Template Matching Using Sum of Squared Difference and Normalized Cross Correlation

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***Abstract*— In digital image processing, template matching is a process to determine the location of sub image inside an image. The sub image, which is called template, usually has similarity with a part of the image. The template can be in different size, color or form. Template matching is famously used in image registration and object recognition. In this paper, we focus on the performance of the Sum of Squared Differences (SSD) and Normalized Cross Correlation (NCC)as the techniques that used in image registration for matching the template with an image. This experiment is aiming to compare the ability of both techniques in term of quality of output image as well as the time taken in execution process. Furthermore, it also to test the effect of template image to output image when there is noise and rotation. This paper provides an explanation about the concept of similarity measure techniques and how the algorithms are implementing in image registration process. Finally, the performance of these methods is tested by making comparison based on the value of correlation coefficient that produced from different image templates.**

Keywords*— *image registration; template matching; sum of squared differences; normalized cross correlation)

I. Introduction

Image registration is a process of finding the corresponding point in two and more images of same scene by using automatic or manual procedure and aligns them into a single integrated image [1, 2, 3]. The images to be used for registration process are commonly same scene but might be acquired from difference sensor or same sensor but at different time or viewpoint [4]. Image registration is mostly used in medical and satellite image to align images from difference camera sources. In digital image processing, image registration process is often used as a preliminary step in order to incorporate multiple images into a single image. In this paper, template matching is used as a methodology for finding areas of a sub image which call template, that match to an image as source image[5]. Templates matching basically compute at each position of the image in order to measures the degree of similarity between the template and the image. To identify the matching area, template is shift around the source image by sliding it. That computation will yield a group of matrices which has the same row and column to source image. Technically, the position of maximum correlation or minimum distortion is considered as the match area. At the last, an experiment will be conduct in order to test the performance of image registration techniques. Those techniques were compared by using the correlation coefficient value that attain from reference image and registered image. These values can be used to prove which method that gives a good images quality. It also gives the guidance for the user to choose a suitable algorithm to achieve optimum results according to different application.

II. Template Matching

Template Matching is a method for searching and finding small parts of an image which match a template image. It concern of comparing a given template with a window of same size in an image and identifying the window that is most similar to the template [6, 7].In template matching, the process will begin with finding the center location of template image and zeros padding in reference image. Zeros padding is necessary to make easier in computation of two signals.

Template

7	7	5
4	3	2
3	8	2

Reference

1	1	1	1	1	1
1	5	7	7	5	1
1	2	4	3	2	1
1	2	3	8	2	1
1	2	2	2	1	1
1	1	1	1	1	1

Fig. 1. Template and Reference Matrix

Figure 1 show two matrices which considered as template and reference image before the process of template matching. Once the process is start, a middle location of the template should be identified early so that the middle point will fall on the first pixel of reference image as shown in figure 2. To find the middle location, you can easily divide template image by two. For this template, the middle location is situated at coordinate (2, 2) where the value is 3. At same time, reference image is pad with row and column of zeros on every side of that image. The number of rows and column with zeros is equal to the length of x-axis and y-axis in template that divided by two.

7 0	7 0	5 0	0	0	0	0	0
4 0	3 1	2 1	1	1	1	1	0
3 0	8 1	2 5	7	7	5	1	0
0	1	2	4	3	2	1	0
0	1	2	3	8	2	1	0
0	1	2	2	2	1	1	0
0	1	1	1	1	1	1	0
0	0	0	0	0	0	0	0

Fig. 2. Template Matching

In figure 2, it shows how the template is attached to reference once the process is begun. The each side of reference image is successfully padded with rows and column of zero. By padding the image with zeros, the centre of template is easily placed on first pixel of reference image. The template is sliding by one pixel at a time around the image looking at a position where the template overlaps the image so that values in the template are aligned with similar values in the image. At each location, the values of image padded and template is calculated by using the similarity measures method (which is SSD or NCC) and the product of that computation is stored into a particular matrix which has same size to reference image. Finally, the matrix that produced after all area of padded image computed is used to determine how similar the template is to that particular area in the reference image.

III. Sum of Squared Differences

Sum of squared differences (SSD) is one of measure of match that based on pixel by pixel intensity differences between the two images [8]. It calculates the summation of squared for the product of pixels subtraction between two images [9]. With this similarity measure, matching point can be determined by consider the location of minimum value in the image matrices. Generally, SSD is directly using the formulation of sum of square error.

$$\iint_A (f-g)^2 \quad (1)$$

If equation in (1) is converted into digital form, then

$$\mathrm{SSD}\,(\mathrm{i,j}) = \sum_{i=0}^{M}\sum_{j=0}^{N}(f(i,j)-g(i+u,j+v))^2 \quad (2)$$

where M is size of rows in reference image and N is size of column while u and v are variable, shift component along x-direction and y-direction respectively. Term of is template which is constant and is not constant where it depend on variable u and v.

IV. Normalized Cross Correlation

Normalized Cross Correlation (NCC) is always chosen as similarity measure due to its robustness [10, 11]. Its computation is more complex if we compare to the previous as it involves numerous multiplication, division and square root operations. This cost is derived using Cauchy Schwarz inequality [12, 13]. Technically, NCC determines the matching point between template and image by searching the location of maximum value in the image matrices. Generally, the NCC computation can be express as

$$NCC(u,v) = \frac{\iint_A f(x,y)\cdot g(x+u,y+u)\,dxdy}{\left[\iint_A f^2(x,y)\,dx\,dy \cdot \iint_A g^2(x+u,y+v)\,dx\,dy\right]^{\frac{1}{2}}} \quad (3)$$

If equation in (3) is converted into digital form, then

$$NCC(u,v) = \frac{\sum_{i,j\in A}\sum[f(i,j) * g(u+i,v+j)]}{\left[\sum_{i,j\in A}\sum g^2(u+i,v+i)\right]^{\frac{1}{2}}} \quad (4)$$

Where u and v are variable, shift component along x-direction and y-direction respectively. The term in numerator of the equation, is nothing but cross correlation between the template and image. Note that, the cross correlation cannot be used as similarity measure because it will produce false template matching result. Therefore, the term in denominator is used as normalized cross correlation to acquired correct match. However, the term of is not used in equation (4) since it is constant. Thus, the term is definitely not importance.

V. Result

In this section, an experiment has been conducted to evaluate the performance of similarity measures. In this experiment, a gray scale image of size 384x512 has been used as reference image for this test. A different size of image is extracted from reference image which used as template image.

After registration between template and reference image, correlation coefficient is apply to prove the performance of the algorithms that used in this registration. Correlation coefficient measures the degree of similarity between reference image and register image. The perfect template matching is considered when the maximum cross correlation coefficient is 0.99. However, there some perfect template matching but the values is below 0.99.

Table 1 gives the values of minimum sum of squared difference and cross correlation coefficient for different size of template images. Meanwhile, in table 2, it has shown the value maximum normalized cross correlation and cross correlation coefficient. In those tables, execution times for each process are provided as well.

TABLE I. CROSS CORRELATION COEFFICIENTS AND MINIMUM VALUE FOR SUM OF SQUARED DIFFERENCES

No. of Sample	*Template Size*	*Minimum SSD value*	*Correlation Coefficients*	*Execution Time (sec))*
1.	50x50	0	0.9998	34.6914
2.	80x80	0	0.9980	89.3317
3.	90x90	0	0.9988	146.3085
4.	150x150	0	0.9961	346.9846
5.	50x150	0	0.9991	107.4601
7.	80x80 with noise	105.3028	0.9901	102.9063
8.	110x110 with noise	233.5743	0.9791	167.8811
9.	110x110 with rotate of 1^{0}	69.3516	0.9925	209.1403
10.	60x60 with rotate of 5^{0}	112.3992	0.9906	81.1320
11.	90x90 with rotate of 5^{0}	552.4084	0.9584	135.2423
12.	90x90 with rotate of 10^{0}	687.0098	0.9531	171.8873

TABLE II. CROSS CORRELATION COEFFICIENTS AND MAXIMUM VALUE FOR NORMALIZED CROSS CORRELATION

No. of Sample	Template Size	Maximum NCC value	Correlation Coefficients	Execution Time (sec)
1.	50x50	42.2062	0.9994	46.2078
2.	80x80	55.1909	0.9980	110.3549
3.	90x90	53.2936	0.9988	169.4819
4.	150x150	64.4309	0.9961	455.7858
5.	50x150	42.5076	0.9980	181.1161
7.	80x80 with noise	53.6376	0.9898	106.8903
8.	110x110 with noise	52.4825	0.9796	226.7805
9.	110x110 with rotate 1^{0}	51.8638	0.9925	408.8509
10.	60x60 with rotate 5^{0}	32.4718	0.9904	153.1226
11.	90x90 with rotate of 5^{0}	47.0063	0.9531	383.3077
12.	90x90 with rotate of 10^{0}	48.0931	0.9601	158.7555

Table 1 give the result for 12 samples of template image which used in registration process. The perfect template matching is considered when the cross correlation coefficient is 0.99. However, template matching could be perfect despite the fact that the maximum values is below 0.99. It occur for sample of 7 and 8 where the cross correlation coefficient value is not exactly 0.99 but the template is match to reference image. For the sample of 11 and 12, template matching produces false image registration.

In table 2, the templates in sample 1 until 10 are match to reference image while template in sample 11 and 12 are not match. In the table, it clearly shows the value of correlation coefficients for false registered image is less than 0.97.

For figure 3 to 7, the template image that extracted from reference image is used in the experiment normally without altering the template. In figure 8 to 12, a noise and rotating is apply on the template image before it is used in image registration algorithms. Each figure provide four separated images which is template image with different size (a), original image with size of 384x512 (b), register image (c) and surface plot in (d). The red rectangle marks in original image indicate as the location of template that extracted from an image.

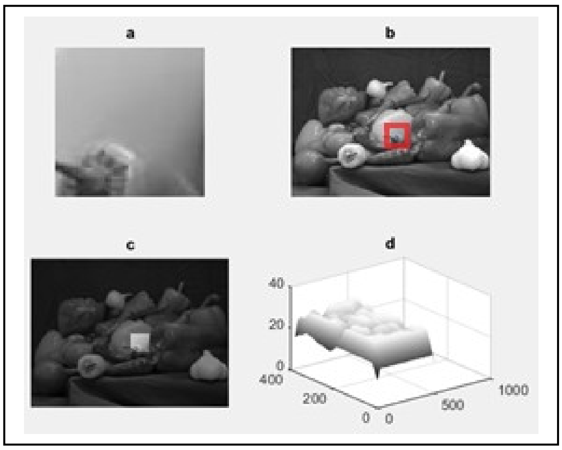

Fig. 3. (a) Template of size 50x50,(b) Reference image, (c) Register image, (d) Surface plot

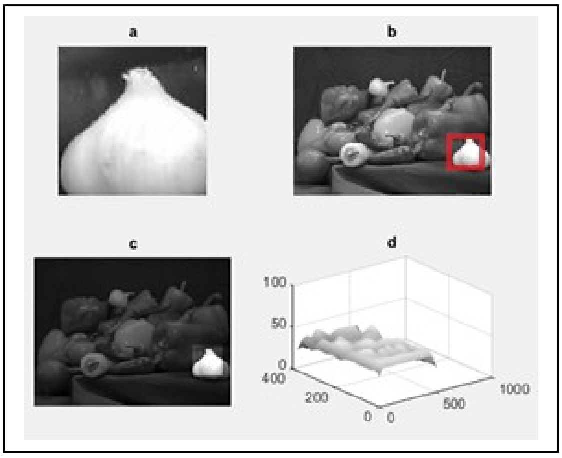

Fig. 4. (a) Template of size 80x80, (b) Reference image, (c) Register image, (d) Surface plot

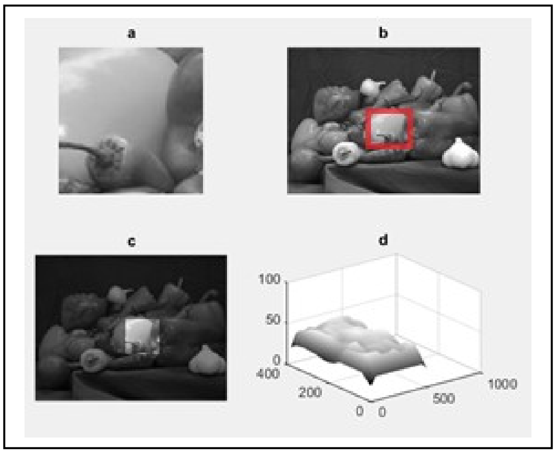

Fig. 5. (a) Template of size 90x90, (b) Reference image, (c) Register image, (d) Surface plot

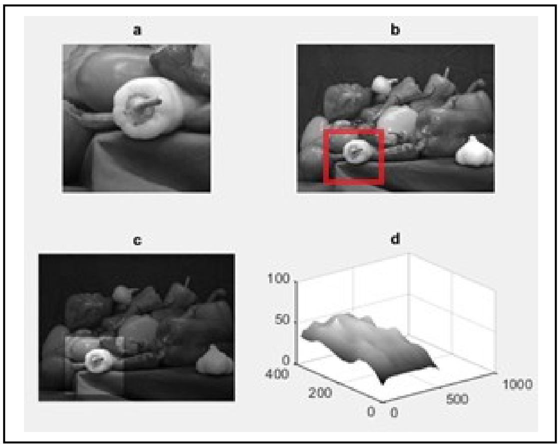

Fig. 6. (a) Template of size 150x150, (b) Reference image, (c) Register image, (d) Surface plot

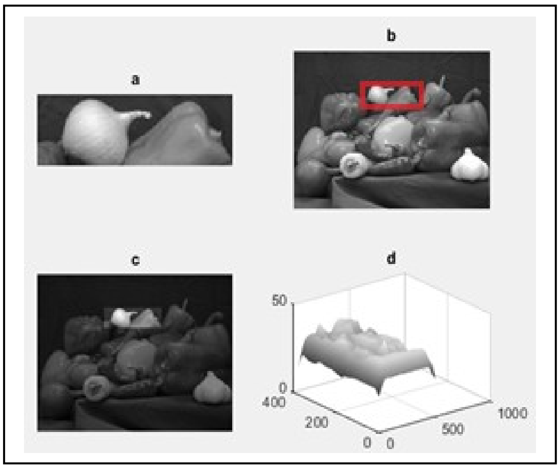

Fig. 7. (a) Template of size 50x150, (b) Reference image, (c) Register image, (d) Surface plot

In figure 8 and 9, the image that extracted from reference image is modified by adding noise before it is used in image registration process. Figure 8(c) and figure 9(c) show the template image with noise is correctly match with reference image.

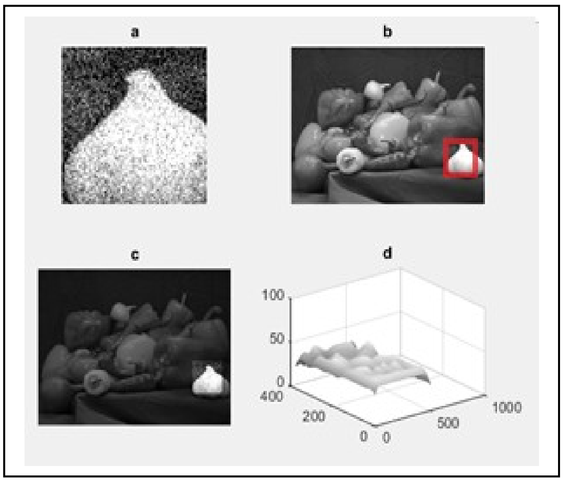

Fig. 8. (a) Template of size 80x80 with noise, (b) Reference image, (c) Register image, (d) Surface plot

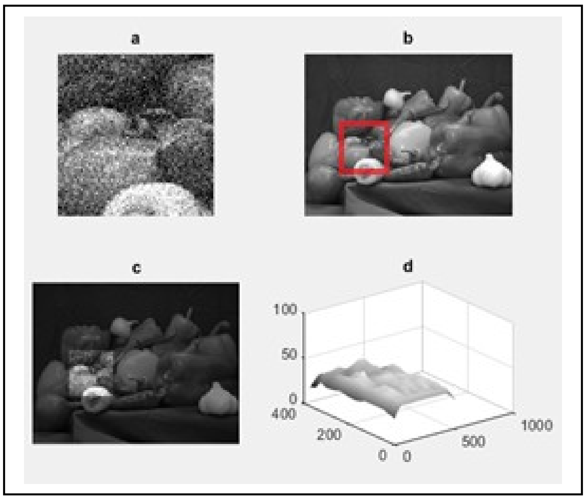

Fig. 9. (a) Template of size 110x110 with noise, (b) Reference image, (c) Register image, (d) Surface plot

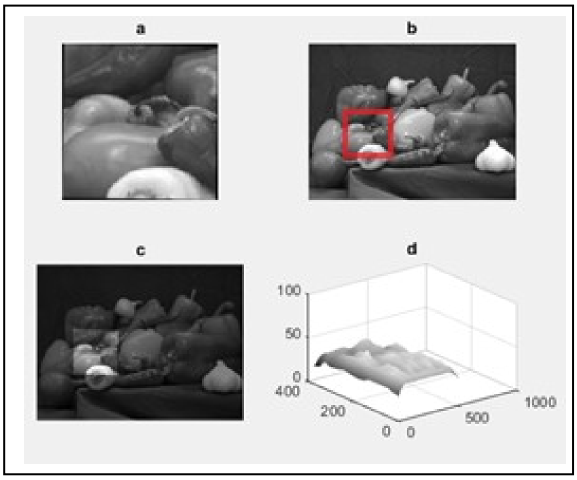

Fig. 10. (a) Template of size 110x110 with rotation of 1 degree, (b) Reference image, (c) Register image, (d) Surface plot

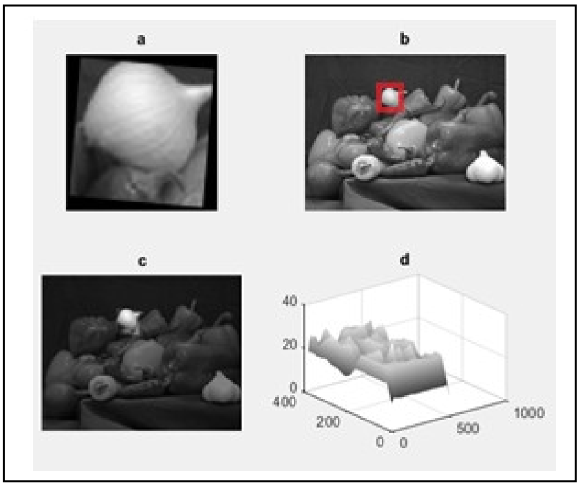

Fig. 11. (a) Template of size 60x60 with rotation of 5 degree, (b) Reference image, (c) Register image, (d) Surface plot

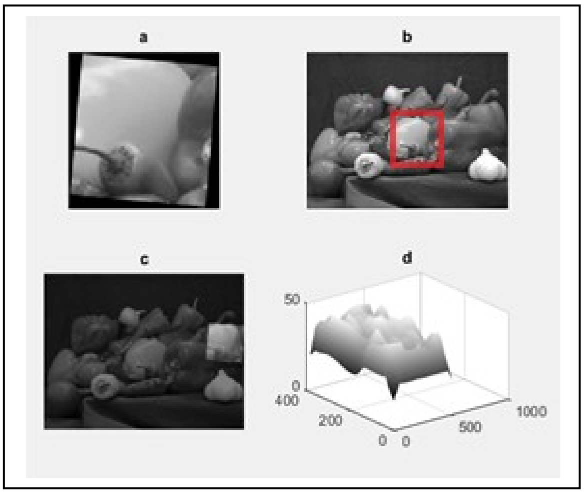

Fig. 12. (a) Template of size 90x90 with rotation of 10 degree, (b) Reference image, (c) False image registration, (d) Surface plot

VI. CONCLUSION

The experiment is carry out to test the method of similarity measure on the number of sample template image with different size and condition. From the study and analysis of result table, came to conclusion that both of algorithms can be used for searching match area between two set of images. From the experiment, SSD and NCC give a perfect template matching when the normal template is used. However, both method failed to give good template matching when some altered template image has been used. Theoretically, SSD is simple among similarity measures method and has less computation cost since it only involve square operation and pixels subtraction between template and the original image. It also take less time in second to search the area in an image which is match to the template. On the contrary, NCC is more complex compare to SSD since it involves multiplication, division and square root operation. Cauchy-Schwarz inequality also involve in NCC to complete the computation. Despite of taking a long time in execution, NCC is more robust than SSD in illumination change.

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