An Approach on Automatic Tracking and Predicting of Satellite Cloud Clusters Based on Active Contour[1]

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Abstract

The tracking and forecasting of satellite cloud images are very important in term of satellite cloud images used in weather forecast. An approach on automatic tracking of multi-target cloud cluster based on VFC Snake model is proposed on the basis of contour extraction and analysis of cloud cluster, this method can automatically acquire the new location of the target cloud cluster at each moment. A specialized detection algorithm is designed to correct the Snake's tracking results, and more accurate contour curves are obtained. For the forecasting of cloud images, the target cloud cluster's displacement obtained in the tracking process is integrated into the cross-correlation matching to improve the matching accuracy of the cross-correlation method, and more accurate cloud motion vectors are obtained. The experimental results show that the tracking based on contour detection and analysis is fast and highly accurate, and the evolution process of cloud cluster can be directly obtained in a period of time (eg, split, merge, die and newborn), preferable results has also been made in forecasting.

Keywords: *active contour, satellite cloud images, tracking and forecasting*

1. Introduction

Mesoscale convective cloud cluster often forms heavy rain, thunderstorms, hurricanes and other inclement weather, so it is an important part of weather forecast business to track and forecast for it.

In consideration of the complexity of cloud cluster movement, this article adopts a deformable template of active contour to establish cloud cluster tracking model, the model automatically acquires the correct position of the target cloud edge under the action of image force, and split and merge in the evolution process of target cloud can be well depicted. We evenly select part of the pixels inside the target cloud cluster, and correlation matching is used to determine their motion vectors by combining with the cloud cluster texture, the movement of the remaining pixels is filled by the nearest neighbor method, the mutations in vector field are eliminated by the mean filter, and short-term forecast for cloud images is made by the linear extrapolation method based on the amended motion vector field.

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2. Automatic Tracking Method of Multi-target Cloud Cluster based on VFC Active Contour

2.1. The Extraction of Initial Contour

First a grayness threshold T gray is determined to binarize the satellite image I (x, y) to B (x, y), the binarized B(x, y) exists some small cloud cluster fragments, they are unfavorable to track because the occurrence and evolution are too fast, so an area threshold T area, is set to filter the connected region which the area is less than the threshold, outer edge of all the target cloud clusters is found out by edge detection technique for remaining connected region, and it is considered as the initial contour of the target cloud cluster.

2.2. Cloud Cluster Split and Merge

Split and detection: providing $\mathbf{I}_t(x, y)$ is the satellite cloud image at time t, $\mathbf{B}_t(x, y)$ is binary image filtered by the threshold Tgray and Tarea, $S_t = \{s_t^1, s_t^2, \ldots s_t^{n_t}\}$ represents n_t contour collection obtained through deformation of the VFC Snake at time t, which s_t^i represents the contour curve of the *i th* target cloud cluster, $R_t = \{r_t^1, r_t^2, \ldots r_t^{n_t}\}$ is region collection obtained by filling S_t, which r_t^i represents a closed region surrounded by the Snake curve s_t^i, defined as follows:

$$\mathbf{L}_t(x, y) = \begin{cases} i, & (x, y) \in r_t^i \quad and \quad \mathbf{B}_t(x, y) = 1 \\ 0, & else \end{cases} \qquad (2)$$

Order l_t^i is a point set of the value of *i* in $\mathbf{L}_t$, namely $l_t^i = \{(x, y) \mid \mathbf{L}_t(x, y) = i\}$, edge tracking technology is applied to obtain all contours $s_t^{i,1}, \ldots s_t^{i,m}$ in l_t^i for each l_t^i （$i = 1, \ldots, n_t$）, if $m > 1$, namely contour s_t^i is split into m sub-contours $s_t^{i,1}, \ldots s_t^{i,m}$, s_t^i is removed from S_t, and the corresponding sub-contour is added.

Merge and detection: if $r_t^i \cap r_t^j \neq \varnothing$, $i \neq j$, namely the Snake curves s_t^i and s_t^j have the overlap, the merge of s_t^i and s_t^j only needs to perform edge tracking for the region of $r_t^i \cup r_t^j$, the obtained contour $s_t^{i'}$ is the merged contour of s_t^i and s_t^j, s_t^i and s_t^j are removed from S_t, and $s_t^{i'}$ is added.

2.3. Cloud Cluster Die and Newborn

At time *t*, if the *i th* target cloud cluster:

① The corresponding contour s_t^i is degenerated into a straight line or a point

② If the area of closed region r_t^i surrendered by corresponding contour s_t^i is less than the set area threshold T_{area}, then the target cloud cluster has been unfit to continue tracking

If it meets one of the above two conditions, you may think one of the target cloud cluster is dead, and delete the corresponding contour s_t^i from the contour collection S_t.

Detection of newborn cloud cluster is similar to the initial contour extraction method, all the closed region (cloud cluster) in cloud images is filtered by applying of grayness threshold T_{gray} and area threshold T_{area}, if a closed region does not intersect with any r_t^i ($i = 1, \ldots, n$), then the closed region is the newborn cloud cluster, the contour $s_t^{n_t+1}$ of closed region is extracted by edge detection, and added to the contour collection S_t; Otherwise, a merge operation is performed.

3. Calculate the Wind Field

3.1. Acquire the Whole Movement of Target Cloud Cluster

The concept of Snake length l and center of gravity c is introduced, providing the Snake curve has *n* discrete contour points, v_k represents the *k th* point on curve, then the Snake's length and center of gravity are:

$$l = \sum_{k=1}^{n} |v_k - v_{k-1}|$$
$$c = (\bar{x}, \bar{y}), \quad \bar{x} = \frac{1}{l}\sum_{k=1}^{n} x_k, \quad \bar{y} = \frac{1}{l}\sum_{k=1}^{n} y_k \qquad (3)$$

s_t^i, s_{t+1}^i represent the contour curves at time *t* and *t + 1* of *i th* target cloud cluster respectively, center of gravity c_t^i, c_{t+1}^i of s_t^i, s_{t+1}^i can be calculated by the formula (3), then the displacement of the *i th* target cloud cluster can be defined as follows:

$$\Delta d_t^i = c_{t+1}^i - c \qquad (4)$$

3.2. Determine the Internal Movement of Cloud Cluster

The specific calculation formula is as follows:

$$R(p,q) = \frac{\sum_x \sum_y [g(x,y,t_1) - \overline{g(t_1)}][g(x+\Delta d_x + p, y + \Delta d_y q, t_2) - \overline{g(t_2)}]}{\{\sum_x \sum_y [g(x,y,t_1) - \overline{g(t_1)}]^2 \sum_x \sum_y [g(x+\Delta d_x + p, y+\Delta d_y + q, t_2) - \overline{g(t_2)}]^2\}^{1/2}} \qquad (5)$$

Where $g(x, y, t_1)$ is grayness of pixel (x, y) inside cloud area at time t_1, $\overline{g(t_1)}$ is the average grayness value of the template window centered on pixel (x, y) at time t_1 on cloud image. $\overline{g(t_2)}$ is the average grayness value of (p,q) th search domain in search window corresponding to cloud image at time t_2, which p, q is displacement and deviation between the center of (p,q) th search domain and template center in the direction of $(\vec{x}, \vec{y})$. $\Delta d = (\Delta d_x, \Delta d_y)$ is the displacement of cloud area subordinated pixel (x, y) between time t_1 and t_2. Through changes of p, q, correlation coefficient of all the search domain and the template corresponding to the search window is calculated, and the maximum correlation coefficient is chosen to determine the displacement vector, namely it is the motion vector of the pixel (x, y) at time t_1.

4. Short-term Forecast

In general, there is no much change in the motion vector field (wind field) of the adjacent time, and this article adopts linear extrapolation method to forecast the cloud images of next moment based on the fact. The basic idea of linear extrapolation: each pixel in cloud image is displaced the same offset in the direction of motion vector, then this image is a cloud image through a linear displacement and forecast.

$$P'(x,y) = P(x,y) + V(x,y)\Delta t \qquad (6)$$

Where $P(x,y)$ represents the location of cloud image pixel (x,y), $V(x,y)$ is the motion vector of pixel (x,y), Δt is the forecasted time interval, then $P'(x,y)$ is the forecasted location of pixel (x,y) at next moment in cloud image.

5. Conclusion

Due to the particularity of the cloud cluster data, and the complexity of cloud cluster movement, they bring great difficulties to track cloud cluster automatically and accurately, VFC active contour is adopted to establish cloud cluster track model in this article, the correct position of the edge of the target cloud cluster can be automatically obtained in the action of image force, therefore, displacement of target cloud cluster between adjacent time can be determined, and evolution information (split, merge, die, newborn, etc.) of target cloud cluster at different moments can easily be obtained. In addition, the displacement of cloud cluster is integrated into the forecast process in this article to improve the matching accuracy of the cross-correlation method, and achieve more accurate wind field. The results also show that more accurate results can be obtained by the proposed method in this paper.

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