DEVELOPMENT OF IRREGULAR CLOUD CLUSTER ENCAPSULATING STRUCTURE FROM SATELLITE INFRARED IMAGES

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Abstract: A major task in flood prediction is the estimation of precipitation. Detection and tracking of convective cloud is an integral part of it. Convective cloud can be detected from thermal infrared (TIR) images because clouds are associated with very low temperature. They can be tracked in a series of TIR images, so that their position can be estimated in order to identify the place of precipitation. For tracking of cloud structures in a series of TIR images, the shape of these structures are required to be determined, so that each cluster can be identified as a single object. Additional features based on the shape can be determined for effective tracking of cloud clusters in a sequence of images.

In the present paper, a cloud cluster encapsulating structure developing technique has been proposed that fits absolutely close to a cluster and does not include any non-cluster pixels at all. The enclosing structure takes exactly the form of the individual cluster and hence is unique for each cluster. It helps to treat a cluster of pixels as a single object and can be helpful in its tracking.

1. INTRODUCTION

Detection of convective cloud and estimation of precipitation are the integral parts of flood prediction process during monsoon. Clouds need to be tracked so that the approximate place of precipitation can be estimated (Das et al. 2009). The convective clouds are associated with very low temperature, hence they can be identified from thermal infrared images (TIR), as they appear light in these images (Mandal et al. 2005, Turiel et al. 2005, Goswami & Bhandari 2011a). Clouds can be tracked from a series of satellite infrared images (Goswami & Bhandari 2011b, Goswami & Bhandari 2011c, Goswami & Bhandari 2012, Vila et al. 2008). In order to track cloud structures, the shape of these structures are required to be determined, so that each cluster can be identified as a single object. Features based on the shape then can be computed for effective tracking of cloud clusters in a sequence of images.

Regular geometric shapes like rectangle, circle, oval, etc. can be used to encapsulate cloud clusters (Mandal et al. 2005). Since a cloud formation seldom takes shape of a regular geometric figure, therefore, a standard geometric structure will include not only the selected cloud cluster pixels, but also non-cluster pixels, which may eventually affect the average pixel value of that particular cluster. Hence, there should not be any regular geometric shape of structure to enclose a cloud cluster, rather should be tailor-made according to the shape of the individual cluster.

In this study, a cloud cluster enclosing structure has been created that takes exactly the form of the individual cluster and hence is unique for each cluster. This enclosure helps to treat a cluster of pixels as a single object and can be helpful in its tracking.

2. CLOUD CLUSTER EXTRACTION

Before the extraction of cloud cluster from the TIR image, segmentation has to be done on it. Figure 1 shows a TIR image taken on 16th June 2011 at 0400 hrs by Kalpana-1 (Indian Meteorological Satellite).

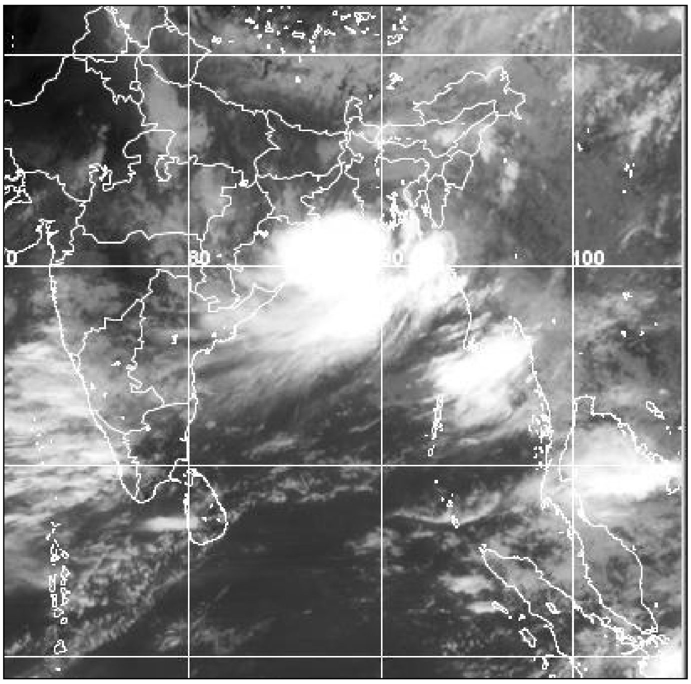

Figure 1: TIR image at 0400 hrs of 16th June, 2011.

Features for each pixel of the image have been calculated using eight neighborhoods. The features are mean, standard deviation, busyness, and entropy (Mandal et al. 2005). Based on these features segmentation is performed on the image using *k-means clustering* (Hartigan & Wong 1979). After the clustering, cold clusters are extracted that represent the cloudy pixels (Figure 2).

Figure 2: Extracted coldest cluster representing cloud.

Each cluster contains connected pixels that are called regions. The connected regions in the selected cluster are labeled using connected component labeling (Di Stefano & Bulgarelli 1999). Figure 3 shows the different connected regions in the selected cloud cluster labeled by different colors.

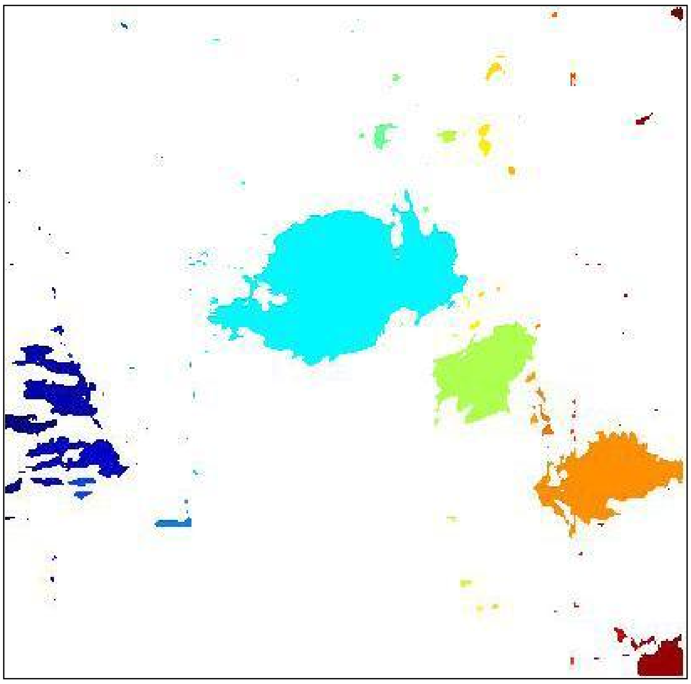

Figure 3: Connected regions in the selected cloud cluster.

The large connected regions in the cloud cluster are then identified (Figure 4). These regions are required to be tracked in the series of TIR images. Figure 4 shows the largest connected region in the selected cloud cluster.

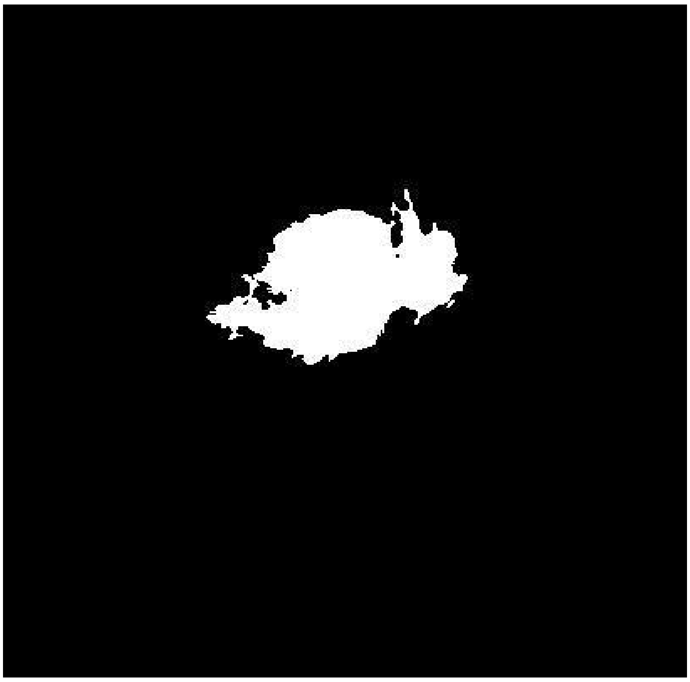

Figure 4: Largest connected region in the selected cloud cluster.

MORPHOLOGICAL OPERATIONS

The extracted cloud cluster has very irregular shape and has few holes too (Figure 4). Before proceeding forward, some morphological operations are required to be implemented on the cluster, so that the boundary of the cluster becomes smooth and the small holes get filled up.

Erosion and dilation are two fundamental morphological operations. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries. The number of pixels added or removed from the objects in an image depends on the size and shape of the *structuring element* used to process the image. Since the shape of the cluster has curves, so the shape of the structuring element is taken as *disk*.

1. Erosion

Erosion of a set A by structuring element B: all z in A such that B is in A when origin of B=z.

$$A \ominus B = \{z|(B)_z \subseteq A\} \qquad (1)$$

This shrinks the object.

2. Dilation

Dilation of a set A by structuring element B: all z in A such that B hits A when origin of B=z.

$$A \oplus B = \left\{z\middle|\left(\hat{B}\right)_z \cap A \neq \phi\right\} \qquad (2)$$

This grows the object.

As the cluster is need to be smoothened and filled up holes without affecting the structure of the cluster, the combination of erosion and dilation using the same structural element has been implemented. The operations opening and closing are performed by combining erosion and dilation.

3. Opening

This is erosion followed by dilation. From equations (1) and (2):

$$(A \ominus B) \oplus B \qquad (3)$$

This eliminates protrusions, breaks necks, and smoothes contours.

4. Closing

This is dilation followed by erosion. From equations (1) and (2):

$$(A \oplus B) \ominus B \qquad (4)$$

Closing smoothes contour, fuses narrow breaks and long thin gulfs, eliminates small holes, and fill gaps in the contour.

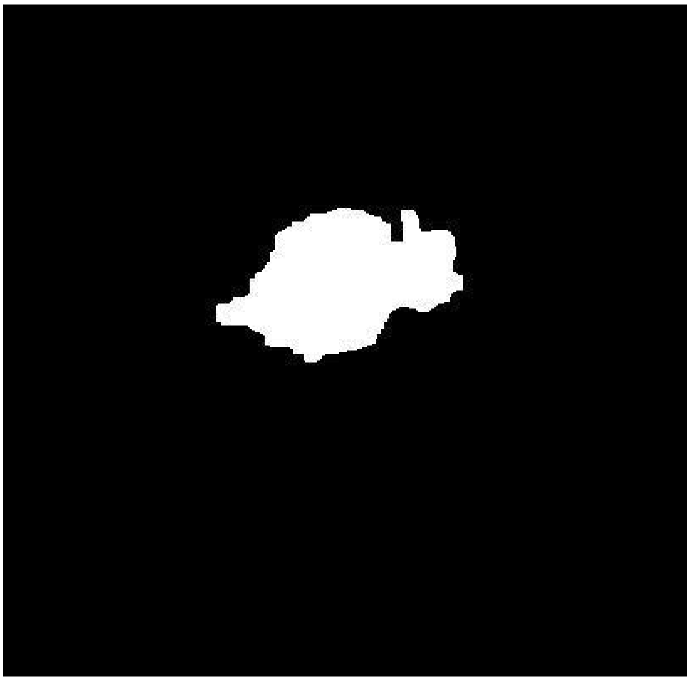

Figure 5: Cloud cluster after morphological operations.

Both opening and closing are done on the image using equations (3) and (4). Figure 5 shows the cluster after the morphological operations.

Now this cluster has to be tracked in a series of images. But before doing that its shape has to be extracted so that some features can be calculated which will aid in the association of the clusters in the consecutive images.

IRREGULAR CLOUD CLUSTER ENCAPSULATING STRUCTURE

In order to track the cloud clusters, it is required to associate a particular cluster in the consequent images. This is possible by considering each cluster as a single unit and calculating some features based on this. These features then can be used to associate the individual clusters in two or more consequent images.

In general, standard geometric shapes like rectangle, circle, oval, etc. can be used to encapsulate cloud clusters (Mandal et al. 2005). Since a cloud is very irregular in shape, therefore, a regular geometric structure will not only include the selected cloud cluster pixels, but also non-cluster pixels, which may affect the features calculated for that particular cluster. Hence, the shape of structure to enclose a cloud cluster should be adjusted according to the shape of the individual cluster.

A cluster encapsulating structure developing technique has been proposed in this paper that fits absolutely close to a cluster and does not include any non-cluster pixels at all. This structure can be stored and represented as a matrix of two rows (for x and y coordinates) and n columns, where n is the number of points that will be taken on the boundary of the structure.

Algorithm: Irregular Cloud Cluster Encapsulating Structure

Input: Binary image I of size [a, b]
Output: Image I and Structure S of size [2, n]

Step 1: Set i=1, j=1, n=0
Step 2: Pick the pixel p= I (i, j)
Step 3: If p=1
    Go to Step 4
    Else
    Go to Step 6
Step 4: Pick 4-neighbors of p: p_1, p_2, p_3, p_4
Step 5: If $p_i \neq 1$
    Set p_i=RED
    S= [i, j]
    n=n+1
Step 6: If i<a and j<b
    i=i+1 and j=j+1
    Go to Step 2
Step 7: Stop

The enclosing structure takes exactly the form of the individual cluster and hence is unique for each cluster. This enclosure helps to treat a cluster of pixels as a single object and a number of features can be computed for each cluster that can be helpful in tracking.

3. RESULTS AND DISCUSSION

The experiment was performed on a TIR image of Indian sector on 16 June, 2011, at 0400 hrs, taken by Indian Meteorological Satellite Kalpana-1.

Usually any regular shape of encapsulating structures is usually generated. Figure 6 and 7 show the rectangular and elliptical structures, respectively, as examples of regular shape. However, the irregular cloud encapsulating structure has been shown by the proposed method (Figure 8).

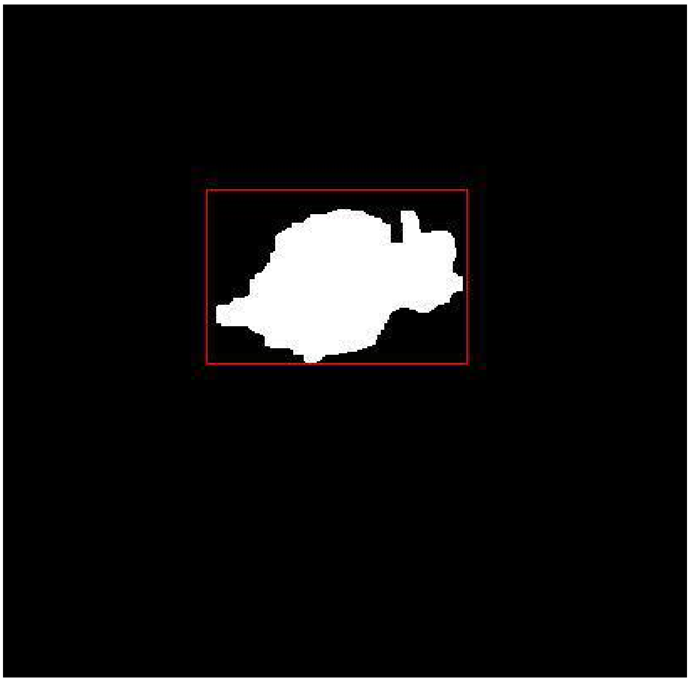

Figure 6: Rectangular cloud cluster encapsulating structure

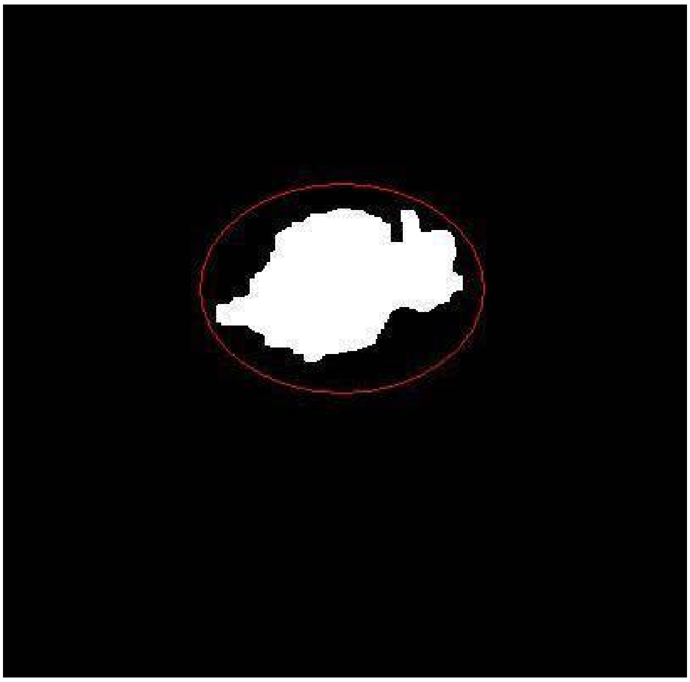

Figure 7: Elliptical cloud cluster encapsulating structure

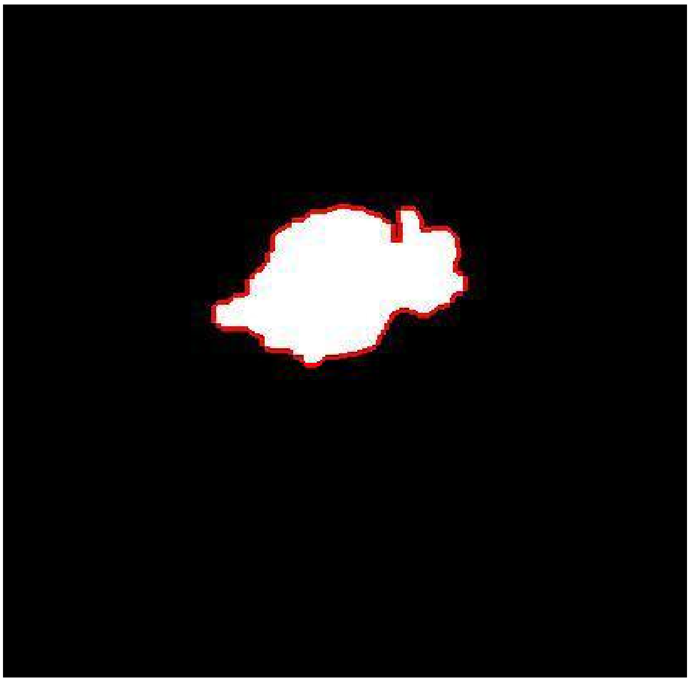

Figure 8: Cloud cluster encapsulating structure.

It's clearly evident from the figures that when rectangular or elliptical structures were used to encapsulate a cloud cluster then a lot of non-cluster pixels were also covered in them. These non-cluster pixels may affect the values of features calculated for the cluster and this may lead to incorrect association of cloud clusters in consecutive images. Whereas the proposed structure (Figure 8) exactly fits the irregular cloud cluster and does not include any non-cluster pixel in its coverage.

4. CONCLUSIONS & RECOMMENDATIONS

In this study, an irregular cloud cluster encapsulating structure generating method has been proposed. Since, a cloud formation mostly does not follow regular shape so the standard geometric shapes like rectangle, ellipse, etc., should be avoided to use for its encapsulation for the better results. If a regular structure is used to represent a cloud cluster, then it will also include non-cluster pixels. This may affect the average pixel value of the cluster. The proposed irregular encapsulating structure is specially created for each cloud cluster. It exactly fits the cluster so it does not include any non-cluster pixel. The structure is unique for each cluster and it binds the pixels in the cluster in a single unit.

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