Detecting Tropical Cyclone Using Infrared Satellite Images

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Abstract

Tropical Cyclone (TC) are among the most destructive natural disasters. Analysis of TC image from infrared satellite images is an active field of research. Many algorithms were developed in past few decades on TC image analysis. The location of TC is always an important and difficult problem. Many researchers have tried to detect the right Region of Interest (ROI) from the image automatically. In this paper, feature extraction method based on modified Morphological processing and the color segmentation approach based on the intensity transformation and color spaces are applied for automatically extraction the location of storms. 45 TCs occurred between 1989 and 2014, are tested and several experiments have been done to evaluate the proposed system.

Keywords: *Satellite Images, Region of Interest, Morphological Processing, Color Segmentation*

1. Introduction

Weather conditions are important roles for agriculture, business, transportation and people's daily lives. Storm is one of the nature hazards. It affects human lives, millions worth of crops and structural damages. Predicting storms and estimating the rain storm direction are essentially needed for preventing and reducing the natural disaster for the weather predictions. The observation of the storm direction is supported to control and protect the possible attacked region of the land. The satellite images can be used in disaster management. Satellites can sometimes provide early warning about disasters through remote sensing [3]. Tropical meteorologists have been applying satellite images for examining tropical storms for almost 25 years. At that time, the intensity estimation was made from the appearance of a storm's heart, its banding, and the size of the cloud pattern. These means was useful for estimating the intensity of tropical storms in most cases, but they had serious shortcomings when the cloud pattern of a storm was either unsure or when it was sustaining severe short-period change [1].

Nowadays, storm prediction is done by detecting the patterns of cloud in order to categorize the intensity of cloud using satellite images [4]. This paper presented an automatic tropical cyclone detection system using infrared satellite images. The feature extraction algorithm is developed based on the Modified Morphological processing for cloud region extraction. The histogram matching method is applied for storm recognition. The multi-storms locations are determined after the reconstruction process.

The rest of the paper is organized as follows. Section 2 commences related research works. Section 3 presents background theory. Section 4 describes Modified Morphological Processing Method. Section 5 explains the overview of the system. Section 6 discusses experimental results and finally, conclusions are drawn in Section 7.

2. Related Works

P.T. Long, [8] proposed to extract typhoon features into slices from the satellite cloud image. Running and statistical image classification methods are used to find the eye and the form of the typhoon. In different resolutions and regions of interest, encoding typhoon satellite images have the rebuilding ability to its fast image by using the vector quantization technique.

B. Sreenvias, B. Narasimaha Chary, and I. Karimnagar, [2] presents the digital image processing with special reference to satellite image. To image data in order to powerfully present the data for order visual interpretation, the improvement approaches are tried for the initial processing of raw image data to improve for geometric distortion. The aim of organization process is to classify all pixels in a digital image into one of various land cover subjects or classes. This classified data may be used to construct thematic maps of the land cover present in an image.

3. Background Theory

This section provides the main characteristics of the ensembles that will be analyzed in the present work**.**

3.1. Morphological Image Processing

Morphology is also called in the mathematical term as the set theory. Most image processing problems use morphology such as merged and robust approach. The meaning of morphology commonly represents a branch of biology that assigns with the appearance and shape of animals and plants. In the circumstance of mathematical morphology, it can be used as a tool for distinguishing the parts of image that are very convenient in the representation and description of region shape, such as skeletons, convex hall and the boundaries. Morphological pruning, thinning and filtering approaches are helpful techniques for preprocessing or post processing. Sets in mathematical morphology states objects in an image. For example, an absolute morphological representation of the binary image is the set of all dark pixels in an image. In binary images, the sets in equation are members of the 2-D integer space Z2, where each element of a set is a tuple (2-D vector) whose coordinates are the (x, y) coordinates of a dark (or white depending on convention) pixel in the image. The elements Z3 can be presented as the set of gray-scale images. In this task, two elements of each component of the set refer to the coordinates of a pixel, and the third consistent to its discrete gray-level value [1], [5] and [6]. Sets in lofty dimensional spaces can include other image features, such as time and color varying elements.

3.2. Logic Operations Involving Binary Images

The dilation, erosion, opening and closing operations are the most basic morphological operations for binary images. The footing of morphological processing is in the mathematically severe area of set theory. However, this level of experience is hardly required. The basic logic operators are AND, OR, and NOT (COMPLEMENT). These operations are functionally complete in the sight that they can be merged. It is a very difficult problem to recognize the objects in an image. One way to solve this task is to transform the gray scale image into a binary image, in which each pixel is limited to a use of either 0 or 1[3]. Most morphological inventions are easy logic operations and very rough. Opening and closing are two mostly used basic operators and they are used to eliminate light (opening) or shadow (closing) details. Morphological operators are pertained to an image with a set of a known shape, called a structural element (SE).

3.2.1. Dilation and Erosion

Dilation and erosion are also the basic operators in morphology. In a binary image to grow or think an object, the operation used dilation. Controlling the formation of the structuring elements, thickening or growing is needed to use as the specific manner.

Dilation of the set M by set N, denoted by M $\oplus$ N, is acquired by first reflecting N about its inception and then changing the result by *m*. All *m* such that M and reflected N changed by that have at least one point in common forms the dilated set.

$$M \oplus N = \{p \mid \left(\hat{N}\right)_x \cap M \neq \phi\} \qquad (1)$$

$\hat{N}$ denotes the reflection of N

$$\hat{N} = \{p \mid p = -n, for n \notin N\} \qquad (2)$$

$(N)_p$ denotes the translation of Q by $p = (p_1, p_2)$

$$(N)_x = \{z \mid z = n + p, for n \notin N\} \qquad (3)$$

$$(N)_p = \{z \mid z = n + p, for n \notin N\} \qquad (4)$$

Thus, dilation of M by N increases the boundary of M. For gray-scales images, equation (5) is easier than the above description

$$(i \oplus q)(g,h) = \max\{i(g-p,h-q) + q(p,q) \mid (g-p), (h-q) \notin\| E_f ; (p,q) \notin E_y\} \qquad (5)$$

Here, t and n denote images I (p,q) and n (p,q). i is being dilated and n is called the structuring element where E_i and E_n are the domain of i and y respectively. In dilation, it is necessary to select the maximum value of i + n in a neighborhood described by n. If all elements of q are positive, the dilated image is brighter than the original and the dark details are either reduced or eliminated [4].

Erosion “decreases” or “narrows” objects in a binary image. The decreasing process is managed by a shape mentioned as a structuring element. Erosion of M by N, denoted by $M \Theta N$, is the set of all **a** such that N translated by **a** is completely included in M,

$$M \Theta N = \{p \mid (N)_p, \subseteq M\} \qquad (6)$$

For gray-scale images,

$$(i\Theta N)(g,h)=\min\{i(g+p,h+q)-n(p,q)\,|\,(g+p),(h+q)\in E_i;(p.q)\in E_n\} \quad (7)$$

Erosion is thus based on choosing the minimum (1) value of (i-n) in a neighborhood defined by the shape of **n**. If all elements of **n** are positive, the output image is darker than the original and the effect of bright details in the input image are reduced if they cover a region smaller than **n**.

3.2.2 Opening and Closing

The subsequent morphological operators are defined in terms of opening and closing. Their expressions for gray-scale and binary images are the same and a distinction will not be henceforth made [9].

M is said to be opened by N if the erosion of M by N is followed by a dilation of the result by N.

$$M\circ N=(M\Theta N)\oplus M \quad (8)$$

Opening results in displacement of narrow peaks. The origin erosion cuts the small parts and darkens the image. The following dilation expands the brightness but does not reestablish the details removed by erosion. Similarly, M is said to be closed by N if M is first dilated by N and the result is then eroded by N. Thus,

$$M\bullet N=(M\oplus N)\Theta N \quad (9)$$

Closing is used to separate dark details from image. The original dilation cuts dark details and creates the image brighter. The erosion that follows darkens the image but does not reestablish the details removed by dilation. Opening as well as closing is unchanged operators i.e., continuous openings do not change an image, nor do successive closings.

$$(i\circ n)\circ n=i\circ n \quad (10)$$

$$(i\bullet n)\bullet n=i\bullet n \quad (11)$$

4. Modified Morphological Processing Method

The cloud region extraction and storm prediction are performed by the modified morphological method. The foundations of morphological operations are opening, closing, erosion and dilation.

The hit-or miss transformed of X by Y = (Y_1, Y_2) is defined as $X\otimes Y=\{X\Theta Y_1)\cap\left(A^c\Theta Y_2\right)$ (12)

This is affected by two erosions.

If X contains the multiple disjoint sets, the small window W which is enclosed by one of the disjoint set X and background may be eliminated by using the relation equation 13.

$$X\otimes Y=(X\Theta Y_1)\cap(X^c\Theta[W-A]) \quad (13)$$

That will reduce the detected region and obtain the very small area of the region. To obtain the full detected region, the above relation can be modified by considering the region filling process as follows:

$$X\otimes Y=(X\Theta Y_1)\cap(X^z\Theta[W-(A\oplus Y)\cap X^c]) \quad (14)$$

The small cloud regions which may not be storm are removed by using the opening, dilation, closing and erosion operations. The predicted storm cloud regions are extracted using the feature extraction method based on the color segmentation and the intensity transformation of color spaces approach. The separated cloud regions are extracted from the rescaling input satellite image.

5. System Overview

The overview of the system is illustrated in Figure. 1.

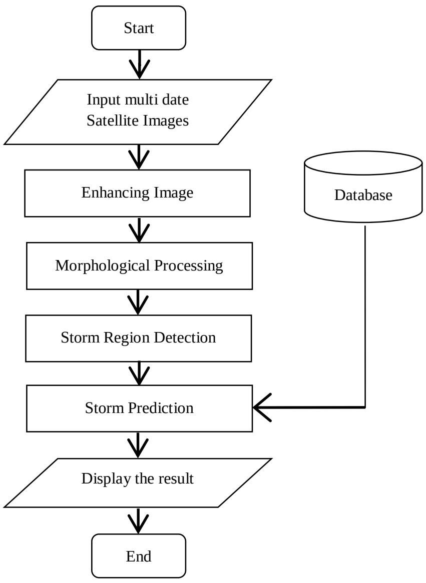
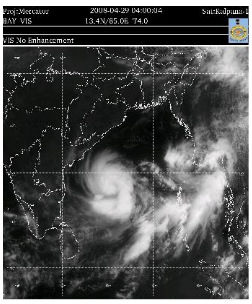


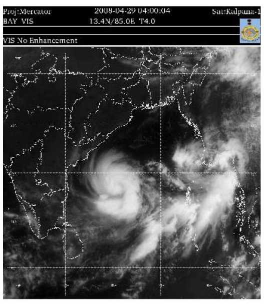
Figure 1. Overview of the proposed system

The multi-date satellite images are obtained from INSAT and the set of input image folders are chosen as the first stage. The second stage is image enhancing stage that is performed for processed images. Rescaling, noise removing and gray scale and binary converting stages are included in image enhancing stage. The storm temperature is represented by gray-level value for the infrared satellite image and it is transferred into 256(0-255) level of gray scale digital images. Image scaling method is used to adjust the gray-scale value of the image. In Morphological processing stage, the small cloud regions which may not be storm are removed by using the erosion, dilation, opening and closing operations. The predicted storm cloud regions are extracted employing the feature extraction method based on the color segmentation and the intensity transformation of color spaces approach. By extracting high intensity feature points, the location of the storm region is detected. The separated storm regions are extracted from the rescaling input satellite image. This detected storm regions were segmented by cropping the detected cloud regions from the image. Histogram matching approach is used in this stage as storm prediction. This process is performed to match the segmented storm region with the storm image database. The various kinds of tropical cyclone images are stored in database as histogram and they will be useful to predict the storm. Finally, the detected storm locations are displayed in the original loaded image as the first stage.

6. Experimental Result

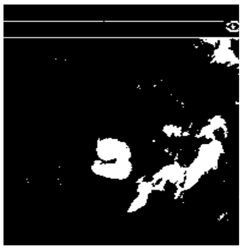
The real image dataset is used in the experiment. There are 45 tropical cyclones and the image dataset of Cyclonic Storm called Nargis land fallen in Myanmar from April 27, 2008 to May 3, 2008 is obtained from the INSAT satellite of India. In order to lessen the damages caused by the cyclone attacks, the storm prediction for disaster management needs to be developed. Some grabbed images of Cyclonic Storm are shown in Figure.2 (a) and (b). Step by step Morphological processing and cloud region extraction is shown in Figure.3 (a), (b) and (c).





(a) **(b)**

Figure 2. Some satellite images



(a) **(b)**

Figure 3 (c). Extraction cloud region

By using the segmented parts, the substantial cloud regions are obtained from the input satellite image as shown in Figure.4. Histogram matching compared the segmented cloud regions and stored various kind of cloud in database. If there is no storm or the storm is disappear, the weather is clear in the input images. The small cloud region is detected in "Image Enhancement" step. Cloud extracting will recognize some input images. After the segmentation of the cloud regions, there is no correlated storm by matching histogram. So, display result will appear as "No Storm".Figure 5 shows the histogram of some storm images.

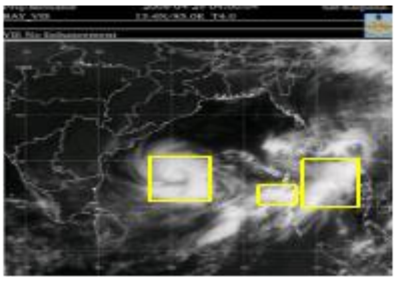


Figure 4. Detecting storm region

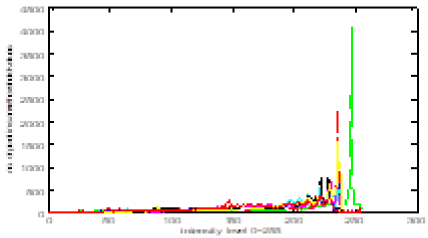


Figure 5. Histogram of some storm images

The accuracy rate is computed by the ratio of the number of images which are truly detected for the storm area and total number of images in experiment. The data set of Nargis Cyclone is tested and the calculation of percentage of the accuracy is increased with the number task. Table.1 shows the accuracy of the result.

$$Accuracy\ rate\ = \frac{No\ of\ True\ detection\ of\ \ the\ storm}{No\ of\ Images} * 100$$

Table 1. Comparison of accuracy result for storm image using two methods

Methods	The Average Accuracies
Morphological Image Processing Method	0.74 (74%)
Proposed Method	0.83 (83%)

7. Conclusion

In this paper, the automatic storm prediction system is developed for natural disaster prevention and mitigation. The modified morphological operation is applied for noise removing, features extraction, small region removing and cloud region extraction using infrared satellite images. Estimating the location of storm is based on the histogram features matching approach that is performed with storm database. The storm location and reconstruction are performed after detecting the substantial cloud regions**.** Identifying intensity of the Tropical Cyclone and tracking the motion of the storm are ongoing research.

References

[1] B. Zita, and J. Flosser, "Image Registration Method", a survey, "Image and Vision computing", pp.977-1000, 21.11.2003.

[2] B. Srinivas, B. Narasimaha Chary, and I. Karimnagar, "Processing of Satellite Image Using Digital Image Processign ", A world Forum on Geospatial, 2011.

[3] E.J. Karen, " A review of the status of satellite remote sensing and image processing techniques for mapping natural hazards and disasters", Landcare Research, PO BOX 40, Lincoln 7640, New Zealand.

[4] J.A. Parikh, and A. Rosenfeld, "Automatic Segmentation Satellite Data", IEEE Transaction on Systems,1978, pp.736-743.

[5] J.B. Gabriel, "Segmentation and Recognition using Structure from Motion Point Clouds", University of Cambridge.

[6] K. Rita, R. Chandan, "Cyclone Track Forecasting Based on Satellite Image Using Artificial Neural Networks", ISPRS *Journal of Photogrammetry* and *Remote Sensing*, November 2009, volume 64, Issue 6,pp.513-521.

[7] M.Sezgin, "Survey over Image Thredsholding Techniques and Quantitative Performance Evaluation", Journal of Electronic Imaging, 2004, pp. 56-73.

[8] P.T. Long, "Typhoon Locating and Reconstruction from the Infrared Satellite Clouc Image", *The journal of MULTIMEDIA*, JUNE 2008,Volume 3, No.2

[9] S. Shah, P. Notarpietro and M. Branca, "Storm Identification, Tracking and Forecasting Using High Resolution Images of Short-Range X-Band Radar",2015.

[10] Y. Zhang, S. Wistar, J.A. Piedra-Fernandez, J.Li, M.A. Steinberg, J.Z. Wang, "Locating Visual Storm Signatures from Satellite Images", "In Big Date, 2014 IEEE International Conference, 2014 October 27, pp 711-720.