International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.6, No.6 (2013), pp.179-192
http://dx.doi.org/10.14257/ijsip.2013.6.6.17

# Image Mosaic based on Cloud Model Cellular Automata

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### *Abstract*

*Owing to the fact that fabric images exhibit strong periodic and their features are difficult to extract, an image mosaic method based on cloud model cellular automata is presented. The edge feature points from two images are extracted by cloud model cellular automata, and then the corresponding feature point pairs are got by the cross-correlation of the gray scale around the feature points. At last the images can be stitched by matched feature point pairs. The experiments show that this method can achieve image mosaic effectively.*

***Keywords:*** *image mosaic, edge detection, cloud model cellular automata, cross-correlation*

## 1. Introduction

In the studies of simulation, detection and identification for fabrics, the fabric image acquisition is essential. Because of the limitations of the conditions of current hardware, in one shot you can not get the same size with the physical image, only to partial range of image capture. For a complete image, we must use image mosaic technology to piece the images together. Currently image mosaic field of image processing has become an important research aspect, and it has high theoretical and practical value [1].

Fabric image is different from general scene image, and it has integrity, symmetry and repeatability. Its cyclicality is strong, and is characterized less. The current image mosaic technologies mainly include feature-based method, exhaustive search-based method, grid-based method and so on. However, these methods are suitable to the images are non-periodic and have more obvious characteristics [2]. The researches which can stitch the images with strong cyclical and difficult features are still rare [3]. In this paper, the theory of cloud model and cellular automata are used for fabric image mosaic, and a new image mosaic method based on cloud model cellular automata is proposed.

## 2. Cellular Automata

Cellular automata (CA)[4] is a dynamical system in which time and space are discrete. The cells are arranged in the form of a regular lattice structure and each must have a finite number of states. These states are updated synchronously according to a specified local rule of interaction. The most elementary composing parts of CA are cells, cell space neighborhoods and rules. The formula is $\mathrm{G} = (S, N, R)$ .G refers to the state of the system. S is the state of cells. N is the relationship between neighbor and R is the rules of evolvement. The following state of each objective cell is based on the present state and evolvement rules of its neighbor cells.

ISSN: 2005-4254 IJSIP

Nowadays, CA has been used widely in sociology, biology, ecology, information science, computer science, physics, mathematics and many other scientific research fields. But it is still the underway step to put CA into image processing.

## 3. Introduction of Cloud Theory

### 3.1. Cloud model

Cloud model[5] is an uncertainty transformation model between a qualitative conception $\tilde{A}$ represented by natural linguistic value and the quantitative representation. U is an universe of discourse (one-dimension or multi-dimension) represented by exact numerical values. The qualitative conception $\tilde{A}$ relative to any element x of U has a random number y= $\mu_{\tilde{A}}$ (x), which has steady trend. Y is the certainty degree of x relative to $\tilde{A}$. The distribution of x in U is called cloud model, or cloud for short. Cloud consists of lots of cloud droplets, every droplet is a concrete realization of the qualitative conception in numerical domain, and this realization has the uncertainty.

The numerical characteristics of cloud consists of expectation(Ex), entropy(En) and hyper entropy(He). It combines fuzziness and randomness of linguistic value, and makes up of the mapping between qualitative conception and quantitative numerical value. Ex is the center of gravity of all cloud droplets in numerical domain, and reflects the coordinate in numerical domain, of which best represents the qualitative conception. En is a variable which describes the double-sided property of qualitative conception, reflects the range of numerical domain which can be accepted by the linguistic value, and reflects the probability that the points of numerical domain can represent the linguistic value. He is the discrete degree of En, called the entropy of entropy; it reflects condensation degree of every numerical value representing the linguistic value, as well as the condensation degree of cloud droplets.

### 3.2. Normal cloud generator

The every branch of social science and natural science has proved the universality of normal distribution[6]. Therefore, normal cloud becomes the most basal cloud; it is the most useful to represent basic linguistic value(linguistic atom) of natural language. In this paper all clouds adopted are normal cloud.

Cloud generator(CG) is the model which can generate cloud; its kinds contain normal cloud generator, backward cloud generator, X condition cloud generator and Y condition cloud generator[7].

When the three numerical characteristics and the number N of droplets are fixed, a cloud can be generated by CG. When the three numerical characteristics are fixed and x= $x_0$, the cloud droplets( $x_0, y_i$ ) are called X condition cloud. When the three numerical characteristics are fixed and y= $\mu_0$, the cloud droplets( $x_i, \mu_0$ ) are called Y condition cloud. The CG which can generates X cloud or Y cloud is called X-CG or Y-CG.

## 4. Edge Detection based on Cloud Model Cellular Automata

Fabric image mosaic is usually divided into two parts: edge feature detection and mosaic. So firstly we will achieve edge detection. There are many edge characteristics information used edge detection of images, everyone has excellences itself. So how to fuse these information should be discussed. In this paper, a method fusing direction information and edge order information based on cloud model CA is introduced.

### 4.1. Direction information measure

Direction information measure [8] can be taken into edge detection of images. It is supposed that the coordinate of current pixel point is (i,j) ,pixel matrix is $I(i_{i,j})$,. N(i,j)refers to the Moore neighborhood. $l_\theta$ is a direct line which cross the centre point and has a angle θ. This line divide N(i,j) into two parts: $S_{\theta 1}$and $S_{\theta 2}$. So the definition of Direction Information Measure M(i,j) is as following:

$$M_{i,j} = d_{\theta\max} - d_{\theta\min} \tag{1}$$

There into:

$$d_{\theta\max} = \max_{0^\circ \le \theta \le 180^\circ} (d_\theta) \tag{2}$$

$$d_{\theta\min} = \min_{0^\circ \le \theta \le 180^\circ} (d_\theta) \tag{3}$$

$$d_\theta = \left| f_{S\theta 1} - f_{S\theta 2} \right| \tag{4}$$

$$f_{S\theta 1} = \sum_{(i,j)\in S\theta 1} a_{i,j} \tag{5}$$

$$f_{S\theta 2} = \sum_{(i,j)\in S\theta 2} a_{i,j} \tag{6}$$

At last a direction information measure matrix which takes matrix $M_{(i,j)}$ as matrix I can be gotten. When the current point direction information measure is large, it can show that there is an edge which goes across in the neighborhood. Contrarily, there isn't.

### 4.2. Edge order measure

The edge of the image not only has the characteristic of gray scale mutation but also shows some order characteristic of its neighborhood. Actually, edge has the neighborhood characteristic, just as follows:

1) There is a gray scale mutation on the edge. 2) Edge is not only a boundary between attributive(gray scale) area. 3) Edge area has a width. 4) Edge has its directivity. 5) Edge has its continuity. A single point can not be called the edge.

So when chose an edge point, not only to consider the directivity, but also need to care the orderliness of its neighbor. We will adopt the two parameters for the edge order measure:

1. The neighbor edge intensity is defined as follows:

$$E_g = \frac{|g_1 - g_2|}{|g_{\max} - g_{\min}|} \tag{7}$$

The maximum and minimum gray scale in the whole image are respectively expressed by $g_{\max}$ 、 $g_{\min}$ . The two neighbors' average gray scale are respectively expressed by $g_1$、 $g_2$. A larger neighbor edge intensity $E_g$ shows a greater full change of the neighbor gray scale, as well as a better orderliness, and all of these may lead to a possibility to be the edge.

2. The width of the neighbor edge isolation is defined as follows:

$$E_d = \frac{E_{d0}}{n+1} \tag{8}$$

$$E_{d0} = \|P_1 - P_2\| = \sqrt{(P_{1x} - P_{2x})^2 + (P_{1y} - P_{2y})^2} \tag{9}$$

Here $P_1$ and $P_2$ respectively refers to the two geometrical centers in two neighbors. A larger neighbor edge width $E_d$ shows a greater possibility in different gray scale area, as well as a better orderliness, and all of these may lead to a possibility to be the edge.

In an ideal edge condition, here it takes a (4+1)×(4+1) rectangle neighbor, so n=2. Before measurement, it is necessary to calculate the neighbor edge intensity matrix: $E_{g(i,j)}$ and the width of the neighbor edge isolation matrix: $E_{d(i,j)}$.

### 4.3. Cloudization of numerical variable

There are three edge characteristics information above used edge detection of images, everyone has excellences itself. So we must fuse these information. In this paper, we use cloud model to do it.

The cloudization of numerical variable is a process. According to the definition of cloud, for a numerical variable in the universe of discourse U, process P constructs set $\tilde{A}$ of the qualitative conception in U, every conception is depicted by one cloud. Process P describes clouds, which represents qualitative conception. The description of cloud is to describe the figure of cloud and (Ex,En,He). The process P is called process of cloudization.

1. This method contains three input variables: direction information, neighbor edge intensity and width of the neighbor edge isolation. Every input variable has two qualitative conceptions{Large, Small}, there are six linguistic values in all. Multi-dimension cloud can realize cloudization of several linguistic values, and can be composed of some one-dimension clouds. So it's very convenient to use one-dimension cloud as basic model. To different systems, the design of cloudization process is different. In this paper, we adopt semi-normal extended cloud to actualize cloudization:

1). Cloudization of direction information

The cloud which shows "Large" has numerical characteristics(Ex1,En1,He), its figure is lower semi-normal spread, here Ex1=$T_2$,En1=($T_2$−$T_1$)/3; The cloud which shows 'Small' has numerical characteristics(Ex2,En2,He), its figure is upper semi-normal spread, here Ex2=$T_1$,En2=($T_2$−$T_1$)/3. Two clouds can be seen on Figure 1.

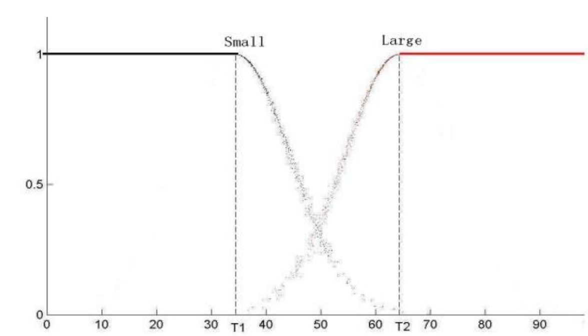



**Figure 1. Cloud of direction information measure**

The numerical value of $T_1$、$T_2$ has a direct effect of the correctness of the edge choosing. Here a gauss fits method is adopted to decide the threshold automatically. Take image lena for example, $T_1=\mu+\sigma$, $T_2=\mu+2\sigma$, $\mu$ is expectation, $\sigma$ is standard deviation, $\mu=4.7$, $\sigma=29.8$, $T_1=34.5$, $T_2=64.3$.

2). Cloudization of neighbor edge intensity

The cloud which shows "Large" has numerical characteristics(Ex3,En3,He), its figure is lower semi-normal spread, here Ex3= $T_3$ ,En3= $T_3$ /3; The cloud which shows 'Small' has numerical characteristics(Ex4,En4,He), its figure is upper semi-normal spread, here Ex4=0,En4= $T_3$ /3. Usually $T_3$ =1/3.

3). Cloudization of width of the neighbor edge isolation

The cloud which shows "Large" has numerical characteristics(Ex5,En5,He), its figure is lower semi-normal spread, here Ex5= $T_4$ ,En5= $T_4$ /3; The cloud which shows 'Small' has numerical characteristics(Ex6,En6,He), its figure is upper semi-normal spread, here Ex6=0,En6= $T_4$ /3. Usually $T_4 = \frac{2\sqrt{2}}{3}$ .

2. This method contains three outputs, which respectively represent the feedback to direction information and edge order information.

Cloud for direction information has numerical characteristics(Ex7,En7,He), its figure is lower semi-normal spread, here Ex7=σ/2,En7=σ/6.

Cloud for neighbor edge intensity has numerical characteristics(Ex8,En8,He), its figure is lower semi-normal spread, here Ex8= $T_3$ /2,En8= $T_3$ /6.

Cloud for width of the neighbor edge isolation has numerical characteristics(Ex9,En9,He), its figure is lower semi-normal spread, here Ex9= $T_4$ /2,En9= $T_4$ /6.

### 4.4. Cloud reasoning

The rules of cloud reasoning are: if three inputs are " Large", the output is "yes", otherwise it's "no".

IF A11 and A21 and A31 THEN B1

IF A12 and A21 and A31 THEN B2

… … …

IF A12 and A22 and A32 THEN B2

A11 and A12 represent "Large" and "Small" of direction information; A21 and A22 represent "Large" and "Small" of neighbor edge intensity; A31 and A32 represent "Large" and "Small" of width of the neighbor edge isolation; B1 represents edge, B2 represents non-edge.

This paper adopts logical operation of cloud to realize multi-condition and multi-rule reasoning. Figure 2 is the model diagram of multi-condition and multi-rule cloud model controller. The number of rules is 9; the number of antecedent of reasoning is 3. Here we use several one-dimension clouds to realize a multi-dimension cloud by multiplier(MF) composed of soft "AND". $CG_{Aij}$ (i=1,2,3;j=1,2) in figure represents X condition cloud generator of linguistic value $A_{ij}$ in rules; the first rule is relative to Y condition cloud generator $CG_{B1i}$ (i=1,2,3) of linguistic $B_1$. The process of reasoning is as following: When a given input vector X(direction information, neighbor edge intensity and width of the neighbor edge isolation of one pixel) stimulates three-dimension clouds composed of $CG_{Aij}$ by MP to generate random numbers $\mu_{Am}$ (m=1,2,…,9), which can reflect the degree of activation of the relative rule. The maximal $\mu_{max}$ is selected by Rules selector(RS), it indicates that the relative qualitative rule is selected. If the first rule is selected, it indicates that this point is an edge point; and then $\mu_{max}$ will control $CG_{B1i}$ (i=1,2,3) to generate three cloud droplets Drop ( $y_{1i}$, $\mu_{max}$ )(i=1,2,3). On the whole, cloud controller generates cloud clusters composed of many cloud droplets, so the outputs should be the mean-values E( $y_{1i}$ )(i=1,2,3).

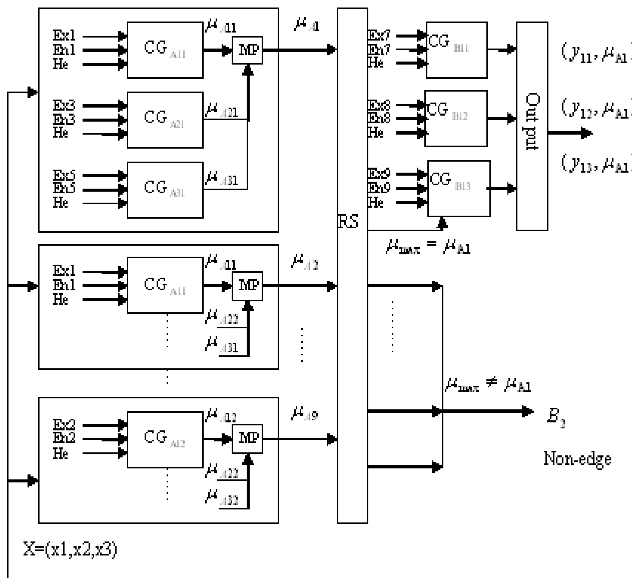



**Figure 2. Cloud model controller of edge detection**

The edge points judged by cloud reasoning are not all edge points. So a new method based on Y condition cloud is used to feed back the matrix M of direction information measure, the matrix $E_g$ of neighbor edge intensity and the matrix $E_d$ of width of the neighbor edge isolation. Its theory is that: to decide the edge point by cloud seasoning; for all of the edge points, the Moore neighborhood which takes those as the centre point is taking into consideration, if its neighborhood accords with the edge structure [9], an edge point in the hypo-neighborhood of the neighborhood edge point may be existed, the hypo-neighbor of the maximal $\mu_{A1}$ ( the degree of activation of the first rule) is to be found among each neighborhood edge point; There is no hurry to take this point as the edge point directly, but to give increment feedback to the direction information and edge order information, at the next moment, another cloud reasoning of the new direction information and edge order information should be taken to decide the edge point. This increment is got from E( $y_{1i}$ ) by cloud reasoning.

### 4.5. Rules of cloud cellular automata

First, taking cell space to correspond to the gray-value matrix I.

Second, calculating the direction information measure matrix M, the neighbor edge intensity matrix $E_g$ and the width of the neighbor edge isolation matrix $E_d$ of matrix I.

Third, using part regulation to judge the edge point and noise point. The requirement for one centre cell(i,j) needs to meet the following part regulation:

1. Using M , $E_g$ and $E_d$ as inputs to make cloud reasoning, and then set up a marker matrix B(b $^{i,j}$ ) and take the point whose corresponding result of cloud reasoning is an edge as 1, and the less one as 0,which refers to the non-edge point.

2. If b $^{i,j}=1$. Observe and study its Moore neighborhood. If its neighborhood accords to the edge structure, then find out the location of the neighborhood cell whose estate is 1. t and sign the corresponding place on the matrices M , $E_g$ and $E_d$ . Find out the cell whose $\mu_{A1}$ is the biggest in its hypo-neighborhood for each founded neighbor cell. Make sure that the following state information measure value, neighbor edge intensity value and width value of the neighbor edge isolation are the sum of the present values and the output values of cloud reasoning. The feed point will not be feedback again.

3. If b $^{i,j}=1$. If its neighborhood doesn't accord to the edge structure, that is to say, it is not the edge point and its next state will be 0.

4. If b $^{i,j}=0$. If its neighborhood accords with any edge structure, it shows that itself is an edge point too. And its following state will be 1.

5. CA begins to evolve, until a stable state (B $^{t}$=B $^{t+1}$).

### 4.6. Experiment of edge detection

Take the above method into the image lena to detect its edge. The result can be seen on Figure 3. Figure 3-b and Figure 3-c are edge images by cloud reasoning, the first one He=0, the second one He=0.1. When He=0, cloud reasoning becomes fuzzy seasoning. Comparing the two edges, the latter one is more subtle. That is to say, the result of edge detection based on cloud reasoning is more rational than fuzzy reasoning.

(a) Lena (b) Cloud reasoning He=0 (c) He=0.1

**Figure 3. Test result of lena graph**

## 5. Image Mosaic based on Edge Points

After extracting the edge of fabric image, we will locate the boundaries range for splicing. This is done by pre-calibration of the camera position. For a given fabric, the two cameras with the same internal parameters are set in the appropriate position. So the overlapping portion of two images will be known.

After getting the overlapping portion of two images, we will count the maximum similarity between two images pixel values in the overlapping portion of two images. We should find every point in image 1 has a corresponding point in image 2 only, and the two points are regarded as the same position.

Let $X_1(x_1,y_1), X_2(x_2,y_2)$ respectively be two random characteristic points of the image $I_1$ and image $I_2$, and the correlation coefficient is defined as follows:

$$Cor(X_1, X_2) = \frac{\mathrm{cov}(X_1, X_2)}{\mathrm{std}(X_1) \times \mathrm{std}(X_2)} \tag{10}$$

In the formula 10, std(·), cov(·, ·) are the standard deviation and correlation function as follows:

$$\mathrm{std}(X) = \sqrt{\frac{\sum_{i=-n}^{n}\sum_{j=-n}^{n}[I(x+1, y+1) - M(X)]^2}{W}} \tag{11}$$

$$Cov(X_1, X_2) = \frac{\sum_{i=-n}^{n}\sum_{j=-n}^{n}[I_1(x_1+i, y_1+j) - M(X_1)][I_2(x_2+i, y_2+j) - M(X_2)]}{W} \tag{12}$$

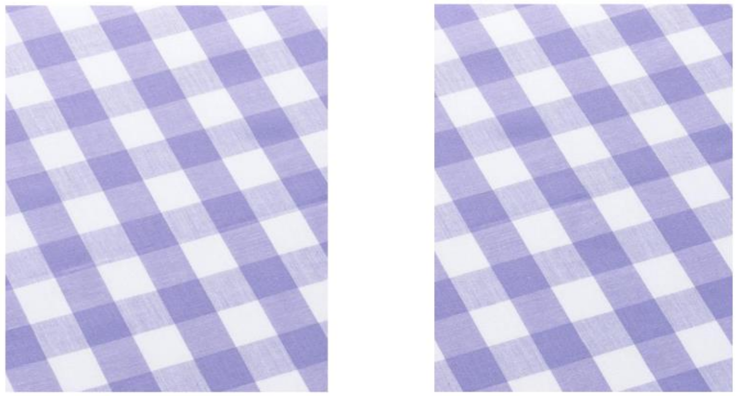
In the formula 12, M(X) is pixel gray average value of relevant part in image $I_1$ and $I_2$.

$$M(X) = \frac{\sum_{i=-n}^{n}\sum_{j=-n}^{n} I(x+i, y+j)}{W} \tag{13}$$

So, in the two images for matching, we select one point (x, y) as the initial point in image 1, and roughly locate the corresponding image point (x’, y’) in another image 2 depending on translation component in the direction of mosaic. Next, we set certain steps i, j, and according to the principle of maximum cross-correlation coefficient do iterative search until the best splice point is acquired.

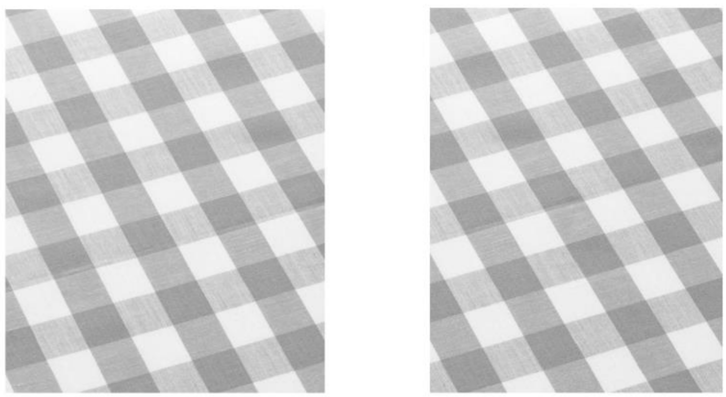
## 6. Experiment of Image Mosaic

In this experiment we chose two different examples of fabric image. The first example which we chose is the fabric image with blue and white squares in Figure 4. The sizes of the two awaiting splicing images are 595×497 and 595×453 pixels. Firstly, the two images in Figure 4 have switched from color image to gray image in Figure 5. Secondly, we get the edge feature points based on cloud model cellular automata method above, and the result is in Figure 6. Finally, we get the result of Image mosaic by formula 10,11,12,13. Figure 7 is the spliced squares image.



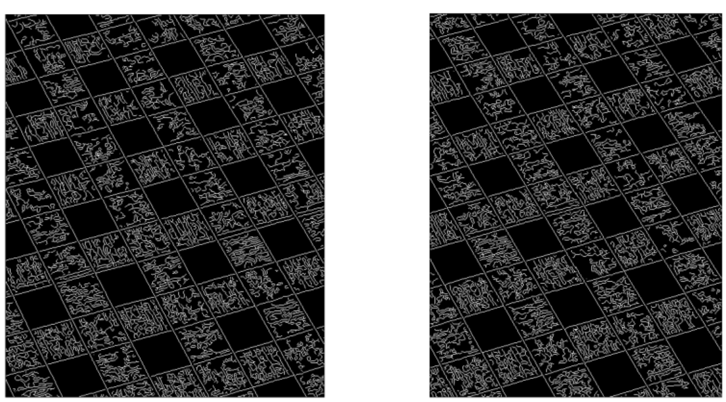
(a) Image 1 (b) Image 2

**Figure 4. Awaiting splicing images with blue and white squares**



(a) Image 1 (b) Image 2

**Figure 5. Gray images of Figure 4**



(a) Image 1 (b) Image 2

**Figure 6. Extraction of edge feature points**

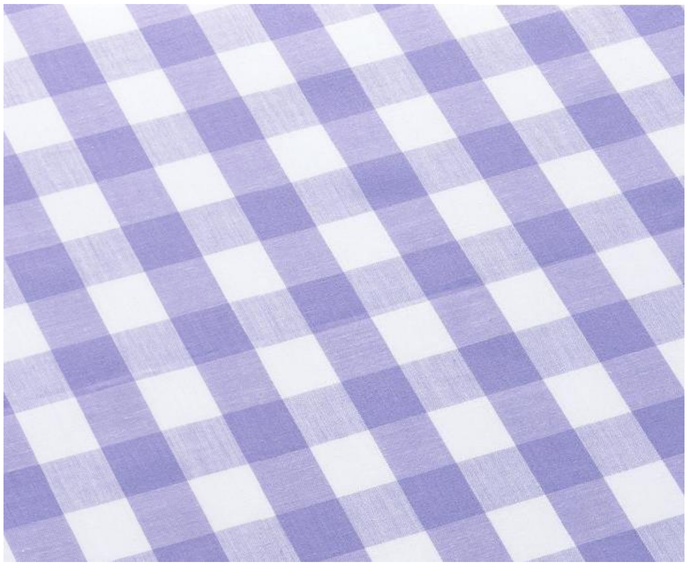


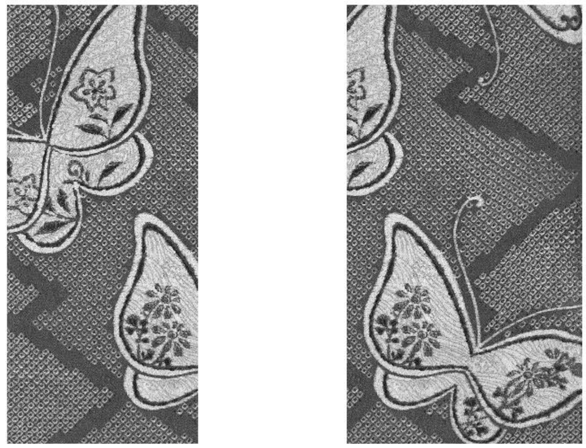
**Figure 7. Spliced squares image of Figure 4**

The second example which we chose is the fabric image with butterfly in Figure 8. The sizes of the two awaiting splicing images are 979×425 and 979×528 pixels. Firstly, the two images in Figure 8 have switched from color image to gray image in Figure 9. Secondly, we get the edge feature points based on cloud model cellular automata method above, and the result is in Figure 10. Finally, we get the result of Image mosaic by formula 10,11,12,13. Figure 11 is the spliced butterfly image.

(a) Image 1 (b) Image 2

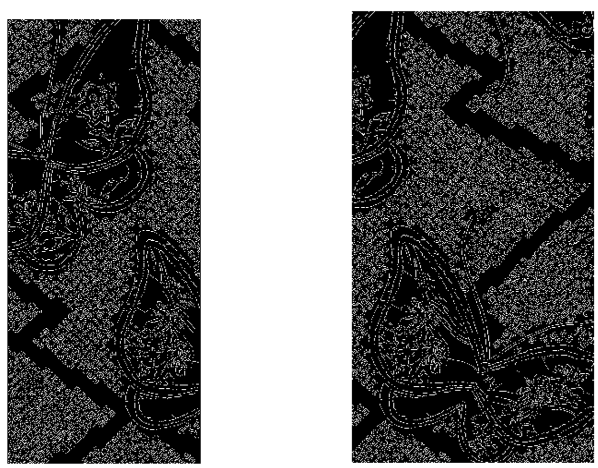
**Figure 8. Awaiting splicing images with butterfly**



(a) Image 1 (b) Image 2

**Figure 9. Gray images of Figure 8**



(a) Image 1 (b) Image 2

**Figure 10. Extraction of edge feature points**

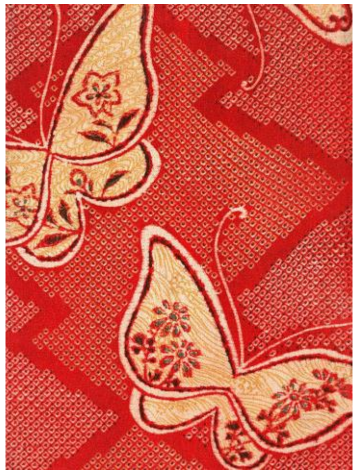


**Figure 11. Spliced squares image of Figure 8**

## 7. Conclusion

Fabric image has integrity, symmetry and repeatability, and its characteristic is less. When the current image mosaic technologies deal with fabric image, there are some shortcomings. Firstly, cloud model and cellular automata theory are used for edge detection, and we can get good edge feature points for image mosaic. Secondly, we calculate the correlation coefficient of edge feature points to get the best splice point. Finally, we complete splicing and get a complete image based on the best splice point. The experiments of specific fabric images show that this method can effectively achieve fabric image mosaic.

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