Two Layer Image Tile Mosaics

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Abstract

This study proposes a method of Two Layer Image Tile Mosaics to preserve detailed depiction of the source image. This method is composed of following three stages. First of all, the upper layer tile is located through a centroidal Voronoi diagram to which an edge avoidance technique is applied, and the position of the lower layer tile is calculated using Delaunay triangulation. Secondly, discover the size and direction field of the tile considering the relation between tiles. Thirdly, adopt a Photomosaics technique to use the image tiles. At this time, the technique of multi-level indexing is used to accelerate the speed of image searching.

The Two Layer Image Tile Mosaics obtained through the above process preserve the detailed depiction of source images effectively.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Picture/Image Generation]: Display algorithms

1. Introduction

The mosaic technique has been an object of interest for many artists from the ancient Greece to these days. Present-day computer science researchers have also studied mosaics. Among them the Photomosaics [SH97] are very popular. The Photomosaics technique makes a mosaic image of grid which is composed of small images in image DB. So, the characteristic of this technique is that result depends on image DB. This means that the expression of some informations (like a important edge) are not guaranteed.

Simulating Decorative Mosaics [Hau01], a typical study of tile mosaics, enables the obtainment of resultant images close to traditional tile mosaics. Tiles are positioned using the centroidal Voronoi diagram (CVD) and edge avoidance techniques to bring important edges into relief. This supplements the disadvantage of the photo mosaic that cannot guarantee the expression of edges, but has a limit that cannot express other information except important edges. Moreover, the usage of unicolor tiles and relatively frequent occurrence of gaps limit the expression of detailed depiction.

The Jigsaw Image Mosaics [KF02] improving this problem locates slightly changed image tiles of various forms as dense as possible by using an energy function. Hence it has an advantage to reduce gap between tiles. In case of using a fixed form of tiles (for example, such as photograph), however, it is difficult to get the effect of locating tiles densely, which is an advantage of this method.

In this paper, we would like to present a new tile mosaic method with the purpose of preserving the detailed depiction by expanding existing methods that have been very limited in expressing detailed depictions. This is summarized by the following two methods: first, strengthen the expression of detailed depiction in detail inside a tile by using the Photomosaic method; and second, the tiles stacked up into two layers for removing gap between tiles expand the region of the detailed depiction expression. Combining these two methods can obtain the Multilayer Image Tile Mosaics with the expression of detailed depiction strengthened.

2. Multilayer Image Tile Mosaics

As in Figure 1, the Multilayer Image Tile Mosaics are composed of two layers. Among them, main tile is explained in section 2.1 and sub tile is explained in section 2.2.

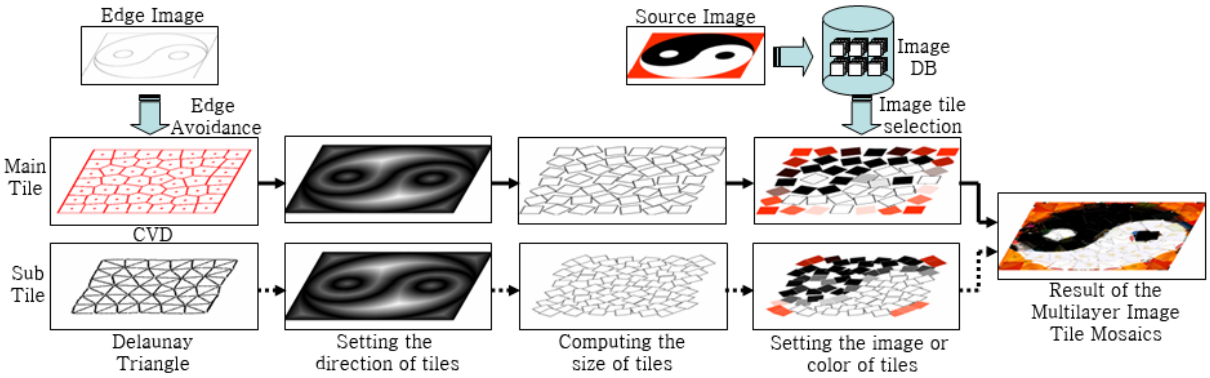


Figure 1: *Process overview of the Multilayer image tile mosaics.*

2.1. Main Tile

2.1.1. Location of the main tiles

Tiles of the same shape and size are used in this paper. In this case, if the distribution of main tiles is fixed, as the overlapping between main tiles and the empty space can be made, main tiles should be evenly distributed in order to reduce this. For that purpose, we used CVD.

We must consider the expression of edge. It is so because the tiles should be able to be located with avoiding edges. This is implemented through the edge avoidance method suggested in Simulating Decorative Mosaics [Hau01]. By locating tiles on the CVD sites that the edge avoidance method is applied, we can obtain tiles that avoid edges and are evenly distributed.

2.1.2. Direction filed of the main tiles

There are limitations in expressing the edge by only placing the tiles to avoid the edge with the edge avoidance CVD. To solve this problem, the tile must be positioned in a perpendicular direction to the edge. We obtained the gradient direction using the Hoff's method [HCK*99].

The Hoff's Voronoi diagram is what the Voronoi diagram is applied on edges, and the direction vertical to gradient can be extracted from it. The regular square tile can be positioned to face the direction of edge if the vertical direction to gradient is used as the tile's direction field.

2.1.3. Size of the main tiles

If the location and direction are set, the size of tile must be decided. The size of the tile has a strong effect on gaps and overlaps. If the size of tiles is small, the possibility is low to have overlapped tiles, but the possibility of gaps between tiles is high. If the size of tiles is big, the possibility is high to have overlapped tiles, but the possibility of gaps between tiles is low. Hausner once proposed a formula related to the size of tiles.

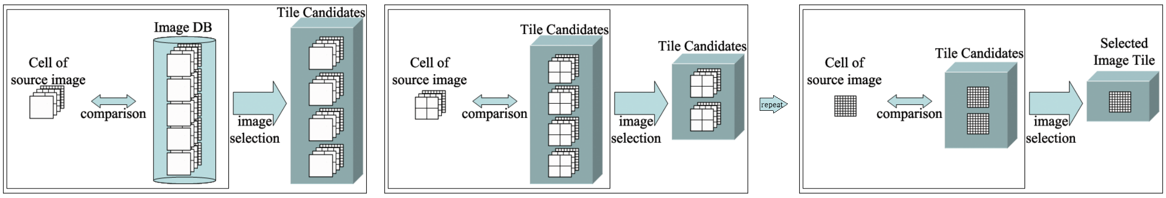
$$d = \delta \times \sqrt{\frac{S_c}{n}} (\delta \leq 1) \qquad (1)$$

d represents size of tile, S_c represents area of canvas, n represents total number of tile and δ is a constant and control relations among them. As the value of δ, Hansner used the coefficient of 0.8 empirically obtained. This value derived appropriate results in many experiments conducted in this study.

2.1.4. Selection of image tiles

By the color sampling method generally used in order to the color of tiles, it is difficult to express the information other than important edges and colors. Because the detailed depiction of the source image is covered with the unicolor tiles. We suggest a method which uses image tiles for the preservation of the detailed depiction of the source image in the resulting image of the mosaics. In this method, the image that looks the most similar to the tile in the source image is selected in the image DB, and the image is adopted for tiles. At this time, the Photomosaics algorithm was used to pick out similar images.

It is very inefficient in terms of speed to search for the most similar image by obtaining and comparing the color distance of grids through direct access to multiple images within the DB acquired through above-mentioned procedure. Usually various Photomosaics implementations use a technique that avoids a direct access by constructing the information on the images of the DB with an index and approach the index to improve the search speed of the image. We constructed a multi-level index and improved the speed of image searching. Multi-level indexing is a technique that constructs the images in the DB with indexes per each level according to the degree of the grid's fraction level and accesses it. It starts at a lower fraction level and gradually increases the level for the similarity comparison to choose the candidate images for final selection. The speed of the search



(a) The comparison in the 1×1 grid level. (b) The comparison in the 2×2 grid level. (c) The comparison in the final level.

Figure 2: *Multi-level index method of the photomosaics*

is enhanced by reducing comparative operations of the image similarity as the number of candidate decreases at higher levels.

The image selected in previous procedure is used for the tile of a relevant area, and the attributes of tiles explained in section 2.1.1, 2.1.2 and 2.1.3 are considered for arrangement.

2.2. Sub Tile

If the size of the tile is obtained by the method suggested by Hausner in section 2.1.3, the following equation(2) about total area $S_t$of tiles can be induced.

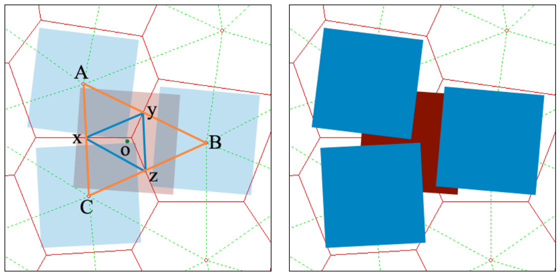
$$S_t = \sum_{1}^{n} d^2 = \sum_{1}^{n} (\delta^2 \times \frac{S_c}{n}) = \delta^2 \times S_c \qquad (2)$$

The total area S_t, which tiles contain, is the summation of each tile, becoming δ^2 times S_c, the total area of the surfaces that tiles will be put on. As Hausner suggested 0.8 as the value of δ, only 64% of the area that tiles will be placed will be filled with tiles, by this method. This means that more than a third of the source image is thrown away. Since equation(2) ignores the tile overlapping, the real amount of thrown away information is more than that.

This paper presents the mosaic method that can minimize the information to be thrown and effectively preserve the information of the image by using the method that allocates the tiles into two layers. The most important of this method is to locate sub tiles in the bottom layer of main tiles. The sub tile is located between main tiles and plays the role of filling the gap. This technique can be applied by adding a layer of sub tile to the tile mosaics implemented by existing method. In this section, we suggest the method which set the position or other attributes of the sub tiles.

2.2.1. Location of the sub tiles

The fact that the polygon is adjacent to each other in the Voronoi diagram which is made by the position of main tile as the site means that the tiles corresponding the polygon are adjacent. As the gaps between tiles occur in areas where the main tiles are adjacent to each other, the location of sub tiles must be decided to cover the polygon boundaries of Voronoi diagram. We propose the use of Delaunay triangulation to decide the location of sub tile. Points A, B and C in Figure 3(a) are the sites of three adjacent polygons in CVD. The main tiles described in blue tetragon in the figure are put in these locations. As is shown in the Figure, there are gaps occurring in between the tiles at the boundary of adjacent three polygons. The x, y, and z, which divide the boundary lines equally in two pieces, implicate the area where the gaps occur. If locating a sub tile (a red square in the figure) on the center of gravity o of the $\triangle xyz$ with these points as vertices, the empty space that has existed between three main tiles will be filled with sub tiles. At this time, the centroid of $\triangle xyz$, which is o, has the characteristic to correspond to the centroid of $\triangle ABC$ which is delaunay triangle made by site of CVD as is shown in figure. Therefore, it is possible to use the center of gravity of the Delaunay triangle for each site as the location of sub tiles. Delaunay triangulation is the dual of the Voronoi diagram. So it is possible to obtain Delaunay triangle from Voronoi diagram and vice versa. Hence, it is easy to calculate the position of sub tile using the position of main tile.



(a) Centroid of the $\triangle ABC$ and $\triangle xyz$ (b) Location of the sub tile

Figure 3: *Placing the sub tiles using Delaunay triangulation.*

2.2.2. Other attributes of the sub tiles

The direction, size and color of sub tiles may be decided similarly to main tiles. For example, the direction of a sub tile can be decided by obtaining the direction perpendicular to the gradient direction of the edge. In addition, the size of the sub tile is calculated by applying the size of the area where the tiles will be located and the number of sub tiles to the equation (1) previously suggested.

3. Results

Figure 4(a) is image of Michelangelo's Libyan Sibyl reproduced in Multilayer Image Tile Mosaics proposed by this paper. It expresses with the sub tiles the detailed depiction of gaps beyond the limits of existing methods. A feeling of solidity was generated by adding shadow effect on the tile, and as a result the formative element unique to the mosaic technique was expressed. Moreover, not only important edges but also those edges not assigned any meaning were expressed, and a natural gradation of color appeared.

Figure 4(b) shows the application of our mosaics to photo image of real life. It is also confirmed in the mosaics applied to photo images that the representation of the original was done relatively faithfully.

4. Conclusion

This paper proposed a new mosaic technique which preserves the detailed depiction of the source image. By using the image in a photograph or a picture as the tiles of mosaics, we have effectively preserved the detailed depiction expression of source images. In addition, by reducing the gap between tiles with the use of two tile layers, we have reduced the information which used to be thrown as tiles were not properly expressed. As a result, we obtained better results than existing studies from the aspect of detailed depictions.

The future researches are to be made on a series of methods that will diversify the size of tiles. In implementing mosaics with colored paper, some attempts have been made to diversify the tile sizes automatically using quad tree. In addition, the weighted Voronoi diagram is expected to be of help in the decision of the location of tiles of various sizes.

(a) the results of mosaics applied to Lybian Sibyl

(b) the results of mosaics applied to photo image of real life

Figure 4: *The applications of Multilayer Image Tile Mosaics*

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