# Tropical Cyclone Determination using Infrared Satellite Image

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**ABSTRACT**

Many sub-continents in the world have the region that are affected by the cyclone in every year. To prevent the loss of life and their assets, cyclone prediction is a major role because of directly related to the lives and household of human being. Satellite images provide an excellent view of clouds which can be used in weather forecasting and especially Infrared Red (IR) satellite images play in many environmental applications. To find the tropical cyclone (TC) center, the basic stage is to extract the main cloud of the cyclone. In manual segmentation, selection of the storm region is complicated, time consuming task and it also need the human experts for every time processing. The semi and fully automatic storm detection is sophisticated and difficult process because of the overlapping between boundaries of the cloud. Fuzzy C-means (FCM) clustering and morphological image processing is applied for segmentation each infrared satellite images. The effectiveness is tested for infrared cyclone image over Kalpana satellite which is obtained from the INSAT satellite of India. 45 tropical cyclones are occurred during the period 1989-2014 over Bay of Bengal. Cyclones Nargis that mainly affected to Myanmar in 2 May 2008 as case study. Experimental results show that the high location accuracy can be obtained.

*KEYWORDS: satellite image; tropical cyclone; FCM*

## INTRODUCTION

Weather prediction is an important role for agriculture, business, transportation and people's daily lives. Storm is one of the nature hazards. Myanmar is accessible to natural disasters especially cyclone, flood, fire and landslides. Tropical cyclones occur during the Pre-Monsoon Months of Mid-April to Mid-May and Post Monsoon months of October and November in Myanmar. Predicting storms and estimating the tropical cyclone direction are essentially needed for preventing and reducing the natural disaster.

Tropical meteorologists have been applying satellite images for examining tropical storms for almost 25 years. This paper presented an automatic tropical cyclone detection system using infrared satellite images. To get the tropical cyclone location automatically, fuzzy c-means clustering and morphological image processing is used in this system. The authors in [1] propose the intelligent location of tropical cyclone center mainly based on image processing method and morphology to get the TC center. The limitation of their method is that it requires some threshold value to segment the tropical cyclone image. David [7] forecast the cyclone using multi-temporal change detected satellite images mainly using FCM method. It can segment the region including storm region and other cloud similar as a storm. The main purpose of this paper is to segment the storm location automatically using FCM and morphological image processing. Image segmentation is one of the sophisticated methods in many areas. There are many segmented methods such as Gabor filter, Edge detection, thresholding, supervised segmentation and unsupervised segmentation. Fuzzy c-mean is one of the unsupervised segmentation method to divide the proper region of interested and non-interested region. It also the most traditional and classical image segmentation algorithm. FCM is modified as a soft extension of the traditional hard C-means. Membership function compute the probability of each clusters belong to a cluster. Thus, it can overcome the difficulties of the hard C-means clustering.

Most image processing problems using morphology such as merged and robust approach. Morphological pruning, thinning and filtering approaches are helpful techniques for preprocessing or post processing. The dilation, erosion, opening and closing operations are the most basic morphological operations for binary images.

### A. Process of the System

The overview of the system is shown in figure 1. 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 preprocessing images. Rescaling, noise removing and gray scale and binary converting stages are included in image enhancing stage. After that, Fuzzy C-means clustering method is to segment the location of all highly dense circular regions of cyclone image. This will include tropical cyclone regions amongst other cloud formations having similar features. The small cloud regions which may not be storm are removed by using the erosion, dilation, opening and closing operations. The detected storm cloud regions are extracted 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.
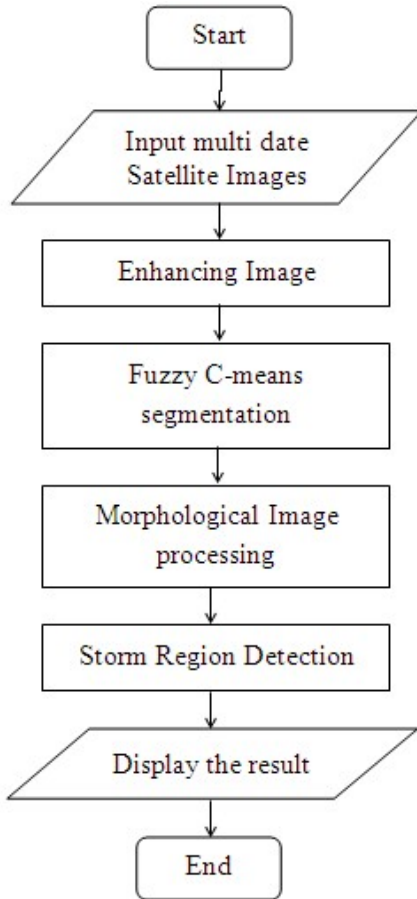
**Figure1. Overview of the system**

## B. Data and Methodology

Sequential tropical cyclone of infrared satellite images used in this research are hourly obtained by Indian meteorological satellite (INSAT) and freely available at http:/www.imd.gov.in/section/satmet /dynamic/insat.htm. This dataset is provide in the file format of JPEG as shown in figure 2.
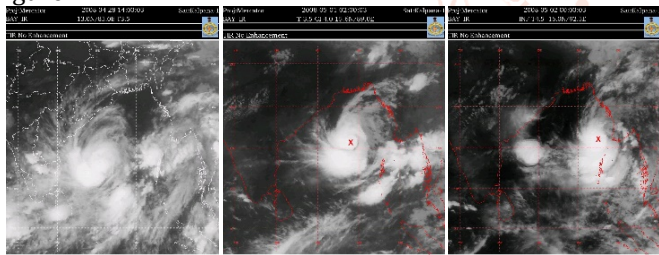


**Figure2. Multi-dated satellite images of Cyclone Nargis**

Feature extraction method is done by using Fuzzy C-means (FCM) algorithms. The function of FCM algorithm can be minimized by the following objective function. Consider a set of unlabeled patterns X, let X={x1,x2,....,xN}, x ∈ Rf, where N is the number of patterns and f is the dimension of pattern vectors(feature). The FCM algorithm focuses on minimizing the value of an objective function. The objective function measures the quality of the partitioning that divides a dataset into c clusters. The algorithm is an iterative clustering method that produces an optimal c partition by minimizing the weighted within groups sum of squared error objective function. Fuzzy c-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters[5] . This method is frequently used in pattern recognition. It is based on minimization of the following objective function in equation 1.

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^m \|x_i - c_j\|^2 \quad , 1 \le m < \infty \quad (1)$$

where m is any real number greater than 1, $u_{ij}$ is the degree of membership of $x_i$ in the cluster j, is the $i^{th}$ of d-dimensional measured data, $c_j$ is the d-dimensional center of the cluster, and $\|*\|$ is any norm expressing the similarity between any norm expressing the similarity between any measured data and the center. Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership $u_{ij}$ and the cluster centers $c_j$ by

$$Ui_j = \frac{1}{\sum_{k=1}^{c} \left[\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right]^{\frac{2}{m-1}}} \qquad C_j = \frac{\sum_{i=1}^{N} U_{ij}^m x_i}{\sum_{j=1}^{N} U_{ij}^m} \quad (2)$$

This iteration will stop when
$max_{ij}\left\{\left\{|u_{ij}^{k+1} - u_{ij}^k|\right\}\right\} < \varepsilon$ where $\varepsilon$ is a iteration between 0 and 1, whereas k are the iteration steps. This procedure coverages to a local minimum or a saddle point of $J_m$.

The footing of morphological processing is in the mathematically severe area of set theory. 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. 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. Opening results in displacement of narrow peaks. The origin erosion cuts the small parts and darkens the image. Closing is used to separate dark details from image.

### 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.

$$M \oplus N = \{ p \mid \left(\hat{N}\right)_x I M \ne \phi \} \quad (3)$$

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

$$\hat{N} = \{ p \mid p = -n, \, for n \notin N \} \quad (4)$$

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

$$(N)_x = \{ z \mid z = n + p, \, for n \notin N \} \quad (5)$$

$$(N)_p = \{ z \mid z = n + p, \, for n \notin N \} \quad (6)$$

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

$$(i \oplus q)(g,h) = \max \{i(g - p, h - q) + q(p,q) \mid (g - p),$$
$$(h - q) \notin \| E_f; (p,q) \notin E_y\} \quad (7)$$

Here, i 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 domains 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,

$$M\Theta N = \{ p \mid (N)_p, \subseteq M \} \qquad (8)$$

For gray-scale images,
$$(i\Theta N)(g,h) = \min \{(g+p, h+q) - n(p,q) \mid (g+p),$$
$$(h+q) \in E_i; (p.q) \in E_n\} \qquad (9)$$

Erosion is thus based on choosing the minimum (i) 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 .

## 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.
$$M \circ N = (M\Theta N) \oplus M \qquad (10)$$

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,

$$M \bullet N = (M \oplus N)\Theta N \qquad (11)$$

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.

$$(i \circ n) \circ n = i \circ n \qquad (12)$$
$$(i \bullet n) \bullet n = i \bullet n \qquad (13)$$

## C. Experimental Results
Cyclone Nargis is used as the case study. It happened 27 May 2008 in Bay of Bangel and it has fallen in Myanmar at 2 May 2008. The mutilated satellite images are obtained hourly from INSAT satellite of India. Before segmentation the cyclone image, image enhancement is needed to perform in

figure 3(a). After enhancing the image, Fuzzy C-mean algorithm is used for segmentation the interested cyclone in the image in figure 3(b).
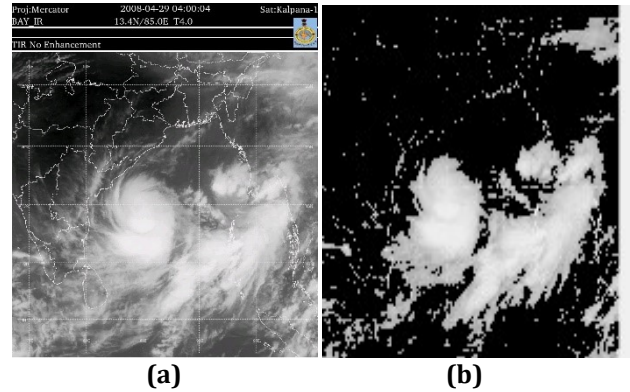


**(a)** **(b)**

Fig.3. Experimental result. (a) Image enhancing using median filtering (b) Segmented by FCM method
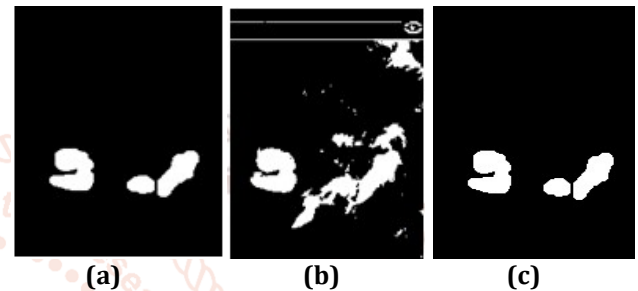


**(a)** **(b)** **(c)**

**Fig.4. Step by step morphological image processing**

The segmented image need to perform by using Morphological image processing method as shown in above figure 4. The location of the storm is segmented in the original input image as shown in figure 5.
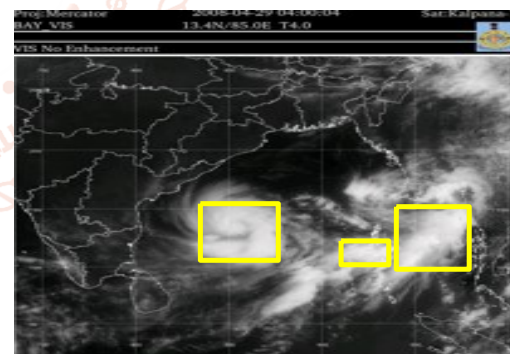


**Fig.5. Storm region detection in input image**

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.

$$\text{Accuracy} = \frac{\text{No of true detection of the storm rate}}{\text{No of images}} *100$$

**TABLE I. Comparison of accuracy result for storm image using two methods**

| Methods | The Average Accuracies |
|---------|------------------------|
| C Means | 0.74 (74%) |
| FCM | 0.83 (83%) |

## D. Conclusion

In this paper, the automatic storm prediction system is developed for natural disaster prevention and mitigation. Applied FCM algorithm is used to segment the location of the tropical cyclone in the input satellite image. After getting the storm and clouds similarities as the storm are also included. To remove the small cloud region, morphological image processing method is applied. The storm region is segmented from the input image and reconstruction are performed after detecting the substantial cloud regions. Identifying the tropical cyclone center and tracking the motion of the storm are ongoing research.

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