

An Empirical Study of the Number of Template Effects on the Efficiency of the Prototype of an Automated Logo Inspection Machine

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Abstract. *A Product packages have logos printed on them. If these logos were defected, manufacturers may lose customers' reputation. In addition, the automation increasingly plays an important role in manufacturing process since it can replace human workforce and decrease human errors. Therefore, a prototype of an automated logo inspection machine using pyramidal matching technique was designed and constructed for demonstration and test the efficiency of the proposed logo inspection machine. The original prototype utilized only one image of the package as a template, the experimental results show that the demonstrated machine can distinguish between the complete logos on packages and the defective ones even though the position of the packages were tilted up to ± 90 degrees. However, if the package positions were 90 or -90 degrees, the accuracy of the template matching was decreased. Therefore, increasing the number of templates used in the pattern matching algorithm could improve the efficiency of the proposed logo inspection machine by utilizing four templates align in 0, +90, -90, and 180 degrees instead of only 0 degree position.*

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1. Introduction

Manufacturing system has been rapidly developed into automation and digitization. Manufacturers can be able to do more efficient management and lower costs while consumers can enjoy a wider range of products at lower prices [1]. Machine vision technology has been rapidly

developed and extended its applications to automated inspection systems. Inspection is the process by which a real product is compared with the predefined specifications. Generally, the inspection process is installed by the end of the production line. The automated inspection technology improves quality of product and productivity, reduces cost of manufacturing, and enhances customer satisfaction [2].

Thus, in this context, a prototype of the package inspection machine is developed for demonstration and testing the efficiency [3]. The prototype machine inspected the logo on products using the pyramidal template matching technique [4, 5]. One template image which align in 0 degree with the loading product position was utilized in the inspection process. The experiments show that the prototype of inspection machine can distinguish between the complete logos and the defective ones on the package despite the position of the packages were tilted up to ± 90 degrees. However, if the target logo positions were 90 or -90 degrees, the accuracy of the template matching in terms of similarity score was decreased. The similarity score plays a major role in the high accuracy, automation manufacturing, which every single product must be tested by the end of the production line, such as pharmaceutical products [2].

Therefore, this research aims to empirical study the effects of the number of template images used in the prototype of the logo inspection machine. If the multiple template images align with different position are utilized in the pyramidal template matching process, they will improve the prototype machine's efficiency in terms of increasing similarity scores.

This paper is organized as follows. The prototype of an automated logo inspection machine is introduced in Section 2. Section 3 describes the concept of the pyramidal template matching technique with multiple template images that were implemented in this empirical study. The experiments used to evaluate the effects of the number of template images and results are presented and discussed in Section 4, and conclusions and suggestions for the future work are given in Section 5.

2. The Prototype of an Automated Logo Inspection Machine

A prototype of an automated logo inspection machine was designed and constructed for demonstration and testing efficiency [3] as shown in Fig. 1. The block diagram shows the hardware components of the prototype inspection machine in Fig. 2. The detail description of the hardware components and their functions start with the image acquisition control sensor detects a product, it sends signal to a microcontroller Arduino Mega 2560. The microcontroller has two tasks; first, to controls the camera via the computer in order to acquire the target image. Second, when the microcontroller obtains the similarity score from the computer that perform the pyramidal template matching process, it controls the green and red status lamps and solenoid valve via 4-channel relay. If the solenoid valve is active, the cylinder sorts the defective logo product out of the conveyor.

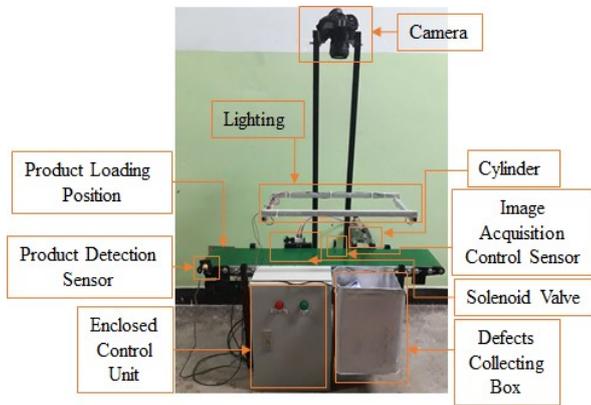


Fig. 1: The automated logo inspection machine

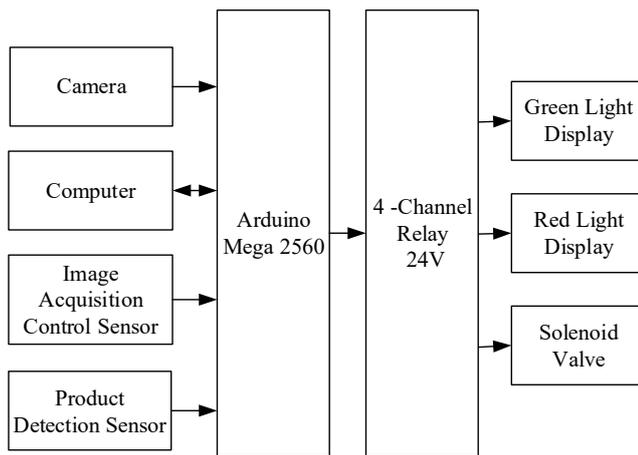


Fig. 2: The block diagram of the hardware components of the prototype of an automated logo inspection machine

The workflow of the prototype of the automated logo inspection machine shown in Fig. 3. The inspection process starts with initialization; loading 4 template images, which align in 0, +90, -90, and 180 degrees with the initial position

on the conveyor, into the computer and load the products on the conveyor belt. Next, the image acquisition control sensor detects whether the product is on the conveyor belt. If a product is detected, the image acquisition controls the camera to take a photograph of the tested logo. The acquired image which is called the target image will be sent to the pyramidal template matching process, then the similarity score is calculated. Consequently, if the similarity score is equal or greater than 90%, the logo is identified as good product and can be continue on the conveyor. The green lamp is on and the counter1 is increased by 1 as well.

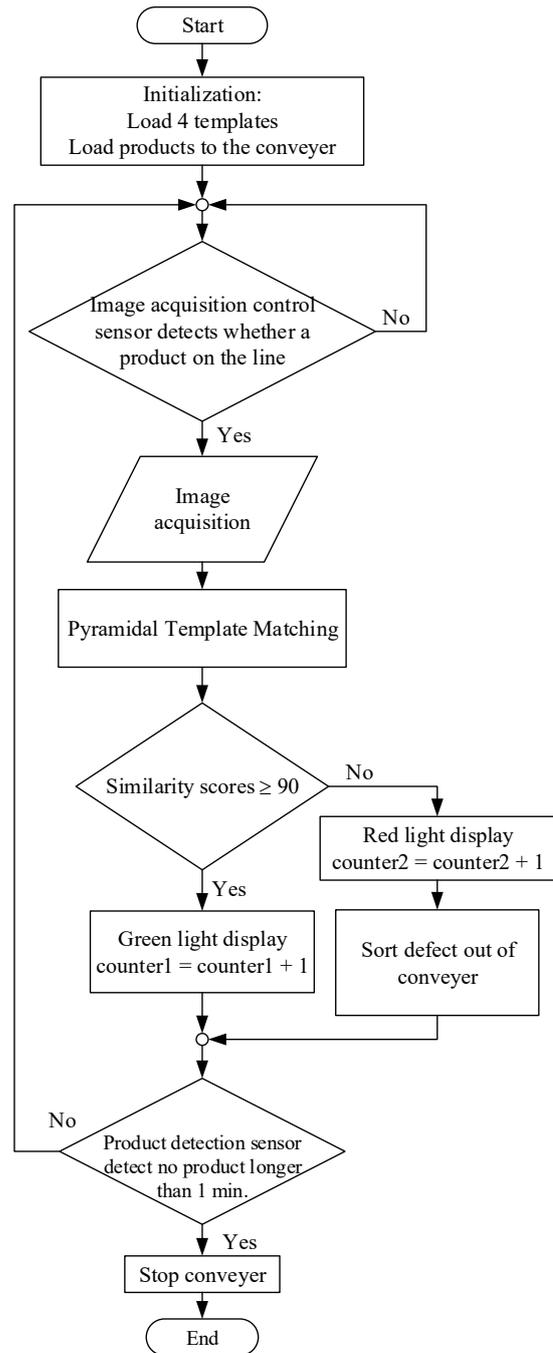


Fig. 3: The prototype of the automated logo inspection machine workflow diagram

Counter1 counts the number of good logos. Otherwise, the logo is identified as defective product and it is sorted out of the conveyor, whereas the red lamp is on and the counter2 is increased by 1. Counter2 counts the number of defective logos. By the end of the process the product detection sensor monitors the products that pass through the conveyor belt. If the product detection sensor cannot detect the product for 1 minute, the sensor sends control signal to stop the conveyor.

3. Pyramidal Template Matching Technique with Multiple Template Images

The template matching is the powerful machine vision technique. The template matching evaluates the degree of similarity between the template image and the target image [6]. One of the most widely used similarity measure is Normalized cross-correlation (NCC), which is robust under uniform illumination changes and has been widely used in object recognition and industrial inspection [7]. The NCC evaluation; $\lambda(i, j)$, at the position (i, j) of the template image $T(i, j)$ of size $n \times n$ and the target image $S(x, y)$ defined as Eq. (1):

$$\lambda(i, j) = \frac{\sum_{x=1}^n \sum_{y=1}^n (S(i+x, j+y) - \bar{S}(i, j))(T(x, y) - \bar{T})}{\sqrt{\sum_{x=1}^n \sum_{y=1}^n (S(i+x, j+y) - \bar{S}(i, j))^2 \sum_{x=1}^n \sum_{y=1}^n (T(x, y) - \bar{T})^2}} \quad (1)$$

; where $1 \leq i < (p-n)$, $1 \leq j < (q-n)$

$$\bar{S}(i, j) = \frac{1}{n \times n} \sum_{x=1}^n \sum_{y=1}^n S(i+x, j+y) \quad (2)$$

$$\bar{T} = \frac{1}{n \times n} \sum_{x=1}^n \sum_{y=1}^n T(x, y) \quad (3)$$

Although NCC is high computational cost, it is the best performance among similarity metrics [7]. The computation time of NCC evaluation can be reduced by using image pyramid [4, 6-7]. Image pyramid consists of samples of both the target and template images which obtained by sampling both of them using Gaussian pyramids in order to reduce spatial resolutions. This method can reduce the size of both target and template images for every successive pyramid level [8]. However, the pyramidal template matching technique used in the prototype of an automated logo inspection machine faced difficulty in matching evaluation in cases of the alignment of the target image is +90 or -90 degree with the template image. The similarity scores were low even though the inspection machine can rightfully distinguish between the good and defective logos. One possible way to increase the efficiency of the prototype machine is using four templates align in 0, +90, -90, and 180 degrees instead of only 0 degree. Therefore, this research empirically studies the effect of the number of template images on the efficiency of the template matching process in terms of the similarity score.

4. Experiments and Results

The logo to be inspected are the logo on twelve cards. The first to sixth cards are complete logos. While seventh to twelfth cards are defective logos. The template images are four complete logo images that align 0, +90, -90, and 180 degrees. All images' resolution is 1920x1080 pixels. The pyramidal template matching performed on the computer with CPU Intel Core i5-5200U 2.7 GHz, RAM 4 GB, and Windows 8.1 operating system.

The experiments performed three times and average out the similarity scores for each card that were inspected. All cards were arranged in eight positions which are 0, +45, -45, +90, -90, +135, -135, and +180 degrees. The experimental results showed in Table 1 are the average similarity scores of the inspection using one template images whereas Table 2 shows the average similarity scores of the inspection using four template images. In addition, Table 3 shows the processing time of the pyramidal matching process for both one template image and four template images.

Results from Table 1 and Table 2 show that the prototype of the automated logo inspection machine can correctly distinguish between the good logo products and defective ones. The first six logos' similarity scores were increased by 12.30% maximum in case of the tested product was align in 135° with the initial position when the four template images were utilized. The total amount of only 6 out of 48 inspection cases which is 12.50% that the similarity scores decreased if four template images were implemented instead of only one template image. The 87.5% of inspection cases show the increased similarity scores.

On the other hand, the seventh to twelfth products, which are defective, produced the decreased similarity scores in case of four template images implementation, especially when the defective product was align in +45° with the initial position. The similarity score was reduced by 62% maximum. The 11 out of 48 inspection cases, which was 22.91%, for defective product inspection that the similarity score were increased, but 77.09% of the inspection cases were found that the similarity scores were decreased.

Overall, the efficiency of the prototype of the automated logo inspection machine was improved in terms of the similarity scores. The higher number of template images increases the similarity scores for the good products and decreases the similarity scores for the defective ones. Thus, if the multiple template images are utilized in the template matching process, the efficiency in terms of accuracy of the automated inspection machine can be improved.

However, the average template matching processing time in case of four template images are increased from one template image. The longest processing time is 12.2 seconds for using four template images while the longest processing time is 2.0 seconds for using one template images. It is 510% increased processing time if four template images were utilized.

5. Conclusion

The number of template images are empirically investigated its effects on the efficiency of the prototype of an automated logo inspection machine. The four template images are utilized in the pyramidal template matching process which results in the efficiency improvement of the

inspection machine in terms of the similarity score. However, the higher efficiency, the higher computational time needed. Therefore, reducing computational cost by improving template matching techniques or image preprocessing for speed enhancing are essential.

Product no.\Position	Similarity Scores							
	0°	+45°	-45°	+90°	-90°	+135°	-135°	180°
1	99.10	94.80	91.38	91.47	93.27	88.41	90.04	90.43
2	95.88	93.90	92.08	90.02	92.07	84.84	90.97	88.97
3	96.39	94.41	93.87	92.93	92.68	90.26	91.47	91.47
4	95.80	94.43	91.96	91.38	93.04	89.32	90.25	91.34
5	95.97	93.77	90.62	91.43	91.97	84.82	87.79	90.25
6	95.84	93.63	89.85	91.46	91.26	87.45	84.91	90.25
7	60.73	61.46	61.68	57.09	65.55	55.30	58.37	53.52
8	68.99	67.66	65.33	65.09	61.77	57.15	64.46	69.99
9	64.44	67.17	62.45	61.62	67.09	65.52	55.55	63.67
10	53.37	53.61	46.38	51.80	55.37	53.06	47.63	52.79
11	47.43	50.76	43.03	47.95	49.48	44.40	42.81	50.22
12	46.71	41.74	-*	-*	-*	-*	-*	-*

-* The template matching process stop matching because the similarity score is less than 40.

Table 1: Average Similarity Scores for One Template Image

Product no.\Position	Similarity Scores							
	0°	+45°	-45°	+90°	-90°	+135°	-135°	180°
1	98.04	93.05	93.79	97.37	97.74	92.95	92.91	97.97
2	97.39	94.94	93.67	97.84	97.92	95.29	92.14	98.44
3	96.50	94.51	92.72	95.20	93.02	92.38	91.32	96.89
4	95.49	93.61	93.01	96.06	94.36	93.49	92.06	96.81
5	96.46	94.57	90.55	95.75	95.98	93.75	88.59	96.90
6	96.70	94.74	92.83	96.29	93.27	93.49	91.75	97.13
7	42.16	43.66	49.30	45.10	54.68	49.74	46.49	51.11
8	51.88	41.63	56.43	42.80	54.60	50.52	46.32	51.76
9	49.70	57.08	55.80	54.67	52.66	53.62	60.41	59.75
10	60.34	54.80	61.60	55.06	59.07	57.84	55.58	59.21
11	45.72	45.20	44.84	46.34	45.36	47.59	45.64	48.71
12	42.05	43.40	-*	40.63	45.48	41.34	43.81	42.87

-* The template matching process stop matching because the similarity score is less than 40.

Table 2: Average Similarity Scores for Four Template Images

No. of template\ Product no.	Pyramidal Template Matching Processing Time (sec.)															
	0°		+45°		-45°		+90°		-90°		+135°		-135°		180°	
	1	4	1	4	1	4	1	4	1	4	1	4	1	4	1	4
1	1.5	11.9	1.7	12.3	1.5	12.0	1.8	12.2	1.6	8.9	2.0	9.7	1.5	8.8	1.8	11.0
2	1.5	12.0	1.6	11.9	1.5	11.4	1.6	10.9	1.6	8.9	1.9	9.5	1.7	10.2	1.6	11.8
3	1.5	11.9	1.6	11.4	1.7	11.1	1.5	10.8	1.8	8.9	1.5	9.9	1.7	11.7	1.7	11.7
4	1.8	11.4	1.6	11.8	1.5	11.7	1.7	10.3	1.6	9.1	1.4	9.9	1.6	11.3	1.8	11.4
5	1.6	11.7	1.6	11.6	1.7	11.0	1.6	10.6	1.9	9.2	1.7	9.6	1.9	11.9	1.9	12.2
6	1.4	11.4	1.5	11.8	1.6	11.4	1.5	10.7	1.7	9.2	1.7	9.7	1.8	11.6	1.7	11.7
7	1.8	8.6	1.8	10.2	1.6	9.8	1.8	9.1	1.7	9.4	1.9	9.1	1.6	9.4	1.9	9.4
8	1.9	8.5	1.6	9.5	1.6	9.9	1.7	8.9	1.4	9.1	1.4	8.9	1.9	10.2	1.7	9.5
9	1.9	8.9	1.7	9.7	1.7	9.9	1.6	9.7	1.6	9.7	1.6	9.3	1.8	9.6	1.4	9.8
10	1.6	8.7	1.8	9.6	1.6	9.5	1.7	9.2	1.7	9.3	1.5	9.0	1.9	10.3	1.8	9.3
11	2.0	10.0	1.8	9.9	1.7	10.2	1.9	9.6	1.7	10.4	1.6	10.2	1.7	9.1	1.8	10.2
12	1.9	9.4	1.6	10.0	1.8	9.8	1.8	9.7	1.5	10.1	1.5	9.5	1.7	8.9	1.6	9.5

Table 3: Pyramidal Template Matching Processing Time (sec.) for One and Four Template Images.

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