Detecting the Storm Movement by Sub Pixel Registration Approach of Newton Raphson Method

Cho Thinzar and Nyein Aye

Abstract—**The change detection, storm detection and forecasting the weather condition consist of in the field of natural disaster management as the essential role. The detecting of the storm direction is provided to manage and to prevent the possible attacked region of the land. The sub pixel registration approach is applied for computing the movement of the interested cloud region. The direction of the storm can be tracked from these computations. Especially, the attacked region of Myanmar Land is forecasted from multi-date satellite image by using the digital image correlation based on the sub-pixel accuracy with Newton Raphson method. The proposed method is very effective because of its experiment and its result.**

Index Terms—**Connected neighborhood, digital image correlation, newton Raphson method, sub-pixel registration algorithm.**

I. Introduction

Human can't be terminated the natural disaster. The weather prediction is very important for human daily life to prevent and reduce the attack of natural disaster. The storm direction detecting system is developed based on the sub-pixel accuracy with Newton Raphson method. The pixel correlation among the images is computed accurately by the Digital Image Correlation (DIC) for motion detection. The main application of DIC is in experimental mechanics. During the last two decades, various applications had been reported for two-dimensional measurement of displacement and strain field using the method of DIC. The most fundamental applications of two-dimensional DIC are found in fracture mechanics studies [1], [2], including measurement of strain field near crack-tips at high temperatures [3], strain measurement near stationary and growing crack-tips [4] and measurement of crack-tip opening displacement during crack growth [5], [6]. H. A. Bruck *et al*. [1] proves that the computation of the digital image correlation using Newton Raphson method of partial differential correction. The integer pixel registration algorithm is used in their correlation computation.

Moreover, DIC should serve as a valuable tool for biomedical research and the two-dimensional in-plane displacement and strain calculation problem and strain deformation [7]-[9]. B. Pan *et al.* [10] describes the performance of three different types of sub-pixel displacement registration algorithms in terms of the registration accuracy and the computational efficiency.

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B. Pan *et al.* [11], investigated the problem of subset size selection in the DIC technique based on the Sum of Squared Differences (SSD) correlation criterion. They assumed that the gray intensity gradients of image noise are much lower than that of speckle image. A theoretical model of the displacement measurement accuracy of DIC is derived for choosing an optimal subset size for speckle patterns. Goh Kok Yong [12] studied the deformation in shear region of glued laminated timber beam by applying the digital image correlation.

More recently, DIC was successfully extended to micro-deformations study of scanning tunneling electron microscopy images as well as macro-deformation in concrete during loading. S. Khairumniza-Bejo and M. Petrou [13] presented the novel detection method based on the elastic image registration for landslides monitoring. They considered the grey level value correlation and geometric deformation for measuring the similarity between two images. The parametric model of image transformation is applied to register images with sub-pixel accuracy.

This paper is presented the development and the limited experimental verification of sub-pixel registration algorithm for storm prediction from the correlated region of successive satellite images. The modified sub-pixel registration algorithm is based on the cross correlation of Newton-Raphson method. Many correlation detecting methods are essentially needed the initial feature point pairs between two images. Unlike the existing correlation approach, the proposed system is not required the predefined matched feature point pairs of base and input image. This algorithm not only measures the displacements but also predict the nearest attack region of Myanmar Land such as Rakhing State, Delta and Taninthari State, etc.

II. Sub-Pixel Registration in DIC

The operation of Digital Image Correlation is required the images of a moving or deforming subject. The numerous sub-images are divided from each image. The center of each sub-image is on the correlation control point from which the sub-pixel displacement will be calculated. The basic principle of DIC is to match two speckle patterns before and after deformation. Typically, a subset of $(2M+1) \times (2M+1)$ pixels from the un-deformed image is chosen to find its location in the deformed image. The displacements of the subset centre can be determined once the location of the subset in the deformed image is found. For the best estimation of the displacements, the following cross-correlation coefficient is most commonly used [1], [3], [10], [11].

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$$C(u,v)=\sum_{x=-M}^{M}\sum_{y=-M}^{M}[f(x,y)-f_m][g(x+u,y+v)-g_m] \times\left(\sum_{x=-M}^{M}\sum_{y=-M}^{M}[f(x,y)-f_m]^2\right)^{1/2} \times\left(\sum_{x=-M}^{M}\sum_{y=-M}^{M}[g(x+u,y+v)-g_m]^2\right)^{-1/2} \quad (1)$$

$f(x, y)$ and $g(x+u, y+v)$ are the grey values of the subset centered at the source and target point located in the reference and deformed images respectively; u and v are the displacements between two subsets; and g_m and f_m are the ensemble averages. Because the minimal unit in digital image is one pixel, the displacement calculated from (1) is an integer multiple of one pixel. Moreover sub-pixel registration can be used in a variety of application areas because it provides a way to accurately measure displacements of individual points of a plane, without any contact and disturbance. The correlation coefficient curve fitting method, gradient based method and bi-cubic are well known sub-pixel registration methods for the sub-pixel accuracy. Now the next section will present the sub-pixel registration algorithm with Newton iteration for Digital Image Correlation.

III. Developed Newton Raphson-Method

For achieving sub-pixel accuracy, interpolation schemes are used to reconstruct a continuous gray value distribution in the deformed images. The higher order interpolation would provide more accurate results, but with the limitation of requiring more computation time.

The Newton-Raphson (N-R) method [1] takes the deformation of the concerned subset between the two images into account. It assumes each of these points (x, y) in the reference image is mapped to (x', y') in the deformed image using the following relations [1], [10], [12].

$$x' = x+u+\frac{\partial u}{\partial x}\Delta x+\frac{\partial u}{\partial y}\Delta y$$
$$y' = y+v+\frac{\partial v}{\partial x}\Delta x+\frac{\partial v}{\partial y}\Delta y \quad (2)$$

where u and v are the displacement components for the subset centre in the x and y directions respectively. The terms Δx and Δy are the distances from the subset centre to the point (x, y).

Including the gradient terms in (2) signifies that the $(2M+1)\times(2M+1)$ rectangular subset surrounding a point P can be stretched or compressed [10]-[12]. The normal strain terms ux, vy sheared as the subset is being optimally matched to the corresponding point in the deformed image. The mapping function permits the matching of square areas from the undeformed image to non-square areas in the deformed image. Only in the case where obvious non-homogenous deformation exists will the N-R method using a second-order shape function lead to an improvement in the registration accuracy.

A simple sum-of-squares correlation function is employed to evaluate the similarity of un-deformed and deformed subsets. This is slightly different to N-R algorithms described in [1], [14]. Let $f(x, y)$ and $g(x', y')$ denote the discrete grey distribution of un-deformed and deformed images respectively. From equation 3 we can see that the sum-of-squares correlation function C with a range of [0, +α] is a function of vector $P=(u,ux,uy, v, vx, vy)^T$.

$$C(P)=\sum_{x=-M}^{M}\sum_{y=-M}^{M}\left[f(x,y)-g(x'-y')\right]^2 \quad (3)$$

When the calculated subsets get the maximum degree of similarity between the interrogated subset and the target subset, the minimum correlation function C is calculated. The nonlinear (3) can be solved using the N-R iteration method.

The integer pixel search result can be used as an initial iteration guess. Thus we can obtain

$$P=P_0-\frac{\nabla C(P_0)}{\nabla^2 C(P_0)} \quad (4)$$

where P_0 is the iteration guess, P is the approximation value after iteration, $\nabla C(P_0)$ is the gradient of the correlation function. In developed approach, P_0 is the approximate region related to the neighborhood of the region of interest. If the region of interest is R $(M\times M)$ rectangular subset, the $(M+3)$ x $(M+3)$ rectangular region included the neighborhood of R is defined as the approximate region P_0. The iteration process is only performed in small rectangular region. It will be reduce the processing times and complexity instead of using the whole pixels in an image.

And $\nabla^2 C(P_0)$ is the second-order derivation of the correlation function, commonly called the Hessian matrix. According to the research of Vendroux and Knauss [1], we can implement an approximation to the Hessian matrix without affecting the calculation accuracy. As a consequence of the approximation, the complexity of particular program calculation process is greatly reduced [10]. Pan B. *et al.* [10] recommended that the iterative Newton–Raphson method gave highest accuracy and best stability for digital image correlation. However processing is much slower than other methods. They evaluate the measurement accuracy and computational efficiency by using the computer-generated speckle images.

In modified Newton-Raphson method, the extracting the ROI region in reference image and searching its correlated region in source image are performed by the intensity variation of the twenty four connected neighbourhood of the extracted features. It will provide to reduce the time complexities. For registration process, the initial correlated feature pairs can be obtained by this computation.

Unlike the first-order linear shape function used in equation (2), we should note that a Newton Raphson method employs a second-order shape function to approximate the deformed subset as in [3]. Schreier and Sutton *et al.* [15] discussed the effects of calculation errors induced by these two shape functions in detail. Actually, in most cases, the linear shape function is a good and accurate approximation to the deformed subset. Therefore, the N-R method using a second-order shape function will not significantly improve the sub-pixel registration accuracy. Although, the second order shape function of Newton method will lead to an improvement in the sub-pixel registration accuracy for non-homogenous deformation case.

For digital images, no grey level information is available between pixels. The sub-pixel grey and grey gradient values are needed in the realization of correlation method. So the selection of the interpolation scheme (Nearest Neighbor, Linear, B-spline) is considered a key factor of the N-R method, as it directly affects the program's calculation accuracy and convergence character.

IV. System Overview

The system overview is illustrated in Fig. 1. The multi-date satellite images are obtained from INSAT. After performing the resizing, gray scale converting and noise filtering steps, the region of interest (ROI) is selected in the first image of the image frames. Then the related region is estimated in second input image. This process will provide to reduce the matching times instead of searching the correlated points in the whole image. The correlation of the ROI region and correlation point pairs in all images are computed by the sub-pixel registration algorithm of Newton Raphson iteration method. The transformation matrix between successive two images can be obtained from the control points pairs. Then the movements of the sub pixel are detected from above transformation.

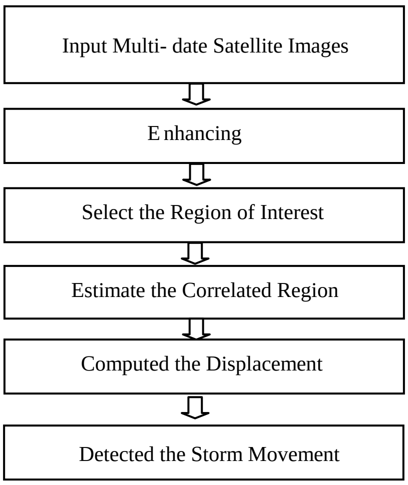
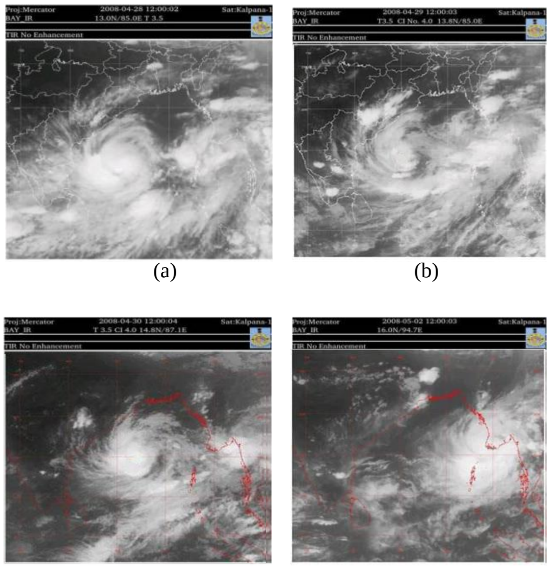


Fig. 1. System over view of the proposed system.

V. Experiment and Results

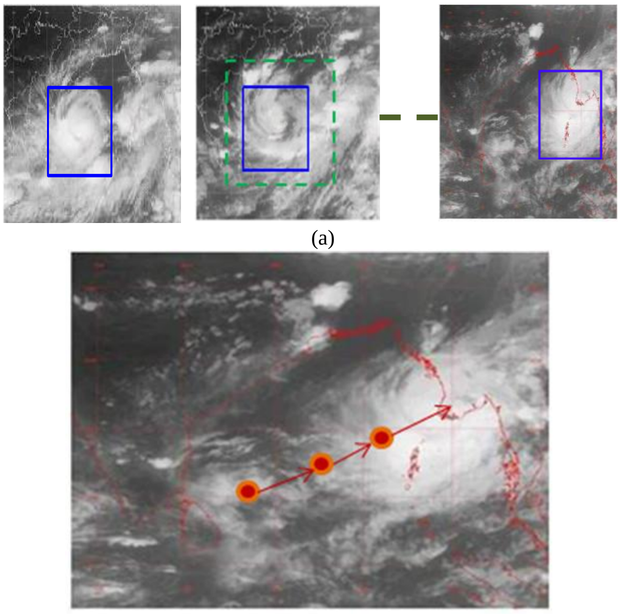
The real image dataset is used in the experiment. The dataset of Cyclonic Storm Nargis formed on April 27, 2008 to dissipate on May 3, 2008 is obtained from the website of KALPANA satellite of India. Some images of Cyclonic Storm Nargis land fallen in Myanmar are shown in the Fig. 2. Fig. 2(a), Fig. 2(b), Fig. 2(c) and Fig. 2(d) are the multi-dates satellite images accquied at 28th April, 29th April, 30th April and 2nd May noon, respectively.

After enhancing stage, the region of interest are manually selected from the first satellite image (Source image) for initial approximation of the match pixel pairs. The correlated region in the second image (target image) is approximated by the extracted feature with 24 connected neighboring approach. The seletect ROI and correlated region in each satellite image are shown in Fig. 3(a). The exact correlated region computed by the sub-pixel registration approach and its result is shown in Fig. 3(b).



(a) (b) (c) (d)

Fig. 2. Some Satellite images



(a)

(b)

Fig. 3. Detection of the storm direction.

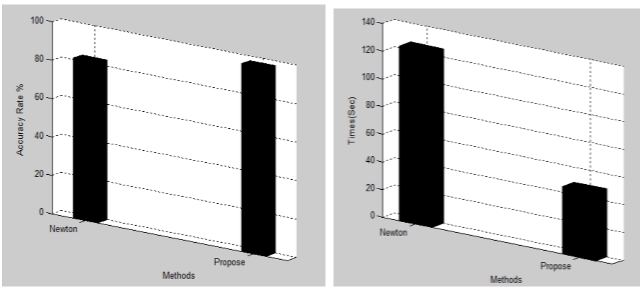


Fig. 4. Comparison of accuracy rate and processing time.

The accuracy rate is computed by the ratio of the number of images which are truly detected the storm area and the total number of images in the experiment.

$$Accuracy\ rate = \frac{No.\ of\ \ TRUE\ detection\ of\ the\ storm\ position}{No.\ of\ \ images} \times 100\%$$

The compairison of the accuracy rate between original Newton methon and proposed approach or modified Newton method for this experiment is shown in Fig. 4(a). The proposed approach needs the less processing time than the traditional Newton method and its comparison result is shown in Fig. 4(b) by bar graph.

VI. Conclusion

The sub-pixel registration algorithm based on the Newton-Raphson method is developed for detecting the correlated region among the images. The second-order derivation of the Newton correlation function is applied. The proposed algorithm automatically computed the correlation of the control points in all images on the ROI region. This approach can not only detect the storm motion but also the object deformation.

The comparison results show the more accurate for the propose approach and it is recommended for measuring the storm movement. According to the results, the accuracy rate is increased above 10% and time complexity is reduced the half of the usual approach. The prediction of the nearest attack region of Myanmar Land is ongoing research work. The comparison of proposed approach with other Gaussian correlation approach will consider as a future work.

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