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Mosaic Rendering using Colored Paper

Yong Jea Gi[1], Young Sup Park[1], Sang Hyun Seo[1] and Kyoung Hyun Yoon[1]

[1]Computer Graphics Laboratory, ChungAng University, Seoul, Korea

Abstract

This paper proposes a new method of simulating colored paper mosaic using computer graphics technologies. This new method focuses on two problems that need to be taken care of in order to simulate colored paper mosaic. The first one is tile generation and the other one is tile arrangement. To get similar result in real art work, we create colored paper object with simple structure. Then, we generate torn colored paper tile by applying voronoi diagram and others to colored paper object. At last, we come up with result images by arranging torn colored paper tile appropriately according to energy function.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: colored paper mosaic, colored paper tile generation, and arrangement

1. Introduction

Mosaic is a technique that uses a pattern or a picture by attaching various tiles such as stone, pieces of broken glass, ceramic pieces, and paper with mortar, lime, cement and glue on a plane. The mosaic technique is much used for painterly decorations in architecture and art works. Furthermore, beyond the application in real life, in computer graphics, there are efforts made to create mosaic images.

This paper proposes a new method of generating colored paper mosaic using computer graphics techniques. To express colored paper mosaic, following two problems should be taken into consideration. First is an algorithm which generates a paper tile that has a torn shape and the second is an algorithm which arranges the paper tile on the appropriate location. In the existing studies on tile mosaic, various tile generation algorithms are proposed. For instance, centroidal voronoi diagram (CVD) [Hau01] and energy-based framework [KF02] are the algorithms that are suggested in order to locate the tile densely in order to arrange the tile appropriately. In contrast, the existing studies on colored paper mosaic ignored the matter of arrangement the paper tile and focused only on the technique of generating paper tiles. For instance, Random method [PKJY00] and random midpoint distribution [SPKY01] are algorithms both proposed for creating torn shaped colored paper tiles. In this paper, we consider the matter of both of tile generation and arrangement for colored paper mosaic.

To generate colored paper tile, we assume that colored paper consists of simple structure (polygon) and material data (texture, color). Then, voronoi diagram [BKOS97] is applied on the colored paper to determine the outline of colored paper tile. And add torn effect by applying random point displacement algorithm onto the determined outline, it finally generates colored paper tiles. Lastly, these generated colored paper tiles are arranged on the optimum location where the calculated energy value according to their location and direction is the largest. This task is repeated until there is no enough space to attach the paper tiles and it finally generates colored paper mosaic.

The tile generation algorithm in this paper has few advantages. First, since the process of generating colored paper tiles is similar to that of tearing the colored paper with hands, it could achieve natural shaped tiles. Second, instead of colored paper, when other types of papers that have other structure or material data such as newspaper and magazine are used, it is easy to get other types of result images.

2. Related work

In the NPR field, there were lots of studies done about mosaic so far. The existing studies on mosaic show impressive results. However, the existing studies only suggest the solution for either the generation or arrangement of the tile.

Hausner [Hau01] proposed a method of arranging tiles similar to the mosaic of ancient Byzantine era using CVD. However, the shape of tiles was limited to squares. To use the mosaic tile that has arbitrary shapes, Kim[Kim'02] suggested energy-based framework. But JIM requires a lot of time in the process of image searching and arrangement in Jigsaw Image Mosaic (JIM). To improve this, Smith [SLK05] applied centroidal area voronoi diagram (CAVD), and Dalal [DKLS06] applied the sum of squared distances (SSD) and fast Fourier transform (FFT). And they also suggested a technique that could create mosaic animation. However, since the existing studies use fixed or pre-determined tiles like square or image, they did not take tile generation into consideration. So, it is hard to directly apply to colored paper mosaic because colored paper tiles are generated dynamically.

The existing studies about colored paper mosaic suggest basic techniques that could generate torn shaped colored paper tiles. Park [PKJY00] applied random method to depict the torn section of colored paper. However, since paper tile is generated too randomly, it resulted in unnatural. To solve this, Seo [SPKY01] suggested random midpoint displacement (RMD) algorithm. RMD is an algorithm generating irregular sections by repeating the displacement of center of the edge perpendicularly. RMD method could enable the generation of natural torn shaped colored paper tile. However, since the existing colored paper mosaic studies did not take the method of arranging colored paper tiles into consideration, the feature lines (edges) of the source image could not be represented accurately. So, Seo [SKPY01] used an image segmentation and quad-tree to maintain the feature lines of a source image. Image segmentation and quad-tree can maintain the feature lines of the source image. but the various shapes of tiles like concave or overlapping of the tiles which is expressed in colored paper mosaic are not represented.

In this paper, we suggest a technique which takes in consideration of the method of generating and arranging colored paper tiles. At first, generate colored paper consists of polygon and material data. Then, tear colored paper. And arrange the generated colored paper tile according to the energy function. In fact, because our algorithm simulate the process of tearing colored paper similar to real, various shapes of paper tile is generated. Also, by adjusting the parameters in the energy functions, we can adjust the degree of overlap and density between colored paper tiles.

3. Preparation

3.1. The structure of colored paper

To simulate the process of real colored paper mosaic, we define the colored paper which consists of two polygon layers like Figure 1. The upper layer represents the color of the colored paper and the lower layer represents the white paper that appears when the colored paper is torn. Also, each layer includes the material data like color and texture image to express the feel of material of paper. We manage these colored papers by establishing color list (L_c) from predefined dataset (in file) of colored paper. The dataset includes the size, texture image, and color of colored paper.

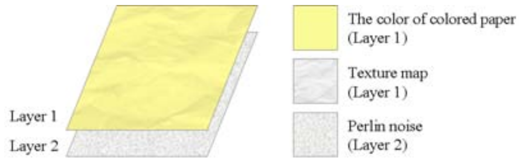


Figure 1: *The structure of colored paper object*

3.2. Source image handling

The inputted source image is segmented into several regions and transformed into the container image. To generate the container image, the image is segmented using mean-shift segmentation [CM02]. However, since it is impossible to extract the feature lines that user expects automatically with mean-shift segmentation. So, The interface is provided the users to merge the segmented regions. Figure 2(b) is an image that the region is merged by the user. Then, extract the feature lines like Figure 2(c), and generate the distance map(D) like Figure 2(d) by caculating the shortest distance between feature lines and each pixel of image. The distance value will be used for calculating energy function to arrange colored paper tiles densely.

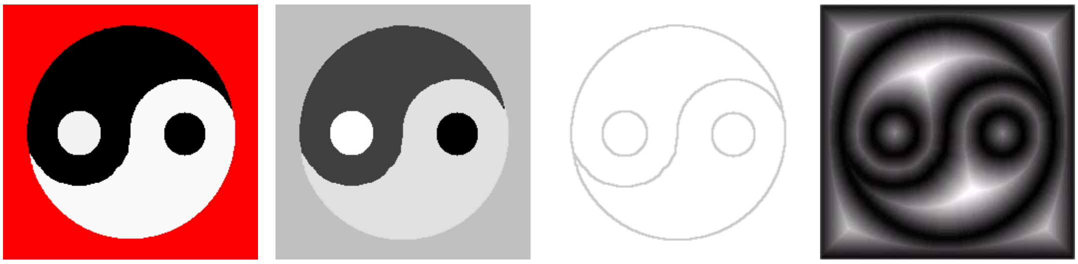
4. Preprocessing

4.1. Initial location of tile

The most basic step in generating mosaic image is to select the initial location which the colored paper tile will be attached. The color and size of tearing colored paper is determined from the initial location. Generally, people attach colored paper tiles based on the bigger pieces from the feature lines of the image. By taking this into consideration, the initial location of the paper tile is defined as location (x,y) in which the $P(x,y)$ is at its maximum. ($D(x,y)$ means distance value of pixel (x,y).)

$$P(x,y) = \sum_{i=x-1}^{x+1} \sum_{j=y-1}^{y+1} D(x,y) - D(i,j) \cdot [x \neq i \& y \neq j] \quad (1)$$

If $[x \neq i \& y \neq j]$ is equals to $x \neq i$ and $y \neq j$, it is 1, it is not, 0. The term of $D(x,y)$ determines the size of colored paper tile and the term of $D(x,y) - D(i,j)$ determines how to close to the feature lines of image. That is, as each term gets larger, it means that the pixel (x,y) is close to feature lines and can attach bigger tiles.



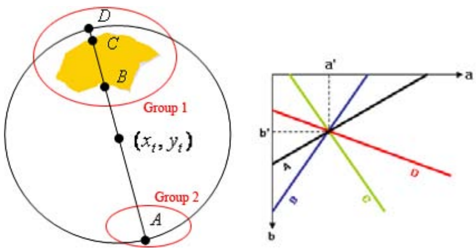
(a) Source image (b) Container image (c) Feature lines (d) Distance map

Figure 2: *Source image handling*

4.2. The color and size of tile

The color of colored paper to each container is determined by average color of the container. First, the threshold value of T_c is determined and select the colors as a candidate which the difference with the container average color is less than T_c from the color list(L_c). Then, one is selected randomly from the candidate on demand.

If the colored paper is selected, determine approximate size of colored paper to be torn. The distance value, $D(x_i, y_i)$, of the initial location (x_i, y_i) refers to the minimum size of colored paper tile that could be attached. So, to attach the tile that is as big as possible, the furthest value $D'(x_i, y_i)$ from (x_i, y_i) is measured by applying Hough transform. First, as in Figure 3(a), the points that have similar gradient from the (x_i, y_i) are grouped into two; one has greater value than y_i and the other group has less value than y_i. Then, in the two groups, select two points that each has the shortest distance from (x_i, y_i) and determine the bigger value between these two points as $D'(x_i, y_i)$. Finally, the size(WXH) of the tile that would be torn is determined as $D(x_i, y_i)XD'(x_i, y_i)$. However, the minimum size(T_{min}) and maximum size(T_{max}) of the colored paper tile is limited by the user.



(a) (b)

Figure 3: *Hough transform*

5. Tile generation

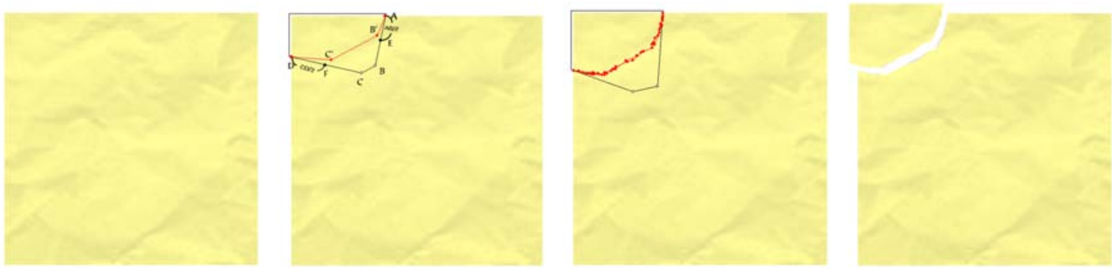
This paper applies voronoi diagram and random point displacement (RPD) algorithm to generate a torn shaped colored paper tile. First, apply voronoi diagram to the colored paper and generate voronoi polygons. Then, randomly select one from the generated polygon placed on the corner and determine as the perimeter of colored paper tile. Next, to achieve more natural colored paper result, smooth the perimeter of the selected polygon and apply torn effect to depict as if the colored paper is actually torn. Finally, tear out the generate polygon from the colored paper to generate colored paper tile. Figure 4 shows the process of tile generation.

5.1. Outline of tile determination

To generate torn colored paper tile, determine the outer perimeter of tearing colored paper tile. We determine the perimeter of the colored paper tile by applying voronoi diagram. First, divide the colored paper tile into the size determined in section 4.2 according to $D(x_i, y_i)XD'(x_i, y_i)$ into many grids. And generate voronoi diagram by placing voronoi sites into each grid. Next, we select which one will be determined for the perimeters of the colored paper tile among the generated voronoi polygons. Generally, people tear colored paper from the perimeter. Therefore, to simulate this process in this paper, determine the polygon including the vertex of the colored paper among the polygons as the outer perimeter of the colored paper tile like black line in Figure 4(b).

5.2. Torn effect

Transform the perimeter to represent as if it is torn colored paper. The polygon generated by voronoi diagram could have rough edges as the polygon depicted in black in Figure 4(b) according to the location of the voronoi sites. When the real person is tearing the colored paper, the rough edges are unnatural since he or she doesn't change the direction of power suddenly when tears a paper. Therefore, in this paper, to create more natural colored paper, apply Bezier curve [Mor99] to smooth out the edges of the polygon. As in Figure 4(b), let the points, A and D as knot vectors and the points E and F that bisect each edge of $\bar{AB}$ and $\bar{DC}$ as control points. However, if the length is shorter than a specific



(a) 2-layerd colored paper object (b) Smooth torn edge (c) Torn effect (d) Tear colored paper tile

Figure 4: *The process of tile generation*

value like $\bar{BC}$, ignore it on the process of generating Bezier curve. This is to create smoother edges represented in red in Figure 4(b). Lastly, transform the smoothed polygon as if the actual colored paper is torn using RPD like red line in Figure 4(c). RPD algorithm represents the irregularity of the torn sections by displacing a random point on the perimeter of the polygon in perpendicular direction. Also, by applying RPD algorithm onto the two layers of colored paper independently, the lower layer, that is the white paper which appears when tearing colored paper could be expressed. Finally, by clipping these modified torn shaped polygons from the colored paper, generate colored paper tile like Figure 4(d).

6. Tile arrangement

When the torn shape colored paper tile is generated, perform the task of arranging this tile onto the appropriate location. The process of arranging colored paper tile is similar to the energy based framework of JIM. However, in contrast, JIM is an algorithm that selects appropriate tiles on a specific location, this paper moves and rotates a specific colored paper tile onto the appropriate location. For each pixel on the perimeter(B) of the tile, let C as container, O as overlapped pixel by another tile, W_e and W_o as weight value, energy function is defined as in equation 2.

$$E = \sum_{i,j \in B} E(i,j) \qquad (2)$$

$$E(i,j) = \begin{cases} -D(i,j) \cdot W_e & (i,j) \notin C \\ -D(i,j) \cdot W_o & (i,h) \in O \\ T_{max}/2 - D(i,j) & \text{else} \end{cases}$$

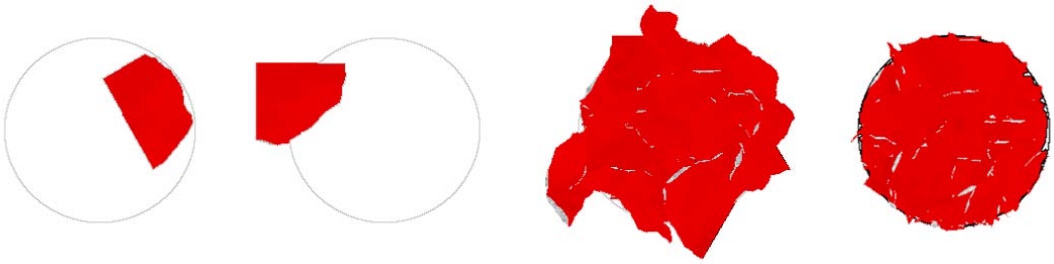
The most appropriate location for attaching colored paper tile is the location which the total of energy function E is at the biggest. The optimum location will be searched until there is no bigger E value in the neighboring pixel starting from the initial location(x_i, y_i). The energy value E could generate various results according to weight value. When W_o is larger than W_e, the tiles are less overlapped like Figure 5(c), and when W_e is larger than W_o, the feature lines of the source image could be maintained like Figure 5(d). Figure 5 shows the result of arrangement according to the weight value. Mostly, it finds the location and direction appropriately as in Figure 5(a), but some times, there are instances where it is inappropriately arranged as in Figure 5(b). In these instances, move the tile inside the container region and apply energy function. Since this algorithm is the brute-force method, it takes a long time in searching for the optimum location. This is a matter to be taken into consideration in the future.

7. Results

All of the final images in this paper are created by setting the value of W_e as 5 and W_o as 2. Figure 6 shows various results depending on the smallest value(T_{min}) of colored paper tile. If the smallest value of tile gets bigger, more grout space will be created so the result image will come out incorrect. This difference is well shown in Figure 6(a) and Figure 6(b). However, if the smallest value of tile is set to be too small to avoid the problems mentioned above, then too many small tiles will be arranged in places so the texture of tile will not be expressed well. Therefore, it is necessary to set appropriate T_{min} value(5 or 6 pixels) of tile in order to get desired result image. And there is unexpected problem occurred in Figure 6(b). It is because colored paper tiles are created in arbitrary shape so tile bigger than container can be generated sometimes. This problem can be solved by limiting the maximum value(T_{max}) of tile in each container region independently. However, the best solution is generating the shape of tile user expected by adjusting the location of voronoi sites. Figure 7, Figure 8 and Figure 9 show another rendering results. Top left portion of result image is source and container image. It took about 40-60 minutes to create result image.

8. Discussion and future work

This paper suggests the method of considering the generation and arrangement of the tile to simulate colored paper mosaic. Through colored paper generation algorithm, more



(a) The best case (b) The worst case (c) $W_e = 1, W_o = 5$ (d) $W_e = 5, W_o = 1$

Figure 5: *Comparison arrangement algorithm according to weight value*

natural and various shaped tiles are generated than the existing studies. And by adjusting the weight value and other parameters of energy function, we can arrange the colored paper tiles to be overlapped or not. The method of this paper is to simulate as the actual colored paper mosaic to achieve more natural colored paper mosaic effect.

However, this paper has some points to solve. First, since the shape of paper tiles are randomly generated, there is a possibility of tile generation that would be larger than the container. To solve this, the method of arranging voronoi sites to generate the tile in the shape that the user intended to is necessary. Second, since our algorithm use only texture image for feel of material, the result is unnatural. So, some methods of representing feel of material to simulate actual colored paper mosaic are necessary. Third, since the algorithm of arranging the tile in this paper is brute-force method, it takes a long time. The algorithm such as FFT or hardware supporting such as GPU should be considered for performance. Finally, if the mosaic image is generated by applying objects that have other characteristics instead of colored paper object, other impressive results could be achieved.

(a) T_{min}=10, T_{max}=80 (b) T_{min}=5, T_{max}=80

Figure 6: *Comparison results according to T_{min} value*

9. Acknowledgement

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Figure 7: *Colored paper mosaic rendering (1024X768, $T_{min} = 6$, $T_{max} = 40$)*

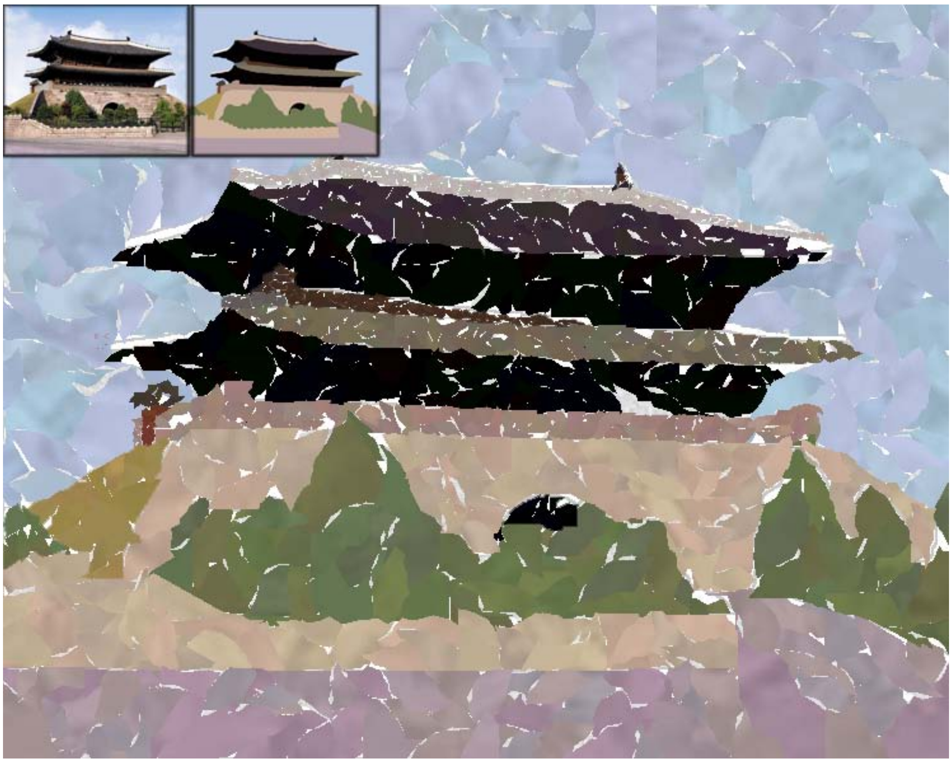

Figure 8: *Colored paper mosaic rendering (750X595, $T_{min} = 5$, $T_{max} = 100$)*