Adhesive image segmentation based on watershed algorithm

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Abstract

Since adhesive image has a deficiency of over-segmentation, the work applied watershed algorithm, whose merits include quick computing speed, closed outline and accurate location, to adhesive image segmentation. In the first few sessions, the basic principle and arithmetic steps of watershed algorithm were illustrated in detail. On this basis, following sessions correspondingly introduced the MATLAB simulation analysis and verification. Through simulation and contrast of the segmentation results by different algorithms, it could be concluded that watershed algorithm, the most effective method, could help split adhesive objects into single ones, while greatly reducing or even eliminating the over-segmentation phenomenon.

Keywords: Image Segmentation, Edge Detection, Threshold Segmentation, Watershed Algorithm, Image Processing, MATLAB Software

1 Introduction

With development of new theories and methods, image segmentation algorithms combined with feature theory are proposed. Thereinto, the image segmentation algorithm based on morphology is widely used at present [1-2]. Adhesive image, with disadvantage of over-segmentation, is segmented using watershed algorithm with advantages such as quick computing speed, closed outline and accurate location. Simulation shows that watershed algorithm, the most effective method, could help split adhesive objects into single ones, while greatly reducing or even eliminating the over-segmentation phenomenon.

2 Principle of watershed algorithm

Watershed algorithm, as an image segmentation method based on mathematical morphology, has been widely used, with advantages such as quick computing speed, closed outline and accurate location. It was firstly introduced into simple binary image processing by Digabel [3] and Lantuejoul [4]. After that, watershed theory was developed by Beucher [5], Vincent [6], et al. to get a general mathematical model for the application of grey-level image segmentation.

The basic thought of watershed algorithm derives from topography. A grey-level image can be seen as a topographic relief, where the grey level of a pixel is interpreted as its altitude in the relief. In the image, the local minimum and adjacent influence region correspond to a catchment basin, with its limits called watershed.

Watershed transformation can be described by the raindrop method. Namely, a drop of water falling on a topographic relief flows along a path to finally reach a local minimum, thus forming a connected region called catchment basin.

By watershed transformation, the original image can be transformed into the marker image using the same marker in a catchment basin and a special marker in watershed in image segmentation field.

3 Mathematical description of watershed algorithm

There is a grey-level image with the maximal and minimal grey levels of *h_max* and *h_min*, respectively. A recursive process is defined as the water level h varies from maximal grey level to minimum. In the recursive process, each catchment basin relevant to different local minimums constantly expands. *X(h)* is a union of sets of catchment basins while water level is *h*. If water level is *h+1*, then a connected component *T(h+1)* will be a new local minimum or a basin expansion of an existent *X(h)*. For the latter, the distances, between each point with an altitude of *h+1* and catchment basins, are calculated according to adjacency relation. If one point is the same distance from more than two basins, then it will not belong to any basin; or else it will belong to the nearest basin, thus producing new *X(h+1)*.

MIN(h) is defined as the local minimum at the altitude of *h*, and *Y(h+1,X(h))*is marked as the set of points, which belong to *X(h)* and have the altitude of *h+1* [7-8].

$$X(h\_\min)=\{p\in D \mid f(p)=h\_\min\}=T(h\_\min)\,, \qquad (1)$$

$$X(h+1)=MIN(h+1)\cup X(h)\cup Y(h+1,X(h))\,. \qquad (2)$$

Watershed transformation *Watershed(f)* is the complementary set of *X(h_max)*, expressed as follows:

$$Watershed(f)=D\setminus(h\_\max)\,. \qquad (3)$$

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4 Procedure of watershed algorithm

(1) Reading grey-level image
(2) Creating structure elements
(3) Enhancing contrast of image
(4) Increasing distances between objects
(5) Transforming goal objects
(6) Valley detection
(7) Watershed transformation
(8) Extracting feature from label matrix

5 Simulation of adhesive image segmentation

Taking image segmentation as research object, the adhesive objects can be segmented into single ones using watershed algorithm.

(1) Reading grey-level image

afm=imread('afmsurf.tiff');
imshow(afm)

Figure 1 shows the original grey-level image.

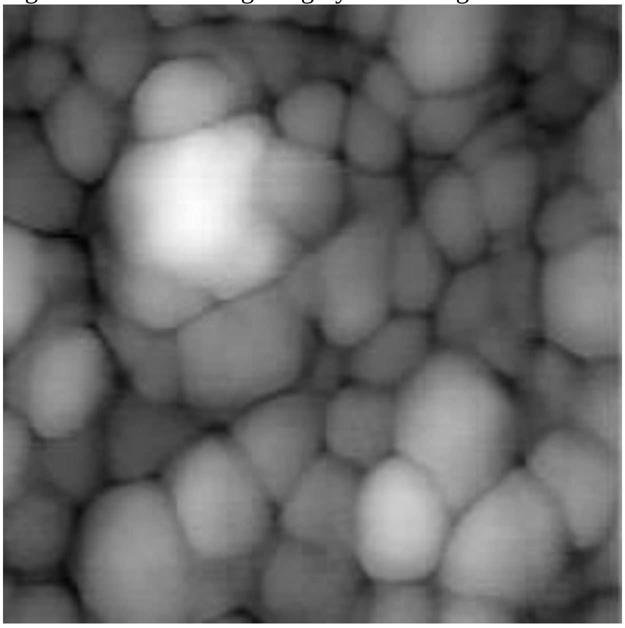


FIGURE 1 Original grey-level image

In Figure 1, adhesive objects with different scales derive that the original image has uneven surface. The valley points of the image can be found using watershed algorithm to achieve effective segmentation of different objects [9-10].

For best segmentation, the goal objects in the image are enhanced to minimizing the number of valley points. Meanwhile, the contrast of the image is increased using top-hat and bottom transformations.

(2) Creating structure elements Se=strel('disk',15);

(3) Enhancing contrast of image

Itop=imtophat(afm,se); % Enhancing contrast by top-hat transformation

Ibot=imbothat(afm,se); % Enhancing contrast by bottom-hat transformation

figure,imshow(Itop,[]),title('tophat result')

figure,imshow(Ibot,[]),title('bottomhat result')

Figures 2 and 3 are the top-hat and bottom-hat images, respectively. The purpose is to enhance contrast of the images.

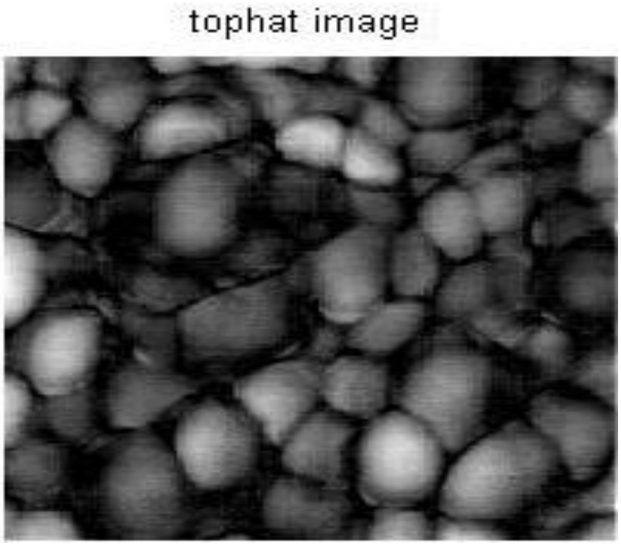


FIGURE 2 Top-hat image

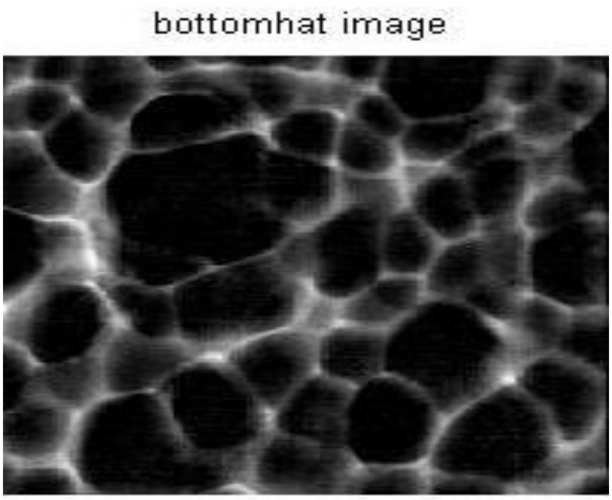


FIGURE 3 Bottom-hat image

(4) Increasing distances between objects

Figure 2 presents that the distances between objects should be increased because of close contact of objects in the image. The original image plus the top-hat transformation image subtracts the bottom-hat transformation image to achieve gap increase between objects [11].

Ienhance=imsubtract(imadd(Itop,afm),Ibot);

%(original+tophat-bottomhat)Increasing contrast of gaps and objects

figure,imshow(Ienhance),title('original+tophat-bottomhat')

Figure 4 shows the image of increased gap.

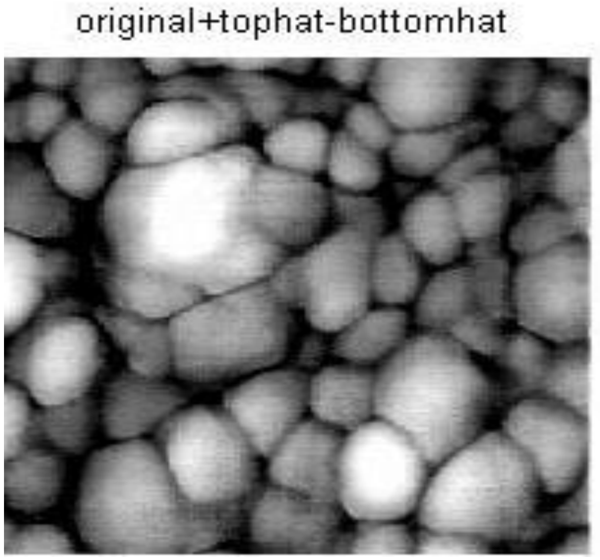


FIGURE 4 Image of increased gap

(5) Transforming goal objects

Before effective detection, valley points of the image are enhanced using imcomplement function.

Iec=imcomplement(Ienhance); %Enhancing valley points of the image

figure,imshow(Iec),title('complement of enhanced image')

Figure 5 shows the image of enhanced valley points.

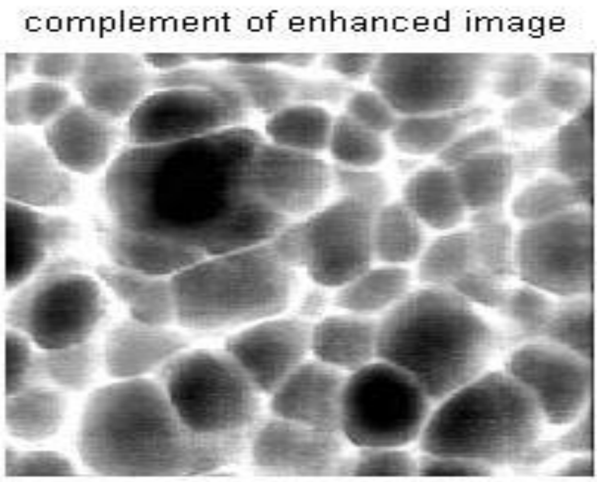


FIGURE 5 Image of enhanced valley points

(6) Valley detection

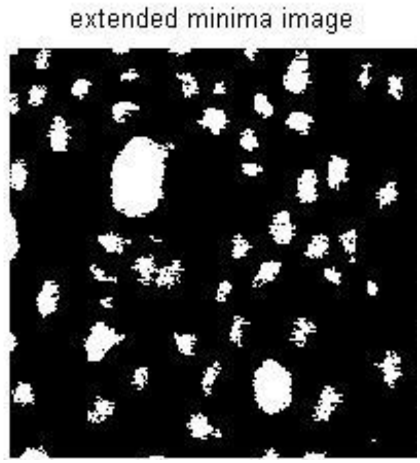
Figure 6 shows the valley detection images after enhancing valley points by Step 5.

Iemin=imextendedmin(Iec,22); %Detecting valley points

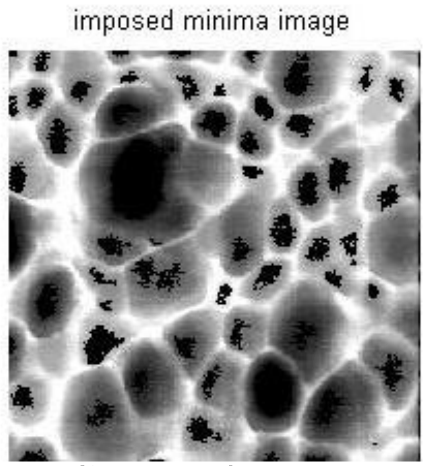
Iimpose=imimposemin(Iec,Iemin); % Detecting valley points

figure,imshow(Iemin),title('extended minima image')

figure,imshow(Iimpose),title('imposed minima image')



(a)Imextendedmin detection image



(b)Imimposemin detection image

FIGURE 6 Valley detection images

(7) Watershed transformation

After pretreatment of the original image, the image after valley detection can be conducted with watershed transformation. Figure 7 shows watershed segmented image, expressed as the visual label matrix.

wat=watershed(Iimpose); % Label matrix derived from watershed transformation

rgb=label2rgb(wat); % Transforming label matrix into color matrix to get watershed segmented image

figure,imshow(rgb),title('watershed segmented image')

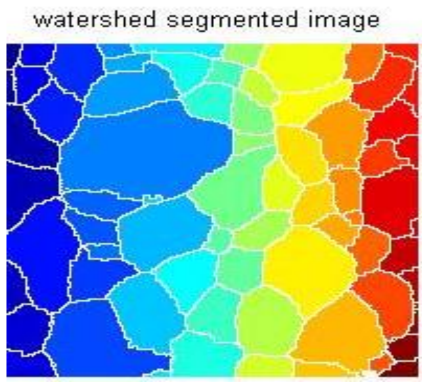


FIGURE 7 Watershed segmented image

(8) Extracting features from label matrix

The features of the image are extracted using regionprops function based on two observed orientations. Figure 8 shows the diagram of extracted features.

```
stats=regionprops(wat,'Area','Orientation'); % Extracting features from label matrix
area=[stats(:).Area]; %Area
orient=[stats(:).Orientation]; %Orientation
figure,plot(area,orient,'b*'),title('Relationship of Particle Orientation to Area');
xlabel('particle area (pixels)'),ylabel('particle orientation (degrees)')
```

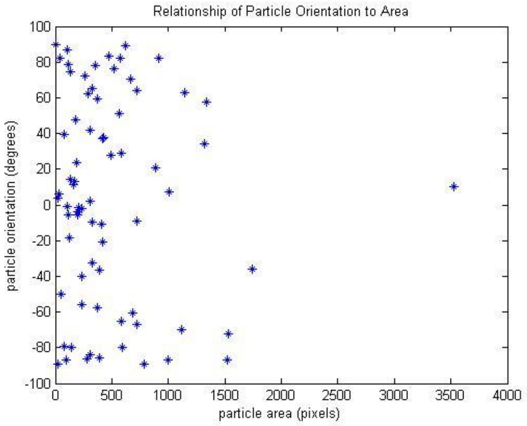
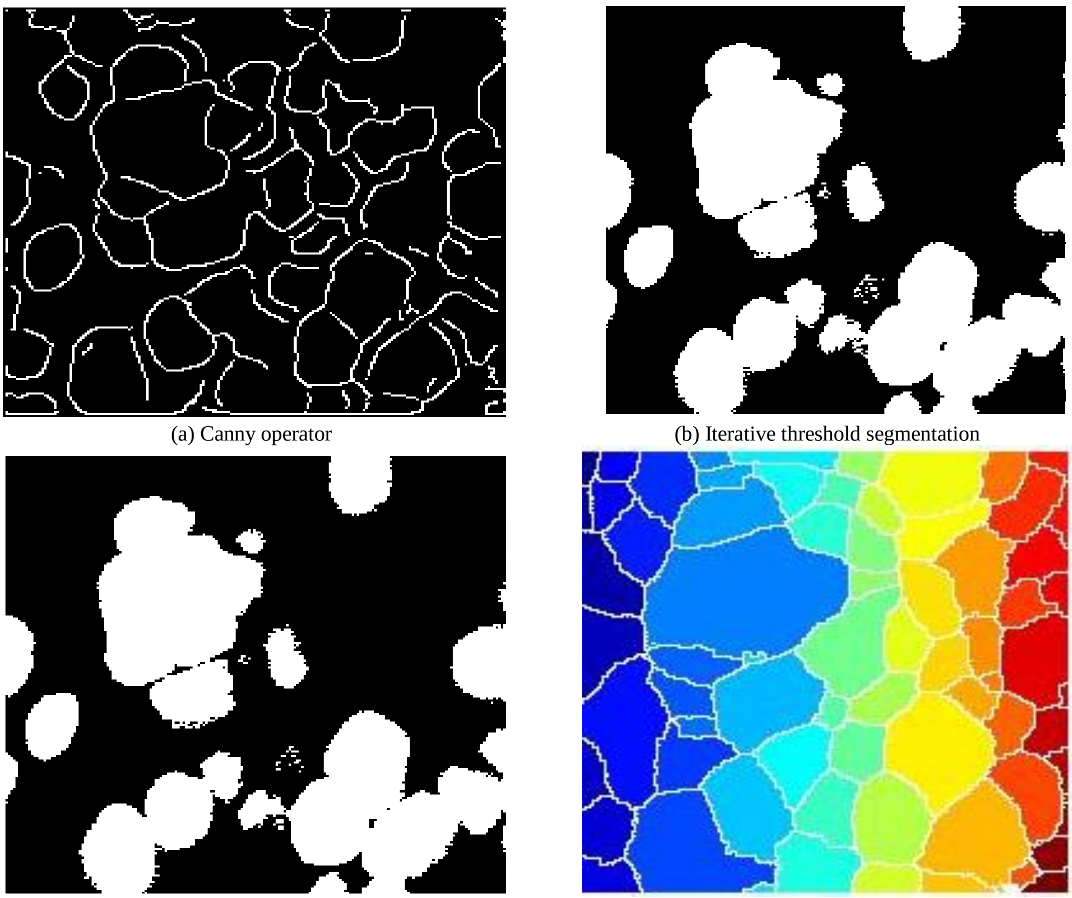


FIGURE 8 Diagram of extracted features

Figure 7 shows that the adhesive objects are transformed into single ones, with over-segmentation reduced. Simulation shows that watershed algorithm, the most effective method, could help split adhesive objects into single ones, while greatly reducing or even eliminating the over-segmentation phenomenon.

6 Comparisons of segmentation results using different algorithms

Segmentation results using different algorithms are contrasted to prove the efficiency of segmentation results using watershed algorithm (See in Figure 9).



(a) Canny operator (b) Iterative threshold segmentation

(c) Ostu segmentation (d) Watershed algorithm

FIGURE 9 Comparison images of segmentation result using different algorithms

Figure 9 shows that watershed algorithm, the most effective method, could help split adhesive objects into single ones, while greatly reducing or even eliminating the over-segmentation phenomenon.

7 Conclusions

Watershed algorithm is applied in the work aiming at slow calculation and low segmentation quality of traditional image segmentation methods, especially for poor performance in adhesive image segmentation. Simulation shows that watershed algorithm, the most effective method, could help split adhesive objects into single ones, while greatly reducing or even eliminating the over-segmentation phenomenon.

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