International Journal of Multimedia and Ubiquitous Engineering
Vol.9, No.3 (2014), pp.1-10
http://dx.doi.org/10.14257/ijmue.2014.9.3.01

Fuzzy Scratch Inspection of Sight-Corrective Spectacle Lenses

Kwang Baek Kim[1], Doo Heon Song[2] and Young Woon Woo[3]

[1]*Department of Computer Engineering, Silla University, Korea*
[2]*Department of Computer Games, Yong-in SongDam University, Korea*
[3]*Department of Multimedia Engineering, Dong-Eui University, Korea*

gbkim@silla.ac.kr, dsong@ysc.ac.kr, ywwoo@deu.ac.kr

Abstract

In this paper, we propose an automatic scratch inspection method to detect small scratches from eyeglasses using fuzzy logic. Inspecting scratches of eyeglasses largely depends on the native eye exam of field opticians that may lead providing possibly harmful eyeglasses to customers at optician's shop. Usually those small scratches are often occurred in the process of transportation rather than that of production thus field opticians have burden of preventing selling defected lenses. Our method computes the possibility of ill-effect by scratch on glasses with membership degree of the scratch size and that of distance between the center and the scratch from candidate scratched areas extracted in the pre-processing phase. Two-phase preprocessing mechanism as this paper offers improves the sensitivity and accuracy of detecting scratches from previous study. Our method is applied to CHEMI MID HL HM sight-corrective dioptric lenses in experiment and it is verified that the proposed method is sufficiently effective by real optician's evaluation.

Keywords: *Dioptric lens, Fuzzy logic, Scratch extraction, Eyeglass inspection, Eyeglass defection*

1. Introduction

Interest in designing an automatic visual defect inspection system in the manufacturing industry keeps growing in recent decade. Those critical defect inspection systems were usually based on fuzzy logic or fuzzy neural network in various products manufacturing such as wood [1], fabric [2], and TFT-LCD [3]. Usually those systems are at the final stage of production cycle for quality assurance

Among such production industries sensitive to defect inspection, eyeglass production and circulation system has a different type of problem in its quality control. Designing spectacle lens involves multiple thin coating processes such as hard coating and UV coating. Thus, it is important not to make any scratch to protect sight vision and reducing visual fatigue effect [4]. In the production cycle, a rigorous defect test is performed with laser beam to make sure that the product has no harmful scratches and the surface of lens is precisely coated [5].

However, in this industry, small scratches of completed products usually occur in the process of transportation from factory to optician's shops unlike others. Although those scratches are minute and still the glass has most functions of the production purposes, those minute scratches may not be identifiable by optician's native eye test before retailing and become the source of complaints from customers.

ISSN: 1975-0080 IJMUE

In this paper, we try to provide an intelligent method to help solving such optician's problem. If opticians are able to detect such small but harmful scratches before selling and provide appropriate actions, the business will be more reliable.

Our proposed method is based on image processing techniques and fuzzy logic. Like previous study [6], we first extract candidate scratched areas in the preprocessing phase and then take into account the size of such areas and distances from the center of the lens to see if those scratches have sufficiently bad effect to customers if sold by fuzzy logic. However, the previous study [6] often failed to extract defects since the lens boundaries were more salient than small scratches in pre-processing phase so that those scratches were not detectable. Therefore, our focus in this paper is on the accurate handling of pre-processing phase by two-phase handling of preprocessing thus subsequent image processing and fuzzy logic schemes become more reliable. This experience will show us the fuzzy logic based intelligent inspection software can solve a good deal of real world problems like lens scratch inspection.

2. Extracting Lens Area with Image Processing

The overall process of detecting and analyzing lens scratches is as shown in Figure 1.

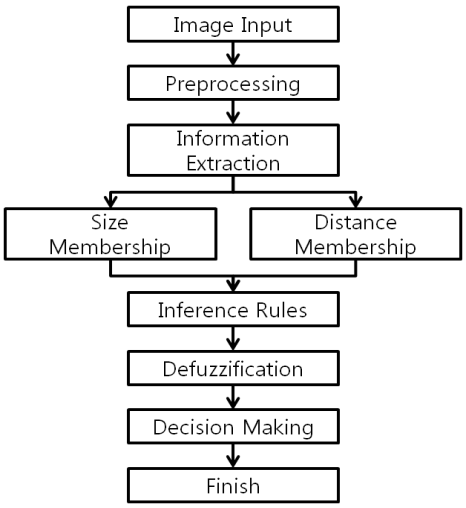


Figure 1. Flow of lens scratch inspection [6]

Applying fuzzy logic to an industrial product defect inspection is not new. If the factors of deciding defect are well chosen, the power of fuzzy membership functions and inference rules can overcome the uncertainty of defect identification as successfully applied to other areas [2, 7, 8].

Since our goal is to identify if the possible scratch has harmful effect to customer's eyes, we provide two factors to make the decision - the size of scratch and the distance from the center of the lens - that would be obtained from the image preprocessing phase.

The very first step of the preprocessing stage is to detect and extract lens boundary. In [6], we used Sobel mask that is good to average salient values out to extract edges of scratches and boundaries. However, that method tends to give too much saliency to boundaries so that small scratches can be ignored thus falsely treat the defected lens as a normal lens. Thus, in this paper, we label the lens area first and Sobel mask is applied only to the inside of the lens after noise removal.

As shown in Figure 2, a series of image processing techniques are applied to detect the lens area.

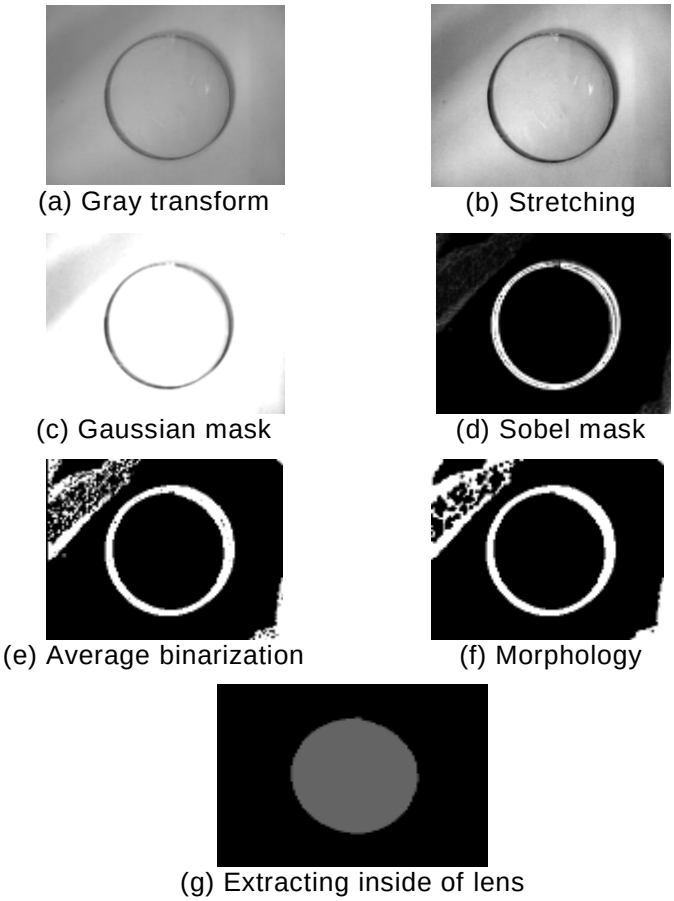


Figure 2. Process of extracting lens area

3. Extracting Scratches with Fuzzy Logic

Only after obtaining lens area, Sobel Mask is again applied to detect edges inside the lens area as shown in Figure 3.

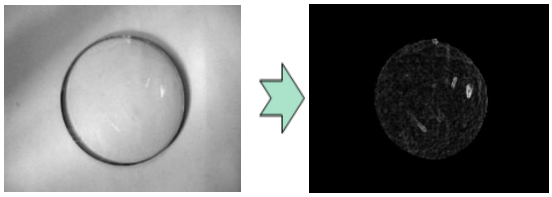
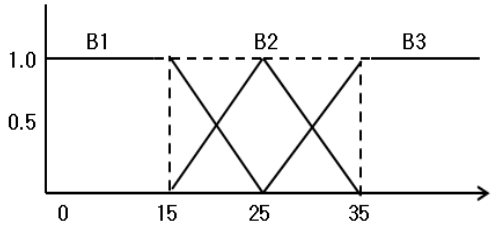


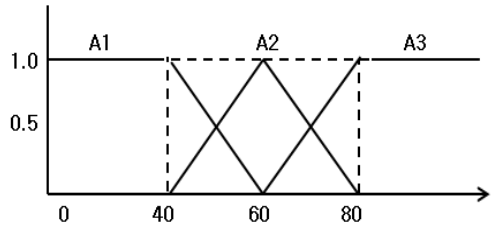
Figure 3. Edge extraction in the lens area

Again, labeling technique is applied to obtain scratches after average binarization of the result of Figure 3. However, reflected light might be extracted as scratches in this process. Therefore, we setup a fuzzy technique to discard those false positives and only extract scratches.

We need two fuzzy membership functions to take features of the scratch as shown in Figure 4.



(a) Membership function for scratch size



(b) Membership function for the distance between the center and the scratch (mm scale)

Figure 4. Fuzzy membership functions for scratch extraction

The membership degree of Figure 4 (a) is decided by formula (1) ~ (3) with respect to the interval B1 ~ B3 as X in the formula below denote the size of the scratch.

$$\begin{aligned} &If\,(X \le 15)\ then\ \mu(X) = 1 \\ &Else\ If\,(X \ge 25)\ then\ \mu(X) = 0 \\ &Else\ \mu(X) = \frac{25 - X}{25 - 15} \end{aligned} \tag{1}$$

$$\begin{aligned} &If\,(X \le 15)\ or\,(X \ge 35)\ then\ \mu(X) = 0 \\ &Else\ If\,(X \ge 25)\ then\ \mu(X) = \frac{35 - X}{35 - 25} \\ &Else\ \mu(X) = \frac{X - 15}{25 - 15} \end{aligned} \tag{2}$$

$$\begin{aligned} &If\,(X \ge 35)\ then\ \mu(X) = 1 \\ &Else\ If\,(X \le 25)\ then\ \mu(X) = 0 \\ &Else\ \mu(X) = \frac{X - 25}{35 - 25} \end{aligned} \tag{3}$$

The membership degree is decided by formula (4) ~ (6) with respect to the interval A1 ~ A3 of Figure 4 (b) as X in the formula below denote the distance between the scratch and the center.

$$If\ (X \le 40)\ then\ \mu(X) = 1$$
$$Else\ If\ (X \ge 60)\ then\ \mu(X) = 0 \quad (4)$$
$$Else\ \mu(X) = \frac{60 - X}{60 - 40}$$

$$If\ (X \le 40)\ or (X \ge 80)\ then\ \mu(X) = 0$$
$$Else\ If\ (X \ge 60)\ then\ \mu(X) = \frac{80 - X}{80 - 60} \quad (5)$$
$$Else\ \mu(X) = \frac{X - 40}{60 - 40}$$

$$If\ (X \ge 80)\ then\ \mu(X) = 1$$
$$Else\ If\ (X \le 60)\ then\ \mu(X) = 0 \quad (6)$$
$$Else\ \mu(X) = \frac{X - 60}{80 - 60}$$

As the size of the scratch is directly proportional and the distance is inversely proportional to the harmful effect to the eyes [4], we need a set of fuzzy inference rules to compute final membership degree. Table 1 shows the inference rules as if-then format and the MIN-MAX inference is applied to make a decision.

Table 1. Fuzzy inference rules

Rule Number	Rule Description
Rule#1	if x is A1 and Y is B1 then W is BM
Rule#2	if x is A1 and Y is B2 then W is B
Rule#3	if x is A1 and Y is B3 then W is B
Rule#4	if x is A2 and Y is B1 then W is SM
Rule#5	if x is A2 and Y is B2 then W is M
Rule#6	if x is A2 and Y is B3 then W is BM
Rule#7	if x is A3 and Y is B1 then W is S
Rule#8	if x is A3 and Y is B2 then W is S
Rule#9	if x is A3 and Y is B3 then W is SM

The effect of scratch to eyes is classified into five different intervals by real world expert's suggestion - S, SM, M, ML, L as S, M, L denotes small, medium, and large in respectively. Figure 5 shows the final decision making membership function and formula (7) shows the center of gravity defuzzification rule [11].

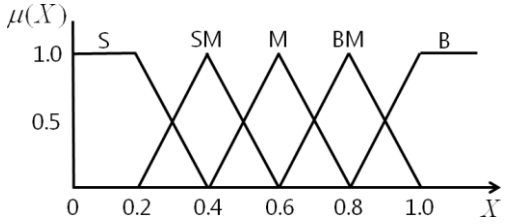


Figure 5. Membership function for bad effect by the scratch

$$p^* = \frac{\sum \mu(Y_i) X_i}{\sum \mu(Y_i)} \tag{7}$$

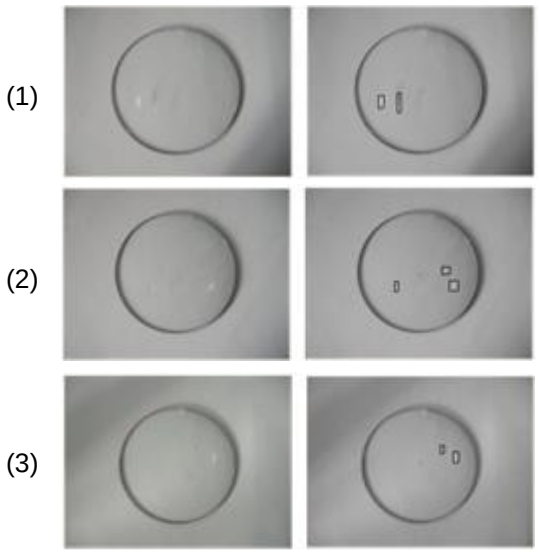
Experimental decision threshold 0.3 was chosen after consulting with real world opticians in that object of having defuzzified value less than 0.3 has extremely low possibility to be a scratch based on the morphological characteristic thus we remove it as noise. Figure 6 shows the result scratches extracted.

(a) Average binarized inside lens area (b) Applying fuzzy logic

Figure 6. Extracting scratches with fuzzy logic

4. Experiment and Analysis

The proposed method was implemented with Microsoft Visual Studio .NET 2008 on an IBM-compatible PC with Intel Pentium-IV 3 GHz CPU and 1.5GB RAM. 10 Digital images of CHEMI MID HL HM sight-corrective dioptric lenses were used in the experiments.

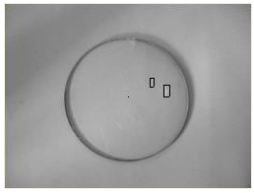


(a) Original images (b) Scratches

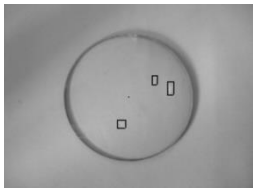
Figure 7. Scratches from the original image by the proposed method

Figure 7 shows the result of extracting scratches from various lens images. In Figure 8, the result demonstrates the case that previous study [6] was incomplete but the new method had more accurate result.

(a) Original lens image



(b) Result from [6]



(c) Result by the proposed method

Figure 8. Comparison with previous study in scratch detection

For those three example cases, our fuzzy logic inference engine determines the membership degree of harmful effect to eyes as Table 2, which is accepted by field opticians.

Table 2. Defect of scratched lens

Image Number	Number of Scratches	Harmful Membership Degree
Image (1)	2	78%
Image (2)	3	76%
Image (3)	2	72%

5. Conclusion

Spectacle lens may have unexpected scratches during the process of transportation. The usual naked eye inspection is not sufficiently reliable to detect those minute scratches on lens. Those small scratches are harmful to protect sight vision and/or increasing visual fatigue effect thus frequently could be the source of customer's complaints.

Our effort to apply fuzzy logic to sight-corrective spectacle lens scratch inspection is to show that the proposed intelligent tool can help opticians in a real world problem solving.

A series of image processing techniques removes inappropriate parts from original lens image and extract scratches. Two-phase preprocessing is designed to compensate the drawback of previous study [6] and the proposed method is proven to be more sensitive and accurate in scratch extraction than the previous one by the experiment. Then two membership functions for the size of the scratch and distance from the center with respect to the fuzzy inference rules decides if the scratched lens is harmful.

Using 10 images provided by optician with different types of dioptric lenses, the proposed method was successful to find scratches and computes the membership degree of such lenses with respect to the harmful effect and the verdict of the result by field expert was acceptable.

However, we also found that the proposed method may not succeed to find scratches too close to the boundary as Figure 9 demonstrates.

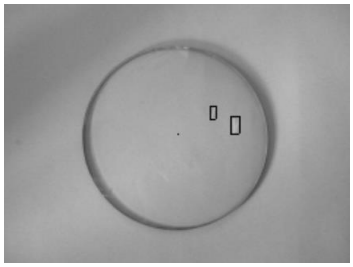


Figure 9. Failed extraction of scratches too close to boundary

However, the purpose of such inspection is usually for sight-corrective lenses (and all we used in this paper also belongs to that class) thus small scratches close to the boundary are not that important or harmful in real world.

The resultant number represented as a membership degree of harmful effect of lens in this paper does not exactly mean that the lens is defective. Thus, the clinical opinions from more opticians and eye doctors are necessary for the future research.

References

[1] G. A. Ruz and P. A. Estévez, "Image segmentation using fuzzy min-max neural networks for wood defect detection", In: Pham D.T., Eldukhri E., Soroka A. J. ed(s) 1st Virtual International Conference on Intelligence Production Machines and Systems (IPROMS 2005), Elsevier, Oxford, (**2005**), pp. 183-188.

[2] J. Liu and H. Ju, "Fuzzy Inspection of Fabric Defects Based on Particle Swarm Optimization (PSO)", Rough Sets and Knowledge Technology, Lecture Notes in Computer Science, vol. 5009, (**2008**), pp. 700-706.

[3] Y. H. Liua, S. H. Lina, Y. L. Hsueha and M. J. Lee, "Automatic target defect identification for TFT-LCD array process inspection using kernel FCM-based fuzzy SVDD ensemble", In Expert Systems with Applications, vol. 36, no. 2, Part 1, (**2009**), pp. 1978–1998.

[4] D. A. Atchison, K. L. Schmid, K. P. Edwards, S. M. Muller and J. Robotham, "The effect of under and over refractive correction on visual performance and spectacle lens acceptance", Ophthalmic and Physiological Optics, vol. 21, no. 4, (**2001**), pp. 255-261.

[5] S. Ryu, S. Lee and J. Song, "Changes of Visual Acuity and Ophthalmic Symptoms in Female Workers examining Silver Plating Products", Journal of the Korea Society for Preventive Medicine, vol. 30, no. 3, (**1997**), pp. 567-576.

[6] K. B. Kim, D. H. Song, J. -H. Cho and Y. W. Woo, "Scratch Inspection of Spectacle Lens Based on Fuzzy Logic, Future Information Communication Technology and Applications, Lecture Notes in Electrical Engineering, vol. 235, (**2013**), pp. 931-938.

[7] K. B. Kim, "A Semiconductor Defect Inspection Using Fuzzy Reasoning Method", Journal of Korean Institute of Maritime Information and Communication Sciences, vol. 14, no. 7, (**2010**), pp. 1551-1556.

[8] G. Yinyu and N. -H. Kim, "A Study on Wavelet-based Image Denoising Using a Modified Adaptive Thresholding Method., Journal of information and communication convergence engineering, vol. 10, no. 1, (**2012**), pp. 45-52.

[9] J. K. Udupa and G. T. Herman, "3D Imaging in Medicine", CRC Press LLC, **(2000)**.

[10] K. B. Kim, D. H. Yu and Y. S. Hong, "Extraction of Muscle from Ultrasound Images of Cervical Regions," INFORMATION-An International Interdisciplinary Journal, vol. 16, no. 4, **(2013)**, pp. 2669-2678.

[11] R. Babuska, "Fuzzy Modeling for Control", Kluwer Academic Publishers, (**1998**).

Authors

Kwang Baek Kim

He received his M.S. and the Ph.D. degrees in Department of Computer Science from Pusan National University, Busan, Korea, in 1993 and 1999, respectively. From 1997 to present, he is a professor, Department of Computer Engineering, and Silla University in Korea. He is currently an associate editor for Journal of The Korea Society of Computer and Information, and The Open Artificial Intelligence Journal (USA). His research interests include fuzzy neural network and application, bioinformatics and image processing.

Doo Heon Song

He received a BS degree in Statistics & Computer Science from Seoul National University and MS degree Computer Science from the Korea Advanced Institute of Science and Technology in 1983. He received his PhD Certificate in Computer Science from the University of California in 1994. Form 1983-1986, he was a researcher at the Korea Institute of Science and Technology. He has been a professor at the Department of Computer Games, Songdam College, Korea, since 1997. His research interests include ITS, machine learning, artificial intelligence, medical image processing, cognitive, and game intelligence.

Young Woon Woo

He received his B.S. degree, M.S. degree and Ph.D. degree in electronic engineering from Yonsei University, Seoul, Korea in 1989, 1991 and 1997, respectively. Since 1997, he has been a professor in Department of Multimedia Eng., Dong-Eui University, Busan, Korea. His research interests are in the area of artificial intelligence, image processing, pattern recognition and medical information.

