# FEATURE-GUIDED PAINTERLY IMAGE RENDERING

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## 1. INTRODUCTION

Non-photorealistic rendering (NPR) refers to any technique which can produce a non-photorealistic image. There are three ways: direct rendering of 3D scenes, transformation from a digital image, and interactive drawing.

In this paper, we present a method for automatically generating a stroke-based painting from a digital image. The rendering process generates rectangular brush strokes with suitable location, orientation and size. Inspired by the real painting process, where a painter will always observe the distinctive features and decide the shape and orientation of the stroke, we apply techniques of image moment functions and texture analysis, from which features are extracted and used to guide the stroke generation. Further more, techniques are also developed for dynamic determination of cropped image size and edge enhancement.

## 2. RELATED WORK

Shiraishi and Yamaguchi [7] used a three-step local source image approximation method to generate strokes: stroke distribution, stroke generation and stroke ordering and painting. Haeberli [2] developed an interactive painting system for quickly producing painted representations of still images. Hertzmann [3] used brush strokes represented by spline curves in several layers: smaller brush sizes for upper layers and bigger sizes for lower ones. Litwinowicz [5], Hertzmann and Perlin [4] developed methods to painterly render video sequences.

In previous methods, the stroke attributes are determined either only by the stroke location point or by the local region colour information. Our method is different in respect of using global feature characteristics.

## 3. TECHNIQUES USED IN IMAGE ANALYSIS

In painterly rendering 2D image process, since no depth information provided, the attributes of the strokes can only be derived from 2D image analysis.

First, we discuss how the local geometric moments [6] can be applied for local source image approximation with a single rectangle. For an $NxM$ image, the geometric moment of $pth$ degree about the x-axis and $qth$ degree about the y-axis is defined as would be

$$M_{pq} = \sum_{x=1}^{N} \sum_{y=1}^{M} x^p y^q I(x, y), \qquad (1)$$

where $I(x,y)$ is an intensity distribution image. The function value is the intensity at the pixel location $(x,y)$. This intensity distribution image can be obtained from a local source image $P$ and a stroke color $C$:

$$I(x, y) = F(d(C, P(x,y)), \qquad (2)$$

where, $d(C_1, C_2) \in R$ is the distance of two colors $C_1$ and $C_2$ in the $LUV$ color space, $d(C_1, C_2)$ is given by the Euclidean distance, and $F(d) \in [0,1]$ is the function that maps the color distance $d$ to the intensity value.

Geometric moment can be used to find the centroid location $(x_0, y_0)$, size $(w, h)$ and orientation $\theta$ of a rectangular stroke to approximate local cropped image:

$$\begin{aligned} & x_0 = M_{10}/M_{00}, \ y_0 = M_{01}/M_{00}, \\ & w = \sqrt{6*(a+c-\sqrt{b^2+(a-c)^2})}, \\ & h = \sqrt{6*(a+c+\sqrt{b^2+(a-c)^2})}, \qquad (3) \\ & \theta = 1/2 * atan(b/(a-c)), \end{aligned}$$

where $a=M_{20}/M_{00}-x_0^2$, $b=2(M_{11}/M_{00}-x_0y_0)$, and $c=M_{02}/M_{00}-y_0^2$.

Next, we show that the texture analysis technique can be employed to discover the texture directionality if an image contains texture. In texture analysis, a histogram of local edge probabilities is used against their directional angle. It was shown in [8] that this histogram represents sufficiently global features of the input picture such as long lines and simple curves. In the discrete case, the magnitude $|\Delta G|$ and the local edge direction $\theta$ of gradient vector are approximated as follows:

$$\begin{aligned} & |\Delta G| = (|\Delta H|+|\Delta V|)/2, \\ & \theta = tan^{-1}(|\Delta V|/|\Delta H|) + \pi/2, \qquad (4) \end{aligned}$$

where $\Delta H$ and $\Delta V$ are the horizontal and vertical differences.

The desired histogram $H_D$ can be obtained by quantizing $\theta$ into n bins and counting the points with the magnitude $|\Delta G|$ over the threshold $t$; i.e.,

$$H_D(k) = N_\theta(k) / \sum_{i=0}^{n-1} N_\theta(i), \ k=0,1,\ldots, n-1, \qquad (5)$$

where $N_\theta(k)$ is the number of points at which $(2k-1)\pi/2n \le \theta \le (2k+1)\pi/2n$ and $|\Delta G| \ge t$.

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A way of measuring the directionality quantitatively from H $_D$ is to compute the sharpness of the peaks. This measure can be defined as follows:

$$F_{dir} = 1 - rn_p \sum_{p=1}^{n_p} \sum_{\phi \in \varpi_p} (\phi - \phi_p)^2 H_D(\phi), \qquad (6)$$

where

$n_p$ : number of peaks,

$\phi_p$: $p$th peak position of $H_D$,

$\varpi_p$ : range of $p$th peak between valleys,

$r$: normalizing factor.

Figure 1 shows two rendered paintings using image moment functions and texture direction analysis. It can be seen that texture analysis produces better result with more accurate orientation (Figure 1(b)).

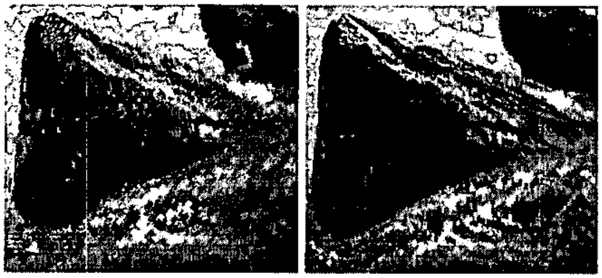

(a) (b)

**Figure1:** Stroke orientation obtained from (a) image moment and (b) texture analysis.

## 4. FEATURE PRESERVATION ALGORITHM

The feature guided painterly rendering process consists of 6 steps with description in subsections 4.1-4.6.

1. Derive feature regions using image segmentation.
2. Extract boundary of each feature region.
3. Obtain feature geometric attributes using image moment and texture analysis.
4. Generate sampling points for drawing the strokes.
5. Generate stroke using global feature and local area.
6. Sort the stroke by their size, draw the strokes from largest to smallest, and blend the strokes on the canvas.

### 4.1 Region Extraction

Color-based image segmentation is used to extract features. The extracted feature regions contain necessary and important information of the source image.

After feature extraction, each feature region $F_i$ in the result map has a label $i$, and all pixels inside the feature region are marked with that label $i$. Figure 2 shows one example.

**Figure 2:** Feature region after segmentation.

### 4.2 Feature Boundary Extraction

Scan the label map to extract feature boundaries. For each feature region $F_i$, from $y = y_k$, we record $x_{min}$ and $x_{max}$ which defines $F_i$ boundary in horizontal line $y = y_k$. The extracted boundary for $F_i$ is a set $(<x_{1k}, x_{2k}>, y_k)$, $k = 0, 1, 2, \ldots, n$, where $x_{1k}$ and $x_{2k}$ denote the x-coordinates of the boundary points of the $kth$ scan line having an ordinate value $y_k$.

### 4.3 Obtain Feature Geometric Attributes

With the extracted boundary, we can determine the geometric characteristics of feature region $F_i$ by computing its moment functions. A rectangle is obtained with proper width $w$, height $h$, centroid $(x_0, y_0)$, and the direction angle $\theta$ . For regions containing directional texture, texture analysis is employed to get a more accurate orientation.

### 4.4 Stroke Distribution

For each pixel in the image, calculate the zero degree moment $M_{00}$. Afterwards, for each pixel along the space-filling curve [1], $1/M_{00}$ is summed up. When the sum reaches the threshold, the pixel is chosen as a sampling point and the sum is cleared and the process continue till all the points in the image are gone through. One example is shown in Figure 3, where darker regions require more sampling points for more details.

**Figure 3:** One example of stroke distribution result.

### 4.5 Stroke Generation

Brush stroke consists of color, location, orientation and size. Region attributes and local area information are used to obtain the stroke attributes. The generation consists of steps:

1. Color Sampling: The color attribute $C$ is defined as the color at the stroke sampling point.
2. Source Image Cropping: The cropped image has similar shape as the feature region where it is. It is a

*wxh* rectangle, where *w/h* is the same with the width/height ratio of the feature region. The center of the cropped image is located at the sampling point.

3. Stroke Attributes Calculation: The location $(x_0, y_0)$, size $(w, h)$ can be determined using image moment. If the corresponding feature region contains oriented textures, the direction angle $\theta$ will be set to be same.

As shown in Figure 4, all strokes in one feature region have the similar shape and orientation. The feature characteristics are well preserved.

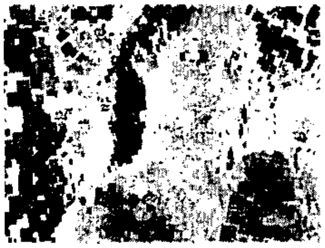


**Figure 4:** Stroke generation using feature region attributes.

### 4.6 Sorting and Stroke Drawing

After all strokes are generated, they are sorted by the area of equivalent rectangle and draw from largest to smallest. When drawing strokes on the canvas, certain blending function should be applied. For example, in Figure 5(a) and 5(b), optical composition and alpha blending are used to generate watercolor and oil painting effect respectively.

(a) (b)

**Figure 5:** (a) Optical blending and (b) alpha blending.

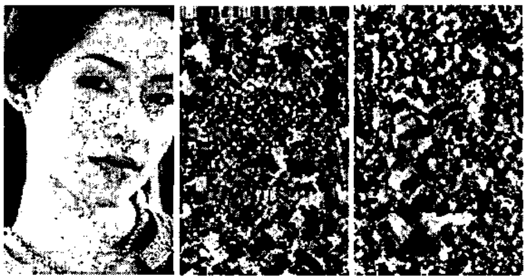
## 5. TECHNIQUES TO IMPROVE PAINTING QUALITY

In this section, we discuss the techniques of dynamic determination of cropped image size and edge enhancement to improve the painting quality.

The cropped image size controls the stroke size and affects the coarseness of the overall painting. If the cropping size is too big comparing with the stroke size, the painting will appear coarse. In order to reveal different degree of details in an image, the cropped image size should be varied.

We find a strategy to dynamically determine the cropped image size. The geometric meaning of this strategy is that: the best cropping size is for the stroke to cover exactly the cropped image. The following procedure shows how to determine the cropping size: starting from the smallest local region size $(w_{min}, h_{min})$, we increase local region by $S_{step}$ each time. Suppose now the size is $(w_i, h_i)$, and zero degree moment $M_{00}$ is $M_{00\_old}$. We then increase local region size by $S_{step}$, and it becomes $(w_i+S_{step}, h_i+S_{step})$. The new $M_{00}$ value is $M_{00\_new}$. If $(M_{00\_new}-M_{00\_old})/(2w_i S_{step}+2h_i S_{step}+2S_{step}^2-2S_{step})>T$, where $T$ is a threshold, we continue increasing; otherwise we stop and the local region size is $(w_i, h_i)$.

Two illustrations in Figure 6 are rendered with black and white strokes to highlight the shape and orientation of the strokes generated using fixed and varied cropping sizes. The average cropping sizes are the same for Figure 6(b) and 6(c), but 6(c) has finer strokes in areas with more details.



(a) (b) (c)

**Figure 6:** (a) Original image. (b) Resulting strokes rendered with fixed and (c) varied sized cropped images.

We further improve the above approach by using varied threshold value $T$. It will give more freedom to cropping image size variation and a better result. The method for determination of threshold $T_i$ for each feature region $F_i$ is as follows:

1. Calculate the average color $C$ in *Luv* color space.
2. Calculate average square color difference throughout the region: $E_i=\Sigma_j (C-C_j)^2/N_i$, where $C_j$ is pixel color value and $N_i$ is the number of pixels in the region.
3. Set threshold value $T_i = (1- E_i/E_0)$, where $E_0$ is for normalization purpose and is set based on experiments.

By applying this technique, threshold value varies among different feature regions. This technique increases the variation range of cropping image size throughout the image. One example comparing the fixed and varied threshold is shown in Figure 7. The method of varied cropping size with varied threshold gives the best result (Figure 7(c)).

(a) (b) (c)

**Figure 7:** An example to show the rendering results of (a) fixed cropping size, (b) varied cropping size with fixed threshold, and (c) varied threshold.

Edge enhancement procedure can add sharp edges to the result painting. This enhancement is applied after the usual rendering process as follows and one example is shown in Figure 8.

1. Pick edge points using Sobel filter.
2. Take these edge points as sample points and compute stroke attributes at every point.
3. Calculate the stroke centered at the edge point using image moment functions. Cropping image size is set to quite small, 4-6 pixels in experiments.
4. Draw strokes at these edge points.

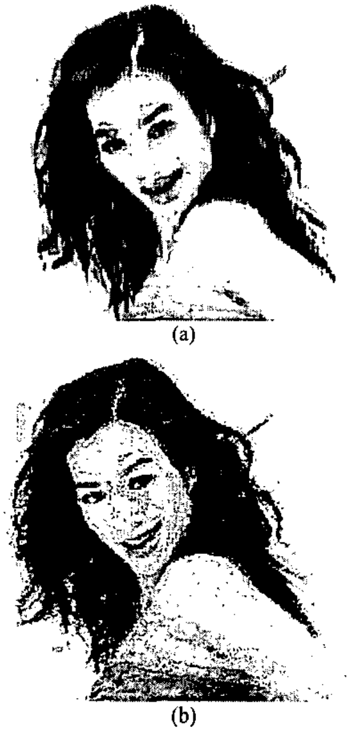


**Figure 8:** (a) Result without edge enhancement and (b) with edge enhancement.

One more result is shown below in Figure 9.

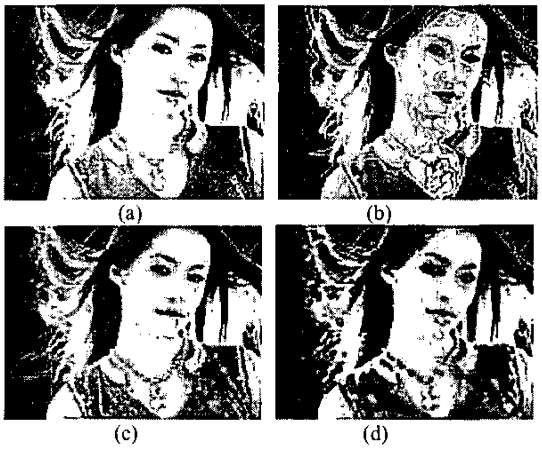


**Figure 9:** (a) Source image. (b) Segmentation result with 43 regions. (c) Rendered results of average size 10 and (d) 14 of local region.

## 6. CONCLUSION

This paper presented the algorithm of using extracted features as guidelines to generate stroke-based painterly rendering image. The image analysis techniques of geometric moments and texture analysis are used to derive stroke attributes. Techniques of dynamic determination of cropped image size and edge enhancement are developed to improve the painting quality. As a result, the main features in the source image are well preserved. It has been implemented using C on UNIX environment.

## 7. REFERENCES

[1] A J Cole. Halftoning without dither or edge enhancement. *The Visual Computer,* 1991, 7:232-246.

[2] P Haeberli. Paint by numbers: Abstract image representations. *SIGGRAPH 1990, 207-214.*

[3] A Hertzmann. Painterly rendering with curved brush strokes of multiple sizes. *SIGGRAPH 1998,* 453-480.

[4] A Hertzmann and K Perlin. Painterly rendering for video and interaction. *NPAR 2000, 7-12.*

[5] P Litwinowicz. Proceeding images and videos for an impressionist effect. *SIGRAPH 1997, 407-414.*

[6] R Mukundan and K R Ramakrishnan. Moment Functions In Image Analysis, theory and applications. published by *World Scientific* in September 1998. ISBN: 9810235240.

[7] M Shiraishi and Y Yamaguchi. An algorithm for automatic painterly rendering based on local source image approximation. *NPAR 2000,* 53-58.

[8] H Tamura, S Mori, and T Yamawaki. Texture Features Corresponding to Visual Perception. *IEEE Trans. on Syst., Man, and Cybern. Vol. 6, No. 4, 1979, 460-473.*