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The Effect of Visual Search Patterns of Non-Geometric Shape Inspection Tasks

Phonsak Lerthiranphanya[#1], Sumalee Chanchalor[*2], Anucha Watanpa[!3]

[#]*Learning Innovation and Technology, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Thailand*
[1]phonsak.ler@kmutt.ac.th

[*]*Department of Electrical Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Thailand*
[2]sumalee.cha@kmutt.ac.th

[!] *Department of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Thailand*
[3]anucha.wat@kmutt.ac.th

Abstract— Product inspection is an important step and a major quality control component for many industrial tasks. Visual inspection is based on the use of the human eye to search surface defects. The objective of this research was to compare three types of visual search patterns, investigate and identify differences between different pattern of visual search in terms of performance measures to identify an effective means of significantly the inspector for non-geometric shape inspection tasks. The random search pattern, vertical search pattern and horizontal search pattern were used to instruct participants on visual inspection. Participants were provided information about number of defect per inspection tasks, provided with verbal description and graphical of the defect types, visual search method of each groups and rotation method for inspected. Then, the trials of visual inspection. The performance of visual inspections measured by the mean search time and the percentage of defects detected for each visual search patterns. Analysis of one-way ANOVA both indicated a significant treatment effect, ($F(2, 15) = 56.425$, $p < 0.05$), ($F(2, 15) = 15.943$, $p < 0.05$). Fisher's Protected LSD Comparison procedure was conducted to determine what differences, least significant difference multiple comparison analysis indicated that the performance of the horizontal search was significantly better than that of the random search and vertical search. One reason for this might be that the horizontal search pattern was a systematic search method that covered the total inspection area.

Based on the results of this study, the horizontal search pattern was the appropriate pattern of visual search of complicated shapes or non-geometric shapes, it is recommended that horizontal search pattern be used in the visual search of inspectors for non-geometric shape inspection tasks.

Keywords— Visual inspection / Visual search pattern / Inspection tasks / Non-geometric shape

I. INTRODUCTION

In industrial manufacturing, product inspection is an important step in the production process. Because product reliability is of utmost importance in most production [1]. The intent of conducting inspection is to verify that a product is free of defects. The important inspection method is that of inspecting for visual appearance. Inspection is a major quality control component for many industrial tasks [2] such as aircraft maintenance, food industry, printed circuit assemblies and die casting process [3], [4]. For example, the die casting process, every die casting workpiece must be inspected for finding out the defects in casting process. Visual inspection is based on the use of the human eye to search surface defects. The criticality of inspection in manufacturing becomes evident when the potential consequences of missed defects are examined. In some cases, defect causing damage to the workpiece. Defective product may be shipped, which may negatively impact customer satisfaction, a workpiece may be classified as defective and have to be reworked or scrapped, resulting in unnecessary expenses for materials and labour. Thus, visual inspection is the important basic element for evaluation of workpiece or components being manufacturing [5]. A visual inspector must develop a strategy by which inspector will inspect a casting. This strategy can be either random or planned. Planned search strategies are commonly referred to as systematic. The systematic search strategies can be improved by training a user on how to use a particular strategy [6], [7]. So that a particular search strategy can be identified as being superior, a method of evaluating the effects of a search strategy must be utilized. To determine the effect of a search strategy that focused on eye movement.

Mostly, visual search and decision making are the two primary components that are important to visual inspection tasks [8], [9], [10]. Visual search and decision making involve identifying defects and making decisions about defect acceptance, it can be defined as the process of locating a defect within the area of interest and deciding whether the defect is acceptable or not [11], [12]. Visual search is as a way of looking for defects and is reflected by the movement of the eyes, can be broadly classified into three search patterns. First, random search pattern, second, vertical search pattern and third, horizontal search pattern. Random search is search process in which each fixation is

equally likely to occur anywhere in the search area [13], as a result, search paths overlap or repetitive inspection of the same area multiple times. But, vertical search pattern and horizontal search pattern is search process in which systematic search, systematic search is good search process because the same area is never inspected more than once or repetitive inspection [14], with little or no search paths overlap. Other than, the rotation pattern is another factor that affects the search accuracy and time. General, there are two types of rotation patterns: free rotation and systematic rotation [15]. Improper visual search patterns, either in defect searches or in rotation patterns could lead to lower inspector performance in terms of search speed as determined by the search time and the accuracy rate of defect detection [16]. Evaluating human visual search performance, visual search can be measured by both performance measures and process measure. The performance measures of inspection speed and defect detection accuracy [17] and the process measure of eye movements [18]. Eye movement parameters such as fixation time, numbers of fixations, sequential indices or scan paths and number of eye movements in the horizontal, vertical or diagonal directions. [18]. Speed and accuracy are often the sole or principal measures of inspection performance in industrial practice.

Moreover, Product complexity was the factor that impact inspection performance [2], [19], preferably complicated shapes or non-geometric shapes. Product complexity can be defined in different ways, depending upon the nature of the product to be inspected. In general, a complex item presents more parts, sub-components or can't specify the shape of workpiece were clear for inspection tasks. For examples, complexity for printed circuit boards has been defined in terms of the number of solder joints [20]. Those result of previous researchers, results indicated that complexity has a significant negative effect on inspection performance [21].

Therefore, if different ways of visual search the same information generate different results, it is of interest to determine which pattern of visual search in the inspection performance for product complexity in terms of preferably complicated shapes or non-geometric shapes. The best pattern of visual search should be more efficient than the others pattern in terms of performance of visual search which measured by speed and defect detection accuracy [18]. This study is to investigate and identify differences between different pattern of visual search in terms of performance measures. Hence, the objective of this research was to compare three types of visual search pattern, investigate and identify differences between different pattern of visual search in terms of performance measures to identify an effective means of significantly the inspector for non-geometric shape inspection tasks.

II. METHODOLOGY

A description of the experimental methodology, which includes detailed information regarding the participants, experimental apparatus, variables, experimental design, procedure and data collection, is presented below.

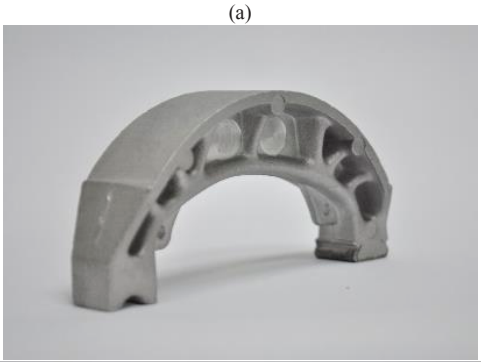
A. Participants

The participants for this experiment were drawn from an employees were selected exclusively at quality control department of company, nine employee's participants attending between the ages of 28-32 years and inspection work experienced between 1-3 years. The criteria to select the participant in the study based on color vision and normal vision (20/20 vision). Ishihara's tests and Snellen chart was used to determine their color vision and visual acuity [11].

B. Experimental Apparatus

The inspection task used in the study was a motorcycle brake shoe from die casting process without defects and include 2 defects types: misrun defect and cold shut defect. The motorcycle brake shoe size 100mm long 50mm wide and 25mm thick. Twenty motorcycle brake shoe was used to inspected. Figs. 1(a) and (b) shows an example of a motorcycle brake shoe from die casting process.

(a)



(b)

Fig. 1. (a,b) A motorcycle brake shoe from die casting process.

C. Variables

Visual search patterns were independent variables. Participants were provided information about visual search patterns, visual search based on the eye movements of three visual search patterns: random search, vertical search and horizontal search. Dependent variable was the mean search time (Sec) and the percentage of defects detected for each visual search patterns.

D. Experimental design

A completely randomized design (CRD) was used for this experiment. The nine participants selected was randomly assigned to three groups of visual search patterns. Then, was randomly assigned to experimental sequences, Table 1 was shown table of experimental design.

TABLE I
TABLE OF EXPERIMENTAL DESIGN

visual search patterns	**Participants sequences and Experimental sequences**		
Random search	P5 (S3)	P4 (S2)	P9 (S7)
Vertical search	P1 (S1)	P6 (S5)	P3 (S4)
Horizontal search	P2 (S9)	P8 (S6)	P7 (S8)

P1-P9: participants' sequences (randomly assigned)
(S1) - (S9): experimental sequences (randomly assigned)

E. Procedure

Initially, an overview of the experiment was presented to the participants. The participants were also shown the workpiece to be inspected and provided information about number of defect per inspection tasks, provided with verbal description and graphical of the defect types, visual search method of each groups and rotation method for inspected defined as systematic rotation [15]. Figs. 2(a) and (b) shows the graphical of the defect types, Fig. 3 shows an example of graphical of the visual search patterns. Then, the trials of visual inspection was conducted.

Trial 1: The participants were performed along of the experimental design. Following the completion of Trial 1, the participants didn't receive the feedback information from inspected.

Trial 2: The participants performed which was identical in to Trial 1 to confirm their performance to visual inspection.

(a)

(b)

Fig. 2 (a) An example of graphical of the misrun defect type (b) An example of graphical of the cold shut defect type

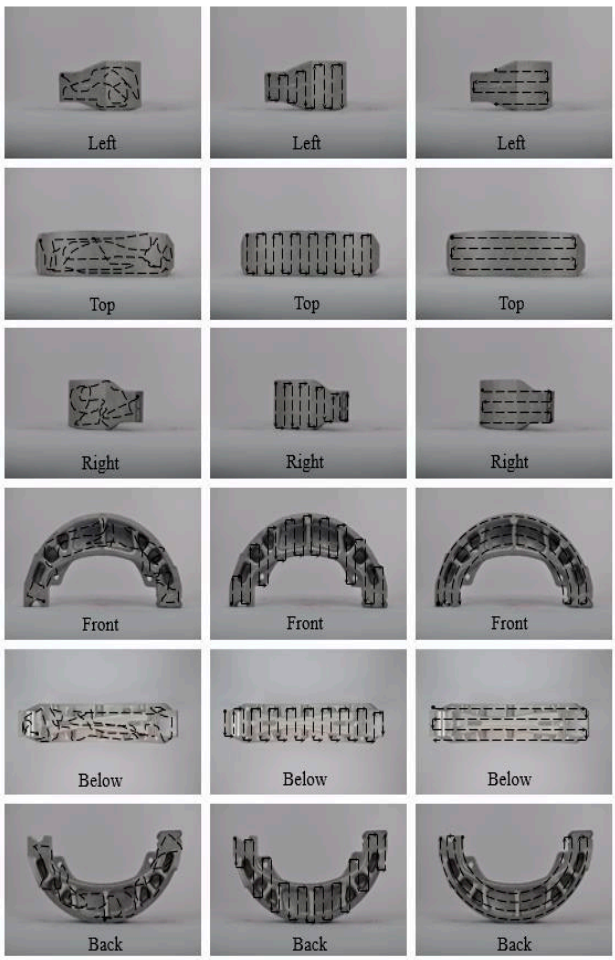


Fig. 3 An example of graphical of the visual search patterns on each side, (a) graphical of the visual random search patterns, (b) graphical of the visual vertical search patterns, (c) graphical of the visual horizontal search patterns

F. Data collection

Performance of inspector was indicated by speed and accuracy. Data was collected: mean search time and the percentage of defects detected for each visual search patterns. Data were gathered from the participants on the overall performance of the inspected relevant to their experimental condition was shown in Table 2 and Table 3.

TABLE II
RESULTS FOR THE MEAN SEARCH TIME EACH OF VISUAL SEARCH PATTERNS (UNIT:SECOND)

Participants		P5	P4	P9
Random search	Trial 1	21.17	18.9	19.36
	Trial 2	18.13	19.46	19.79
Participants		P1	P6	P3
Vertical search	Trial 1	25.63	26.85	25.27
	Trial 2	23.71	21.59	25.44
Participants		P2	P8	P7
Horizontal search	Trial 1	17.07	14.91	13.07
	Trial 2	17.35	14.8	13.98

TABLE III
RESULTS FOR THE PERCENTAGE OF DEFECTS DETECTED EACH OF VISUAL SEARCH PATTERNS (UNIT: PERCENTAGE)

Participants		P5	P4	P9
Random search	Trial 1	50	60	60
	Trial 2	60	60	70
Participants		P1	P6	P3
Vertical search	Trial 1	80	80	70
	Trial 2	70	80	60
Participants		P2	P8	P7
Horizontal search	Trial 1	70	90	90
	Trial 2	90	80	90

III. ANALYSIS

A. Results

Each of this data was used to analyze for normality test in order to verify that data collect from subjects was normal. The statistical analysis for normality test of mean search time and percentage of defects detected data respectively. These data proved that a normally distributed, the statistic was not significant (*P-value* = 0.430 and 0.065), ($p > 0.05$). Then, data analysis by a one-way analysis of variance (One-Way ANOVA) was used to analysis. The One-Way ANOVA results was shown in table 4 and graph shown a comparison of mean search time and percentage of defects detected spent in visual inspection for visual search patterns was shown in Fig 4 and Fig. 5.

TABLE IV
THE STATISTICAL ANALYSIS OF ONE-WAY ANOVA FOR MEAN SEARCH TIME AND PERCENTAGE OF DEFECTS DETECTED

Visual search patterns	Mean search time (Sec)		Percentage of defects detected	
	Average	Std. deviation	Average	Std. deviation
Random search	19.47	1.01	60	6.32
Vertical search	24.75	1.85	73.33	8.16
Horizontal search	15.2	1.69	85	8.37
F-test	56.425*		15.943*	

* . The mean difference is significant at the 0.05 level.

The average of mean search time and percentage of defects detected by each participant was calculated. The average of mean search time for the random search, vertical search and horizontal search, respectively, was 19.47 sec, 24.75 sec and 15.20 sec (Table 4.), the percentage of defects detected for the random search, vertical search and horizontal search, respectively, was 60.00%, 73.33% and 85.00% (Table 4.). Refer to Table 4, the statistical analysis of one-way ANOVA for mean search time and percentage of defects detected respectively. Both indicated a significant treatment effect (F (2, 15) = 56.425, *P-value* = 0.000, $p < 0.05$), (F (2, 15) =15.943, *P-value* = 0.000, $p < 0.05$).

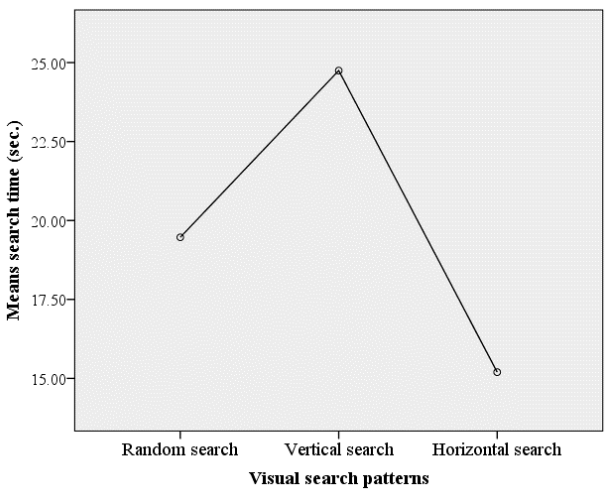


Fig. 4 Graph showing a comparison of mean search time spent in visual inspection on each of the visual search patterns

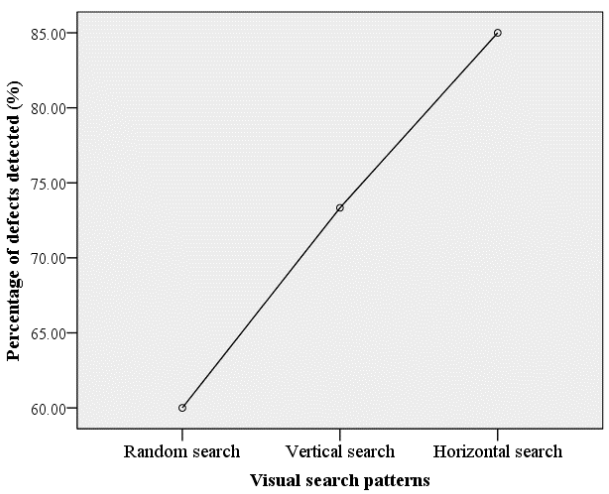


Fig. 5 Graph showing a comparison percentage of defects detected spent in visual inspection on each of the visual search patterns

The compare inspector's performance based on visual search patterns, conducted on each of the dependent variable. Fisher's Protected LSD Comparison procedure was conducted to determine what differences. The results

of the multiple comparison analysis was shown in table 5-6.

TABLE V
RESULTS OF MULTIPLE COMPARISONS ANALYSIS FOR MEAN SEARCH TIME (FISHER'S PROTECTED LSD)

	Random search	**Vertical search**	**Horizontal search**
Random search	-	-5.28	4.27*
Vertical search	-	-	9.55*
Horizontal search	-	-	-

* . The mean difference is significant at the 0.05 level.

TABLE VI
RESULTS OF MULTIPLE COMPARISONS ANALYSIS FOR PERCENTAGE OF DEFECTS DETECTED (FISHER'S PROTECTED LSD)

	Random search	**Vertical search**	**Horizontal search**
Random search	-	-13.33*	-25.00*
Vertical search	-	-	-11.67*
Horizontal search	-	-	-

* . The mean difference is significant at the 0.05 level.

Fisher's Protected LSD comparison procedure was conducted to determine what differences, existed among the three groups. The results of the multiple comparison analysis are tabulated in Table 5 and Table 6, where "*" indicates that the means of the treatment pairs being compared are significantly different from each other at the level of 0.05 ($\alpha = 0.05$).

IV. CONCLUSION AND DISSCUASSION

The objective of this research was to compare three types of visual search patterns, investigate and identify differences between different pattern of visual search in terms of performance measures to identify an effective means of significantly the inspector for non-geometric shape inspection tasks. Based on the results of this study, it was indicated that inspector performance on the three visual search patterns about mean search time and percentage of defects detected performance was performed significantly different at the level of 0.05.

The horizontal search pattern was the best pattern of visual search, because it be more efficient than the random search and vertical search pattern both theoretically and experimentally in terms of performance of visual search which measured by speed and defect detection accuracy, the horizontal search pattern was a systematic search method that covered the total inspection area of complicated shapes or non-geometric shapes. The horizontal search pattern was systematic behaviour assumes perfect memory where each fixation area will be viewed only once per scan of the search area. The systematic search behaviour produces better inspection performance. Thus, should efforts to make inspectors follow a more systematic search pattern can improve search performance for non-geometric shape inspection tasks. This result is consistent with those of previous researchers [15] who have shown that the horizontal search pattern was the search pattern theory that states that systematic searching with eye movement from left to right provides the most accurate and faster inspection. Moreover, this result is consistent with those of previous researchers [11] who have shown that participants who were provided feed forward information on an expert's eye movements were more successful in adopting a systematic search strategy, the search in a systematic manner, helped increase were able to manage their time for each inspection tasks more effectively. So, if inspectors are trained to adopt a systematic search pattern, this should lead to better search performance. This indicated that if inspectors want to have better inspector, they should be used visual inspection method on horizontal search pattern.

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