International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:3, No:3, 2009

Edge Detection in Digital Images Using Fuzzy Logic Technique

Abdallah A. Alshennawy, and Ayman A. Aly

***Abstract*—**The fuzzy technique is an operator introduced in order to simulate at a mathematical level the compensatory behavior in process of decision making or subjective evaluation. The following paper introduces such operators on hand of computer vision application.

In this paper a novel method based on fuzzy logic reasoning strategy is proposed for edge detection in digital images without determining the threshold value. The proposed approach begins by segmenting the images into regions using floating 3x3 binary matrix. The edge pixels are mapped to a range of values distinct from each other. The robustness of the proposed method results for different captured images are compared to those obtained with the linear Sobel operator. It is gave a permanent effect in the lines smoothness and straightness for the straight lines and good roundness for the curved lines. In the same time the corners get sharper and can be defined easily.

***Keywords*—**Fuzzy logic, Edge detection, Image processing, computer vision, Mechanical parts, Measurement.

I. Introduction

OVER the last few decades the volume of interest, research, and development of computer vision systems has increased enormously. Nowadays they appear to be present in almost every sphere of life, from surveillance systems in car parks, streets, and shopping centers, to sorting and quality control systems in the majority of food production. Thus, introducing automated visual inspection and measurement systems are necessary, specially for the two dimensional mechanical objects, [1:8]. In part due to the substantial increase in digital images that are produced on a daily basis (e.g., from radiographs to images from satellites) there is an increased need for the automatic processing of such images, [9,10,11]. Thus, there are currently many applications such as computer-aided diagnosis of medical images, segmentation and classification of remote sensing images into land classes (e.g., identification of wheat fields, and illegal marijuana plantations, and estimation of crop growth), optical character recognition, closed loop control, content-based retrieval for multimedia applications, image manipulation for the film industry, identification of registration details from car number plates, and a host of industrial inspection tasks (e.g., detecting defects in textiles, rolled steel, plate glass, etc.). Historically much data has been generated as images to facilitate human analysis (it is much easier to understand an image than a comparable table of numbers), [12]. And so this has encouraged the use of image analysis techniques over other possible methods of data processing. In addition, since humans are so adept at understanding images, image based analysis provides some aid in algorithm development (e.g., it encourages geometric analysis) and also helps informally validate results. While the role of computer vision can be summarized as a system for the automated (or semi-automated) analysis of images, many variations are possible, [9,13]. The images can come from different modalities beyond normal gray-scale and colour photographs, such as infrared, X-ray, as well as the new generation of hyper-spectral satellite data sets. Second, many diverse computational techniques have been employed within computer vision systems such as standard optimization methods, AI search strategies, simulated annealing, genetic algorithms, [14,15, 16].

Usage of specific linear time-invariant (LTI) filters is the most common procedure applied to the edge detection problem, and the one which results in the least computational effort. In the case of first-order filters, an edge is interpreted as an abrupt variation in gray level between two neighbor pixels. The goal in this case is to determine in which points in the image the first derivative of the gray level as a function of position is of high magnitude. By applying the threshold to the new output image, edges in arbitrary directions are detected. In other ways the output of the edge detection filter is the input of the polygonal approximation technique to extract features which to be measured, [1].

A very important role is played in image analysis by what are termed feature points, pixels that are identified as having a special property. Feature points include edge pixels as determined by the well-known classic edge detectors of PreWitt, Sobel, Marr, and Canny [17:21]. Recently there has been much revived interest [22,23] in feature points determined by "corner" operators such as the Plessey, and interesting point operators such as that introduced by Moravec. [24,25] Classical operators identify a pixel as a particular class of feature point by carrying out some series of operations within a window centered on the pixel under scrutiny. The classic operators work well in circumstances where the area of the image under study is of high contrast. In fact, classic operators work very well within regions of an image that can be simply converted into a binary image by simple thresholding as shown in Fig.1. To be definite as to the failings of classic operators: classic edge detector tends to give poor results for labeling edge pixels, when an edge, although

Abdallah A. Alshennawy, Assistant Professor, Design and prod. Eng. Dept. Tanta University, Egypt (e-mail: abd_alshennawy@yahoo.com).

Ayman A. Aly, Associate Professor, is with Mechatronics section, Assiut University, 71516, Egypt (e-mail: ayman_aly@yahoo.com).

definite, represents only a smallish gray-scale jump. Yet often such edges are clearly visible to the human eye. In summary, feature points are characterized by their relationship to pixels values within some local window.

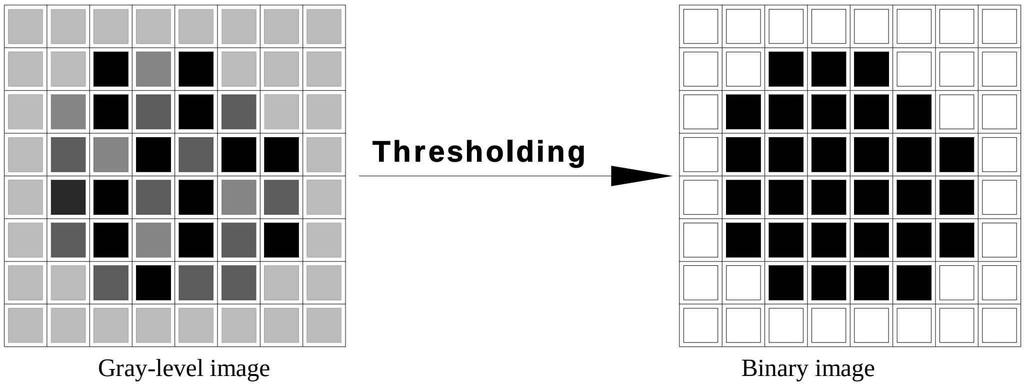


Fig. 1 Measuring the object elongatedness in gray-level and binary images

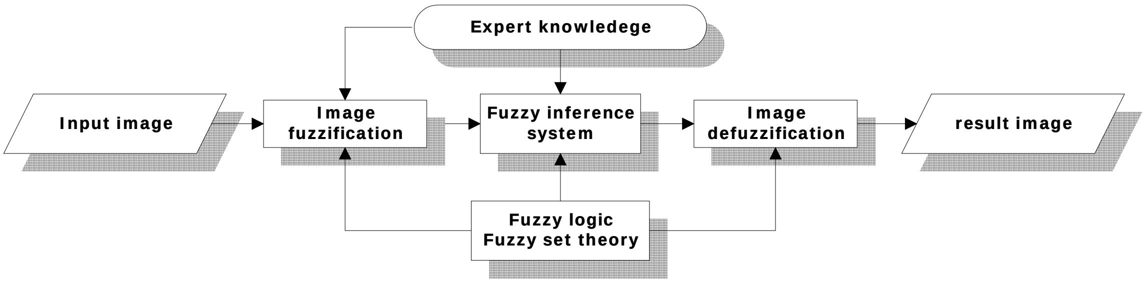


Fig. 2 The general structure of fuzzy image processing

Recent research has concerned using neural Fuzzy Feature to develop edge detectors, after training on a relatively small set of proto-type edges, in sample images classifiable by classic edge detectors. This work was pioneered by Bezdek et al, [26] who trained a neural net to give the same fuzzy output as a normalized Sobel Operator. However, work by the writer and collaborators has shown that training NN classifiers to *crisp* values is a more effective variant of Bezdek's scheme. The advantage of the *neural fuzzy* edge detector over even the traditional edge detector on which the *neural fuzzy* form was based is very apparent.

In the system described in [27, 28], all inputs to the fuzzy inference systems (FIS) system are obtained by applying to the original image a high-pass filter, a first-order edge detector filter (Sobel operator) and a low-pass (mean) filter. The whole structure is then tuned to function as a contrast enhancing filter and, in another problem, to segment images in a specified number of input classes. The adopted fuzzy rules and the fuzzy membership functions are specified according to the kind of filtering to be executed.

In this paper a novel FIS method based on fuzzy logic reasoning strategy is proposed for edge detection in digital images without determining the threshold value or need training algorithm. The proposed approach begins by segmenting the images into regions using floating 3x3 binary matrix. A direct fuzzy inference system mapped a range of values distinct from each other in the floating matrix to detect the edge.

A. Fuzzy Image Processing

Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification as shown in Fig. 2. The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values).

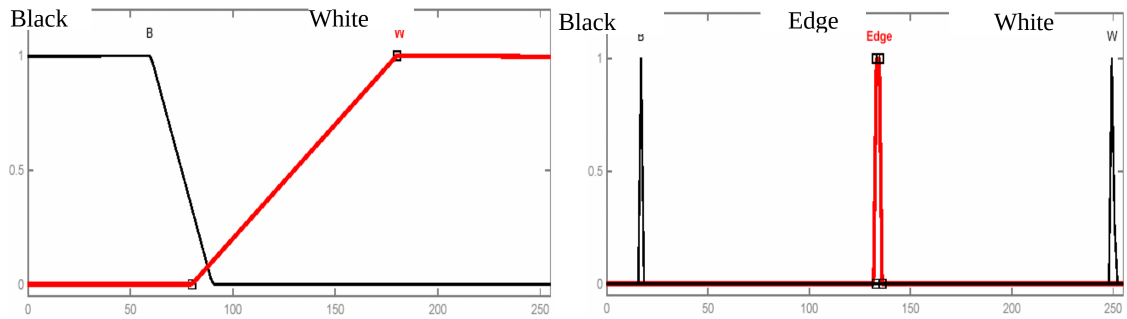
After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach, a fuzzy integration approach and so on, [29].

B. Fuzzy Sets and Fuzzy Membership Functions

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", Edge and

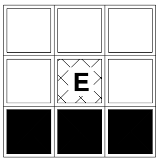
International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:3, No:3, 2009

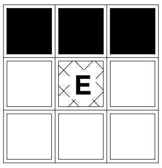
"white". The adopted membership functions for the fuzzy sets associated to the input and to the output were triangles, as shown in Fig.3.



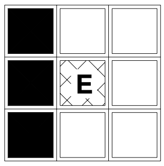
(a) (b)

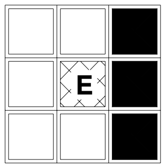
Fig. 3 Membership functions of the fuzzy sets associated to the input and to the output



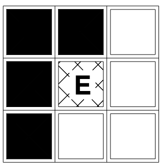


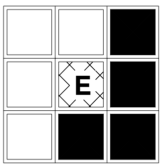
Rule1	If {(i-1, j-1) & (i-1, j) & (i-1, j+1) } are whites If {(i, j-1) & (i, j) & (i, j+1) } are whites If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are blacks	checked pixel is **Edge**
Rule2	If {(i-1, j-1) & (i-1, j) & (i-1, j+1) } are blacks If {(i, j-1) & (i, j) & (i, j+1) } are whites If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are whites	checked pixel is **Edge**
Rule3	If {(i-1, j-1) & (i, j-1) & (i+1, j-1) } are blacks If {(i-1, j) & (i, j) & (i+1, j) } are whites If {(i-1, j+1) & (i, j+1) & (i+1, j+1)} are whites	checked pixel is **Edge**
Rule4	If {(i-1, j-1) & (i, j-1) & (i+1, j-1) } are whites If {(i-1, j) & (i, j) & (i+1, j) } are whites If {(i-1, j+1) & (i, j+1) & (i+1, j+1)} are blacks	checked pixel is **Edge**



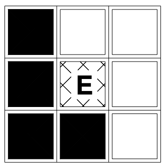


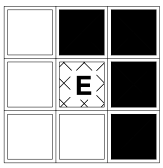
(a)





Rule5	If {(i-1, j) & (i-1, j-1) & (i, j-1) & (i+1, j-1)} are blacks If {(i-1, j+1) & [i, j+1] & (i+1, j+1) &(i+1, j)} are whites If (i, j) is white	checked pixel is **Edge**
Rule6	If {(i-1, j) & (i-1, j-1) & (i, j-1) & (i+1, j-1)} are whites If {(i-1, j+1) & [i, j+1] & (i+1, j+1) & (i+1, j)} are blacks If (i, j) is white	checked pixel is **Edge**
Rule7	If {(i-1, j-1) & (i, j-1) & (i+1, j-1) & (i+1, j)} are blacks If {(i-1, j) & (i-1, j+1) & (i, j+1) & (i+1, j+1)} are whites If (i, j) is white	checked pixel is **Edge**
Rule8	If {(i-1, j) & (i-1, j+1) & (i, j+1) & (i+1, j+1)} are blacks If {(i-1, j-1) & (i, j-1) & (i+1, j-1) & (i+1, j)} are whites If (i, j) is white	checked pixel is **Edge**





(b) Fig. 4 The Fuzzy System rules

[i-1, j-1]	[i-1, j]	[i-1, j+1]
[i, j-1]	[i, j]	[i, j+1]
[i+1, j-1]	[i+1, j]	[i+1, j+1]

Floating mask 3x3

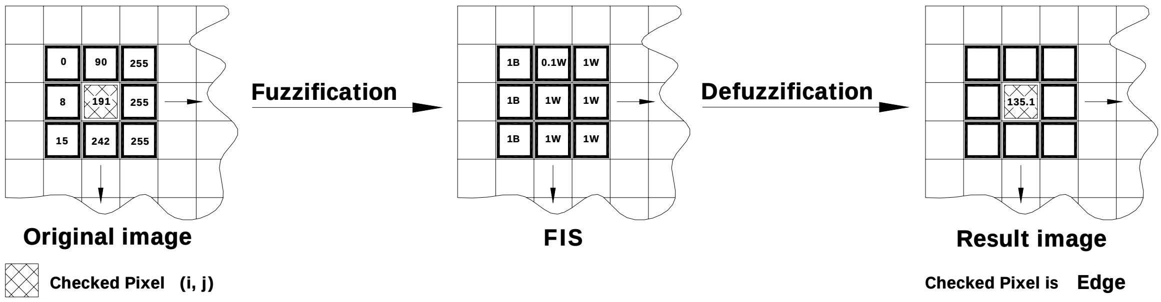


Fig. 5 Steps of fuzzy image processing

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 lom of the resulting membership function. The values of the three memberships function of the output are designed to separate the values of the blacks, whites and edges of the image.

C. Inference Rules Definitions

The inference rules is depends on the weights of the eight neighbors gray level pixels, if the neighbors weights are degree of blacks or degree of whites. The powerful of these rules is the ability of extract all edges in the processed image directly. This study is assaying all the pixels of the processed image by studying the situation of each neighbor of each pixel. The condition of each pixel is decided by using the floating 3x3 mask which can be scanning the all grays. In this location, some of the desired rules are explained. The first four rules are dealing with the vertical and horizontal direction lines gray level values around the checked or centered pixel of the mask, if the grays represented in one line are black and the remains grays are white then the checked pixel is edge (Fig.4-a). The second four rules are dealing with the eight neighbors also depending on the values of the gray level weights, if the weights of the four sequential pixels are degree of blacks and the weights of the remain fours neighbors are the degree of whites, then the center pixel represents the edge (Fig.4-b). The introduced rules and another group of rules are detecting the edges, the white and the black pixels. The result images contribute the contours, the black and the white areas. 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 as shown in Fig. 5. The output of the FIS according to the defuzzification is presented again to the values from 0-255. and then the black, white and edge are detected. From the experience of the tested images in this study, it is found that the best result to be achieved at the range black from zero to 80 gray values and from 80 to 255 meaning that the weight is white.

III. Experiments

The proposed system was tested with different images, its performance being compared to that of the Sobel operator and the proposed FIS method. The firing order associated with each fuzzy rule were tuned to obtain good results while extracting edges of the image shown in Fig. 6, where we used this image as comparative model for the classical Sobel operator and the FIS method. The original image is shown in part a of Fig. 6. The edge detection based on Sobel operator using the image processing toolbox in MATLAB is illustrated at the part b. The white pixels on the map indicate there are edges, thus will be preserved from smoothing. There is obviously some noise left on the edge map and some of the edges are corrupted. By applying the new FIS on the image to detect its edges, it is found that the modified version of edge map has less noise and less edge corruption as shown on the image of Fig.6.c.

For the segmentation task, a thin edge is better because we only want to preserve the edge rather than the details in the neighborhood. The values of the edge map are normalized to the interval of 0 and 1 to represent the edginess membership values.

The original captured image is shown in Fig.6.a. We observe, in part b, that the Sobel operator with threshold automatically estimated from image's binary value does not allow edges to be detected in the regions of low contrast. So which results in two edges being detected (double edges) at the left side of part b. The FIS system, in turn, allows edges to be detected even in the low contrast regions as illustrated in part c. This is due to the different treatment given by the fuzzy rules to the regions with different contrast levels, and to the rule established to avoid including in the output image pixels not belonging to continuous lines.

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:3, No:3, 2009

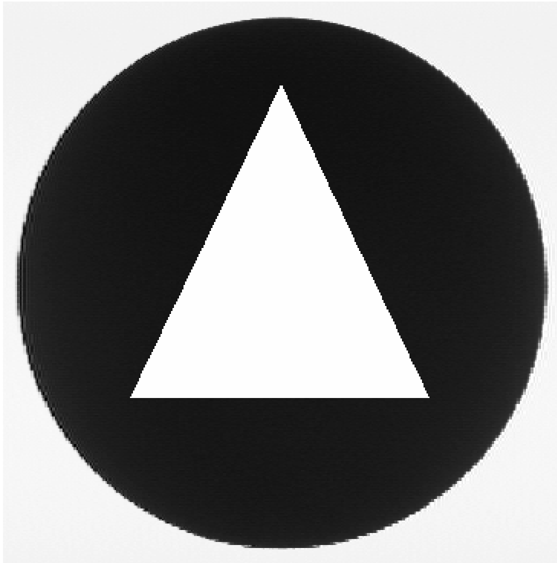


Fig.6-a. Original captured picture
for test triangular edges

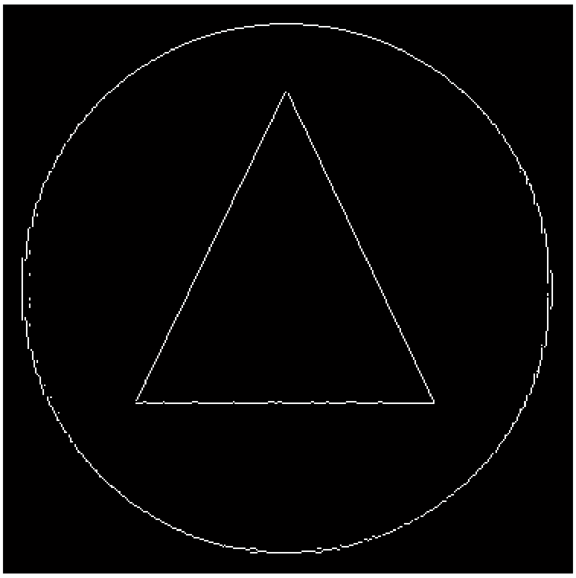


Fig.6-b. Edge map detected using classical
Sobel operator.

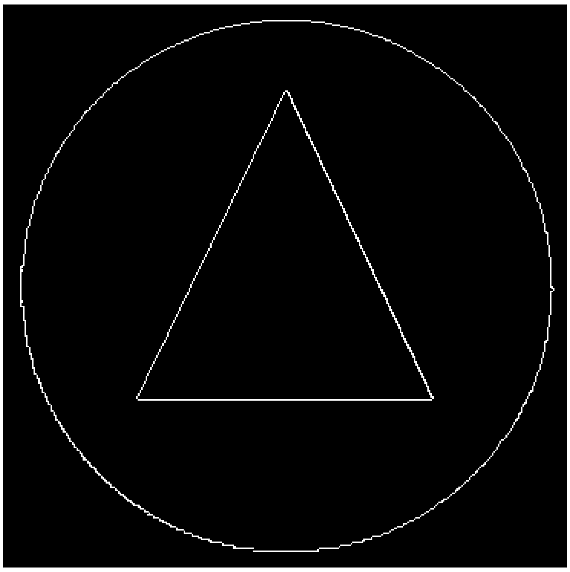


Fig. 6-c. Image edges are extracted using
fuzzy inference rules.

In Fig. 7, a synthetic image of a measured object with its edges detached in black is shown part a. When Sobel operator is applied to this image, a disconnected edge appeared on the left side,. The adoption of fuzzy rules specifically established to avoid double edges results in obtaining an image with single edges when the FIS system is applied to the same image (c). It is gave a permanent effect in the lines smoothness and straightness.

To demonstrate the enhancement of the performance on the edge detection, with different gray level image of the gear tooth are shown in Fig.8. The resulting images of our fuzzy technique seem to be much smoother with less noise in the flat areas and sharper in the edgy regions than the conventional Sobel operator.

Fig.7-a. Original captured picture for test of circular and rectangular edges.

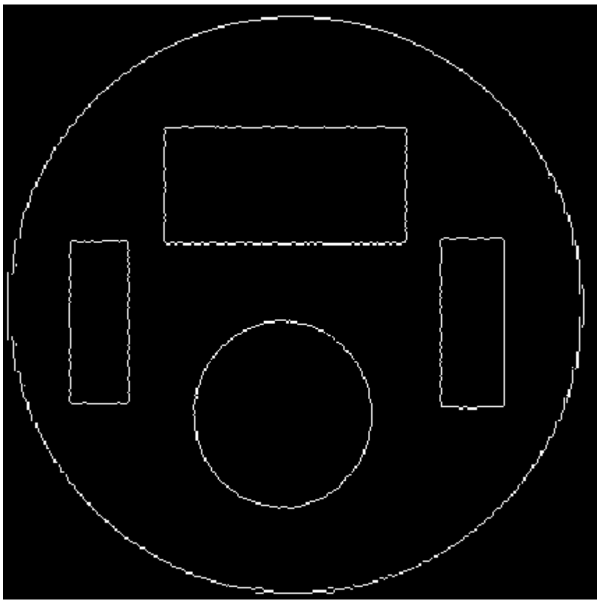


Fig. 7-b. Edge map detected using classical Sobel operator.

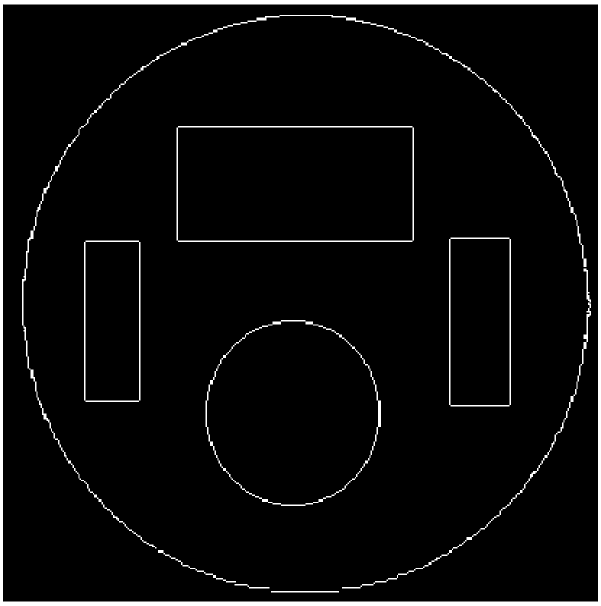


Fig. 7-c. Edges detected by the FIS system where the same designed rules are used.

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:3, No:3, 2009

Fig.8-a. Original captured picture for test of gear tooth edges

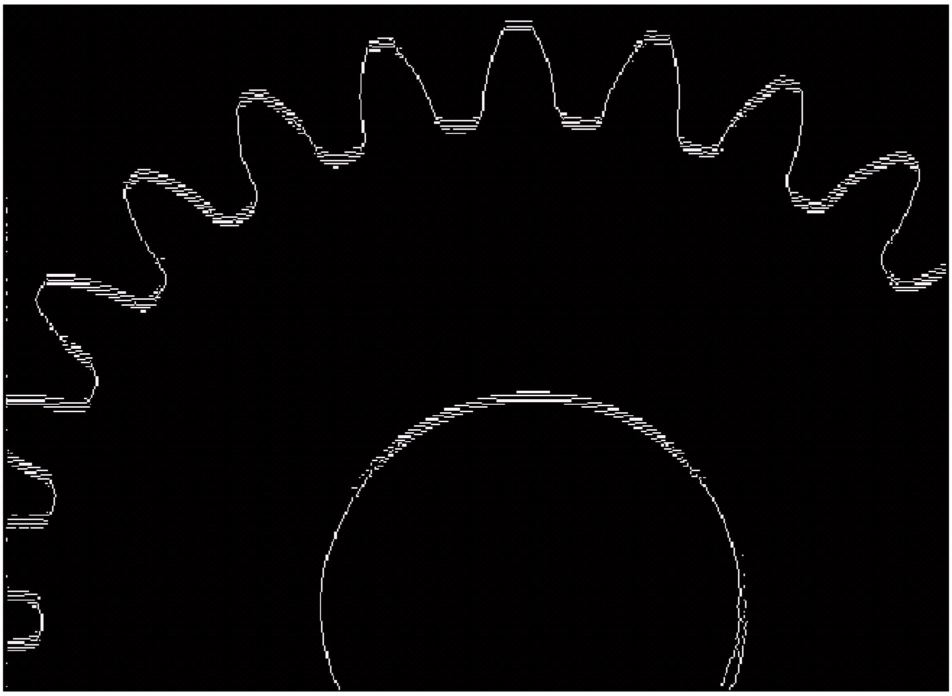


Fig. 8-b. Edge map detected using Sobel operator in Matlab

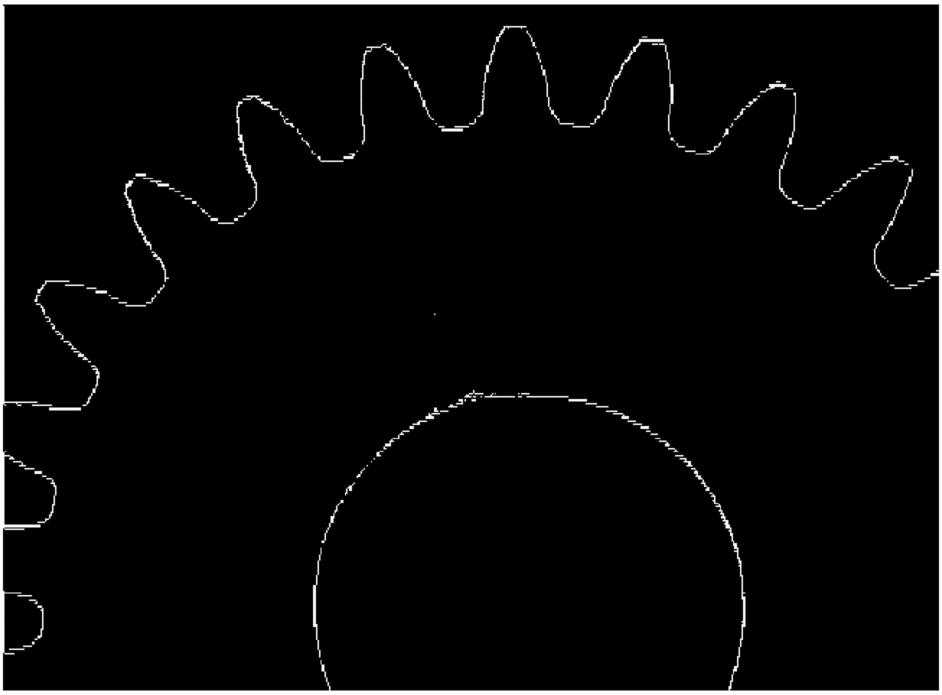


Fig. 8-c. Edges detected by the proposed FIS system

IV. Conclusion

Because of the uncertainties that exist in many aspects of image processing, fuzzy processing is desirable. These uncertainties include additive and non-additive noise in low-level image processing, imprecision in the assumptions underlying the algorithms, and ambiguities in interpretation during high level image processing. For the common process of edge detection usually models edges as intensity ridges. Nevertheless, in practice this assumption only holds approximately, leading to some of the deficiencies of these algorithms. Fuzzy image processing is a powerful tool form formulation of expert knowledge edge and the combination of imprecise information from different sources.

The designed fuzzy rules are an attractive solution to improve the quality of edges as much as possible. One past drawback of this type of algorithm was that they required extensive computation. These results allow us to conclude that:

- The implemented FIS system presents greater robustness to contrast and lighting variations, besides avoiding obtaining double edges.
- It is gave a permanent effect in the lines smoothness and straightness for the straight lines and for the curved lines it gave good roundness. In the same time the corners get sharper and can be defined easily.

References

[1] I.M. Elewa, H.H Soliman and A.A. Alshennawy. "Computer vision Methodology for measurement and Inspection: Metrology in Production area ". Mansoura Eng. First conf. Faculty of Eng. Mansoura Univ., March 28-30,1995,Pp. 473-444.

[2] A. A. Alshennawy, "Measurement and Inspection of Three Dimensional Objects Using Computer Vision System", Pd.D thesis, Mansoura University, Egypt, 2003.

[3] H. D. Hofmann, "Application of Intelligent Measurements with Metrical Image Processing for Quality Control", presented at the 5th International Conference, PEDAC' 92, Alexandria, EGYPT, December 1992.

[4] R.T. Chin., C.A. Harlow, "Automated Visual Inspection: A survey ", IEEE Trans. Pattern Anal. Machine Intell., Vol. PAMI-4, pp. 557-573, November 1982.

[5] P. Rummel, "GSS – A Fast, Model-Based Gray-Scale Sensor System for Workpiece Recognition", Proceed. of 8th International Conf. on Pattern Recognition, pp. 18-21, Paris, France, Oct. 27-31, 1986.

[6] B. G. Batchelor, D. A. Hill and D. C. Hodgson (Eds.), "Automated Visual Inspection", IFS Publications Ltd., UK, 1985.

[7] A. M. Darwish and A. K. Jain, "A Rule Based Approach for Visual Pattern Inspection ", IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. 10, No. 1, pp. 56-68, January 1988.

[8] G. Maitre, H. Hugli, F. Tieche and J. P. Amann, "Range Image Segmentation Based on Function Approximation", published at ISPRS90, Zurich, Sept. 1990.

[9] Md. Shoiab Bhuiyan, Yuiji Iwahori, and Akira Iwata., Optimal edge detection under difficult imaging conditions. Technical report, Educational Center for Information Processing and Dept. of Electrical and Computer Engineering, Nagoya Institute of Technology, Showa, Nagoya, 466-8555, JAPAN.

[10] Srinivasan,M. V., Chahl, J. S.,Weber, K., Venkatesh, S., Nagle, M. G., and Zhang, S.W.: Robot navigation inspired by principles of insect vision, Robotics Autonom. Systems 26(2/3) (1999), 203–216.

[11] Suh, I. H. and Kim, T.W.: Fuzzy membership function-based neural networks with applications to the visual servoing of robot manipulators, IEEE Trans. Fuzzy Systems 2(3) (1994), 203–220.

[12] Md. Shoaib Bhuiyan, Hiroshi Matsuo, Akira Iwata, Hideo Fujimoto, and Makoto Sato. An improved neural network based edge detection method. Technical report, Dept. of Electrical and Computer Engineering and Dept. of Mechanical Engineering, Nagoya Institute of Technology, Nagoya, JAPAN 466.

[13] I. Fourmousis, U. Burgin, M. Tonetti, and N.P. Lang, "Digital image processing I Evaluation of gray level correction methods in vitro", Clin. Oral Impl. Res., pp.1-11, Sept. 1993.

[14] H.G. Grondahl, K. Grondahl, and R.L. Webber, "A digital subtraction technique for dental radiography", Oral Surg., vol.55, number 1, pp.96-102, Jan. 1983.

[15] P.F. van der Stelt, W.J. van der Linden, W.G.M. Geraets, C.L. Alons, "Digitized pattern recognition in the diagnosis of periodontal bone defects", Journal of Clinical Periodontology, vol. 12, p.822-827, 1985.

[16] Santiago Aja, C. Alborola, J. Ruiz, “Fuzzy anisotropic diffusion for speckle filtering”, IEEE Intl. Conf. on Acoustics, Speech, and Signal Processing, Vol. 2 , 2001, pp. 1262-1264.

[17] G.I. Sanchez-Ortiz, A. Noble,“Fuzzy clustering driven anisotropic diffusion: enhancement and segmentation of cardiac MR images”, Nuclear Science Symposium, Vol. 3 , 1998, pp. 1873 -1874.

[18] R.L. Webber, U.E. Ruttimann, and R.A.J. Groenhuis, "Computer correction of projective distortions in Dental Radiographs", J. Den. Res., vol. 63, No. 8, pp.1032-1036, August 1984.

[19] Song Wang, Feng Ge, Tiecheng Liu, "Evaluating Edge Detection Through Boundary Detection", Department of Computer Science and Engineering, University of South Carolina, Columbia, SC 29208, USA, 2006.

[20] Ivan Christov, " Multiscale Image Edge Detection",1.130/18.327, Spring 2004, Final Project, May 12, 2004.

[21] Nor Ashidi Mat Isa, " Automated Edge Detection Technique for Pap Smear Images Using Moving K-Means Clustering and Modified Seed Based Region Growing Algorithm", International Journal of The Computer, the Internet and Management Vol. 13.No.3 (September-December, 2005) pp 45-59.

[22] C.C. Leung, F.H.Y. Chan, K.Y. Zee, P.C.K. Kwok, "Compensation of bending errors in Intra-oral Radiographs using Block-by-Block Image Scaling", IEEE Trans. On Biomedical Engineering. (In manuscript).

[23] C.C. Leung, P.C.K. Kwok, K.Y. Zee, F.H.Y. Chan, and S.T.F. Lo, "Minimizing the bending error in Intra-oral Radiographs using Point-by-Point Interpolation with image scaling", Proceedings of the EMBEC'99, Part II, pp.1050-1051, Nov. 1999. Vienna.

[24] W.F. Chen, X.Q. Lu, J.J. Chen, and G.X. Wu, "A new algorithm of edge detection for color image: Generalized fuzzy operator", Science in China (Series A), Vol.38, No.3, pp.468-473, 1998.

[25] C.C. Leung, F.H.Y. Chan, W.F. Chen, P.C.K. Kwok and K.Y. Lam, “Thyroid Cancer Cells Boundary Location by a Fuzzy Edge Detection Method” ICPR’2000, Sept. 2000.

[26] Kuo, R. J.: A robotic die polishing system through fuzzy neural networks, Comput. Industry 32(3) (1997), 273–280.

[27] Tizhoosh H.R., “Fast fuzzy edge detection”, Proceedings of Fuzzy Information Processing Society, 2002, pp. 239-242.

[28] Lin, C. T. and Lee, S. G.: Reinforcement structure/parameter learning for neural network based fuzzy logic systems, IEEE Trans. Fuzzy Systems 2(1) (1994), 46–63.

[29] Ayman A. Aly, H. Ohuchi and A. Abo-Ismail, “Fuzzy Model Reference Learning Control of 6-Axis Motion Base Manipulator”, 7th IEEE International Conference on Intelligent Engineering Systems, Luxer, March, 2003.