

# Stained Glass Rendering with Smooth Tile Boundary

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**Abstract.** We introduce a new glass tile generation method for simulating Stained Glass using region segmentation algorithm and cubic spline interpolation method. We apply a Mean shift segmentation algorithm to a source image to extract a shape of glass tile. We merge regions by user input and use morphological operation to remove the invalid shape. To make the shape of glass tile, we apply cubic spline interpolation and obtain the leading and the region with smooth boundary. Next, we re-segment the region using the spline curves. Finally we apply the transformed colors to each region to create a whole glass tile.

## 1 Introduction

This study is to make the Stained Glass image that looks like manually produced by artists using the 2D image as the input. The Stained Glass rendering is a field of NPR(Non-Photo realistic Rendering) and it is very much different from the traditional realistic rendering. While the rendering primitive of the realistic rendering is a pixel that of the Stained Glass rendering is a region, the collection of the pixels. Therefore the output image may be varied according to the size and the shape of the area. In this paper, we would like to introduce a new method to create glass tile. The Stained Glass is made by cutting and pasting the glass therefore the unit of the Stained Glass is a glass tile. As conventional algorithm used to create a glass tile simply using region segmentation, it could not have the Stained Glass like feeling if the region segmentation were not appropriate. In order to resolve this problem, we interpolated the boundaries between the regions, re-segmented each segmented area to create the region to compose glass tiles.

## 2 Related Work

Although many different studies have been performed since the studies regarding the NPR were started Strothotte[1], Recently, there have been many trials to simulate the Stained Glass using computer technology.

In Photoshop, The Stained Glass filter is one of them. The Stained Glass filter of the Photoshop basically makes the image using Voronoi Diagram having random Voronoi sites(Hoff[5]).

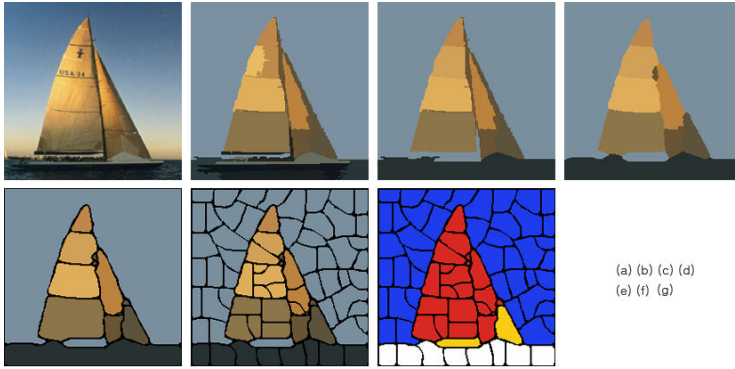
Mould[2] approached to the studies on the Stained Glass in different ways. This method dividied the input image using the region segmentation method based on the color, and then it mitigated the segmented regions applying the morphological operation. However the regions created by Mould[2] method are far from the formative structures.

### 3 Glass Tile Generation for the Stained Glass

#### 3.1 Region Generation of Glass Tiles

It is very important to abstract the segments that can be expressed in glass tiles. In this study, we used the Mean Shift segmentation algorithm(Comanicu[4]) to generate the basic segmented regions creating the glass tiles(Fig. 1(b)).

Additionally, as the regions with unexpected shapes can be created from the application of the segmentation algorithm, we made it possible for the user to merge the regions through input(Fig. 1(c)).



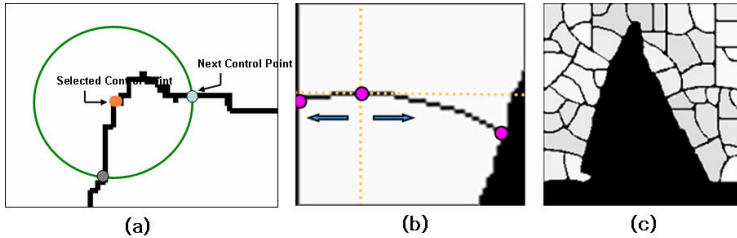
**Fig. 1.** Stained glass rendering process (a) Input image (b) Mean shift segmentation (c) Region merge (d) Morphological operation (e) Region boundary interpolation (f) Region re-division (g) Rendered image after color transform

#### 3.2 Interpolation of the Region Boundaries

In order to purify each segment, we used morphological operations (Fig. 1(d))and the cubic spline interpolation(Fig. 1(e)). because the abstracted regions have improper shaped regions created by the Mean Shift segmentation algorithm and the rough boundaries in the form of noise.

Although Mould[2] tried to resolve those two problems using the morphological operations only, this study used it to remove the improper shaped segments and used the cubic spline interpolation to make the rough boundary.

Next, to make the boundaries of the mitigated shaped regions smooth, we applied the cubic spline interpolation. In order to calculate cubic spline interpolation we need to select the control point. To select the control point, we defined the distance of the control point and then selected the point on the boundary with the pre-set distance from the current control point (Fig. 2(a)).



**Fig. 2.** (a)Search control points for spline interpolation (b)Region re-segmentation process (c)Re-segmentation result

We applied the same method to create the leading that fills the gaps between glasses in the actual stained glass during the interpolation process. It is to abstract the parts that did not create the segment as the leading by creating and applying the smaller spline curves than the basic segments.

### 3.3 Re-segmentation of the Region

For securing the formative beauty that shown in the actual stained glass. We re-segmented the large segment region(Fig. 1(f)).

In the re-segmentation process, we made random curve and re-segmented the regions based on the curve.

First of all, select a random point on the region and identify two points on the boundary near the selected point to use them as the control points. Based on the selected three points, create a curve using the cubic spline interpolation (Fig. 2(b)). We limited the number of the control points as three because if we use too many points on the segment it would bend the curve too much. It is improper to apply the over-bent curve to the stained glass rendering (Fig. 2(c)).

### 3.4 Determination of the Colors for Each Region

Mould[2] converted the colors in the input image to the colors that could be used in the Middle Age to designate the colors of the glass tiles. We applied the same method to this study. Through this process, we could have the strong color contrast effects(Fig. 1(g)).

## 4 Conclusion

In this study, we created the shapes of the smooth glass tiles similar to those in the actual stained glass by interpolating the boundaries between the segments to simulate the stained glass image, and then created the frame shape of leading with irregular thickness that we could find between the glass tiles. Additionally we created the formative characteristics that composed a meaningful segment by gathering small glass tiles through the re-segmentation of the segment. We also expressed the strong color contrast through the color conversion process(Fig. 3). Additionally, to emphasize the formative shapes, we highlighted the boundaries before re-segmentation with thick lines. As the stained glass is mainly used in windows, we gave the round light source effects to the image so that we could get the lighting effects. Fig. 3 shows the comparison between the image after the light source effect application and the image from Mould[2].

Actual stained glass is made of color glasses.

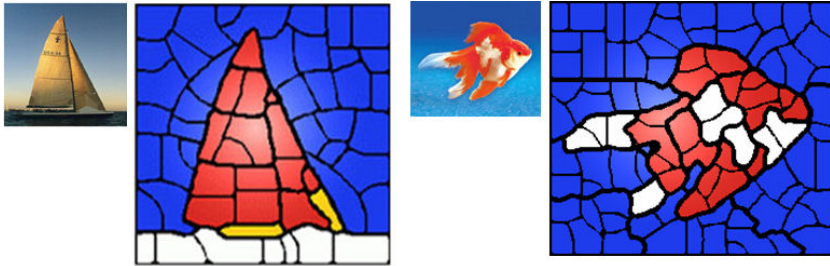


Fig. 3. Result Images

## References

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