intuitionistic fuzzy pairs. Notes Intuit. Fuzzy Sets **19**(3), 1–13 (2013)
2. Atanassov, K.: Intuitionistic fuzzy logics as tools for evaluation of data mining processes. Knowl.-Based Syst. **80**, 122–130 (2015)
3. Atanassov, K: Interval-Valued Intuitionistic Fuzzy Sets. Springer, Switzerland (2020). https://doi.org/10.1007/978-3-030-32090-4
4. Atanassov, K.: On Intuitionistic Fuzzy Sets Theory. Springer, Berlin (2012)
5. Bureva, V., Yovcheva, P., Sotirov, S.: Generalized net model of fingerprint recognition with intuitionistic fuzzy evaluations. In: Kacprzyk, J., Szmidt, E., Zadrożny, S., Atanassov, K.T., Krawczak, M. (eds.) IWIFSGN/EUSFLAT -2017. AISC, vol. 641, pp. 286–294. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-66830-7_26
6. Huo, G., Zhang, Q., Zhang, Y., et al.: Multi-source heterogeneous iris recognition using stacked convolutional deep belief networks-deep belief network model. Pattern Recogn. Image Anal. **31**, 81–90 (2021)

7. Hu, X., Li, X., Li, Y., Tang Y., Zhang, D.: A new method and implementation of blind restoration algorithm for moving fuzzy license plate image based on frequency-domain characteristics. Int. J. Pattern Recogn. Artif. Intell. **35**(08), 2154024 (2021)
8. Kim, T., Sotirova, E., Shannon, A., Atanassova, V., Atanassov, K., Jang, L.: Interval valued intuitionistic fuzzy evaluations for analysis of a student's knowledge in university e-learning courses. Int. J. Fuzzy Log. Intell. Syst. **18**(3), 190–195 (2018)
9. Kostadinov, T., Bureva, V.: Pattern recognition with intuitionistic fuzzy estimations. Notes Intuit. Fuzzy Sets **23**(2), 88–94 (2017)
10. Michalıkova, A.: Intuitionistic fuzzy sets and their use in image classification. Notes Intuit. Fuzzy Sets **25**(2), 60–66 (2019)
11. Mukherjee, S.: Denoising with discrete Morse theory. Vis. Comput. **37**, 2883–2894 (2021). IF: 2.601
12. Sogi, N., Zhu, R., Xue, J., Fukui, K.: Constrained mutual convex cone method for image set based recognition. Pattern Recogn. **121**, 108190 (2019). IF:7.196
13. Sotirova, E., Shannon, A., Atanassova, V., Atanassov, K., Bureva, V.: Interval valued intuitionistic fuzzy evaluations for analysis of students' knowledge. In: Intuitionistic and Type-2 Fuzzy Logic Enhancements in Neural and Optimization Algorithms (2020)
14. Wang, Y., Qi, Y., Yao, H., Gong, D., Wu, Q.: Image editing with varying intensities of processing. Comput. Vis. Image Underst. **211**, 103260 (2021). IF: 3.876
15. Xiao, G., Wang, H., Ma, J., et al.: Segmentation by continuous latent semantic analysis for multi-structure model fitting. Int. J. Comput. Vis. **129**, 2034–2056 (2021). IF: 7.410