FUZZY LOGIC METHODS AND IMAGE FUSION IN A DIGITAL IMAGE PROCESSING

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Abstract. *Although the basics of image processing were laid more than 50 years ago, significant development occurred mainly in the last 25 years with the entrance of personal computers and today's problems are already very sophisticated and quick. This article is a contribution to the study of the use of fuzzy logic methods and image fusion for image processing using LabVIEW tools for quality management, in this case especially in the jewelry industry.*

Keywords

Fuzzy logic, image fusion, image processing, LabVIEW.

1. Introduction

Using methods based on the properties of fuzzy logic and fuzzy sets in the computer image processing is not in the spotlight. It is certainly possible to accept that this topic based on fuzzy decision making can be at least an interesting alternative, especially where some the other methods may fail or give problematic results. In the literature can be found the fundamentals of fuzzy logic and fuzzy sets, i. e. in [10], also refer to the sources [11], or [13].

2. Short Fuzzy Logic History

Investigating of the truth and truthfulness, or rather consistency between claims and reality is as old as humanity itself and is one of the fundamental roles not only in the judiciary, but also in philosophy and science. As one of the first classical philosophical views on the truthfulness expressed Aristoteles (*384 BC, †322 BC) with his statement: "*True is to say about something what is, that it is, and about something what is not, that it is not*", from which it can be concluded that the claim can be either true or false, and any other (third) option does not exist. Similarly, expressed in medieval catholic philosopher and scholastic Thomas Aquinas (*1225, †1274) saying the sentence: "*Truth is the conformity of knowledge with reality*." In modern times the development of knowledge led to the need for an accurate quantitative description of phenomena observed and systematic processing of data based on the verification of truth claims by their objective measurement. In this sense, the modern era astronomer, physicist and philosopher Galileo Galilei (*1564, †1642) endowed to the nascent modern science his statement: "*We must measure what is measurable and make measurable what is not yet*".

Deeper exploration and discovering the diversity of the world gradually petered out to a realization that more accurately measure one variable, the less he knows about others. This complementarity quite accurately expressed by Albert Einstein (*1879, †1955) in his aphorism: "*As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality*". Perhaps the best known and most widely used formulation of the above considerations in physics is the Heisenberg uncertainty principle formulated by physicist Werner Heisenberg (*1901, †1976). According to this basic principle of quantum mechanics is currently impossible to accurately measure the position of the particle and its momentum. The more certainly one of the variables, the less we know about the other. This means (unfortunately), even the best improvement measuring techniques does not allow to obtain accurate results.

The natural result of the current philosophical considerations was the search for truth or falsehood, as a form of binary logic. When applying mathematical knowledge, however, often encounter the problem of complexity describe a seemingly simple phenomena. It shows that the accuracy at all costs is violent. Distinguished mathematician, philosopher and writer Bertrand Russell (*1872, †1970) in his work *Vagueness* describing one of the first term for uncertainty, *vagueness*, among other things said: *"... traditional logic usually assumed that precise symbols are used. This does not apply to this earthly life, but only for the existence of the supernatural existences ..."*. Another, who used the concept of vagueness in a logical description of reality, was a mathematician and philosopher Max Black (*1909, †1988). In his work, *Vagueness: An exercise in logical analysis* of 1937 dealt with the nature and observability of vagueness and its relationship to logic. Significantly to the theory of mathematical logic contributed works of mathematicians and logicians concentrated in the Lvov-Warsaw School a mathematician Jan Lukasiewicz (*1878, †1956). He developed multi-valued logic, first with truth values from the set of elements {0, ½, 1}, called ternary logic, later with the truth values of a continuous range of values <0, 1>.

Our (say very simply: European) thinking emerging from the classical Aristotelian two-valued logic "true / false" is rather strange reasoning based on a logic with multiple levels. In some oriental philosophies on the contrary, this very natural way of thinking. Take as an example of classical Chinese (Taoist) philosophy based on the "dialectical" rivalry of two opposing but yet complementary forces: Yin and Yang. Elements Yin (feminine, dark, passive force) and Yang (masculine, bright, creative force) are descriptions of complementary opposites, which are not taken literally. Every animate and inanimate part of the universe is always a little Yin and a little bit Yang. All forces in nature have both two states and these states are in continual motion.

It is interesting, but probably understandable, that a major impulse to change the Aristotelian understanding of truth came indirectly from the age-old conflict of cultures, from the culturally connected to Persian culture. In 1965 was published an article *Fuzzy Sets* [18], which started an important stage in the development of logic and problems of vague sets. The author of this work, a mathematician and professor of computer science Lotfi Zadeh Askar (*1921), born in Baku, was the first, who used to define membership functions into the set instead of the originally the term "vague" (vagueness) the new word "fuzzy". This word for their unique (and still fresh significance) then undertook in other languages.

3. Fuzzy Logic in an Image Processing

The theory of fuzzy sets and fuzzy logic is based on the work of the so-called *membership functions*, it usually indicates $\mu_A(x)$, which describes the degree of membership of element x in fuzzy set A. In the case of image processing are described the properties of individual elements (i. e. picture elements - pixels) of the image function $f(x)$ and their affiliation to a definite value of brightness. In this paper we consider some of the methods that use fuzzy logic to identify the edges in the image.

It is known from the theory of image processing (e. g. [13]) that for the perception of important places is in the image preprocessing necessary to find the edge points in the image (edgel – edge element), pixels in the image, which suddenly changes brightness values. For search of edge points can be used although known edge detectors (e. g. by Prewitt, Sobel, Marr [7] or Canny [4]), but these classic methods work well when explored part of the image is enough contrast. The result is an image converted by a simple thresholding to a binary image.

Classical edge detector tends to give erroneous results in the identification of edges formed by the points with low-resolution grayscale, although the human eye is able to detect these edges (of course in conjunction with experience). Generally we can say that the edge points are characterized by certain properties within the investigated image area.

With fuzzy logic using can be designed edge detector based on a relatively small training set of edge patterns recognized by classical edge detectors. This method [3] based on the theory of neural networks gives similar results as the Sobel operator. In the currently used procedures for image recognition is applied to the input image with a high pass filter (i. e. we are only interested in changes in the image), then performs edge detection (e. g. Sobel filter) and finally low-pass filtering (i. e. remove the "remaining" single points, etc.). The whole structure is so tuned to the contrast enhancement and in another case to the segmentation of images into a specified number of input classes. Adaptive fuzzy rules and fuzzy membership functions are specified depending on the type of filtration.

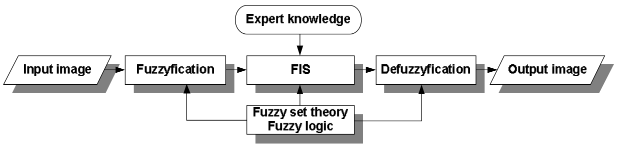


Fig. 1: Structure of the fuzzy image processing.

Fuzzy image processing is (according to [1]) a summary of all the approaches to understanding, representation and processing of images, their segments and features as fuzzy sets. Representation and processing depends on the selected fuzzy technique and solved the problem. Fuzzy image processing has three main stages: coding of image data (image Fuzzification), modification of membership values to fuzzy sets (fuzzy recognition system, FIS – Fuzzy inference system) and the results decoding (image Defuzzification), as shown in Fig. 1. The main power of fuzzy image processing is mainly in the intermediate step, a change of membership function values.

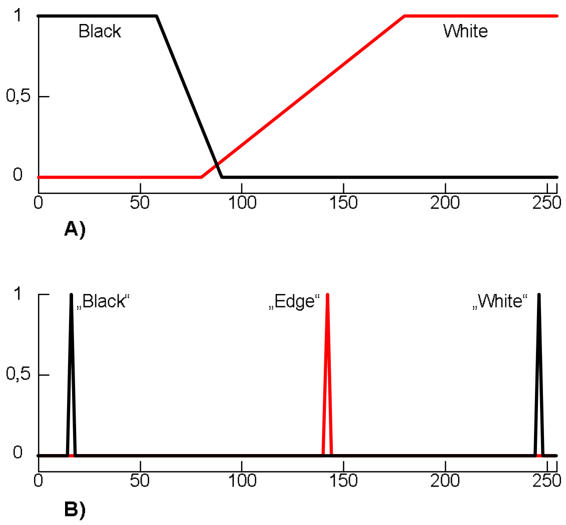


Fig. 2: Membership function of the input image (A) and output image (B).

The input image is quantized into 8-bit grayscale, so the value of imaging, i. e. brightness, takes values in the interval <0, 255>. Brightness can associate with linguistic terms “Black”, “White”, “Edge”, or “Edge point” respectively. Membership function for fuzzy set elements of the input image has the shape of a triangle, as shown in Fig. 2A. It is evident that the pixels considered as “Black” may acquire brightness values in the interval (60, 90), pixels considered as “White” brightness values in the interval (80, 170). So it is no easy to set the exact threshold level and is therefore highly advisable to use methods of fuzzy logic. Figure 2B shows an example of the desired shape of the output image membership function, it is evident that the edge points are located in a relatively narrow interval of the values (here, for example, brightness values around 140).

4. Example of Search Methods of Edges Points with the Help of Fuzzy Logic

Recognition methods based on fuzzy reasoning strategy are designed to detect edges in digital images without prior determination of threshold values or needs of training algorithm. In our example we divide the image into regions by using of the floating matrix 3×3 pixels. The image data are transformed from the plane of brightness values (gray levels) in the plane belonging to fuzzy sets (Fuzzification) according to fuzzy rules. In our case, we will examine the discretized image of size $M \times N$ image function $f(x)$ then can be written for example in the form $f(m, n)$, where $m = 1, 2, \dots M$ and $n = 1, 2, \dots N$. For our case we define four rules, which consider the brightness value of eight neighboring pixels around the examined pixel (i, j), as shown in Fig. 3.

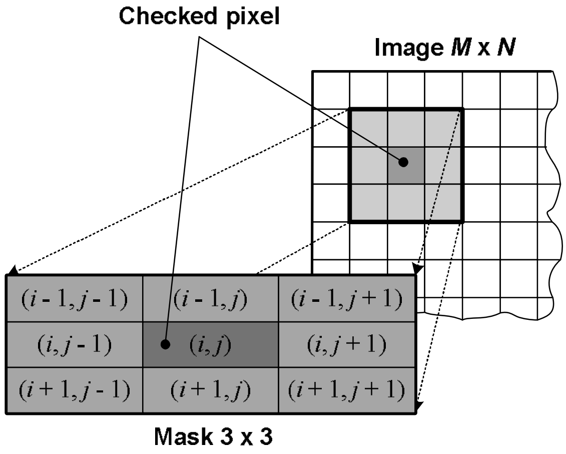
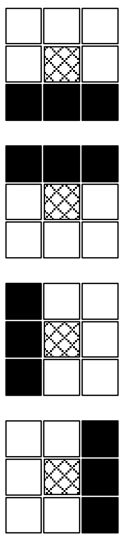


Fig. 3: Mask 3×3 pixels in fuzzy edge detection methodology.

Fuzzy rules (Fig. 4) for our case are relatively simple and allow us to get acquainted with the principle of applying fuzzy logic in image processing. Each of the fuzzy rules are created in the form of a conditional language expression of the logical implication IF X THEN Y, where X and Y are fuzzy statements, and X is a fuzzy condition (antecedent, ancedent) and Y is a fuzzy consequence (succedent, consequent). The aim is to identify pixels that are logically edge points of the investigated image. The described method analyzes the brightness values of all pixels in the 8-neighborhood (by mask 3×3) of the image center pixel (i, j), and if conditions are met, the center pixel is considered as the edge pixel and marked.



Rule 1:
IF { $f(i\text{-}1, j\text{-}1)$ & $f(i\text{-}1, j)$ & $f(i\text{-}1, j+1)$ } are „whites“
& IF { $f(i, j\text{-}1)$ & $f(i, j)$ & $f(i, j+1)$ } are „whites“
& IF { $f(i+1, j\text{-}1)$ & $f(i+1, j)$ & $f(i+1, j+1)$ } are „blacks“,
THEN $f(i, j)$ is „edgel“

Rule 2:
IF { $f(i\text{-}1, j\text{-}1)$ & $f(i\text{-}1, j)$ & $f(i\text{-}1, j+1)$ } are „blacks“
& IF { $f(i, j\text{-}1)$ & $f(i, j)$ & $f(i, j+1)$ } are „whites“
& IF { $f(i+1, j\text{-}1)$ & $f(i+1, j)$ & $f(i+1, j+1)$ } are „whites“,
THEN $f(i, j)$ is „edgel“

Rule 3:
IF { $f(i\text{-}1, j\text{-}1)$ & $f(i, j\text{-}1)$ & $f(i+1, j\text{-}1)$ } are „blacks“
& IF { $f(i\text{-}1, j)$ & $f(i, j)$ & $f(i+1, j)$ } are „whites“
& IF { $f(i\text{-}1, j+1)$ & $f(i, j+1)$ & $f(i+1, j+1)$ } are „whites“,
THEN $f(i, j)$ is „edgel“

Rule 4:
IF { $f(i\text{-}1, j\text{-}1)$ & $f(i, j\text{-}1)$ & $f(i+1, j\text{-}1)$ } are „whites“
& IF { $f(i\text{-}1, j)$ & $f(i, j)$ & $f(i+1, j)$ } are „whites“
& IF { $f(i\text{-}1, j+1)$ & $f(i, j+1)$ & $f(i+1, j+1)$ } are „blacks“,
THEN $f(i, j)$ is „edgel“

Fig. 4: Example of the fuzzy rules (Algorithm 1).

Test algorithm for the implementation of this fuzzyfication system for search of edge pixels in the image can be described as follows:

Algorithm 1:

1. Input is a grayscaled image $M \times N$, each element (pixel) is described by the value of image function

$f(m, n) = f_{mn}$, where $f_{mn} \in$ <0, 255>, m = 1, 2, … M, n = 1, 2, … M.

2. Create the auxiliary array **A** (size $M \times N$, at the end will mention the output image) and initially is setting to a constant value **A**(m, n) ← 255 for all m = 1, 2, … M and n = 1, 2, … N.
3. Set a counter j ← 2.
4. Set a counter i ← 2.
5. Find values $f(i, j) = f_{ij}$ of all pixels in the neighborhood 3×3 and verify the validity of rules in Fig. 4. In case of validity set **A**(i, j) ← 0.
6. Repeat for all i = 2, … M - 1 from the step 5.
7. Repeat for all j = 2, … N - 1 from the step 4.
8. Finally array **A** now contains the output image.

Note: To express the logical product (i. e. logical AND operation) is in the individual fuzzy rules in Fig. 4 used character &, in the algorithm description is used character ∧. To express the logical sum (i. e. logical OR operation) is in the description in Fig. 4 used the character ∨.

The algorithm uses two vague (fuzzy) values: “white” and “black”, by which classify ambiguous brightness values of all pixels around the surveyed central pixel. The auxiliary array **A**, which will form as a resulting output image with founded edge points, first fill (in accordance with Fig. 2B) with value "most white" (in our case 255) and during the classification (i. e. identification of the FIS system – according to the structure of Fig. 1) the pixels marked as “edge point” are filled with value “most black” (in our case 0).

To verify the methods of fuzzy logic in image processing in LabVIEW will be our first task realization algorithm for edges searching using the above-described algorithm. Figure 5 shows the block diagram of the test program.

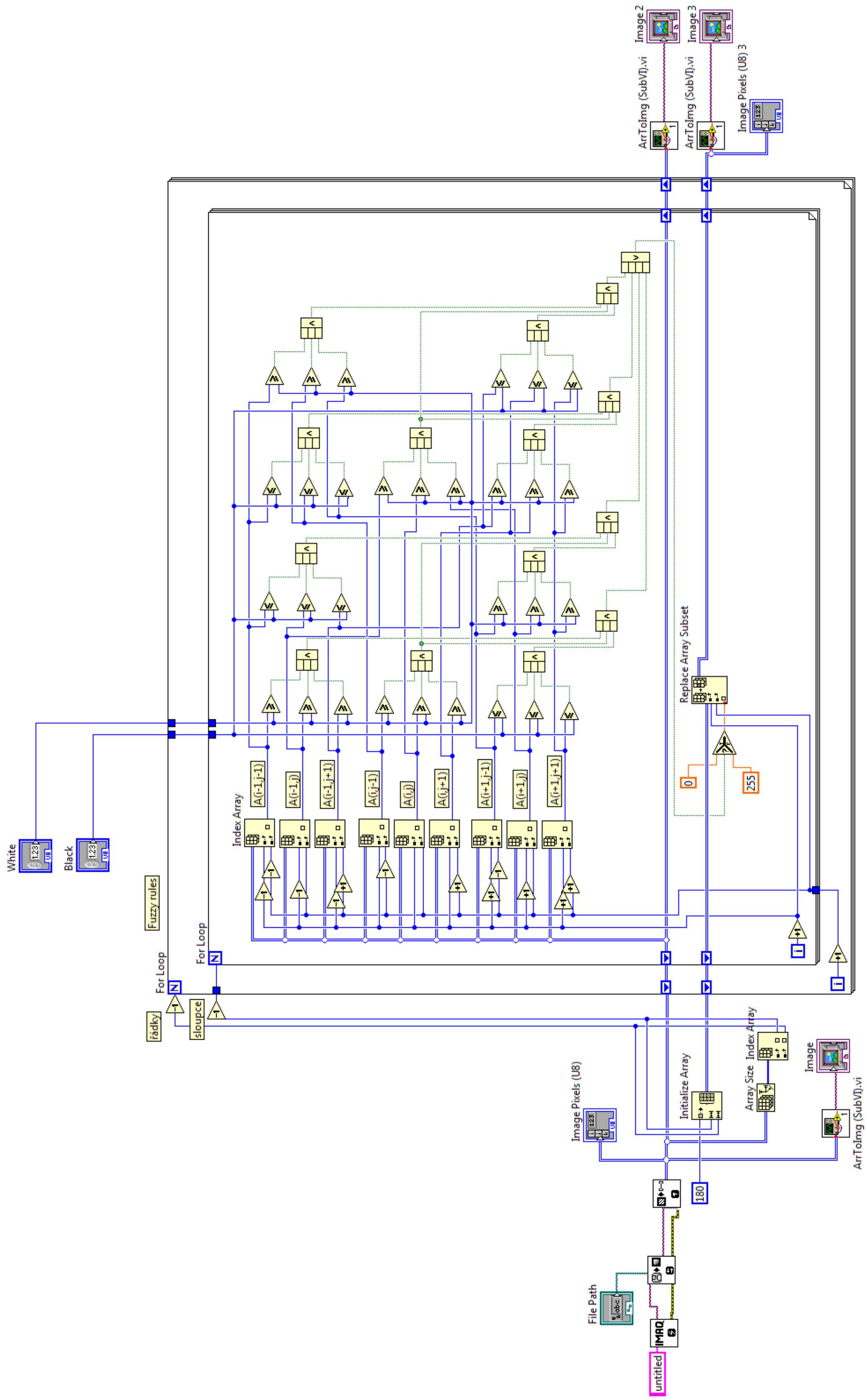


Fig. 5: Block diagram of the test program in LabVIEW.

Figure 6 left shows an example of the input image and Fig. 6 right shows the resulting output image with founded edge points.

Fig. 6: Example of fuzzy image processing – edge detection, left: input image, right: output image with detected edge points.

We can observe in this demonstration program changes in the output image by changes of values "white", or "black" respectively. To obtain the output image shown in Fig. 6 right were set values "black" = 110 and "white" = 50. It would also be interesting and in practice most useful to add another rules and to allow more accurate and more effective edge detection.

The great advantage of fuzzy logic methodology is the use of logic functions and achieves in comparison with traditional methods the relatively higher processing speed.

5. Image Fusion

In many cases it is necessary to solve the problem of image reconstruction (e. g. if it is damaged, noisy, poor lighted, blurred, defocused, etc.). For this purpose you can use the solution using the image fusion [14], or [12]. This method uses the integration of all available information about the picture (usually different views of the same scene, for example, an image is focused always on a different part of the image or other object in the image) to create the best possible final image quality. Of course the term "quality" depends on the requirements of specific applications. Currently, image fusion has an important position in medical applications.

Imagine (Fig. 7) the original image is laid out into N "transmission" channels carrying information about the same image. On each channel is visible a certain degradation and consequently also the random noise. So we obtain N acquired images with varying degrees of degradation of the original image.

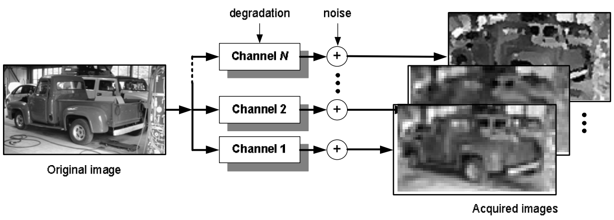


Fig. 7: Model of the image degradation.

Let $u(x, y)$ is the original (in ideal case two-dimensional) image and C_i ($i = 1, 2, \ldots N$) are different sources of visual information (channels), then can be written the relationship:

$$C_i(x, y) = D_i(u(x, y)) + E_i(x, y), \qquad (1)$$

where D_i is the operator describing the degradation of the i-th image and E_i is additive random noise. Ideally, the operator D_i will be featuring equality and a component E_i will be equal to zero. It can be assumed that the combination of images (which we call *image fusion*) from various sources (channels), we obtain the final image $\hat{u}$, which gives a better result than we would get on the original image from the individual sources C_i. Fusion methodology based on various properties of the degradation operators D_i. We also assume that every point on the image, i. e. pixel (x, y), can be obtained undistorted from at least one source (channel).

In image fusion we get out from the comparison of images from various sources (channels) and identify the source (channel) in which the pixel (or area) is undistorted and unbroken parts connection into the final acquired image with the following formula:

$$\hat{u} = A_1\, C_1 + A_2\, C_2 + \ldots + A_N\, C_N\ , \qquad (2)$$

where A_i is the general operator which (simply expressed) selects from the i-th image (channel) C_i only the undegraded parts. Figure 8 shows a general method of image fusion.

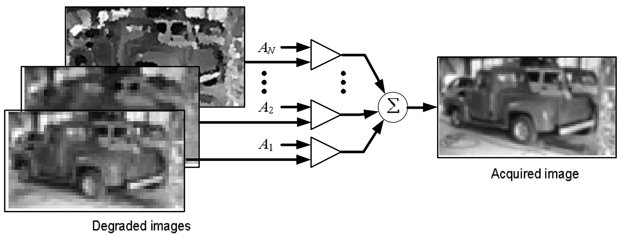


Fig. 8: Model of the image fusion.

For searching for fused image is described algorithm (inspired by [12]) using fuzzy decomposition. To simplify the interpretation we will consider all the images represented by functions of one variable from interval $\langle a, b \rangle$.

Algorithm 2:

1. Let $k = 1$ and $\varepsilon > 0$. Each sources (channels) C_i denote as a function ${}^k f_i$, $i = 1, 2, \ldots N$.
2. Let $n = 2^k$. Calculate the direct and inverse fuzzy transform (F-transform) of all functions ${}^k f_i$ for $i = 1, 2, \ldots N$. Direct F-transform denote as $\mathbf{F}_n[{}^k f_i]$ a inverse F-transform as ${}^k f_{F,n,i}$, $i = 1, 2, \ldots N$.
3. Calculate ${}^{k+1} f_i = {}^k f_i - {}^k f_{F,n,i}$, $i = 1, 2, \ldots N$.

4. If $\max_{<a,\, b>}|^{k+1}f_i| > \varepsilon$, then $k \leftarrow k+1$ and repeat from the step 2. If $\max_{<a,\, b>}|^{k+1}f_i| \leq \varepsilon$, set $k_{max} \leftarrow k$.
5. Calculate „fast“ direct F-transform $\mathbf{F}_n[s_k] = [{}^kS_1, {}^kS_2, \ldots {}^kS_n]$, where ${}^kS_j$ is the largest of all absolute values $\mathbf{F}_n[{}^kf_i]_j$, $j = 1, 2, \ldots n$.
6. Calculate „fast“ inverse F-transform s_k with components $\mathbf{F}_n[s_k]$.
7. Let $k \leftarrow k - 1$ and if $k \geq 1$, repeat from the step 5.
8. Calculate $\hat{s} = \sum_k s_k$ for $k = 1, 2, \ldots k_{max}$ and acquired image $\hat{s}$ will be considered as image fusion.

If some part of the functions is affected by degradation, then (as described in [12]) is the fuzzy transformation component close to zero, because in the step 5 we select components with the largest absolute value.

To verify the possibility of image fusion was created (based on the above described Algorithm 2) relatively simple processing solution for illustration with only two input images ($N = 2$), so the formula (2) goes to the simplified form:

$$\hat{u} = A_1\, C_1 + A_2\, C_2\,, \tag{3}$$

and in our case, we will verify the operators A_1, or A_2 respectively, in the form of logical expressions:

$$\begin{aligned} A_1 &= 1, \quad if\ C_1(i,j) > C_2(i,j), \\ A_1 &= 0, \quad if\ C_1(i,j) \leq C_2(i,j). \end{aligned} \tag{4.1}$$

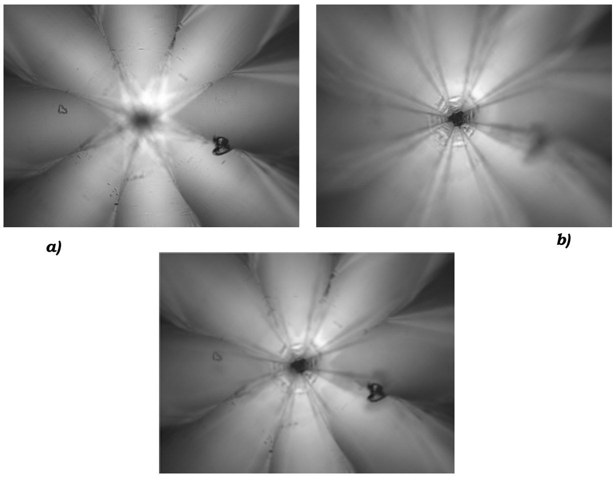
$$\begin{aligned} A_2 &= 1, \quad if\ C_1(i,j) \leq C_2(i,j), \\ A_2 &= 0, \quad if\ C_1(i,j) > C_2(i,j). \end{aligned} \tag{4.2}$$

For each pixel of the final (fused) image $\hat{u}(i, j)$ will then apply:

$$\begin{aligned} \hat{u}(i,j) &= C_1(i,j), \quad if\ C_1(i,j) > C_2(i,j), \\ \hat{u}(i,j) &= C_2(i,j), \quad if\ C_1(i,j) \leq C_2(i,j). \end{aligned} \tag{5}$$

So the resulting image is composed from the pixels that have (in this case) the greatest brightness value.

Figure 9 shows an example of image fusion of the investigated object, in our case, images of jewelry stone. These images were scanned with an optical system with vertical coaxial light source. It is obvious that the investigated stone has at its edges (Fig. 9a) and its peak (Fig. 9b) defects (apparently caused by mechanical damage). By scanning such small objects such as jewelry stones, plays a large role depth of focus of the optical system. Usually we cannot find all defects in the stone in one view. It is therefore necessary to get more views, to merge their image fusion and work with the resulting image. Fig. 9c shows an example of image fusion of input images (Fig. 9a and Fig. 9b).



c)

Fig. 9: Example of image fusion, a) image focused into stone, b) image focused on the bottom peak of the stone, c) image fusion of both images.

Note that for the classification of this type of images should be very carefully and with knowledge of the issue to vote both the lighting and shooting method, and consequently also the method of processing acquired images. Sometimes it is even possible to analyze scanned images separately (i. e. each image separately and then express the resulting assessment as a sum of partial evaluation). Also this procedure can be considered as image fusion.

6. Conclusion

The main aim of the article is to present examples of the use of fuzzy logic in image processing to find of edge points in the image and a simple application of image fusion by the identification of the subject properties in the image. Practical applications are then made in the programming environment of LabVIEW. The test results suggest that the use of fuzzy methods can bring new quality to the image processing solutions, particularly with regard to the relatively high demands on processing speed. The author was inspired in particular by articles [14], then [1] and others and is a continuation of his article [15], respectively [16].

References

[1] ALSHENNAWY, A. A. and A. A. ALY. Edge Detection in Digital Images Using Fuzzy Logic Technique. *World Academy of Science, Engineering and Technology, International Journal of Information Technology* [online]. 2009, vol. 5, iss. 4, p. 264-269; [cit. 2011-11-05]. ISSN 1305-2403. Available at: http://www.waset.org/journals/waset/v53/v53-40.pdf.

[2] BARKHODA, W., T. F. AKHLAQIAN and O.-K. SHAHRYARI. Fuzzy Edge Detection Based on Pixel's Gradient and Standard Deviation Values, In: *Proceedings of the International Multiconference on Computer Science and Information Technology*. 2009, p. 7-10. [cit. 2011-11-05]. ISBN

978-83-60810-22-4. Available at: http://www.proceedings2009.imcsit.org/pliks/53.pdf.

[3] BEZDEK, J. C., J. KELLER, R. KRISNAPURAM and N. R. PAL. *Fuzzy models and algorithms for pattern recognition and image processing*. Springer, 2005. p. 576. ISBN 0-387-24515-4.

[4] CANNY, J. A. Computational Approach to Edge Detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 1986, p. 679-698, [cit. 2011-11-05]. ISSN 0162-8828. Available at: http://www.limsi.fr/Individu/vezien/PAPIERS_ACS/canny1986.pdf.

[5] CINTULA, P. *From Fuzzy Logic to Fuzzy Mathematics*. FJFI CVUT Praha, 2004 [cit. 2011-11-05]. Available at: http://www2.cs.cas.cz/~cintula/thesis.pdf. Doctoral dissertation

[6] HLAVAC, V. and M. SONKA. *Pocitacove videni*. Praha: GRADA, 1992. ISBN 80-85424-67-3.

[7] MARR, D. and E. HILDRETH. Theory of Edge Detection. *Proceedings of the Royal Society of London. Series B, Biological Sciences*. Feb. 29, 1980, vol. 207, iss. 1167, p. 187-217 [cit. 2011-11-05]. ISSN 0962-8452. Available at: http://www.cim.mcgill.ca/~langer/646/PAPERS/MarrHildreth80.pdf.

[8] MATHUR, S. and A. AHLAWAT. Application of Fuzzy Logic on Image Edge Detection. *Information Science and Computing, Book 5, Intelligent Technologies and Applications* [online]. 2008, Sofia, p. 24-2; [cit. 2011-11-05]. ISSN 1313-048X. Available at: http://www.foibg.com/ibs_isc/ibs-05/IBS-05-p03.pdf.

[9] MITTAL, V. *Edge Detection Technique Using Fuzzy Logic*, Computer Science and Engineering Dep., Thapar University, Patiala (India), 2008; [cit. 2011-11-05]. Available at: http://dspace.thapar.edu:8080/dspace/bitstream/10266/576/1/Edge+Detection+Technique+Using+Fuzzy+Logic.pdf.

[10] NOVAK, V. *Zaklady fuzzy modelovani*. Praha: BEN, 2000. ISBN 978-80-7300-009-9.

[11] PERFILIEVA, I. *Fuzzy Transforms*. 2004. Research report iss. 58, University of Ostrava, IRAFM 2004, Ostrava, [cit. 2011-11-05]. Available at: http://irafm.osu.cz/research_report/58_rep58.pdf.

[12] PERFILIEVA, I. and M. DANKOVA. *Image Fusion on the Basis of Fuzzy Transforms*. 2008 Research report iss. 122, University of Ostrava, IRAFM Ostrava 2008. Available at: http://irafm.osu.cz/research_report/123_rep122.pdf.

[13] SONKA, M., V. HLAVAC and R. BOYLE. *Image Processing, Analysis, and Machine Vision*. Toronto: Thomson Learning, 2008 [cit. 2011-11-05]. Available at: http://www.icaen.uiowa.edu/~dip/LECTURE/lecture.html, (the older publication). ISBN 049508252X.

[14] VAJGL, M. and M. KOTYRBA. Aplikace fuzzy transformace na zpracovani obrazu. *Automatizace*. 2010, vol. 53, iss. 1-2, p. 53-56 [cit. 2011-1-05]. ISSN 0005-125X. Available at: http://www.automatizace.cz/article.php?a=2754.

[15] VLACH, J. Zaklady zpracovani obrazu v prostredi LabVIEW. *Automatizace*. 2009, vol. 52, iss. 1, p. 40–41; [cit. 2011-11-05]. ISSN 0005-125X. Available at: http://www.automatizace.cz/article.php?a=2421.

[16] VLACH, J. Hledani usecek a kruznic s vyuzitim Houghovy transformace pri zpracovani obrazu. *Automa*. 2011, vol. 17, iss. 2, p. 42–44 [cit. 2011-11-05]. ISSN 1210-9592. Available at: http://www.odbornecasopisy.cz/res/pdf/42983.pdf.

[17] VYSOKY, P. Fuzzy logika–moda, ci zmena paradigmatu? *Vesmir*. 1994, vol. 73, iss. 6, p. 313 [cit. 2011-11-05]. ISSN 1214-4029. Available at: http://www.vesmir.cz/clanky/clanek/id/3410.

[18] ZADEH, L. A. Fuzzy Sets. *Information & Control*. 1965, vol. 8, p. 338-353 [cit. 2011-11-05]. ISSN 0019-9958. Available at: http://www.bisc.cs.berkeley.edu/zadeh/papers/Fuzzy%20Sets-1965.pdf.

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