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IMAGE REGISTRATION BY TEMPLATE MATCHING USING NORMALIZED CROSS-CORRELATION

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***Abstract*— Template matching is used for many applications in image processing. Cross Correlation is the basic statistical approach to image registration. It is used for template matching or pattern recognition. Template can be considered a sub-image from the reference image, and the image can be considered as a sensed image. The objective is to establish the correspondence between the reference image and sensed image. It gives the measure of the degree of similarity between an image and template. This paper describes medical image registration by template matching based on Normalized Cross-Correlation (NCC) using Cauchy-Schwartz inequality. The algorithm for template matching using NCC is implemented in MATLAB. The algorithm does the template matching and uses the Cauchy-Schwartz's inequality to simplify the procedure. The developed algorithm is robust for similarity measure. An experimental result with medical images registration with noise and without noise is shown in the results section.**

Key Words: Normalized Cross-correlation (NCC), Cauchy-Schwartz inequality, Image registration, Template Matching.

I. INTRODUCTION

Template matching is one fundamental task occurring in countless image analysis applications. Template matching is the process of finding the location of a sub image, called a *template*, inside an image. There are number of methods for image registration. Here we have discussed the template matching application for matching a small image which is a part of big image with given big image. Once a number of corresponding templates are found, their centers are used as corresponding control points to determine the registration parameters. Template matching involves comparing a given template with windows of the same size in an image and identifying the window that is most similar to the template [1, 2].

The basic template matching algorithm consists in calculating at each position of the image under examination a distortion function that measures the degree of similarity between the template and the image. Then, the minimum distortion, or maximum correlation, position is taken to locate the template into the examined image. Typical distortion measures are the Sum of Absolute Differences (SAD) and the Sum of Squared Differences (SSD) [3, 5]. However, as far as template matching is concerned, Normalized Cross Correlation (NCC) is often the adopted for similarity measure due to its better robustness [1, 2, 3].

II. TEMPLATE MATCHING USING NORMALIZED CROSS-CORRELATION (NCC)

Suppose for the given image g, we want to match the template f as shown in Fig.1. Simple method for measuring similarity or mismatch measure is by taking the absolute difference between template f and given image g over a region$\mathcal{A}$.

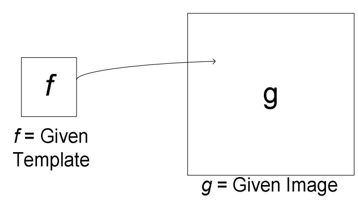

Figure 1. Template matching, $f < g$

The maximum value of absolute difference will give the similarity measure. Generally f is very small image compare to given image g. If we take the sum of difference square between template f and given image g over a region A, then in analog form equation is

$$\iint_{\mathcal{A}} (f-g)^2 \tag{1}$$

And in digital form, generally image having 2-D,

$$\sum_{i,j\epsilon\mathcal{A}}\sum\left(f(i,j)-g(i,j)\right)^2 \tag{2}$$

If we expand the above equation (2.1),

$$\iint_{\mathcal{A}}(f-g)^2=\iint_{\mathcal{A}}(f)^2+\iint_{\mathcal{A}}(g)^2-\iint_{\mathcal{A}}(2fg) \tag{3}$$

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For given template the term $\iint (f)^2$ is fixed and for given image the term $\iint (g)^2$ is also fixed or constant. The term $\iint (f\text{-}g)^2$ will give the degree of mismatch. If this both terms are constant then remaining term $\iint (2fg)$ is a measure of similarity between template f and image g [1, 2, 3].

A. Cauchy-Schwartz Inequality

This inequality is given by

$$\iint_{\mathcal{A}} (f.g) \le \sqrt{\iint_{\mathcal{A}} (f)^2 \iint_{\mathcal{A}} (g)^2} \tag{4}$$

and above equation is equal, when g = cf, Where c is constant. If we convert this equation into digital form then,

$$\sum_{i,j\varepsilon\mathcal{A}} \sum \left(f(i,j) * g(i,j) \right) = \sqrt{\sum_{i,j\varepsilon\mathcal{A}} \sum f^2(i,j) \sum_{i,j\varepsilon\mathcal{A}} \sum g^2(i,j)} \tag{5}$$

and equal, when $g(i,j) = c\, f(i,j)$. If image energy varies with the position then matching equation (3) can fails [4].

$$\iint_{\mathcal{A}} f(x,y)\ .\ \mathrm{g(x+u,\ y+v)dxdy} \ \le$$
$$\left[\iint_{\mathcal{A}} f^2(x,y) \mathrm{dx\ dy} \iint_{\mathcal{A}} g^2(x+u,y+v) \mathrm{dx\ dy} \right]^{1/2} \tag{6}$$

Where u and v are variable, shift component along x-direction and y-direction respectively. In the above equation (6), $f(x, y)$ is very small and it is zero outside a region. The LHS of equation (6) has the term

$$\iint_{\mathcal{A}} f(x,y) . \mathrm{g(x+u,\ y+v)dxdy}$$

is nothing but cross correlation between f and g. The term

$$\iint_{\mathcal{A}} g^2(x+u,y+v)\mathrm{dxdy}$$

is not constant and depends on u and v position. So we can not use cross-correlation, we have to go for normalized cross-correlation. As per Cauchy-Schwartz Inequality

$$\int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} f(x,y)\, \mathrm{g(x+u,\ y+v)dxdy} \le \mathrm{C}_{fg} \tag{7}$$

$$\mathrm{NCC} = \frac{\mathrm{C}_{fg} = f.g}{\left[\iint_{\mathcal{A}} g^2(x+u,y+v)\mathrm{dxdy} \right]^{1/2}} \tag{8}$$

Above equation (8) gives the normalized cross correlation. The maximum value of above ratio will give the measure of similarity in the given image g. The Normalized Cross-covariance is the linear correlation coefficient of statistics and is equivalent to the normalized cross correlation of the zero mean equivalents of f and g [4, 5]. It is given by

$$C(f,g) = \frac{n\Sigma fg - \Sigma f \Sigma g}{\sqrt{(n\Sigma f^2 - (\Sigma f)^2)(n\Sigma g^2 - (\Sigma g)^2)}} \tag{9}$$

Where n = number of pixels in the template
f = Template
g = Image part under template

III. IMPLEMENTATION OF NCC ALGORITHM

The algorithm for template matching using NCC is implemented in MATLAB. The following algorithm does the template matching and uses the Cauchy-Schwartz's inequality to simplify the procedure.

i. Load the original image and template.

ii. Pad the image on all the sides with zeros so that the center of the template falls on the very first pixel of the main image when kept on the top-left corner as shown in Fig. 2

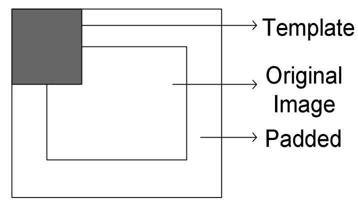

Figure 2. Template Matching

a Calculate the size of the template.

b Pad rows of zeros on the top and bottom of main image. The number of rows is equal to the size of template in y-direction divided by 2.

c Pad columns of zeros on the left and right side of the above image with number of columns equal to the size of template in z-direction divided by 2 and the length of columns being main image size in y-direction plus size of template in y-direction.

iii. Now, move the mask over the entire image and simultaneously calculate the values of summation of template padded image under the template and store it in an array.

iv. Also calculate the values of padded image under the template's square and sum all the values. Take the square root of the obtained value and store it in an array.

v. Divide the result obtained in step (iii) by the result obtained in step (iv).

vi. Find the position where the maximum value in the above result falls. The co-ordinates so obtained will give the best match of the template and calculate maximum cross-correlation coefficient.

vii. Recover the template from the main image using the above obtained co-ordinates and the size of template.

IV. IMPLEMENTATION OF NCC ALGORITHM

We present the results for medical image registration by template matching. The experiments are conducted on gray scale brain image of size 512 x 512. The different size of template is extracted from the original image.

First, we have tested the image registration with un normalized cross-correlation. Fig.3 shows the false image registration with unnormalized cross correlation. Fig. 3(a) show the original image and the template of size 80 x 80 are extracted from original image is shown in Fig.3(b). Using simple cross-correlation the generated image for registration shows the false location in the image is shown in Fig.3(c) and Fig.3(d) shows its NCC plot. So we can conclude that simple cross correlation is not used for image registration.

The Perfect registered image using NCC algorithm as discussed in earlier section with different template size is shown in the Fig.4 to Fig.6.

Table.I shows the Maximum NCC Value and Cross correlation coefficient with different template size for image registration. For perfect template matching the value of maximum cross correlation coefficient is 0.99. With Noise the maximum cross correlation coefficient is not 0.99 but this value can be considered for match.

TABLE I. MAXIMUM NCC VALUE AND CROSS-CORRELATION COEFFICIENT

Sr. No.	Template size	Maximum NCC value	Recovered (X,Y) co-ordinate	Maximum Cross Correlation Coefficient
1.	50x50	5151	(255,163)	0.9992
2.	80x80	8096	(168,144)	0.9999
3.	90x90	9986	(343,209)	0.9987
4.	150x150	16040	(299207)	0.9994
5.	50x150	9764	(309,276)	0.9993
6.	110x80	9452	(255,179)	0.9989
7.	80x80With Noise	7686	(168,144)	0.8824
8.	110x110With Noise	10600	(230,221)	0.7690

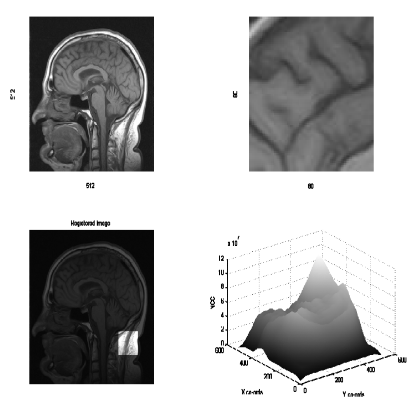

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Figure 3. (a) Original Image of size 512 x 512 (b) Template of size 80 x 80 (c) False Image Registration (d) NCC plot

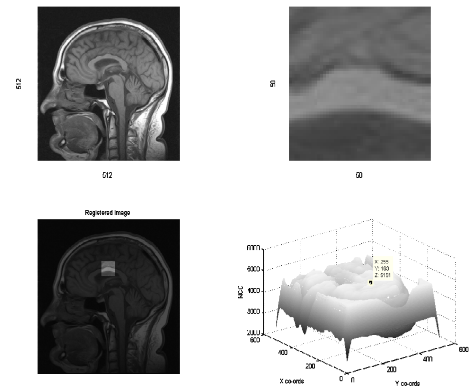

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Figure 4. (a) Original Image of size 512 x 512 (b) Template of size 50 x 50 (c) Registered Image (d) NCC plot

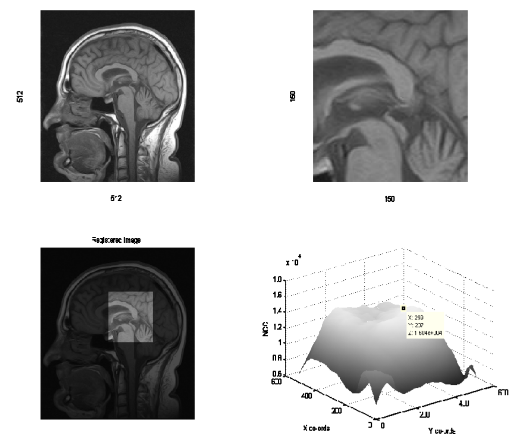

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Figure 5. (a) Original Image of size 512 x 512 (b) Template of size 150 x 150 (c) Registered Image (d) NCC plot

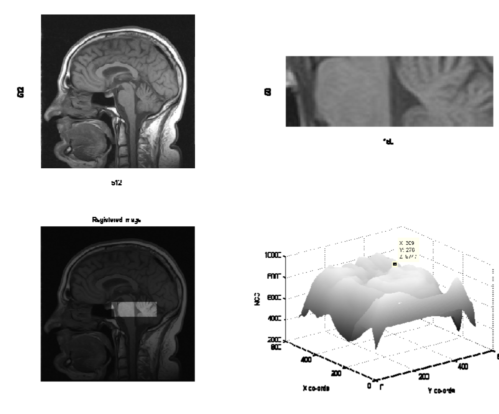

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Figure 6. (a) Original Image of size 512 x 512 (b) Template of size 50 x 150 (c) Registered Image (d) NCC plot

Fig.7 shows the results of image registration by changing contrast and adding noise in the templates. The result shows the correct image registration with noise and contrast change.

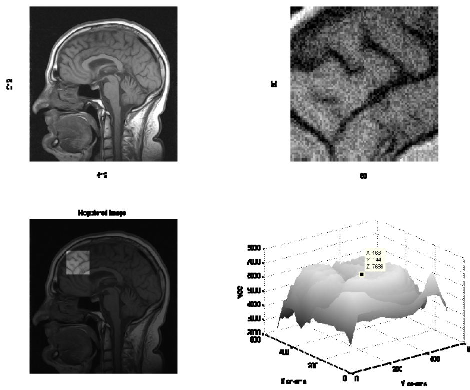

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Figure 7. (a) Original Image of size 512 x 512 (b) Template of size 80 x 80 with noise(c) Registered Image (d) NCC plot

Fig.8 shows the image registration by rotating template (size 90 x 90) 25^0 and use the NCC algorithm. It is clear from the result of Fig.8(c) for rotated template normalized cross-correlation shows the false image registration.

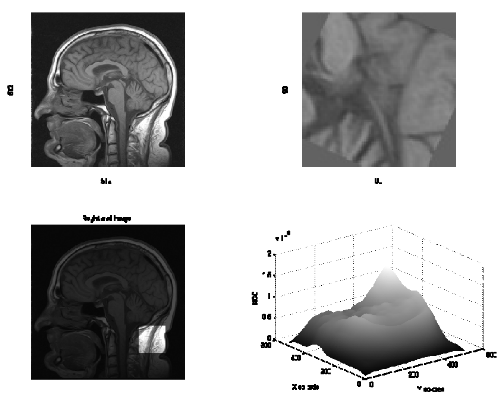

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Figure 8. (a) Original Image of size 512 x 512 (b) Rotated template of size 90 x 90 (c) False Image Registration (d) NCC plot

V. CONCLUSION

We have described a template-matching algorithm, for image registration based on NCC using Cauchy-Schwartz Inequality relying on similarity measures. It is clear that Normalized Cross-Correlation (NCC) is the ideal approach to image registration by template matching.

It gives perfect template matching in the given reference image. The Maximum Cross-correlation coefficient values indicate the perfect template matching with noise and without noise condition. This approach gives registered image, if the sensed images do not have any rotation or scaling.

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