A Fundamental Study on the Effect of Visual Guidance to Inspectors Using Visual Indicator on Defect Detection in Visual Inspection Utilizing Peripheral Vision

Ryosuke Nakajima[1(✉)], Kosuke Fujie[2], Takuya Hida[2], and Toshiyuki Matsumoto[2]

[1] Seikei University, Tokyo, Japan
nakajima@st.seikei.ac.jp
[2] Aoyama Gakuin University, Kanagawa, Japan
a5711069@aoyama.jp, {hida,matsumoto}@ise.aoyama.ac.jp

Abstract. In recent years, it is reported that a number of inspectors in the visual inspection process of industrial products utilized not only the central vision but also the peripheral vision. The visual inspection has been realized with both efficiency and accuracy. However, for the inspectors of many manufacturing industries to adopt this method, visual guidance is necessary for visual attention. Therefore, to obtain the fundamental knowledge for training of the visual inspection method, this study considers the effect of visual guidance on the defect detection performed by inspectors using visual indicators. Specifically, the presence or absence of visual guidance, defect location, and defect characteristics (luminance contrast between defect and inspection model and size) are designed as experimental factors. Further, the effect on inspection accuracy is evaluated with six subjects. As a result, it is clarified that the presence or absence of visual guidance does not affect the defect detection regardless of the defect location and defect characteristics. That is, the visual guidance is not an impediment to inspection accuracy; it is suggested that the visual guidance is an effective tool for the education and training of the visual inspection method utilizing peripheral vision.

Keywords: Visual inspection · Peripheral vision · Visual guidance

1 Introduction

To supply high-quality products to the market, manufacturing industries provide as much attention to product inspection as to processing and assembly. Two types of inspections exist: functional inspection and appearance inspection. In functional inspection, the effectiveness of a product is inspected. In appearance inspection, small visual defects such as scratches, surface dents, and unevenness of the coating color are inspected. The automation of functional inspection has advanced because it is easy to determine whether a product works [1, 2]. However, it is not as simple to establish

I. Moon et al. (Eds.): APMS 2018, IFIP AICT 536, pp. 465–472, 2018.
https://doi.org/10.1007/978-3-319-99707-0_58

standards to determine whether the appearance of a product is defective. First, many different types of defects exist. Second, the categorization of a product as non-defective or defective is affected by the size and depth of the defect. Third, some products have recently become smaller and more complex. Finally, the production has shifted to high-mix, low-volume production. It is thus difficult to develop technologies that can capture small defects and create algorithms that can identify multiple types of defects with high precision. Therefore, appearance inspection still strongly depends on human visual inspection [3–6].

As visual inspection is performed by humans, inspection efficiency and inspection accuracy differ among different inspectors. This is a common problem in many manufacturing industries. Recently, a visual inspection method utilizing peripheral vision was proposed [7–11], and the effectiveness of the method has been reported by manufacturing factories [12]. Human vision can be divided into two ranges. Central vision is the 1°–2° range of vision on either side of the center of the retina. The remaining range is known as peripheral vision. The spatial resolution of human vision decreases significantly with the increase in this angle from the center of the retina [13]. The visual inspection method utilizing peripheral vision involves two steps: First, a wide spatial range is searched by peripheral vision; subsequently, the type of defect is decided using the high-spatial resolution of the central vision. Thus, low-level processes such as sampling and clustering are processed using peripheral vision, whereas high-level processes such as discrimination are processed using central vision, such that the amount of information to be processed is reduced. This allows for efficient visual information processing to be realized [14]. The visual inspection method utilizing peripheral vision which can be realized high inspection efficiency and accuracy has been expected.

Based on the background above, in order to widely adopt the inspection method to the inspectors of many manufacturing industries, the authors considered the effect of inspection area, inspection time, eye movement, viewing distance, and other factors on defect detection [15–17]. The authors have also developed a training system to educate and to train inspectors using computers [18]. Through these studies, to educate and train the visual inspection method utilizing the peripheral vision, it is necessary to appropriately determine the points to be fixed, attention/consciousness range, and visual timing. It is found that to visual guidance for visual attention is necessary. However, it is possible that the visual guidance using a visual indicator affect an impediment to inspection efficiency and inspection accuracy, and their relationship has not been clarified.

Therefore, to obtain fundamental knowledge for the training of the visual inspection method, this study considers the effect of visual guidance on inspectors using visual indicators for defect detection. Specifically, an experiment is implemented using the presence or absence of visual guidance, defect location, and defect characteristics (luminance contrast between defect and inspection model and size) as experimental factors. The effect of these factors on the inspection accuracy is examined.

2 Experimental Design

2.1 Experimental Tasks

The experimental subjects are tasked with visually inspecting a model that is displayed on a monitor (MF403KIT42inch, METASIGN Inc.). A model with height and width both equal to 300 mm is used. The background color of the inspection model is set to an achromatic color (RGB values: (50, 50, 50)).

If no defect is detected, the subject presses the SPACE KEY on the keyboard, and the next inspection model is displayed. If a defect is detected, the subject presses the ENTER KEY. The experimental layout is shown in Fig. 1. To ensure a uniform visual distance between each subject and the inspection model, the chin holder is placed at a distance of 400 mm from the inspection model to fix the head position of a subject.

2.2 Experimental Factors

Presence or Absence of Visual Guidance
The presence or absence of the visual guidance is set to two different patterns. The inspection model with a black 10 mm diameter circle (as a fixation point) is set as the presence of visual guidance (Fig. 2-a). On the other hand, the inspection model without a black circle is set as the absence of visual guidance (Fig. 2-b). To lead the inspection utilizing peripheral vision, the subjects are requested to focus only on the center of the inspection model during the experiment.

Defect Locations
The inspection model is divided into sixteen parts (4 × 4 horizontally and vertically), and the defect is located at the center of either one of those parts. As shown in Fig. 2-c, the parts are divided into four areas, from area ① to area ④, according to the distance from the fixation point.

Defect Characteristics
The defect characteristics are defined by the luminance contrast between the inspection model and the defect, and by the size. The shape of all defects is circular. The luminance contrast of each defect is one of the three following levels: 0.10, 0.15, and 0.20. The defect size is specified by a diameter of 0.50 mm, 0.75 mm, and 1.00 mm. These defects are determined by assuming the standard of the appearance inspection. The list of defects using this experiment is shown in Fig. 3.

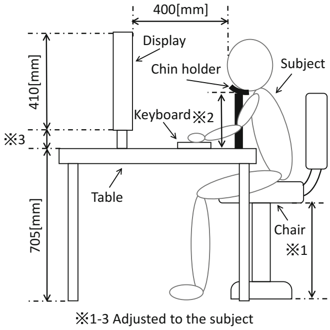


Fig. 1. Experimental layout

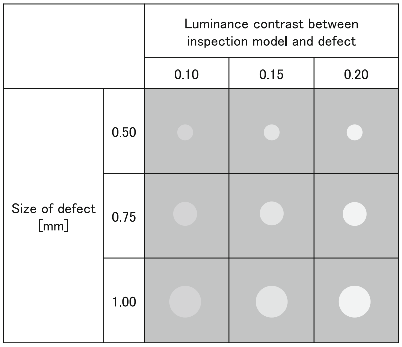
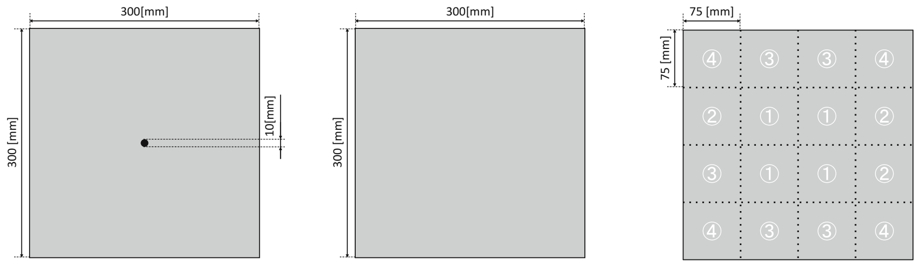


Fig. 3. Defects using the experiment



a. Inspection model (Presence of visual guidance)

b. Inspection model (Absence of visual guidance)

c. defect locations

Fig. 2. Inspection model and defect locations

2.3 Experimental Procedure

Six subjects, aged between 21 and 24 years, are employed in this experiment. Only subjects with a corrected eyesight score (decimal visual acuity) higher than 1.0 were employed. To familiarize the subjects with the experiment, an overview was provided and the experiment procedure was explained. In addition, the subjects were requested to perform some preliminary experiments. In the experiment, the task was to inspect 288 inspection models (144 non defective, 144 defective) for each case with the presence or absence of visual guidance.

The experimental room temperature was set between 18 °C and 24 °C, and the humidity was set between 40% and 60%. Since the luminance of the inspection model and the defect were affected by the external and internal light (such as fluorescent lighting), the experiment was implemented in a dark room. A written statement of the purpose and contents of the experiment was provided to the subjects, and informed consent was obtained from all subjects.

Using the results of the experiment, obtained using the aforementioned procedures, the defect detection rate was calculated, which is the number of detected defects divided by the number of total defects. It is expressed by Eq. (1) and is used as the evaluation index of the inspection accuracy.

$$\mathit{Defect\ detection\ rate}\ [\%] = \frac{\mathit{Numuber\ of\ detected\ defects}}{\mathit{Number\ of\ total\ defects}} \quad (1)$$

3 Experimental Results

3.1 Individual Characteristics of Subjects

Using the defect detection rate, the effect of the presence or absence of visual guidance is examined. Owing to the possibility that the individuality of the subject might influence the results, the uniformity of the results for all subjects is verified.

The defect detection rate of each subject is shown in Fig. 4. As a result of the Smirnov–Grubbs test shows no outlier values in the defect detection rates of any of the subjects. Therefore, the data from six subjects are used.

3.2 Effect of Visual Guidance on Inspection Accuracy

To analyze the effect of the presence or absence of visual guidance on the inspection accuracy, three-way ANOVA (analysis of variance) is executed with the presence or absence of visual guidance (2), defect location (4), and defect characteristics (9) as the factors. The ANOVA table is shown in Table 1. As a result, a significant difference is not observed for the main effect of the presence or absence of visual guidance, and their mutual interactions. On the other hands, a significant difference of 1% is observed for the main effect of the defect locations, defect characteristics, and their mutual interactions. The relationship between each experimental factor is shown in Fig. 5.

From the above, it is clarified that presence or absence of visual guidance does not affect the defect detection, regardless of the defect locations and the defect characteristics. That is, it is found that the visual guidance is not an impediment to inspection accuracy.

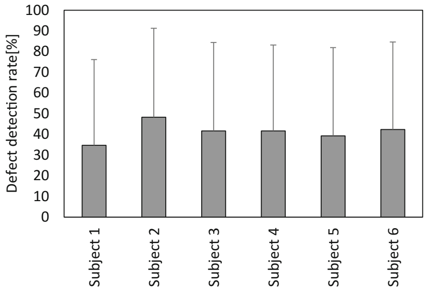
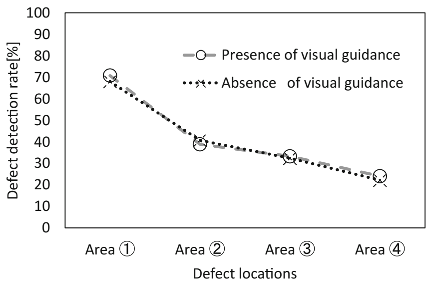


Fig. 4. Defect detection rate for each subject

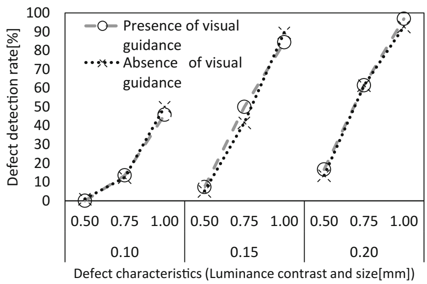
Table 1. ANOVA for defect detection rate

Factor	Sum of squares	Degrees of freedom	Mean square	*F*-value	Significant difference
Subject(S)	0.70	5	0.14		
Presence or absence of visual guidance(A)	0.01	1	0.01	0.27	
S × A	0.17	5	0.03		
Defect location(B)	12.90	3	4.30	65.43	**
S × B	0.99	15	0.07		
Defect characteristics (C)	47.02	8	5.88	146.88	**
S × C	1.60	40	0.04		
A × B	0.03	3	0.01	0.45	
S × A × B	0.36	15	0.02		
A × C	0.17	8	0.02	0.95	
S × A × C	0.89	40	0.02		
B × C	6.69	24	0.28	10.84	**
S × B × C	3.09	120	0.03		
A × B × C	0.44	24	0.02	1.13	
S × A × B × C	1.94	120	0.02		
Total	76.99	431			

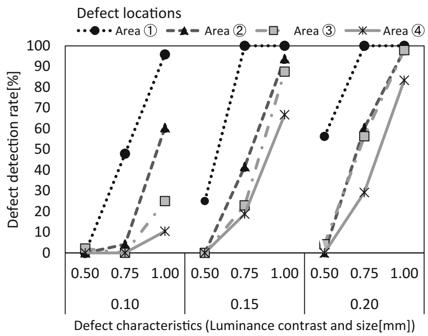
$p < 0.05$: *, $P < 0.01$: **



a. Relationship between presence or absence of visual guidance and defect locations



b. Relationship between presence or absence of visual guidance and defect characteristics



c. Relationship between defect locations and defect characteristics

Fig. 5. Interaction between experimental factors

4 Conclusion

To obtain fundamental knowledge for the training of the visual inspection method, this study considered the effect of visual guidance on the inspectors using a visual indicator on the defect detection, experimentally. As a result, it is clarified that the presence or absence of the visual guidance does not affect the inspection accuracy (the defect detection), regardless of the defect location and the defect characteristics. That is, the visual guidance is not an impediment to inspection accuracy. It is suggested that the visual guidance is an effective tool for the education and training of the visual inspection method utilizing peripheral vision.

As future tasks, we will consider in more detail the method of efficient education and training of the visual inspection method utilizing peripheral vision, including the knowledge garnered from this study. Further, we will also consider the work design and the standardization of the visual inspection method utilizing peripheral vision.

Acknowledgement. This study was supported by Grant-in-Aid for JSPS Fellows (14J09642), JSPS Grant-in-Aid for Research Activity Start-up (16H07202), Special Research of Faculty of Science and Technology in Seikei University.

References

1. Aoki, K.: Review on in-process inspection. J. Jpn. Soc. Non-Destr. Insp. **63**(8), 433–435 (2014)
2. Aiyama, H.: Review on magnetic particle, penetrant and visual testing. J. Jpn. Soc. Non-Destr. Insp. **63**(8), 384–390 (2014)
3. Nickles, G.M., Melloy, B.J., Gramopadhye, A.K.: A comparison of three levels of training designed to promote systematic search behavior in visual inspection. Int. J. Ind. Ergon. **32**, 331–339 (2003)
4. Yeow, P.H., Sen, R.N.: Ergonomics improvements of the visual inspection process in a printed circuit assembly factory. Int. J. Occup. Saf. Ergon. **10**(4), 369–385 (2004)
5. Lee, F.C., Chan, A.H.: Effects of magnification methods and magnifier shapes on visual inspection. Appl. Ergon. **40**(3), 410–418 (2009)
6. Chang, J.J., Hwang, S.L., Wen, C.H.: The development of a training expert system for TFT-LCD defects inspection. Int. J. Ind. Eng. Theory Appl. Pract. **16**(1), 41–50 (2009)
7. Sasaki, A.: Syuhenshi Mokushikensahou [1]. Japan Inst. Ind. Eng. Rev. **46**(4), 65–75 (2005)
8. Sasaki, A.: Syuhenshi Mokushikensahou [2]. Japan Inst. Ind. Eng. Rev. **46**(5), 61–68 (2005)
9. Sasaki, A.: Syuhenshi Mokushikensahou [3]. Japan Inst. Ind. Eng. Rev. **47**(1), 55–60 (2006)
10. Sasaki, A.: Syuhenshi Mokushikensahou [4]. Japan Inst. Ind. Eng. Rev. **47**(2), 53–58 (2006)
11. Sasaki, A.: Syuhenshi Mokushikensahou [5]. Japan Inst. Ind. Eng. Rev. **47**(3), 67–72 (2006)
12. Sugawara, T., Shinoda, S., Uchida, M., Sasaki, A., Matsumoto, T., Niwa, A., Kawase, T.: Proposal of a new inspection method using peripheral visual acuity focusing on visibility and inspection angle of defective items during product inspection. J. Japan Ind. Manage. Assoc. **62**(4), 153–163 (2011)
13. Ikeda, M.: Meha Naniwo Miteiruka. Heibonsya, Tokyo (1999)
14. Yoshida, C., Toyoda, M., Sato, Y.: Vision system model with differentiated visual fields. Inf. Process. Soc. Japan **33**(8), 1032–1040 (1992)

15. Nakajima, R., Tanida, K., Hida, T., Matsumoto, T.: A study on the relationship between defect characteristics and conspicuity field in visual inspection. Jpn. J. Ergon. **51**(5), 333–342 (2015)
16. Nakajima, R., Shida, K., Matsumoto, T.: A study on the effect of inspection time on defect detection in visual inspection. In: Prabhu, V., Taisch, M., Kiritsis, D. (eds.) APMS 2013. IAICT, vol. 414, pp. 29–39. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-41266-0_4
17. Nakajima, R., Shida, K.: A study on the effect of different presentation method on defect detection rate in visual inspection. J. Soc. Bio Mech. Japan **36**(4), 234–240 (2012)
18. Nakajima, R., Inagaki, I., Matsumoto, T.: Development of a training system for visual inspection method utilizing peripheral vision. J. Japan Ind. Manage. Assoc. **66**(3), 267–276 (2015)