Computer Simulation Research on Batik Crack Patterns

K. J. Fang1.2, Y. Tang 2, S.H. Fu2; 1Laboratory of Fiber Materials and Modern Textiles, The Growing Base for State Key Laboratory, Qingdao University, 308 Ningxia Road, Qingdao 266071, China; 2Key Laboratory for Eco-Textiles of Ministry of Education, Jiangnan University; 1800 Lihu Road, Wuxi 214122, China.

Abstract

Batik has attracted many people's attention because of its unique crack patterns. How to render this kind of handcraft patterns using inkjet printing technology is the present objective of this article. Through analysis of crack characteristics on handmade batik, an improved efficient algorithm of crack simulation was proposed based on distance transform. Firstly, the initial position of crack was determined by distance transform, secondly the spread direction of crack determined using gradient distance transform. Finally, the dyeing of cracks was simulated using Multiplicative Color Model to express the different features of cracks and the junction between old and new ones. Results of our experiments demonstrate that the proposed method can produce lifelike crack simulation, and the perfect image effects can be achieved by adjusting parameters.

Introduction

Batik has a long history due to its unique ethnic art style. Its greatest charms and characteristics mainly lie on the crack patterns generated from the natural cracking of wax in processing. Due to the extremely low productivity of the handcraft batik, researchers intend to imitate such patterns on fabrics using textile printing technologies. The effects of the imitated batik are determined by the details of cracks in the batik patterns to a great extent. The cracks of handmade batik is meticulous, natural and with rich hierarchies but no fixed circulation pattern units, while the cracks of imitated batik fabric employing screen printing technology, on the other hand, is rigid, repeatedly permutated and has fixed patterns, which lost the real batik style. Textiles adopting the rising inkjet printing are highly articulated and lifelike as well as with vivid color transition [1], which could express the particular effects of the handcraft dyeing in a great extent. The original manuscript for the inkjet printing requires digitalized patterns, yet one of the difficulties which designers might encounter in the process of making the digitalized batik pattern is the crack simulation. Based upon this, this paper presents a preliminary research on the realization of computer simulation for batik cracks.

Currently the research on the simulation of various cracks mainly focuses on animation field and applies to the status of the natural crack of glass, ceramic glaze and mud, the algorithm adopted normally is based on physical simulation, such as using Spring Mass Meshes [2] or Finite elements methods [3,4,5]. These algorithms have the advantage of high sense of reality for various crack patterns, however, they also requires large calculated amount and complicated process. Although there have been many researches on simulation method for various cracks, only few works on the topic of batik crack have been published, designers still use graphics software in the process of drawing digitalized batik patterns. By taking advantage of scanning handcrafted batik textile or secondary manuscript of batik printing, Lawrence [6] collects crack graphics and sketching the cracks by hand in PhotoShop, then defines the cracks as a pattern and filled into the batik images. It is Wyvill [7] who firstly puts forward the distance transform algorithm that can generate realistic batik cracks. We present a simple and efficient method to simulate the cracks in batik, using the distance transform based on the reference [7] and [8].

Visual Characteristics of Batik

Characteristics of cracks in real batik

Batik is a resist class printing method and surface design technique used to design fabric. Liquid wax is painted onto cloth and the cloth is then dyed. The dye does not affect the cloth where it is painted with wax. During the dying process, dye seeps into the cracks creating an effect referred to as cracking. The amount of cracking can be controlled by the type of wax, number of waxing, and disturbance to the waxed fabric. If the fabric is folded, twisted, or manipulated after the wax has hardened it will cause increased cracking. When the design is finished, the wax is removed through boiling or ironing.

Generally, wax will form irregular distributed crack patterns during the natural cracking, and also present different thickness and density, which depends on the processing methods. Cracks are formed in time order. The older cracks will be dyeing for a longer time than the younger cracks, so that the older cracks are wider and darker than the newly formed parts. Some parts of the cracks will be dyed for several times if this process is repeated to form a certain image on cloth. Therefore, the re-dyed cracks will be wider than those cracks only dyed for a single time. In addition, cracks will be becoming wider and darker at junctions. The wider cracks are generally lead to deeper color and clear texture, forms a strong sense of the lines which present a bold artistic effect. While thinner cracks often reflect in lighter color and gentle lines which make people feel soft.

Figure 1 *Real Batik*

Figure 1 shows a handmade batik pattern with white flowers on blue background. The used wax is 60% paraffin wax with 40% beeswax, dyed in room temperature and the fabric is cotton. It can be see from the figure that the natural cracks are randomly distributed with various widths. A crack will run until meeting the edge of the wax or another crack either of which will stop it. The cracks will become wider at junctions at different degree. The depth of color between cracks and background are basically the same.

Key Points for Crack Simulation

The followings are three key points for crack simulation summarized from the characteristics mentioned above:

- Generate cracks in different width and the junctions should be wider.
- Generate cracks in different density and distribute randomly.
- The color of cracks could be adjusted to match with the batik dyeing.

Our Approach

Cracks in handcraft batik are mainly due to dyeing of cracks formed by crazing of wax. During the dyeing process the cracks are tending to grow with the penetration of dye solution. At the same time other cracks are formed at different locations of the printed fabrics. And the new formed cracks are thinner and shorter compared with the old ones. So the length and width of a crack is determined by its forming time. These different kinds of cracks can be expressed by distance transform, a simulation algorithm we adopted in this article. Furthermore, we add an "age" parameter in distance transform to express older and younger cracks with different width. We also find that at junctions cracks have different width. Considering all these points the density and distribution of cracks are controlled through changing the amount of cracks and stochastic function. In addition, we applied a Multiplicative Color Model in color simulation to match with the nature of light sources, fabrics and dyes for the purpose of animation.

Distance Transforms

In this section, we use the following definitions: M defines the image domain, W defines the part of M that is covered with wax, and the set C consists of the border of W together with all cracks (where the border of the wax domain also counts as one or more cracks). In order to achieve a plausible distribution of cracks, we take the following two aspects into account: 1) all newer cracks run from one older crack to another older crack; 2) distance analysis for each point.

The first aspect mentioned above is easier to achieve, while distance transform will be needed. The distance transform here refers to the distance to the point p in W that is nearest to p:

$$D(p) = \min(|p - v|, p \in W, v \in C)$$

It is worth noting that the distance in the above formula not only means Euclidean Distance, it is also suitable for the distances in other forms. Literature [9] proposes a simple and effective of distance transform, here we mainly refer to this method to carry out distance transform.

In fact, older cracks are wider than younger cracks. In order to simulate this feature, we add an "age" parameter in traditional distance transform. The "age" parameter of point is denoted by $a(p)$, older cracks' a (p) is larger.

The extended formula is as follows:

```
for ( pixel p in C )
{ D(p) = 0; a(p) = numCrack – n
for ( pixel p in (W-C )
{ D(p) = infinity;
   a(p) = 'undefined';
}
for ( pixel p : scan from top left to bottom right )
{ for ( pixel q in upper left half neighbourhood(p) )
        if ( D(q) +|q-p| < D(p)
           { D(p) = D(q) + |q-p|;
              a(p) = a(q);
           }
}
for ( pixel p : scan from bottom right to top left )
{   for ( pixel q in lower right half neighbourhood(p) )
        if ( D(q) +|q-p| < D(p)
           { D(p) = D(q) + |q-p|;
              a(p) = a(q);
           }
}
```

Whereas neighborhood (p) denotes p's neighborhood, it could be 3*3, 5*5, 7*7, etc.

Figure 2 is a simulated batik using our crack generation algorithm. Whereas (a) is a original digital batik pattern with white flowers on blue background rendered by Illustrator; after taken distance transform for wax region in (a), we got an image as shown in (b), the lighter parts mean higher $D(p)$ values.

(a) (b)

Figure 2 *Original batik image and the result after performing the distance transform. (a) Simulated the batik of white pattern on blue background, the white area is wax mask. (b) The result after performing the distance transform on the source image.*

Crack simulation

A wax-processing step of the algorithm is as follows:

1) crack initialization.
2) find suitable starting point.
3) define the propagation direction (apply random perturbation to stimulate the real cracks) .
4) find the next location along the propagation direction.
5) crack will run until meeting the older crack.
6) update $D(p)$ and $a(p)$ through distance transform.

In the initialization phase, we set an "age" for current crack and perturbation parameter for the propagation direction. In addition, an extremely step is to generate an random seeding point then using this seeding point as a start to seek crack's initiated location.

We set the location of local maximum of $D(p)$ to be the initiated position of crack since the cracks are mainly caused by stirring force during the dyeing process. Cracks propagate along the gradient $D(p)$, then the cracks will follow the nearest paths to the older cracks, which are complying with the realistic cracks. Gradient $D(p)$ at point p denotes $g(p)$, $g(p)$ is defined as:

$$g(p)=\left[\frac{\partial D(p)}{\partial x},\frac{\partial D(p)}{\partial y}\right]$$

For image processing, derivatives operation could be used to approximate the corresponding differences model. In actual simulation, we perturb $D(p)$ with a Gaussian random noise. From the final outputs, we can see that it achieves the purpose of animation.

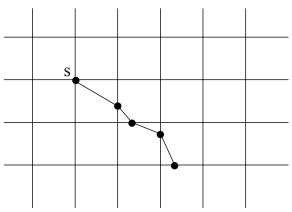

***Figure 3** The spread of cracks*

After identified the propagate direction, it needs to find the next position along the propagate direction. Calculating methods are indicated in figure 3, whereas the nodes in the grid refers to pixels, s denotes the starting position, the lines linked two points means the propagate direction. It can be seen from the figure that sub-pixel accurate is reached.

A crack will run until meeting another crack. It should be noted that only half of crack is produced at that time. The crack will run along the opposite direction from starting position s to produce another half of crack. Then we will update $D(p)$ and $a(p)$ though distance transform mentioned in previous section. After completion of this crack, the cycle is repeated for the next crack until meet the required amount of cracks.

In realistic crack, besides the impact of age, junction between a crack and an older crack will be wider. To this aim, we keep track of the distances between p and the nearest junction, as said $d(p)$. Distinguishing from literature [8], we adopt a more effective and simpler method, $d(p)$ is defined as:

$$d(p)=\max(0,T-|p-x|)$$

Which T is distance threshold, x is the nearest junction to p.

Some parameters can be controlled to affect the look of image:

1）the total number of crack, more cracks, much thicker.

2）the generation of stochastic seeds during initialization phase. The seeds could be chosen according various methods in different region to affect the density of cracks.

3）noise parameters, the lager the parameters are, the randomicity in propagate direction is more obvious.

4）the value of distance threshold T in $d(p)$ is bigger, the cracks in junction are wider.

Dye Simulation

We adopt a Multiplicative Color Model for dye coloring. Final color of point p denotes as $c(p)$，the definition of $c(p)$ is:

$$c_i(p)=s_i r_i \prod_j t_{i,j}^2(p)$$

Whereas i=1,2,3 are three samples of visible light spectrum in standard RGB format, s_i is the spectral distribution of light source, r_i denotes the reflection coefficient to the fabric, $t_{i,j}$ denotes the spectral transmission coefficient of i to layer of dye number j. s_i and r_i are empirically determined. $t_{i,j}$ is determined as:

$$t_{i,j}(p)=1-e_j(p)(1-t_{i,j0})$$

Where $e_j(p)$ is dye concentration, depending on $D(p)$, $a(p)$ and $d(p)$, $t_{i,j0}$ is the spectral transmission coefficient at maximal dye concentration, which could be empirically determined.

We adopt a different method with literature [8] to determine $e_j(p)$, as follows：

$$k_1=a(p)/\max(a)$$

$$k_2=d(p)/\max(d)$$

$$k=coff*\max(k_1,k_2)$$

$$e_j(p)=\max(0,1-D(p)/k)$$

Where max (a) and max (d) denote the maximal values of $a(p)$ and d(p) respectively, $coff$ is accommodation coefficient, the optimal $coff$ can be found by experiments. It's clearly that if one point is in an older crack or closer to the junction, the value of k is higher, thus $e_j(p)$ is lower while $t_{i,j}$ is higher, so that the dye color is deeper and present wider crack in local region.

Results and Discussion

We use MATLAB to compute the above crack simulation and dye simulation algorithm to produce three batik images of 100, 200 and 300 cracks respectively. We produce a convincing visual simulation of the batik cracks by adjusting crack's width and noise parameters as well as areas of junctions. The cracks are indigotic, which are the same with the back color i=12, 0, 70. Figure 4 is the resultant image generated by running the crack simulation. The image shows that it is complying with the real crack in terms of the density, random distribution, width divergence due to the generating time and width divergence at junctions between younger cracks and older cracks.

(a) (b) (c)

***Figure 4** Different simulated crack effects through adjusting some parameters on one source image (a) The pattern effect by 100 crack numbers (b) The pattern effect by 200 crack numbers (c) The pattern effect by 300 crack numbers*

We select picture (a) of figure 4, a simulated numeric batik image with 100 cracks to be as the inkjet printing test picture and, then to print imitation batik crack pattern (as shown in figure 5). Comparing with the handmade batik, the simulated cracks are extremely realistic.

Figure 5 *Imitating batik using inkjet printing*

Conclusions and future work

We have proposed an improved simulation methods of batik cracks based on distance transform. The results show that the proposed method can imitate authentic batik crack patterns. Digital batik patterns produced by computer simulation techniques can be used in inkjet printing, so that the traditional industry using screen printing to produce imitation batik would be replaced by the more realistic printing techniques. At the same time using computer simulation of crack pattern in batik can avoid flaws by manual operation. Inkjet printing technology for mass process of traditional handmade batik products will have a wide application prospect. However, this method currently still has some limitations. Some detailed variations of crack patterns have not yet been considered, such as the penetration of dyes, variations in dyeing color and also the rendering is still not realistic enough too. All of these are our further research directions in the future.

References

[1] H. Ujiie, Digital printing of textiles (Woodhead Publishing, Abington, 2006) pg. 343.

[2] A. Norton, G. Turk, B. Bacon, et al. “Animation of fracture by physical modeling,” Vis Comput, 7(4), 210 (1991).

[3] K. Hirota, Y. Tanoue, T. Kaneko. “Generation of crack patterns with a physical model,” Vis Comput, 14(3), 126 (1998).

[4] J.F. O’Brien, J.K. Hodgins, Graphical modeling and animation of brittle fracture. In Proceedings of SIGGRAPH99, Computer Graphics Proceedings, Annual Conference Series, ACM, pg. 137.(1999).

[5] H.N. Iben, J.F. O’Brien, “Generating Surface Crack Patterns,” Graph Models, 12(1),1 (2009).

[6] G.M. Lawrence, Digital Printing and Traditional Surface Design Techniques, M.A. thesis(North Carolina State University,2002) pg.60.

[7] B. Wyvill, K.V. Overveld, S. Carpendale, Rendering cracks in Batik. Proceedings of the 3rd international symposium on Non-photorealistic animation and rendering, pg.61. (2004).

[8] A.K. Jain, Fundamentals of Digital Image Processing, Chapter 9(Prentice-Hall, New Jersey, 1989) pg.342.

Author Biography

Professor K. J. Fang received his Ph.D. in textile chemistry from China Textile University (1993). His research interest recently focuses on the development of nano-scale pigment dispersions and pigment inks, and pretreatment process of fabrics for inkjet printing. He has published two book and about 100 papers on textile chemistry and eco-technologies of textiles.