國立交通大學

資訊科學與工程研究所

碩 士 論 文

中 國 水 墨 畫 嶺 南 派 風 格 之 錦 鯉 合 成

The Synthesis of Lingnan School Painting for Embroidered Fish

研 究 生：張欣怡

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中 華 民 國　九 十 五　年 六 月

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中國水墨畫嶺南派風格之錦鯉合成

研究生：張欣怡　　　　　　　　　　指導教授：施仁忠 教授

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摘　　要

嶺南畫派是本世紀興起的重要中國水墨畫畫派之一。以傳統國畫技巧為基礎，結合西畫技巧，而成為此派的特色。嶺南派的題材廣泛，許多作品都可看到以花鳥、走獸、昆蟲和魚等為主角。本篇論文即著重於嶺南畫派中的錦鯉畫法，使用者輸入一張錦鯉張照片，系統自動抓出影像輪廓、魚鰭和魚鱗資訊，產生毛筆效果。再利用畫家上色方法去模擬水和顏料在紙上的擴散，並仿造嶺南畫派的渲染技法。如此，使用者便能透過現有的錦鯉圖片，不需要瞭解複雜的水墨技巧，在短時間產生具有嶺南派風格的繪畫。

The Synthesis of Lingnan School Painting for Embroidered Fish

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ABSTRACT

Since the beginning of twentieth century, the Lingnan School Painting is an important Chinese Ink Painting school. It's characteristic is based on the traditional Chinese Painting skill and Combined the skill of the western drawing. The subject matter of the Lingnan Painting is widespread, and it contains Birds and Flowers Painting, Beast Painting, Insect Painting and Fish Painting, etc. In this thesis, we focus on the embroidered fish drawing in the Lingnan Painting. Input a photo of embroidered fishes, we apply the brush strokes to the outline and simulate the water and pigment diffusion effects on paper to imitate washing skill. Therefore, user may generate the Lingnan Painting style easily without familiar with the complicated painting skills.

Acknowledgements

First of all, I would like to express my gratitude to my advisor, Prof. Zen-Chung Shih for his guidance and patience, and Prof. Tien-Chun Chang for her guidance about skill of the Chinese Painting. Also, I appreciate all the members in Computer Graphics and Virtual Reality Laboratory for their comments and help in these days.

I dedicate the achievement of this work to my family and friends, and thanks for their support and encouragement. Special thanks go to my boy friend. Without his support and company, I couldn’t fully focus on my study.

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CHAPTER 1

Introduction

1.1 Motivation

Since the beginning of twentieth century, the Lingnan School Painting is an important Chinese Ink Painting school. A different from traditional Chinese Ink Painting is that it uses vivid color. The subject matter of the Lingnan Painting is widespread, and it contains Birds and Flowers Painting, Beast Painting, Insect Painting and Fish Painting, etc. Chinese Ink painting over the years develop mainly on the North (for example, Beijing and Shanghai ,etc.), but southern art is significant gradually in recent years, and so the Lingnan School Painting paid attention to day by day.

In this thesis, we propose a system to synthesize realistic style of the Lingnan Painting specific on embroidered fishes. Since the pronounced of 'fish' and 'surplus' is the same, there is meaning that has enough and to spare, so Chinese like making pictures for the material with the embroidered fishes. And there are almost ponds with embroidered fishes in the traditional Chinese building, so it is simple to obtain embroidered fishes's photo.

1.2 Overview

In our system, we simulate two important processes, sketching the contour and coloring. Figure 1.1 shows the flow of our proposed system. First of all, the user inputs a reference image of embroidered fishes. The user needs to input the image which has labeled information about the position of fins.

In sketching the contour, user needs to draw a line as fish spine. The system will look for edge points, and generate the position of fins automatically. Then we define stroke and apply brush model to generate a drawing similar to Chinese Writing Brush.

In coloring, we first look for the washing region. The system generates color which is similar to Traditional Chinese Painting pigment and the input image. The user can control washing effect by adjusting proper parameters, for instance, the color of drawing and the quantity of the color pigments.

Finally, when sketching the contour and coloring are complete, the composition of these images and applied background produces the final result.

1.3 Thesis Organization

The rest of this thesis is organized as follows. In chapter 2, we review the related works of computer-synthesized Chinese-Ink Painting in Non-Photorealistic Rendering. In chapter 3 we introduce the features of the Lingnan School Painting. In chapter 4, we introduce the stroke model and describe the details of stroke generator. Chapter 5 describes the procedure for color diffusion. Then experimental results of our system are shown in chapter 6. Finally, chapter 7 is the conclusions and future works.

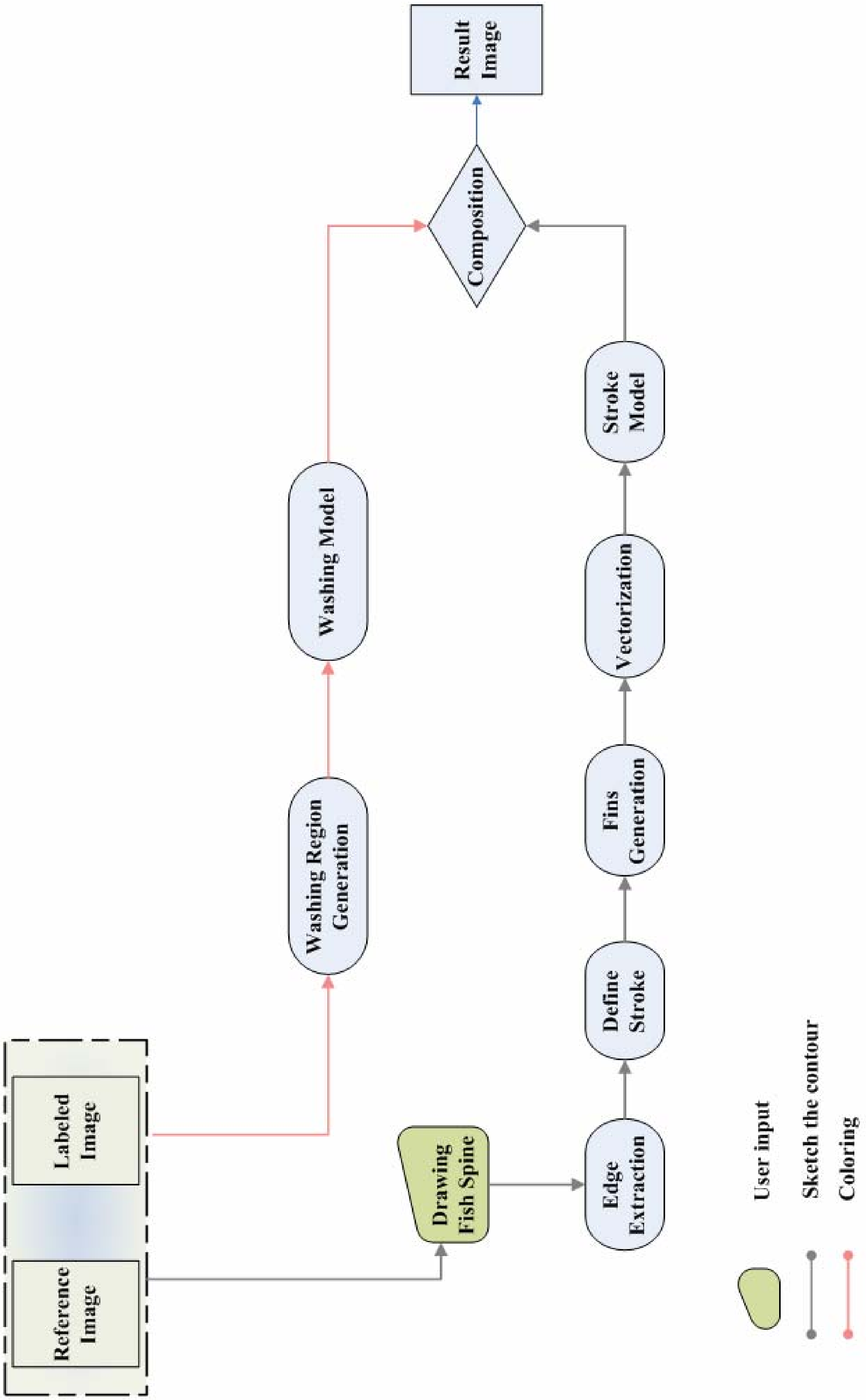


Figure 1.1 The System flowchart

CHAPTER 2

Related Works

In this chapter, we discuss some previous works related to Chinese Ink Painting on two topics: brush model, ink, and color diffusion.

2.1 Brush Models

In order to simulate the characteristics of real brushes, the researcher often needs to define an appropriate brush model. Strassmann's hairy brushes model [17] provided mathematical model on simulating traditional Japanese art of sumi-e. His work describes stroke shape flexibly and renders strokes by adjusting the distribution of ink. Saito and Nakajima [15] provided a three-dimensional physically-based brush model for Japanese calligraphy and sumi-e paintings. Users can draw strokes on a computer with a pen-type input device.

There are several researches [9,21,22,23] simulating Chinese Writing Brush in Chinese Ink Painting. Weng [21] proposed a method to mimic the Chinese Ink

Painting in different styles. His algorithm was based on a physically-based brush model and simulates the bristles of Brush. The region where the brush contacts the paper is a circular area. The bristles are distributed uniformly in this region and considered as a footprint. The footprints inside the circle rotate an angle along the tangent direction. For generating different kinds of stroke, decreasing parameter, concentration parameter, difference parameter, and discontinuity parameter are used to determining the amount of ink deposited onto the paper from each bristle. Wong et al. [22] used an inverse cone to represent the virtual brush. Since Weng's work simulates Chinese Writing Brush realistically, we define the brush model which is similar to Weng's work. Details will be discussed in section 4.1.1.

2.2 Ink and Color Diffusion

The most important feature of Chinese Ink Painting is the effect of ink diffusion produced by the incredible absorbency of Hsuan paper which is the particular material for Chinese Ink Painting. This phenomenon in Chinese ink painting is different from western painting. In western paintings, for example watercolor, the absorbency of paper is not so high that water and color pigment both flow on paper. Therefore, a shallow water simulation is needed to simulate the color pigments flowing above paper. Small [16] has proposed a parallel approach to the problem of predicting the action of pigment and water when applied to paper fibers. Elaborate and realistic behaviors can be achieved by repeating the computation for each cell in the paper over many steps. Curtis and Anderson [17] employ a more complex shallow water fluid simulation, and use a Kubelka-Munk model to compute the color of a stroke painted on another stroke.

In Chinese ink painting, a technique proposed by Lee [14] considers the characteristics of ink and also incorporates a random or regular fiber mesh structured paper model. Huang et al. [11] proposed a physically-based ink diffusion model by simulating the interaction among water particles, carbon particles and paper. Yu and Lee [24] proposed a local equilibrium model (LEM) for movement of ink and water between neighboring cells on the paper, and a layer model which represents the movement of water and ink between neighboring cells on the paper.

In this thesis, based on the Curtis's shallow water fluid simulation [17] and Yu's model [24], we simulate the results of washing on the Hsuan paper.

CHAPTER 3

Background

3.1 Preliminary of Lingnan School Painting

In this section, we introduce the history of Lingnan School Painting and the character of Lingnan School Painting when painter painting.

3.1.1 The History about Lingnan School Painting

Lingnan is the South of Five Ranges (五嶺) composed of Tayu Mountains (大瘐嶺), Qitian Mountains (騎田嶺), Dupang Mountains (都龐嶺) , Mengzhu Mountains (萌諸嶺) , and Yuecheng Mountains (越城嶺) . The region covered by the name Lingnan has changed with time. Today, "Lingnan" and "Guangdong" (廣東) can almost be treated as synonyms. Clearly, according to the geographical position, Lingnan School Painting rises and develops from Guangdong.

In the beginning of twentieth century, Gao Jian-Fu (高劍父,1879-1951), Gao Qi-Feng (高奇峰,1889-1933) and Chen Shu-ren (陳樹人,1884-1948) created a new

Chinese art through a synthesis of East and West and brought forth a new movement in Chinese painting. Then they found “Lingnan School Painting”. They are so prominent that they are hailed as the “Three Masters of Lingnan” (嶺南畫派三大家).

3.1.2 The character of Lingnan School Painting

“Lingnan School Painting” is based on the traditional Chinese Painting skill and Combined the skill of the western drawing. A different from traditional Chinese Ink Painting is that it uses vivid color. Figure 3.1 is “Endless The Joy of Carp” which worked by Chao Shao-Ang (趙少昂『九如圖』).

Figure 3.1 “The Joy of Carp” which worked by Chao Shao-Ang

Painters of Lingnan School Painting like to painting by using Horse Hair Brush (山馬筆) to showing bold and unconstrained. In washing, they put a cushion under the paper and moisten the paper. Since there is oil that does not absorb water on the surface of cushion, water floats on the paper. Then using “a row of brushes” (排筆) to wash layer by layer gradually.

In this thesis, we focus on imitating the sketch of contour by using Horse Hair Brush and wash a layer by layer using a row of brushes.

3.2 The Painting Procedure for Embroidered Fish

We explain the procedure of drawing Lingnan School Painting on embroidered fishes in this section. We use the compositions created by Lin Hu-Kuei(林湖奎) [1] who is a budding young talent of Lingnan School Painting.

The painting process of Lingnan School Painting can be divided into four steps. First, painters draw the outline of the fish body and gill, and notice the range of the fishes's tail swing. Second, painters draw fins by using pale ink and side-stroke, and paint the eye with dark ink. Third, moisten the paper, apply chocolate (赭石色) to the body of Embroidered Fish and white lead (鉛白) to the white scales. Finally, when the paper where the body of the fish was painted is still wet, washing body by vermeil (朱紅). Figure 3.2 shows this process.

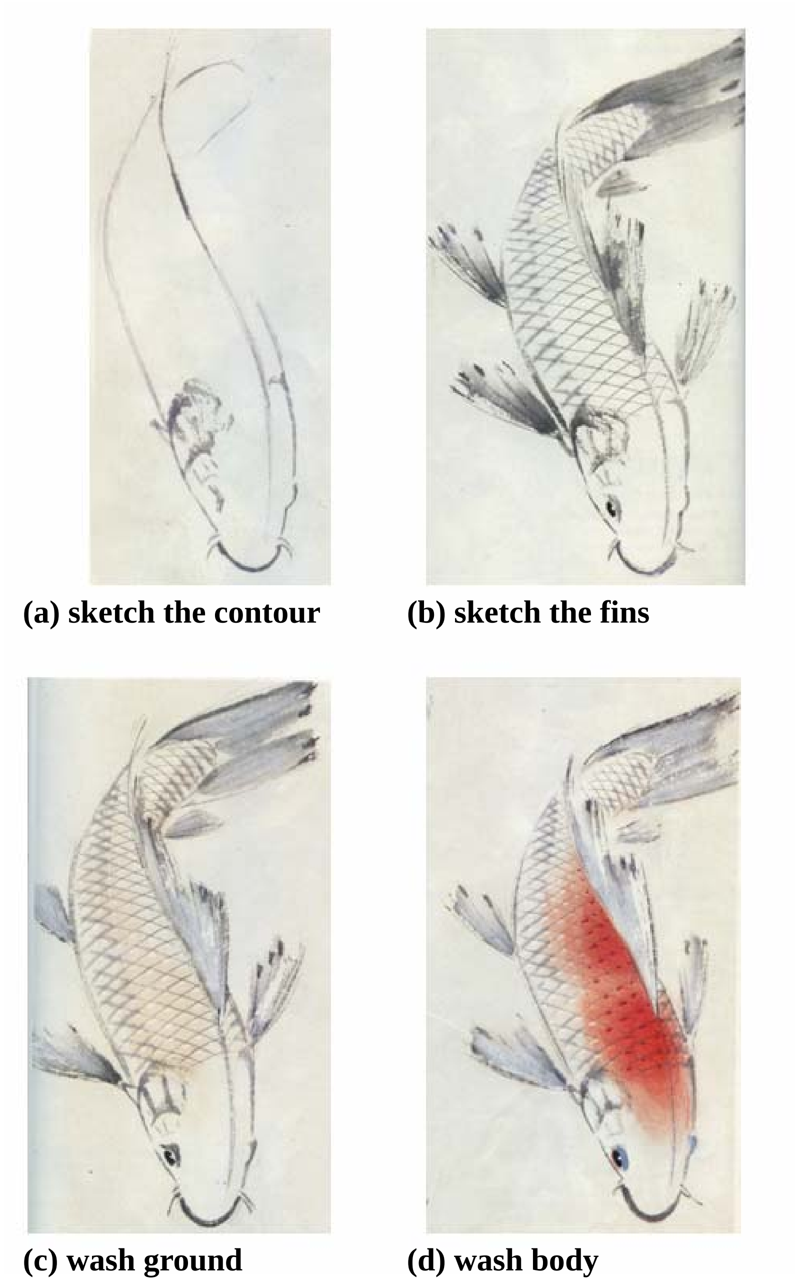


Figure 3.2 A procedure of painting

CHAPTER 4

Stroke Generation

In this chapter, we describe how to obtain the stroke information from input image and generate stroke of fishes scale and fins automatically. After we obtain this information, brush stroke should be applied on them. Figure 4.1 shows the flowchart of sketching.

In sketching the contour of embroidered fishes, painters draw the shapes and position realistically. But they draw fish's scales and fins according to their aesthetic feeling. The Horse Hair Brush is commonly used in this process, and we will also simulate the brush model for Horse Hair Brush style. We introduce our proposed brush model which has two kinds of style: center stroke and side stroke.

This chapter is organized as follows. In section 4.1, we introduce the brush model, discuss the movement and rotation of brush, and present the ink depositing model. Then we describe the contour sketching of fish's body and scales in section 4.2 which contains the edge extraction, the stroke definition, the vectorization, and the application of brush strokes. Section 4.3 explains the generation of fins.

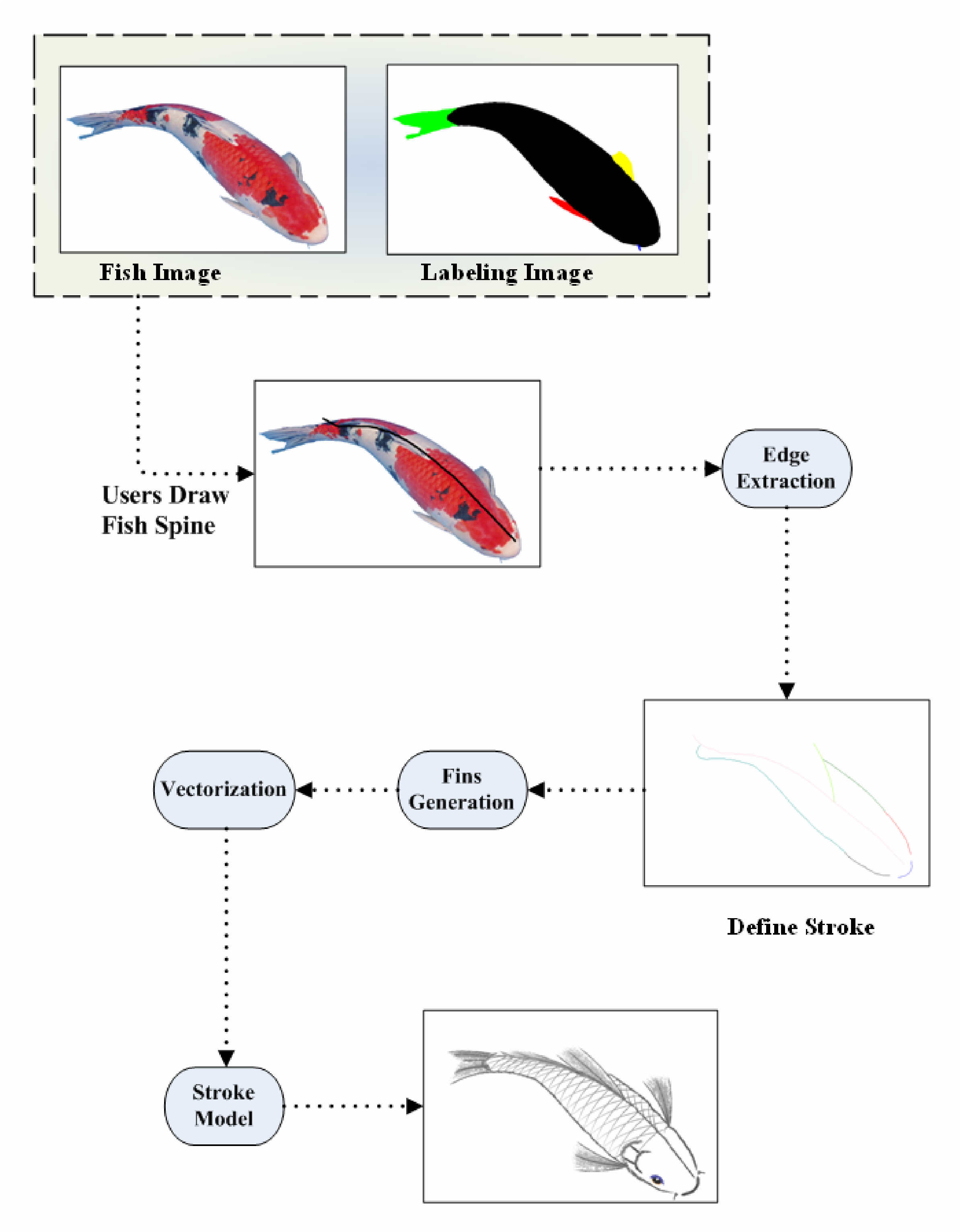


Figure 4.1 The flowchart of contour sketching

4.1 The Brush Model of Horse Hair Brush

The painters of Lingnan School Painting like to use Horse Hair Brush. The painting which painted by Horse Hair Brush has the characteristics of bold and generous. In this section, we introduce two brush models for different strokes: center stroke and side stroke.

4.1.1 Center stroke

Weng's model [21] focuses on simulating center stroke effect. Center stroke means that painter place the tip of brush in the middle without any slanting. Therefore we use a single circle to simulate the contact region of brush and paper. Consider Figure 4.2. Let *o* and *r* be the center and the radius of the circle, respectively. There are many bristles inside the circle, where each bristle will generate a footprint, denoted as h_i, on the paper.

$$h_i = (r_i, \theta_i) \tag{4.1}$$

where *i* is index of the of bristles. r_i is the distance from *o* to h_i.

In our implementation, we partition the center angle into 100 parts and select 5 points on each radius to generate 500 footprints totally, as shown in Figure 4.3. Our experiments show that 500 bristles are enough. In this way the footprints can be generated efficiently. The location of a footprint with respect to center *o* thus can be represented as:

$$h_i = (r_i \cos\theta_i, r_i \sin\theta_i) \tag{4.2}$$

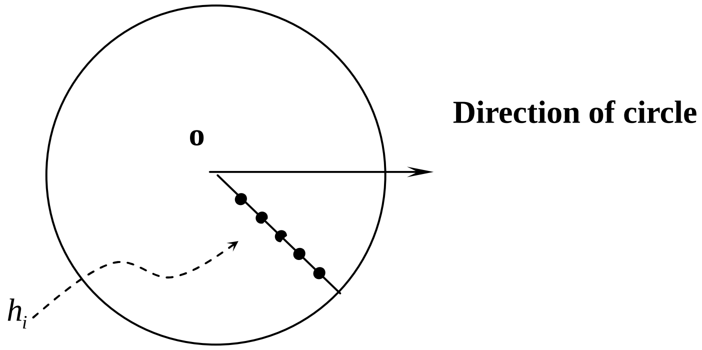


Figure 4.2 The contact region of brush on canvas

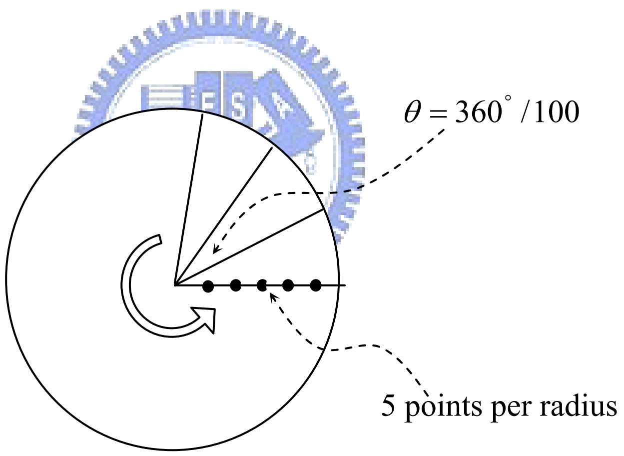


Figure 4.3 The placement of bristles.

During painting process, the brush moves its contact region along the stroke trajectory. We use Cardinal Spline to simulate the stroke trajectory. Since it is an interpolating curve, we could obtain interpolated points between two neighboring control points. Figure 4.4 shows the generated trajectory by arranging control points.

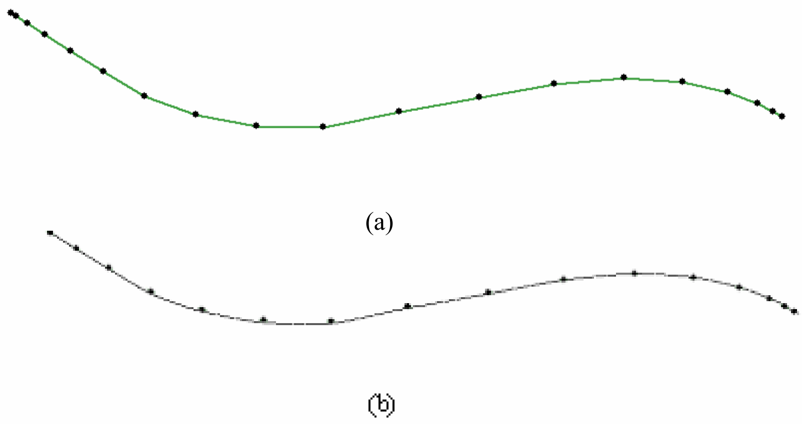


Figure 4.4 (a) Control points (b) Interpolating curve

The radius of the contact circle represents the width of the stroke at each point on the paper. We refer Ho's model [12] to determine this value. Figure 4.5 shows the radius changed along the variation of tangent line of stroke trajectory. We can calculate radius r_i by adjusting parameters of S_1, S_2, *base*, *k* ,*start*, and *End*. S_1 and S_2 are the thresholds of the curve two extremities. $Q(x)$ is a Bezier curve. The value of *base* means the minimum radius and *k* adjust degree for θ. θ is the included angle of tangent lines between $Q(x_i)$ and $Q(x_{i+20})$ as shown in Figure 4.6 because $Q(x_{i+20})$ could provide a suitable angle to preserve the quality in our implementation. The value of *start* and *end* represent the initial and terminal radius respectively. m is the x unit variation.

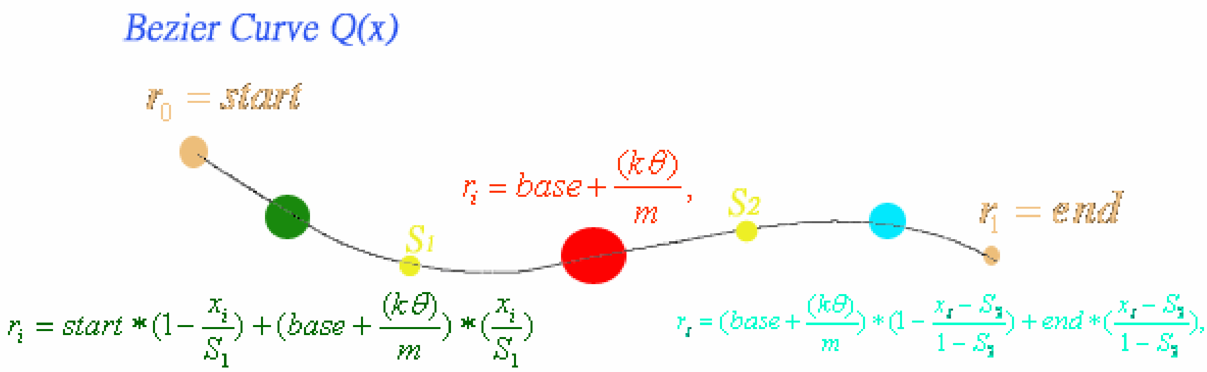


Figure 4.5 The change of radius

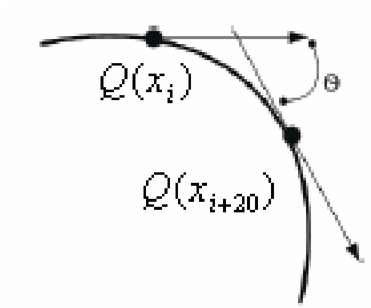


Figure 4.6 The θ representation

We define the radius as follows:

$$
r_i = \begin{cases} start*(1-\frac{x_i}{S_1})+(base+\frac{(k\theta)}{m})*(\frac{x_i}{S_1}), & \text{if } 0 \le x_i \le S_1 \\ base+\frac{(k\theta)}{m}, & \text{if } S_1 < x_i < S_2 \\ (base+\frac{(k\theta)}{m})*(1-\frac{x_i-S_2}{1-S_2})+end*(\frac{x_i-S_2}{1-S_2}), & \text{if } S_2 \le x_i \le 1 \end{cases} \quad (4.3)
$$

Consider Eq.4.3, when the value of x is smaller than S_1, we simulate the effect of initial drawing. The radius is linear variation from start to the radius of point S_1. In real painting, painters usually draw heavier to generate thicker stroke when the line's curvature becomes larger. So when x lies between S_1 and S_2, the size of radius depends on the variation of line curvature. Finally, when x is greater than S_2, the radius is also linear variation from the radius of point S_2 to *end*. It simulates the ending of the stroke when painting

When the brush moves along the stroke trajectory, the direction of the circle should be aligned to the tangent direction. We use an approximate tangent vector *T* at point (x_i, y_i) as follows:

$$T(x_i, y_i) = (x_i - x_{i-1}, y_i - y_{i-1}) \tag{4.4}$$

The new coordinates of bristles after rotation are:

$$h_{i,x}{}' = (h_{i,x}\cos\phi - h_{i,y}\sin\phi) + o_x$$
$$h_{i,y}{}' = (h_{i,y}\cos\phi + h_{i,x}\sin\phi) + o_x \tag{4.5}$$

where ϕ is the angle between T and x-axis, as shown in Figure 4.7

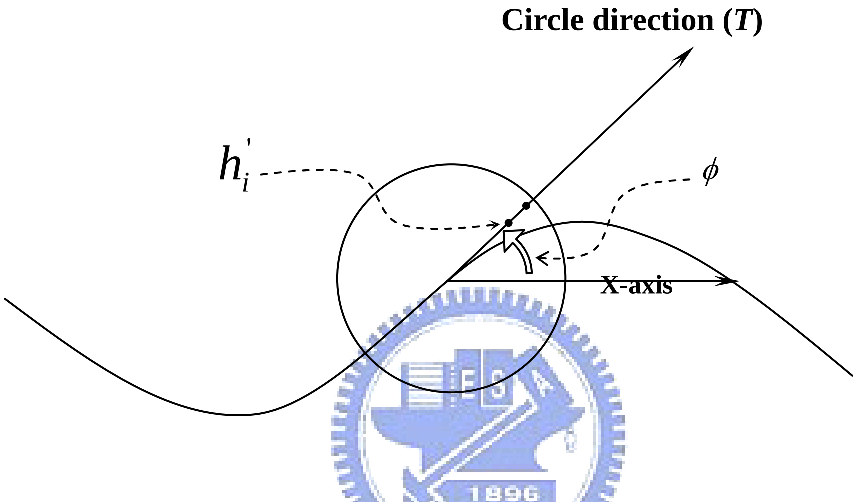


Figure 4.7 The rotation of circle direction

Then, by Equations (4.2) and (4.5), the location of a pixel to be painted can be obtained by the following equation:

$$h_{i,x}{}' = (r_i\cos\theta_i\cos\phi - r_i\sin\theta_i\sin\phi) + o_x \tag{4.6}$$
$$h_{i,y}{}' = (r_i\sin\theta_i\cos\phi + r_i\cos\theta_i\sin\phi) + o_y$$

Figure 4.8 shows the strokes painted in different number of bristles.

(a) Stroke trajectory

(b) Stroke by *start*=3.0, *base*=3.0, *end*=4.0, *k*=0.3, S_1=0.35, S_2=0.85

(c) Stroke by *start*=8.0, *base*=13.0, *end*=0, *k*=0.6, S_1=0.35, S_2=0.85

(d) Stroke by *start*=4.0, *base*=7.0, *end*=9.0, *k*=0.1, S_1=0.2, S_2=0.8

Figure 4.8 Examples of brush model

4.1.2 Side stroke

Side stroke means that painter tilts brush when painting. Therefore we use two ellipses to simulate the initial and terminal contact region of brush and paper, and insert additional two ellipses to control direction of bristles as shown in Figure 4.9.

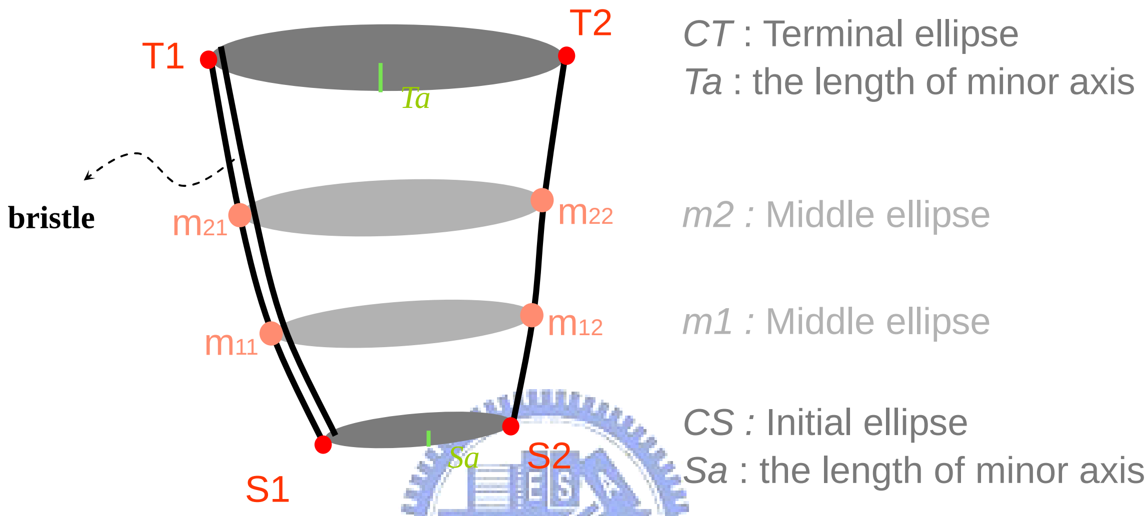
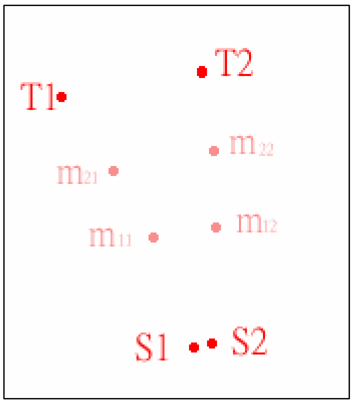
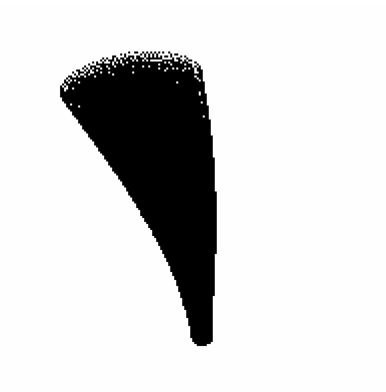


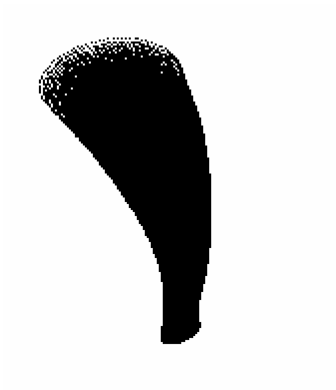
Figure 4.9 Side stroke brush model

The length of major axis of the initial ellipse (terminal ellipse) is half of the distance between S1(T1) and S2(T2), and the length of minor axis is *Sa*(*Ta*) which is given by user. The lengths of minor axis of middle ellipses are obtained by the linear interpolation of *Sa* and *Ta*. Each ellipse is divided from the center angle into 100 parts and select 10 points on each radius to generate 1000 footprints totally. We use Cardinal Spline to join points which has the same position in each ellipse. So when we want to apply side stroke, we should have eight control points and two length of major axis. Figure 4.10 shows the side strokes painted in different lengths of minor axis.



(a) Input points S1, S2, T1, and T2





(b) Stroke by Sa=5, Ta=10

(c) Stroke by Sa=5, Ta=15

(d) Stroke by Sa=10, Ta=20

Figure 4.10 Examples of Side stroke

4.1.3 Ink Depositing Mechanism

As discussed in Sections 4.1.1 and 4.1.2, we can obtain the locus of bristles on the paper. Next we should determine the amount of ink that deposited onto the canvas.

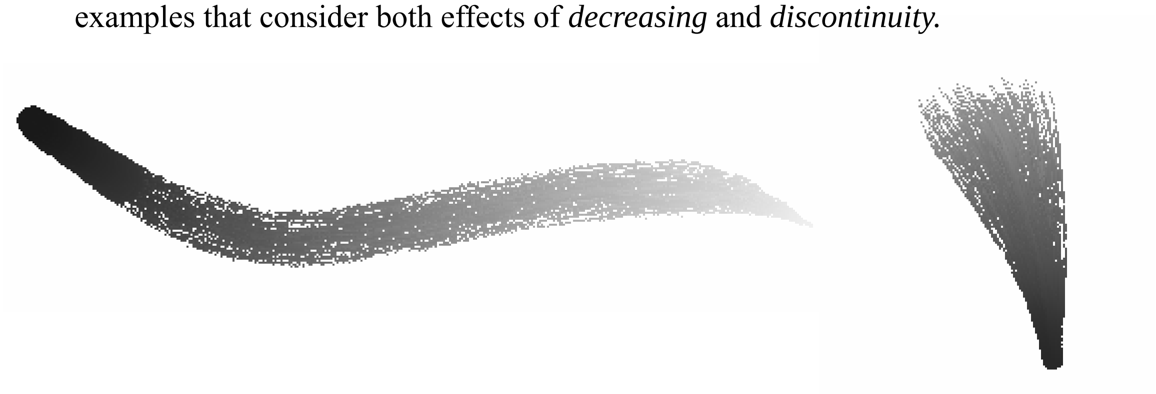
In this section, we discuss the ink depositing model to simulate the amount of ink deposited and its effects on canvas. We refer to Weng's model [21] and use two parameters to control painting styles: *decreasing* and *discontinuity*.

The decreasing parameter describes the decreasing rate of the amount of ink remaining on the brush. Given the initial and final gray values, we can control the changes of gray level linearly along the path of each bristle. Figure 4.11 shows xamples that only consider the effect of *decreasing* parameter.

(a) Center Stroke **(b) Side Stroke**

Figure 4.11 Examples only considers the effect of decreasing parameter

The discontinuity parameter describes bristles may out of ink and leave discontinuous gaps on its path during the painting process. This happens when there is not enough ink remaining on the brush. To simulate this effect, the maximum gap size is predefined in an array, *discontinuity,* and each bristle is mapped to *discontinuity* randomly to get its max gap size. Once a bristle deposits ink, its discontinuous gap size can not be larger than its max gap size. Besides, the discontinuous gap size keeps decreasing until it equals to zero during the brush moving process. Figure 4.12 shows examples that consider both effects of *decreasing* and *discontinuity.*



(a) Center Stroke **(b) Side Stroke**

Figure 4.12 Examples consider the effect of decreasing and discontinuity

After setting up the brush model, we apply stroke onto the canvas. We consider the move of ink. The spread of ink on canvas is simulated by using low-pass filters to blur the stroke. For example, as shown in Figure 4.13, by using a 3 x 3 mask, the gray level of p_4 will be:

$$p_4 = \frac{1}{9}\sum_{i=0}^{8} p_i \tag{4.7}$$

$\frac{1}{9}p_0$	$\frac{1}{9}p_1$	$\frac{1}{9}p_2$
$\frac{1}{9}p_3$	$\frac{1}{9}p_4$	$\frac{1}{9}p_5$
$\frac{1}{9}p_6$	$\frac{1}{9}p_7$	$\frac{1}{9}p_8$

Figure 4.13 A low-pass filter

Figure 4.14 show the result which use low-pass filters.

(a) Center Stroke **(b) Side Stroke**

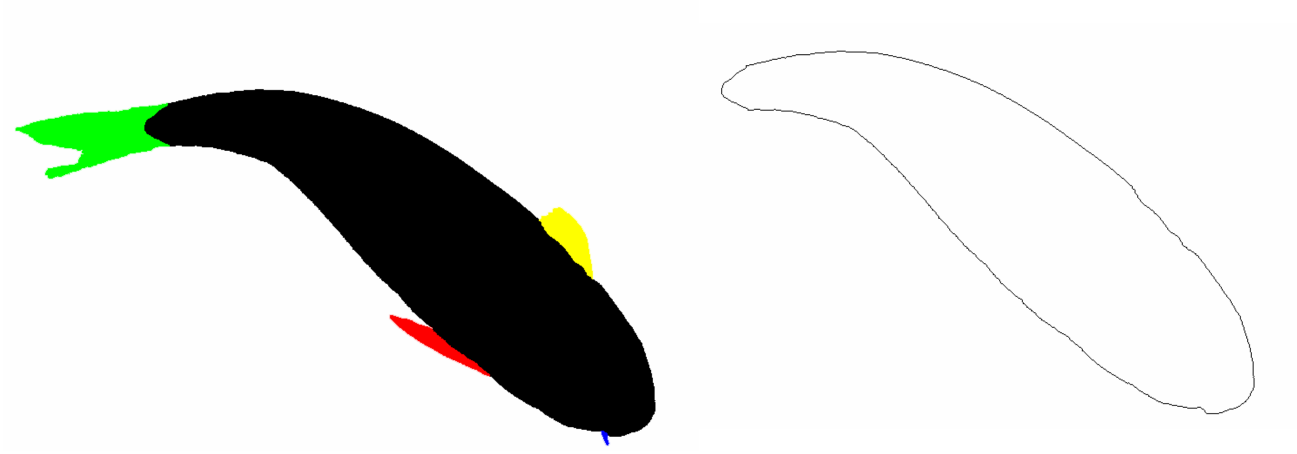
Figure 4.14 Final resulting

4.2 Contour Sketching on Fish's Body and Scales

In this section, we introduce the procedure for sketching the contours of Fish's body and scales according to the input image. We classify the stroke into six kinds of type: head, cirri, gill cover, spine, body and fish scales.

4.2.1 Edge Extraction

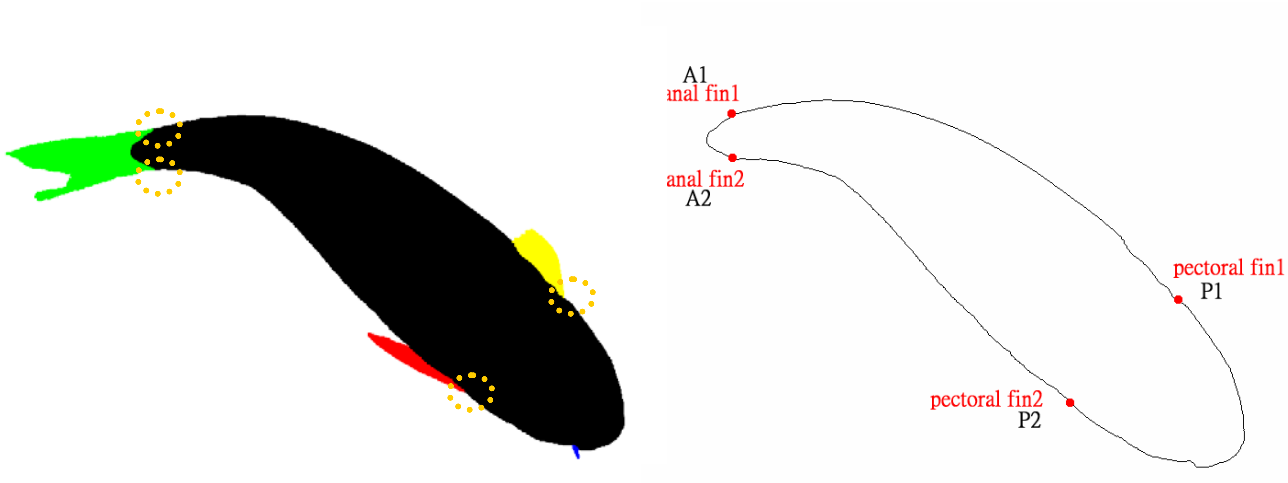
First, users input reference and labeling images. The system finds out the outline of fish body from labeling images as shown in Figure 4.15.



(a) Labeling Image **(b) Outline of fish body**

Figure 4.15 Outline of fish body

We look for two extremities of anal fin (A1 and A2) and pectoral fins (P1 and P2) along the outline of fish body, these points are data points when system defines stroke (Figure 4.16). The feature of extreme anal fin points (A1 and A2) is that there are three kind of difference point which contains body, anal fin, and background in neighborhoods. And the features of pectoral fin points (P1 and P2) are that there are three kinds of difference point which contains body, pectoral fin, and background in neighborhoods. Figure 4.16 shows the position of these four points.



(a) The relationship of labeling image and data points

(b) The relationship of outline and data points

Figure 4.16 The position of data points

4.2.2 Stroke Definition

When we find out the data points, we can determine head stroke according to the size of fish head. Spine stroke is drawn by user; our system only record curve user drew. Figure 4.17 shows the position of head and spine stroke.

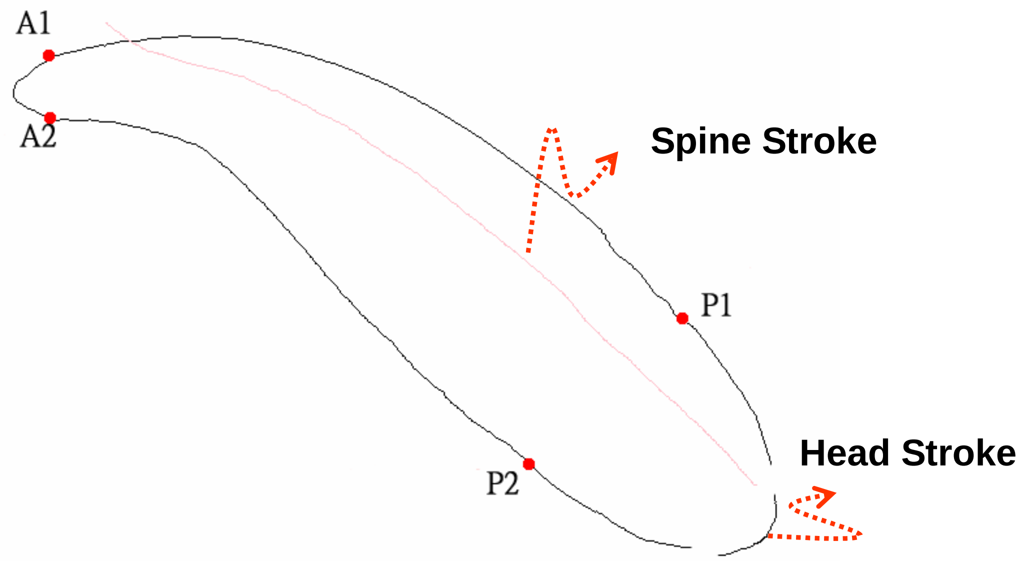


Figure 4.17 The position of head and spine stroke

The information of cirri is not always acquired from the reference image, so our system generates it automatically. Its shape is controlled by three control points, and size is scaled according the size of fish. After the relative place of the control points is determinate, we transform them to fish head and join them by using Cardinal Spline. Figure 4.18 shows the process of generating cirri stroke. There are four cirri for each fish.

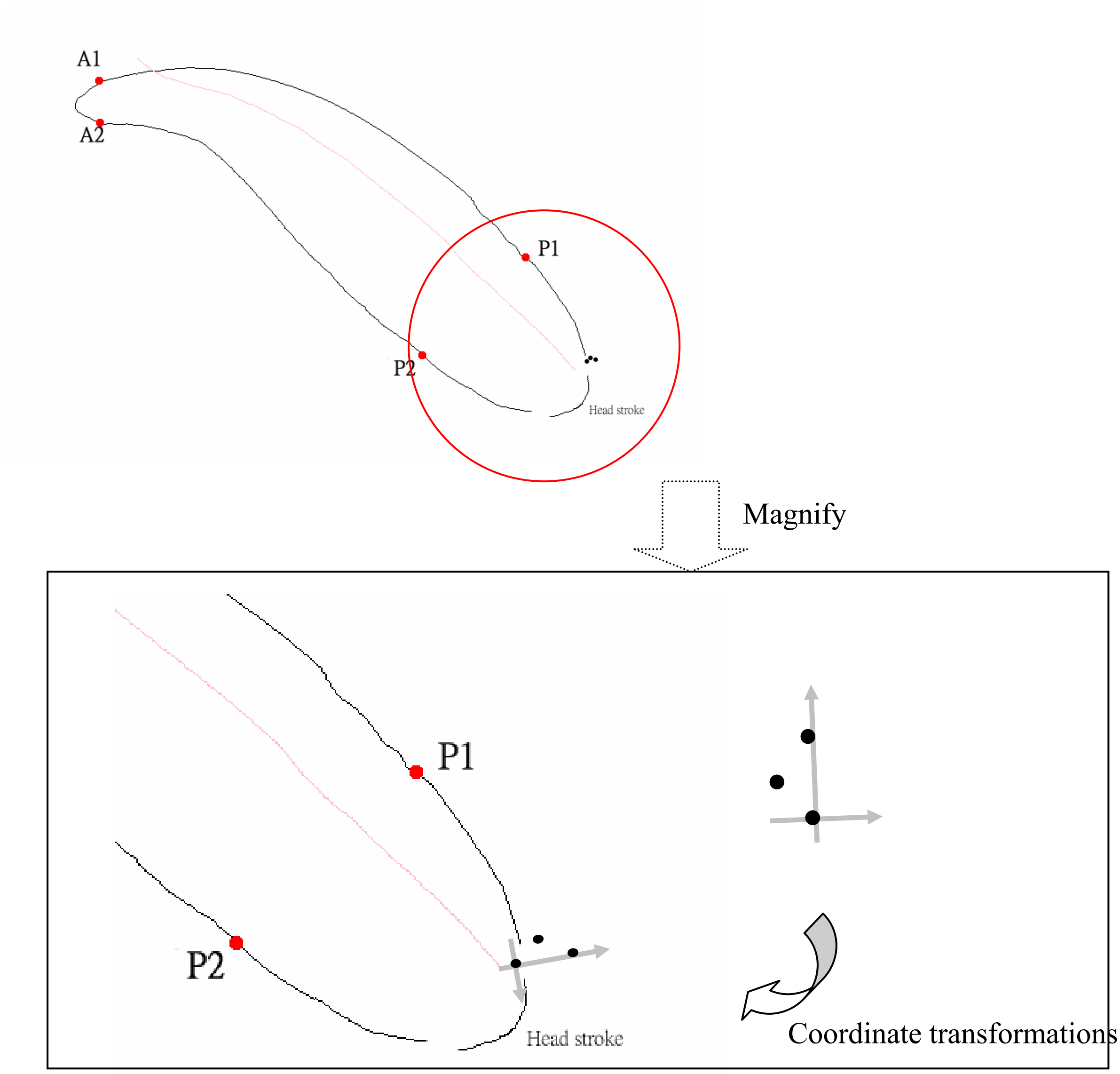


Figure 4.18 The process of generating cirri stroke

The method of generating gill cover stroke is similar to cirri. The differentiation between them is that the number of control points of gill cover stroke is four. Figure 4.19 shows the process of generating cirri stroke.

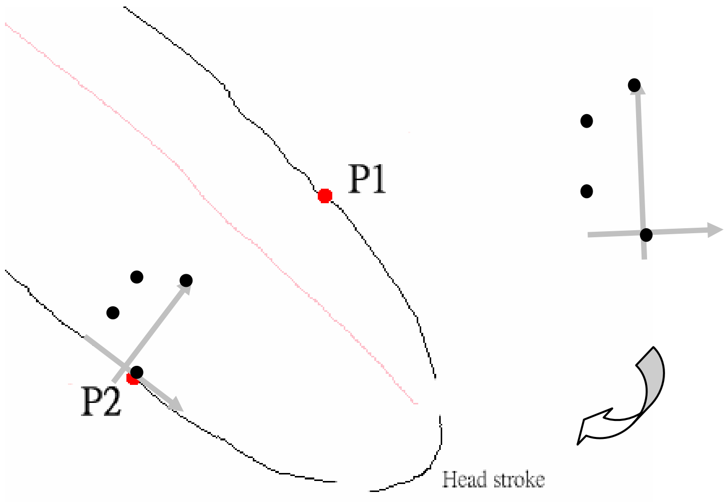


Figure 4.19 The process of generating gill cover stroke

There are two strokes of body stroke: one is from pectoral fin point which one of data points to the intersectional point of spine along body outline; the other is to the intersectional point of dorsal fin along body outline. The generation of dorsal fin is illustrated in next section. Figure 4.20 shows the location of body stroke.

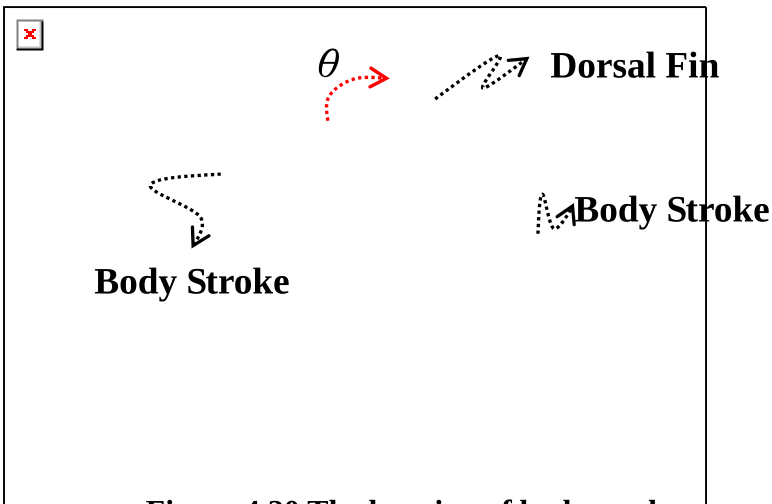


Figure 4.20 The location of body stroke

Painters draw fish scale from spine stroke to body stroke regularly and repeatedly, and our system simulate scale according to the same method.

Fish eye is drew in advance, our system transform it to appropriate location and scale it based on the size of fish. as shown in Figure 4.21.

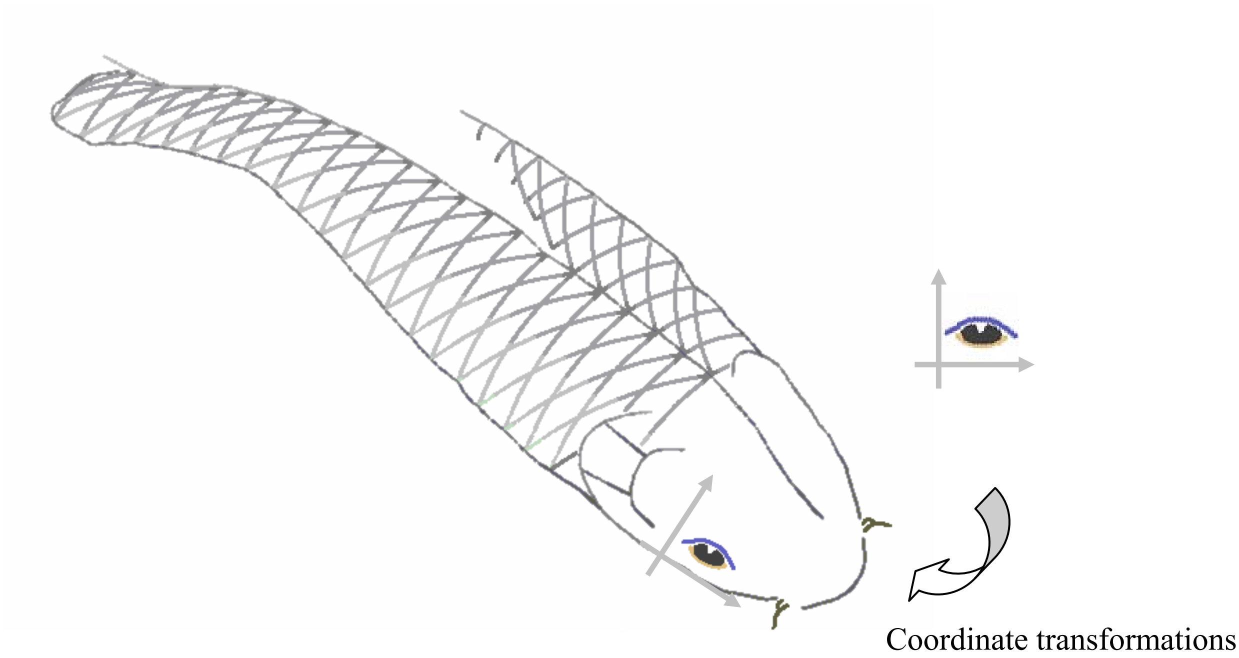


Figure 4.21 The process of generating fish eye

4.2.3 Vectorization

The goal of vectorization is to generate a smooth stroke. After finding out all strokes, we extract a few sample points for each stroke, then use Cardinal Spline to join them.

4.2.4 Apply Brush Mode

After vectorization, we apply the center stroke of brush model to each stroke, as shown in Figure 4.22.

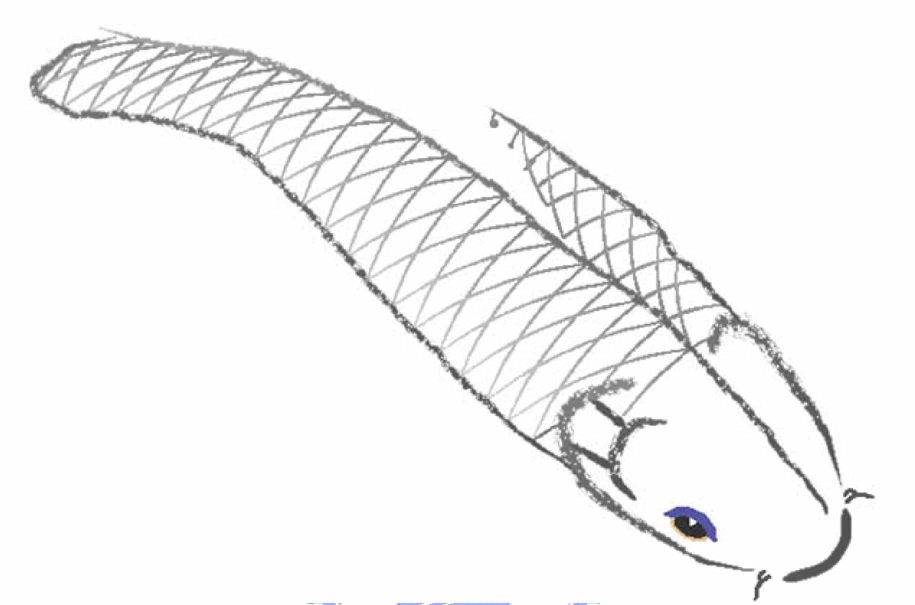


Figure 4.22 Stroke applied by brush model

4.2 Contour Sketching on Fins

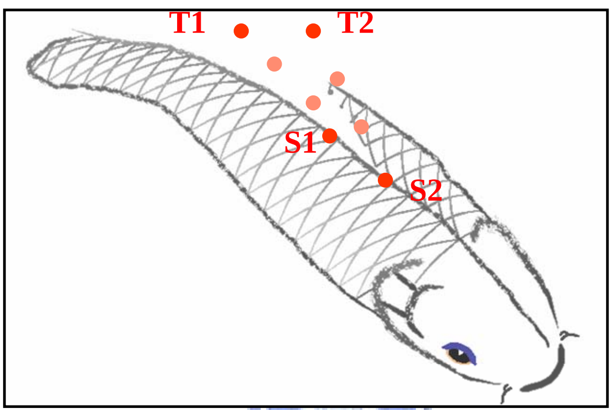
The fins of real fish and of painter drew is different, so our system generate fins according to the style of painter drew.

4.3.1 Sketching Positions Generation

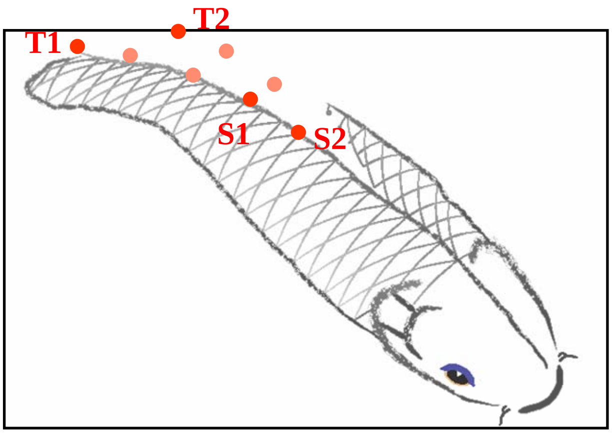
There are three kinds of Fish's scales: dorsal fin, pectoral fin and anal fin. In order to apply side stroke, each stroke needs eight control points. These control points of every fin are generated using different methods as follows:

Dorsal Fin

Painters usually use two side strokes to paint dorsal fins. First stroke forms an included angle θ with the spine, and second stroke is painted along spine stroke. The angle θ is defined by our system, but users can modify it. The control points of two side stroke are determined based on the size of fish. Figure 4.23 shows the position of control points of dorsal fin.



(a)



(b)

Figure 4.23 (a) First stroke. (b) Second stroke.
The red points are initial and terminal points.
The orange points are inserted points.

Pectoral fin

There are two features for Pectoral fin. One is that it is close to Pectoral fin which one of data points, and the others is that it forms an included angle with the fish body. Figure 4.24 shows the position of control points of pectoral fin.

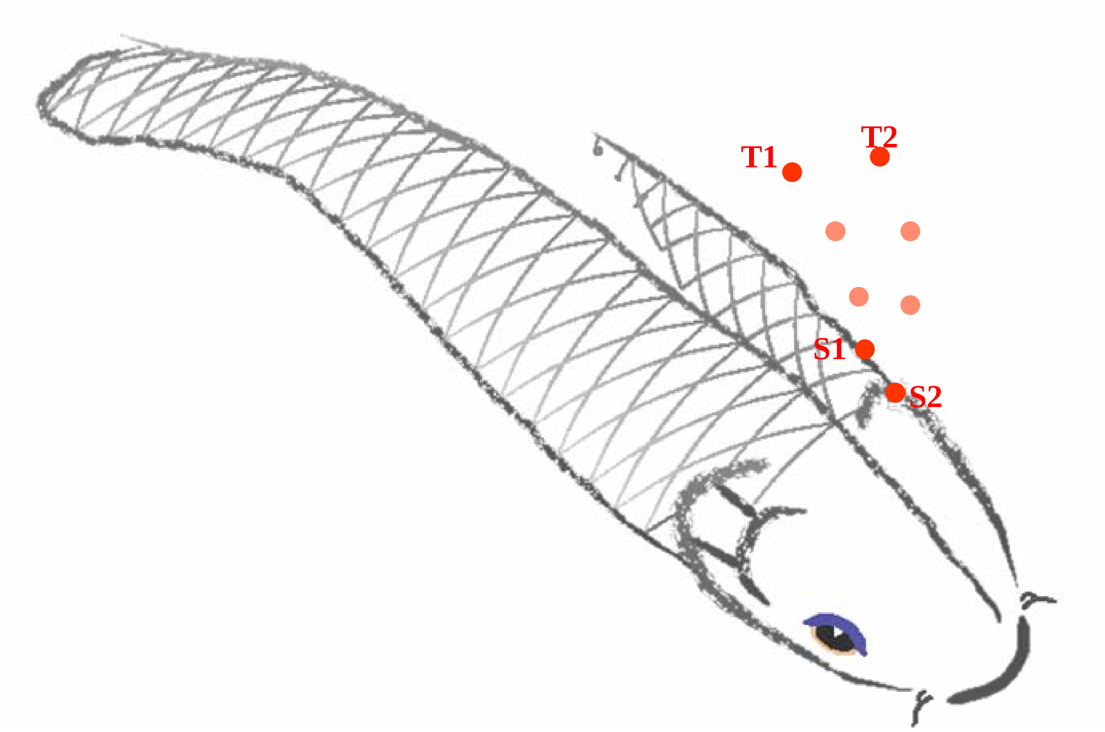


Figure 4.24 Control point of pectoral fin
The red points are initial and terminal points.
The orange points are inserted points.

Anal Fin

There are two strokes for anal fin, and they are drawn between Al and A2 which are the data points. Anal fin swings the same way as the body. To simulate this effect, we find two points (B1 and B2) in the outline of body, and calculate symmetrical points ($B1'$ and $B2'$) based on the line which joint A1 and A2 (data points). Figure 4.25 is a diagrammatic explanation. The orange points are obtained by the same method. Since anal fin is drew using two strokes, we compute the middle points of the above found points. These points forms control points of anal fin stroke.

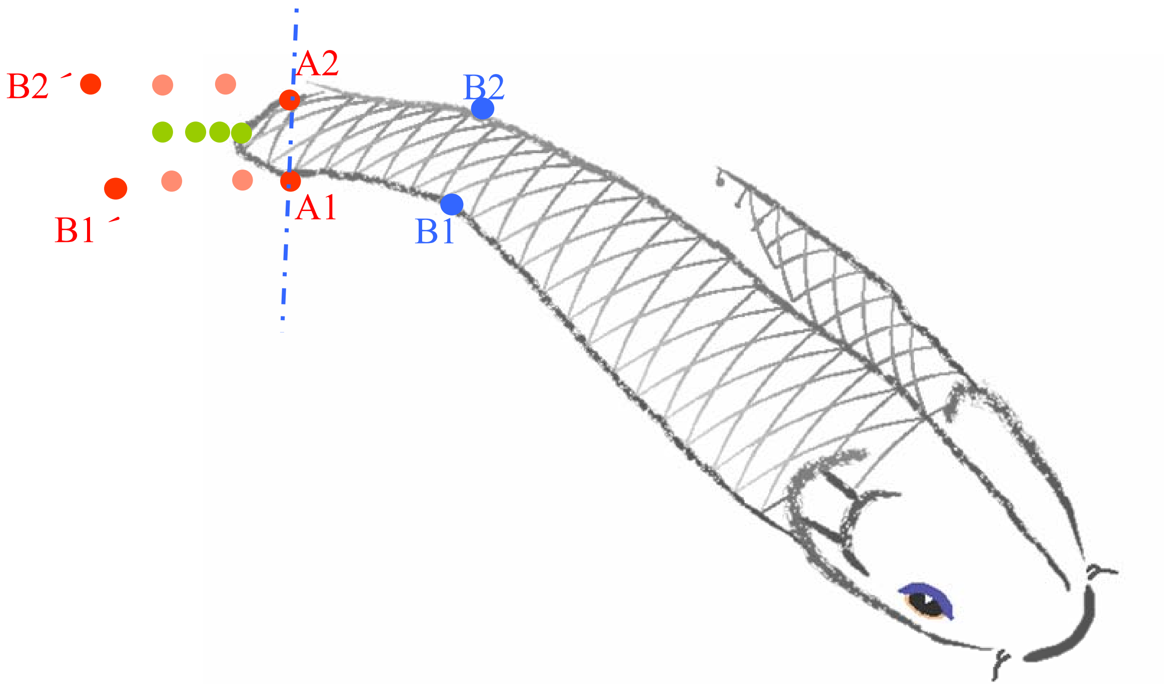


Figure 4.25 Control points of anal fin

4.3.2 Apply Brush Model

After control points of all fins are generated, we apply the side stroke brush model. The system draws lines inside fins randomly, as shown in Figure 4.26.

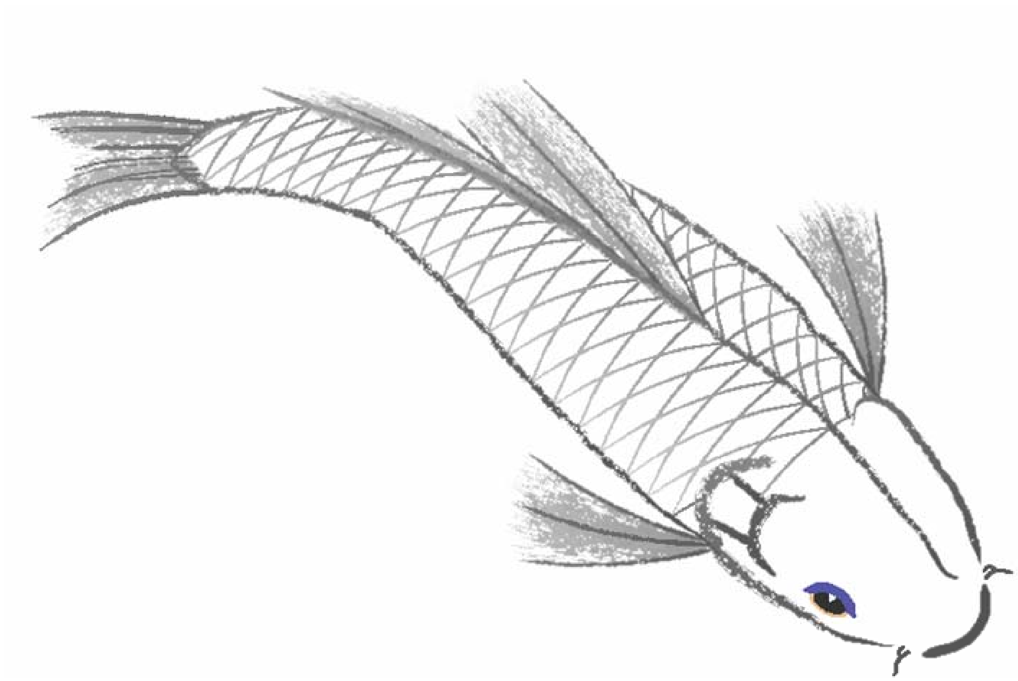


Figure 4.26 The result of sketching

CHAPTER 5

Washing

In this chapter, we discuss the dyeing effect in our system. First, we get the information about color from input image. Then we simulate pigments which move above and inside the paper. Finally, we blend the washing image and sketching image. Figure 5.1 shows the flowchart of washing.

In Lingnan School Painting, washing is an important skill to show stereo and gradational feeling. Painters put a cushion under the paper when washing. Then they moisten the paper, and use “a row of brushes” to wash layer by layer gradually. Because there is oil that does not absorb water on the surface of cushion, water flows above the paper. The water diffusion happens above and inside the paper.

In section 5.1, we talk about the generation of washing region. Then we explain our proposed washing model in section 5.2. It consists of the paper model, Layer model, the moving of water flow, and pigment diffusion process. Then we use “Subtractive Color Mixture” to model the overlapping of mixture in section 5.3.

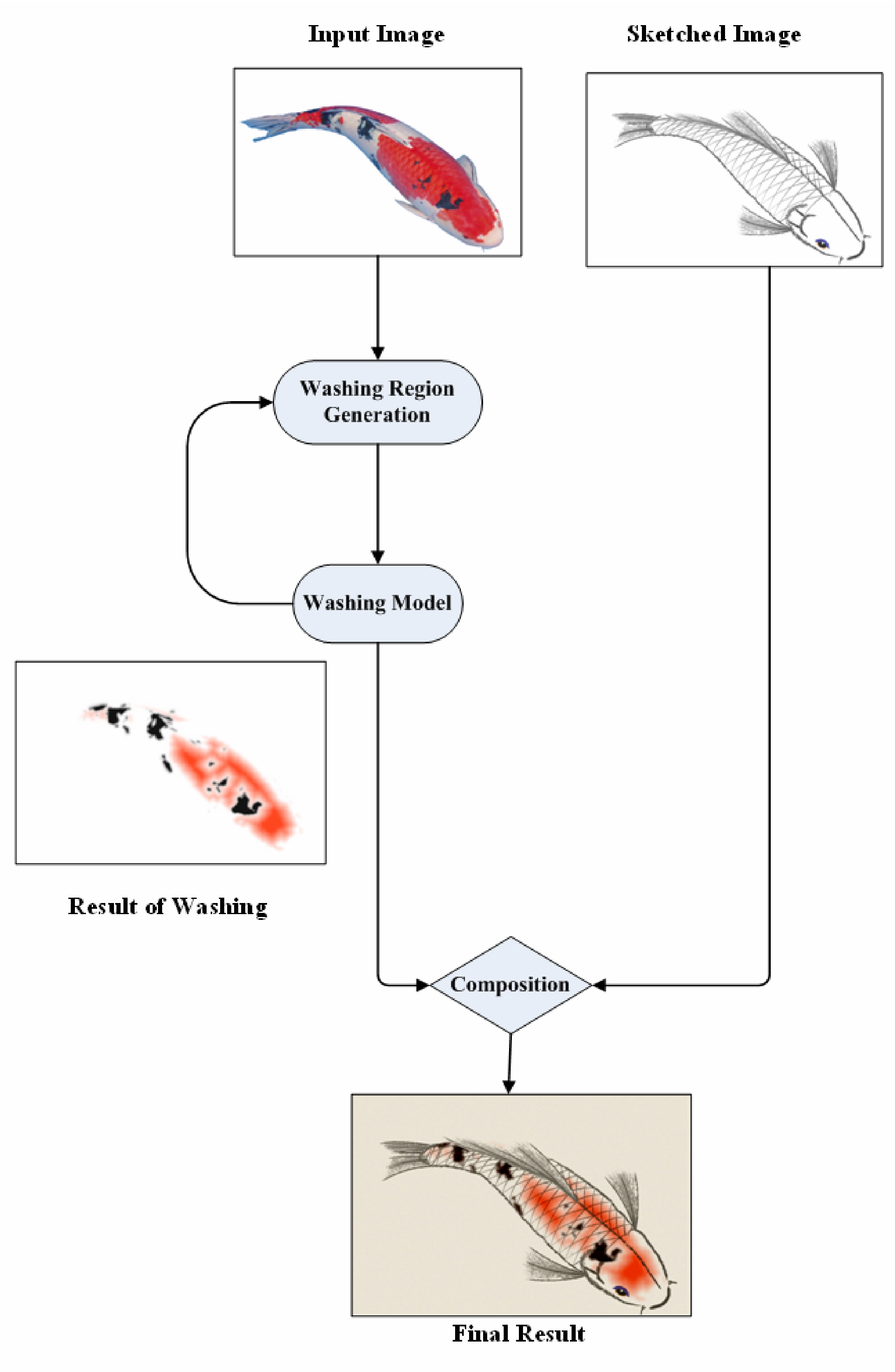


Figure 5.1 Flowchart of washing

5.1 Washing Region

We scan image in raster-scan order, and find out the range of color which we want to wash. The range of color is defined in advance, but users can modify it. After finding out regions which we want to wash, user can determine to use gradational color or the same color in washing region.

5.2 Washing Model

This section introduces how we simulate the washing of Lingnan School Painting. Our model simulates the water flowing above and inside paper. Because painters put a cushion under the paper when washing, there is oil that does not absorb water on the surface of cushion. Water flows above the paper. After a while, water is absorbed into the paper, and diffused by capillary phenomenon. Curtis [17] proposed "Shallow-water layer" to simulate water and pigment flow above the surface of the paper. Yu [24] proposed a layer model which represents the movement of water and pigment between neighboring cells into the paper. In paper modeling, we reference Curtis's and Yu's model. In water flowing, we reference Navier-Stoke Equation and Local Equilibrium Model (LEM) to simulate but make some modifications.

Paper Model

In paper model, paper is composed of paper cells. Each paper cell is called a papel[14]. Each papel has eight neighboring papels which are connected by fiber. The number of fibers which connect two neighboring papels is determined randomly [13]. Figure 5.2 shows an example for the relationship among neighboring papels inside the paper.

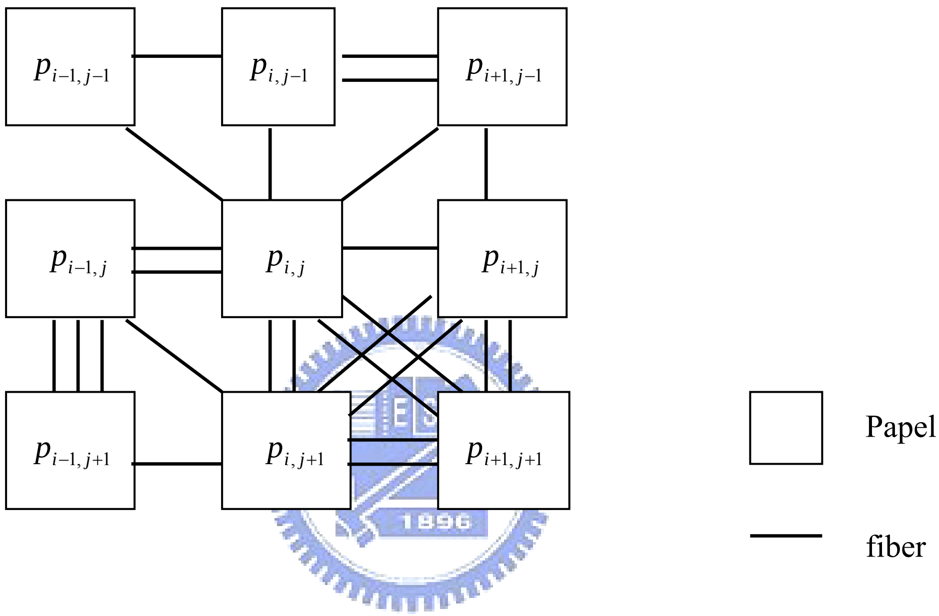


Figure 5.2 The relationship among neighboring papels inside the paper

To represent the diffusion phenomenon, the layer model is proposed. In the layer model, each papel inside the paper is divided into three layers: surface layer, absorption layer, and deposition layer. Besides there is a “shallow-water layer” above the paper. Figure 5.3 shows the layer model.

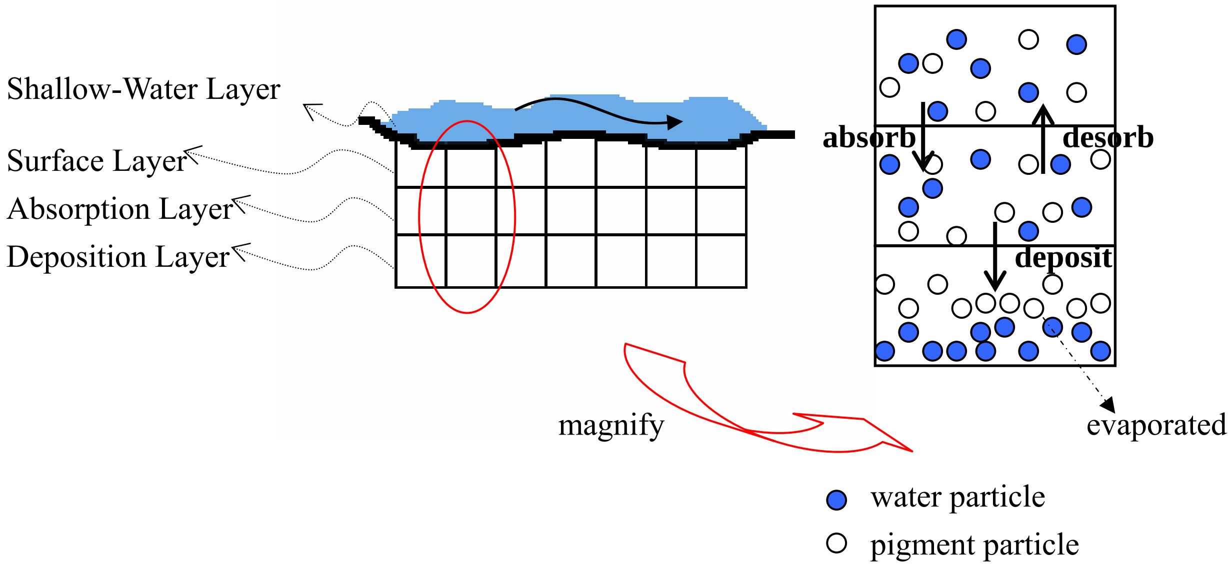


Figure 5.3 The layer structure of papel.

Simulate Diffusion Phenomena

First, the initial water (pigment) quantity is ***W*** (***P***). When water particles flow, pigment particles move with it simultaneously. In hydrodynamics, Navier-Stoke Equation describes fluid motion which considers viscous fluid. Eq.(5.1) is 2D Navier-Stokes Equation.

$$\frac{\partial u}{\partial t} = -(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}) + \mu\nabla^2 u - \frac{\partial p}{\partial x}$$
$$\frac{\partial v}{\partial t} = -(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}) + \mu\nabla^2 v - \frac{\partial p}{\partial y} \qquad (5.1)$$

where u : the velocity in y direction
v : the velocity in x direction
μ : viscosity (In all of our example, we set 0.3)
p : water pressure

The water (pigment) quantity move to neighboring papel of x direction is

$\sigma \cdot u \cdot W(\sigma \cdot u \cdot P)$ and y direction is $\sigma \cdot v \cdot W(\sigma \cdot v \cdot P)$. σ is a adjusting parameter.

We use Navier-Stokes Equation to simulate water flowing above the paper. At the same time, water and pigment also are absorbed by surface layer, and quantity absorbed in the surface layer is determined by the constant ratio s (We set 0.4).

$$W_{i,j}^{f} = W_{i,j} \cdot s \qquad (5.2)$$
$$P_{i,j}^{f} = P_{i,j} \cdot s$$

where $W_{i,j}^{f}$ ($P_{i,j}^{f}$) denotes the quantity of water (pigment) absorbed by surface layer, and $W_{i,j}$ ($P_{i,j}$) denotes the quantity of water (pigment) in Shallow-water layer.

In surface layer, water flows to neighboring papels if $W_{i,j} > W_{i,j}^{k}$. $W_{i,j}^{k}$ denotes the water quantity of k'th neighboring papel. The quanity of $W_{i,j}^{k}$ and $P_{i,j}^{k}$ are determined by the following equations.

$$W_{i,j}^{k} = \varepsilon \cdot W_{i,j} \cdot (\alpha_1 \frac{N(f_{out}^{k})}{N(f_{out})} + \alpha_2 \frac{(W_{i,j} - W_{i,j}^{k})}{W_{sum}}) \qquad (5.3)$$
$$P_{i,j}^{k} = \varepsilon \cdot P_{i,j} \cdot (\alpha_1 \frac{N(f_{out}^{k})}{N(f_{out})} + \alpha_2 \frac{(W_{i,j} - W_{i,j}^{k})}{W_{sum}})$$

$$W_{sum} = \sum_{k=1}^{8} u(W_{i,j} - W_{i,j}^{k}) \qquad (5.4)$$

where $N(f_{out})$ denotes the total number of neighboring fibers which is connected to the papel $p_{i,j}$ and the water quantity is smaller than $W_{i,j}$. $N(f_{out}^{k})$ denotes the number of fibers which connects $p_{i,j}$ and $p_{i,j}^{k}$. α_1 and α_2 are weights, and ε is an adjusting parameter(In our system, we set $\alpha_1 = 0.2, \alpha_2 = 0.8, \varepsilon = 0.4$). $u(x)$ is the unit function, i.e. if $x \ge 0$, then $u(x) = x$, otherwise $u(x) = 0$.

The water and pigment absorbed by absorption layer is determined by the following equation.

$$W_{i,j}^{a} = W_{i,j} \cdot (\alpha - (\alpha - \beta) \cdot \frac{W_{i,j}^{d}}{W_t})$$
$$P_{i,j}^{a} = P_{i,j} \cdot (\alpha - (\alpha - \beta) \cdot \frac{W_{i,j}^{d}}{W_t}) \qquad (5.5)$$

where $W_{i,j}^{a}$ ($P_{i,j}^{a}$) denotes the absorbed quantity of water (pigment), α and β denote the maximum and minimum absorption ratio, respectively. W_t denotes the maximum quantity of water which could be deposited in the deposition layer and $W_{i,j}^{d}$ denotes the remaining water quantity in the deposition layer. (In our system, we set $\alpha = 0.15, \beta = 0.07$)

The absorbed water and pigment is desorbed to the surface layer or deposition layer in the next time. The desorbed quantity to the surface layer is determined as following.

$$W_{i,j}^{ds} = W_{i,j}^{a} \cdot (\gamma + (\rho - \gamma) \cdot \frac{W_{i,j}^{d}}{W_t})$$
$$P_{i,j}^{ds} = P_{i,j}^{a} \cdot (\gamma + (\rho - \gamma) \cdot \frac{W_{i,j}^{d}}{W_t}) \qquad (5.6)$$

where $W_{i,j}^{ds}$ ($P_{i,j}^{ds}$) denotes the desorbed quantity, γ and ρ denote the maximum and minimum desorption ratio, respectively. (In our system, we set $\gamma = 0.75, \rho = 0.24$)

The quantity deposited in the deposition layer is determined by the constant deposited ratio d .

$$\begin{aligned} W_{i,j}^{d} &= W_{i,j}^{a} \cdot d, && \text{if } W_{i,j}^{d} < M_{cup} \\ P_{i,j}^{d} &= P_{i,j}^{a} \cdot d, && \text{if } W_{i,j}^{d} < M_{cup} \end{aligned} \tag{5.7}$$

where $W_{i,j}^{d}$ ($P_{i,j}^{d}$) denotes the quantity of water (pigment) deposited, and M_{cup} is maximum capacious quantity of water in the deposition layer.

Diffusion Process

In Huang's [11] ink diffusion process, the whole process includes skeleton finding, initial area pipelining and propagation process. Since diffusion which we simulate is regions, there is no need to find the skeleton and initial area pipelining. Water particles in the most outer region in initial area diffuse first. Water particles in the second most outer region then diffuse right after the former diffusion. In other words, water particles in the second largest number of region index of papels diffuse right after water diffusion in the largest number of region index finished, as shown in Figure 5.4. Although each of the processes of water diffusion in diffused region seems discrete, it is actually a continuous diffusion process in a global view.

In real world, the wet region will dry out gradually. This phenomenon is called *evaporation*. The evaporation of water is a complicated process in which many factors play a role. One important factor is the contact area with atmosphere [17]. When other

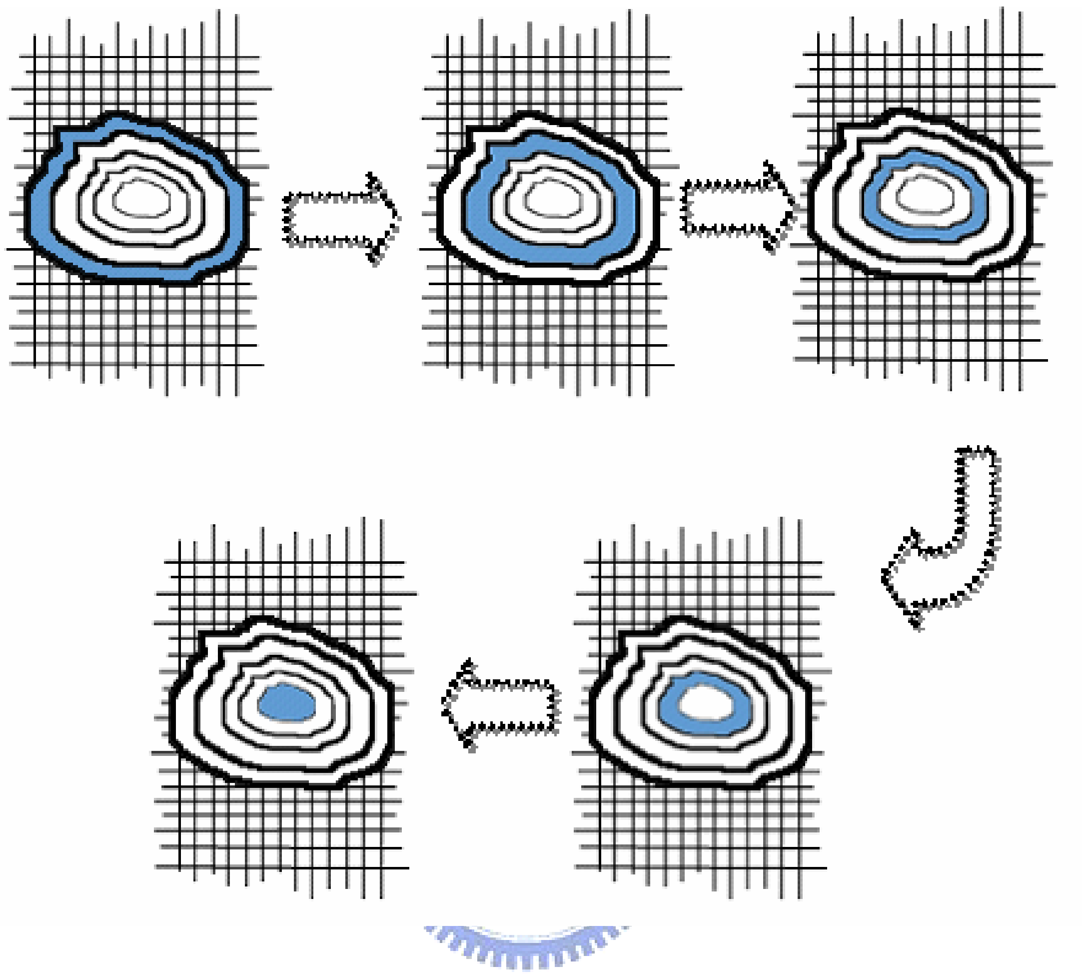


Figure 5.4 The Diffusion process

factors are almost fixed, larger contact area results in higher rate of water evaporation. In Huang's [11] thesis, the contact area of each papel with atmosphere is equal. Based on the equality of the contact area of all papels, the rate of water evaporation in each papel of the paper is approximately equal. There is another important factor which is in opposite to the evaporation of water, called humidity [17]. For the simplicity and the demand of our theorem, we assume that the number of water particles evaporated in papel p at step t-th, E_p^t, depends on the humidity H ($0 \le H \le 1$) and is expressed by the equation,

$$E_p^t = h(1-H) \times Water_p \tag{5.8}$$

where $Water_p$ is the number of water particles in papel p, and function $h(x)$ yields a coefficient for the evaporation of water, where $0 \le x \le 1$. Figure 5.5 shows an example of the function h. The less the humidity, the greater is the amount of water evaporated.

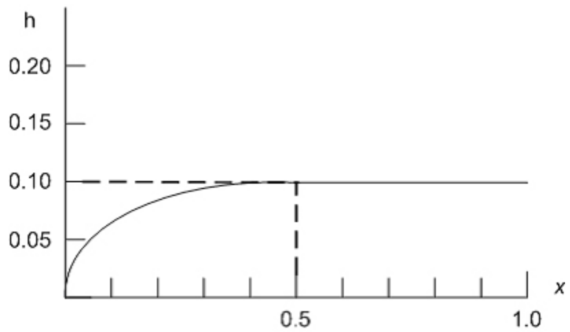
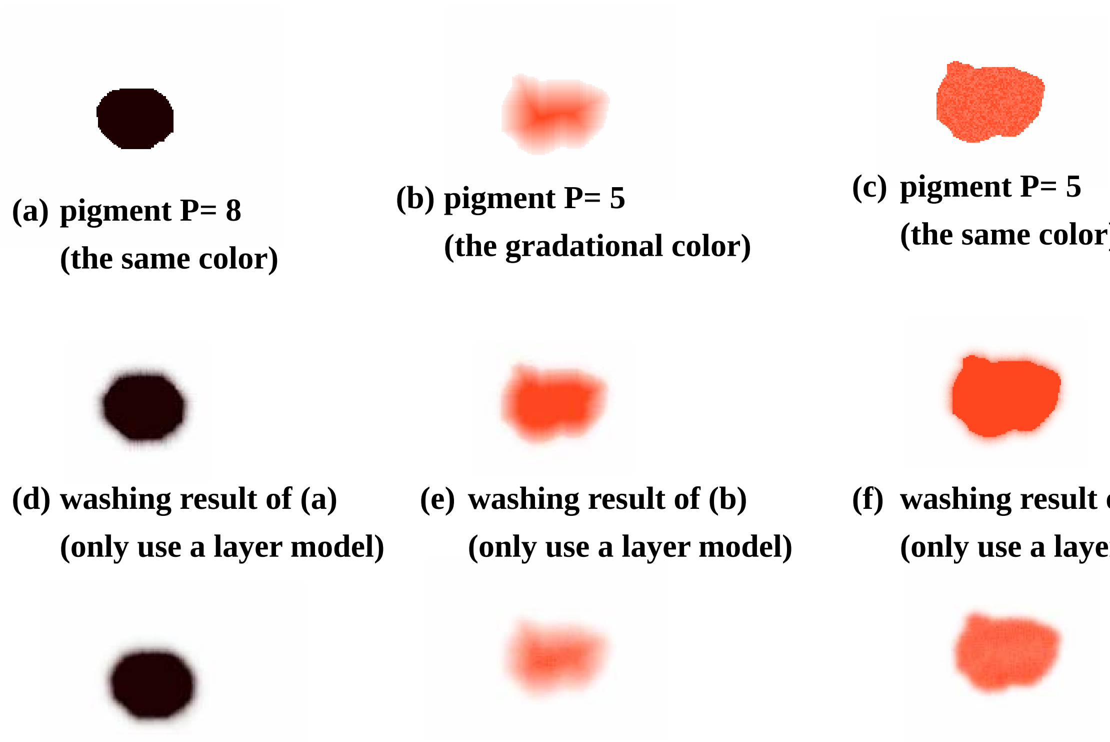


Figure 5.5 Function $h(x)$ for determining the quantity of water evaporated (Courtesy of Huang)

Figure 5.6 show the result of washing, and we moisten the whole paper in these cases. Figure5.6 (a), (b), and (c) show the region of coloration. The results which only use a layer model are shown in Figure5.6 (d), (e), and (f). Moreover, the results of our proposed model are shown in Figure5.6 (g), (h), and (i).



(a) pigment P= 8 (the same color)
(b) pigment P= 5 (the gradational color)
(c) pigment P= 5 (the same color)
(d) washing result of (a) (only use a layer model)
(e) washing result of (b) (only use a layer model)
(f) washing result of (c) (only use a layer model)
(g) washing result of (a) (our proposed method)
(h) washing result of (b) (our proposed method)
(i) washing result of (c) (our proposed method)

Figure 5.6 Samples results of washing

5.3 Color Mixture

Every time after simulating the effect of washing, we will start to do the color mixture. We take Subtractive Color Mixture to model the overlapping of color in our system. When our system washes next color, we set the result which already washed is background. Then foreground and background are combined to next result.

Figures 5.7 and 5.8 show some examples of washing and the result of combining with contour sketching.

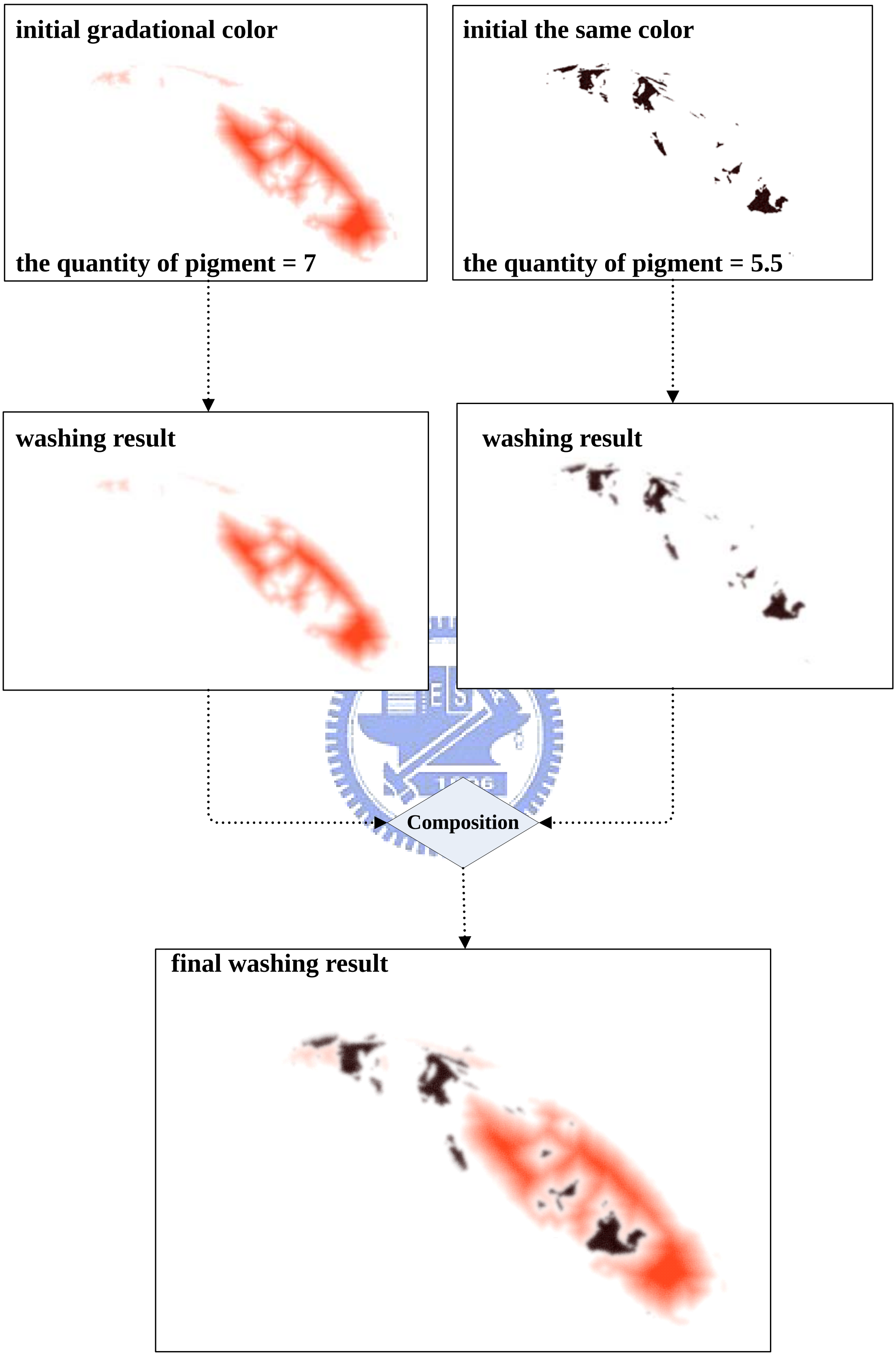


Figure 5.7 Result of washing and combined image

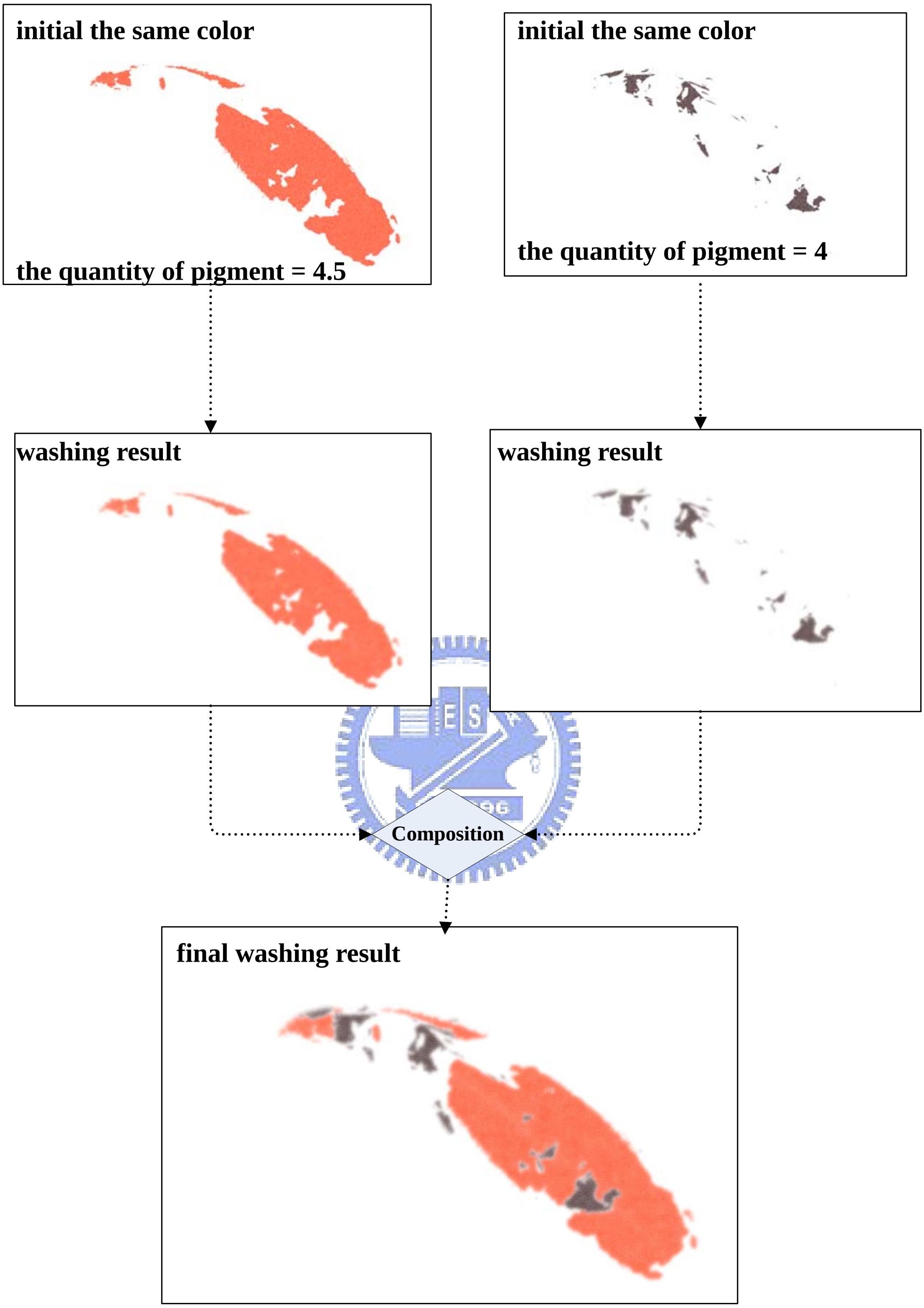


Figure 5.8 Result of washing and combined image

CHAPTER 6

Implementation and Results

In this chapter, the implementation and results are presented. The input sources are reference image and labeling image. The background of reference image is removed beforehand, and the labeling image indicates the place of fins. The algorithm is implemented in C# language with an Intel 1.6GHz CPU and 768MB RAM.

After our system combines results of contour sketching and of washing, we apply a background. Background is generated according to the position of fishes. The pixel near fish body is deep green color, and color change thin gradually as the distance from fish changes far.

Example 1 is a 1200×700 image as shown in Figure 6.1. Figure 6.2 shows the results of contour sketching. Figure 6.3 shows the result of washing. The final result of this example which already applies background is shown in Figure 6.4.

Figure 6.1 The original image of example 1

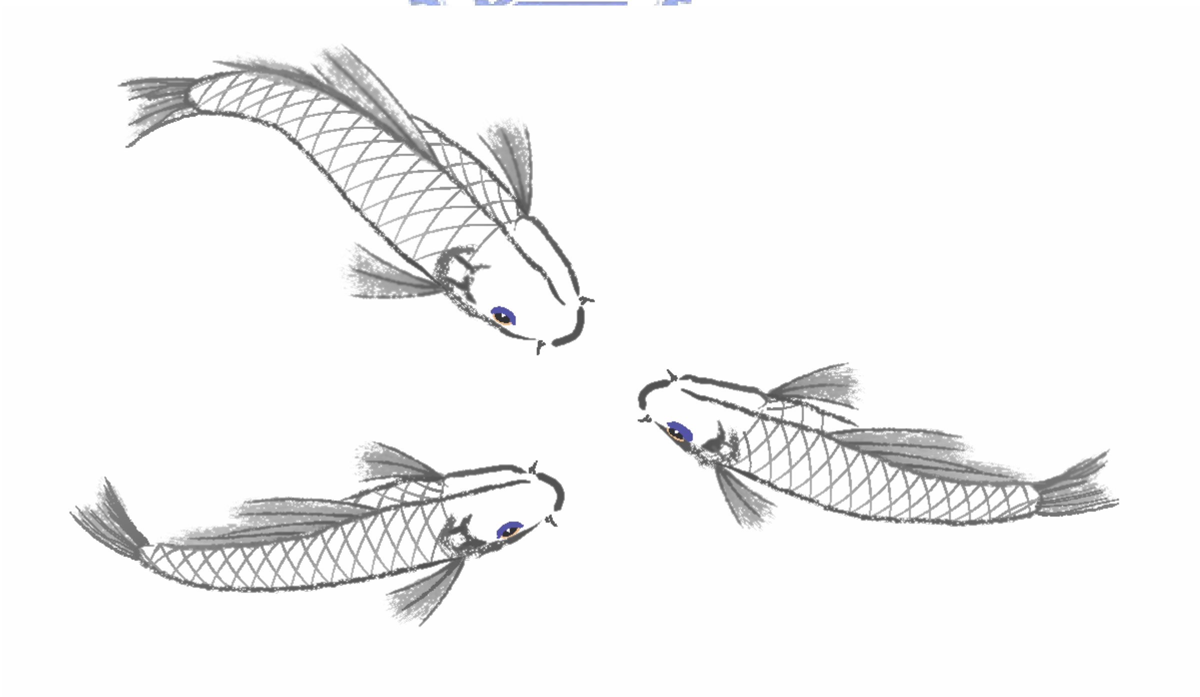


Figure 6.2 The contour sketching of example 1

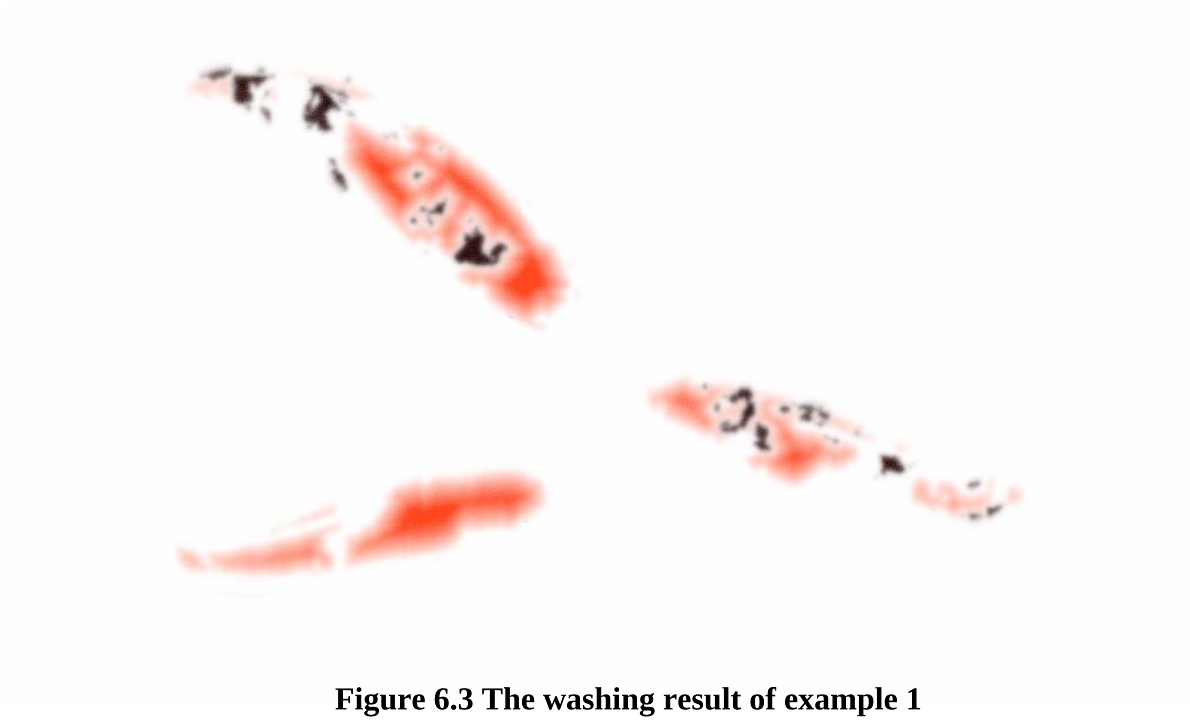


Figure 6.3 The washing result of example 1

Figure 6.4 The final result of example 1

Example 2 is a 1000×580 image as shown in Figure 6.5. Figure 6.6 shows the results of contour sketching. Figure 6.7 shows the result of washing. The final result of this example which already applies background is shown in Figure 6.8.

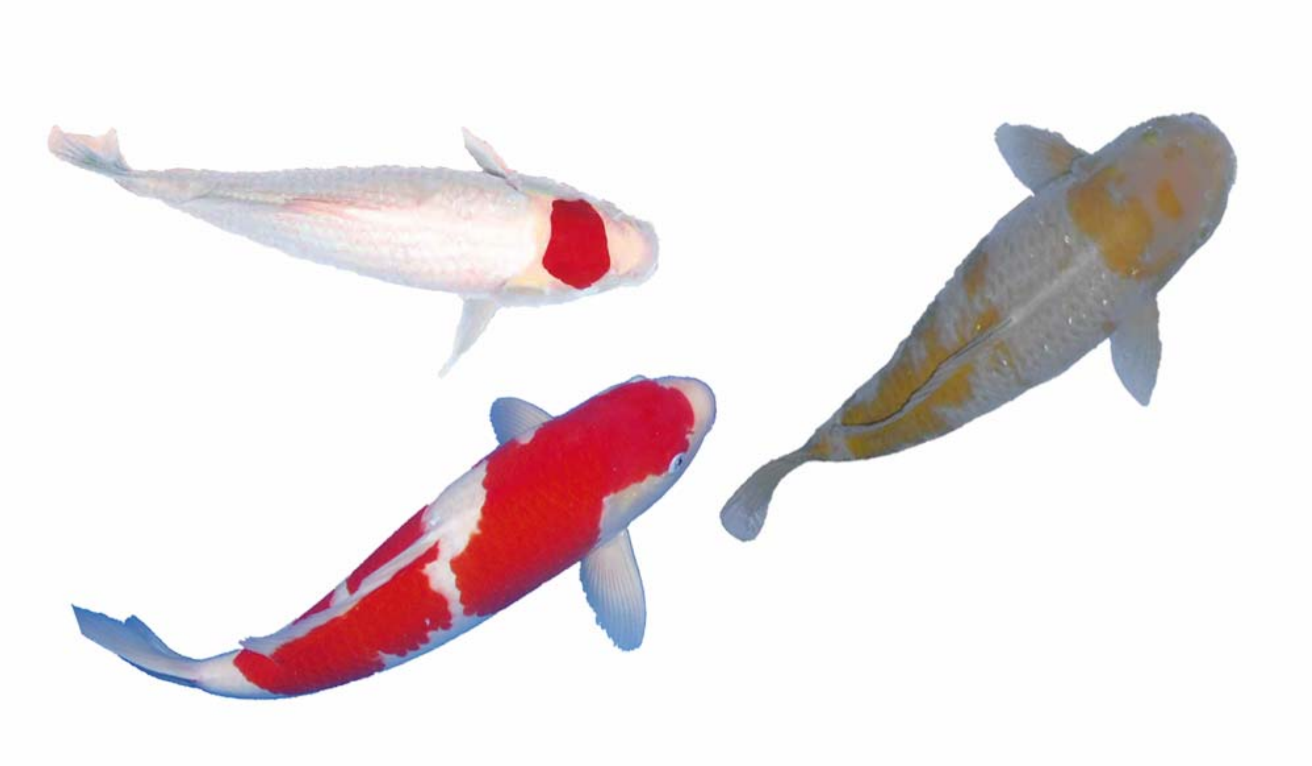


Figure 6.5 The original image of example 2

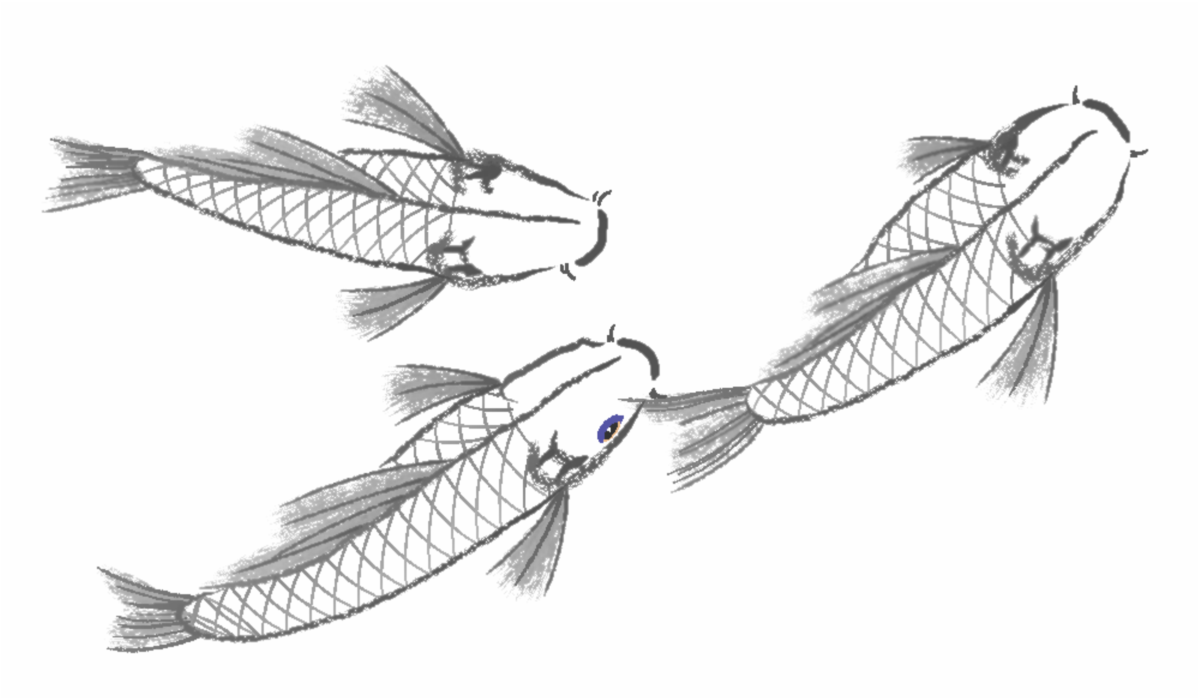


Figure 6.6 The contour sketching of example 2

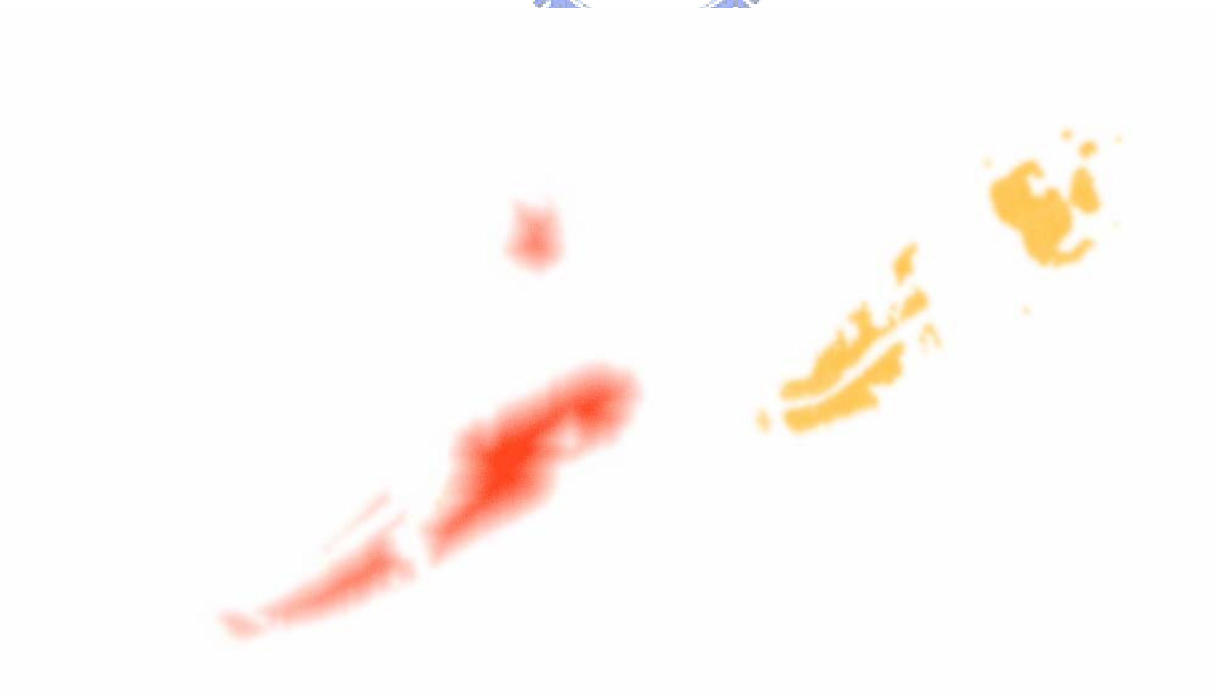


Figure 6.7 The washing result of example 2

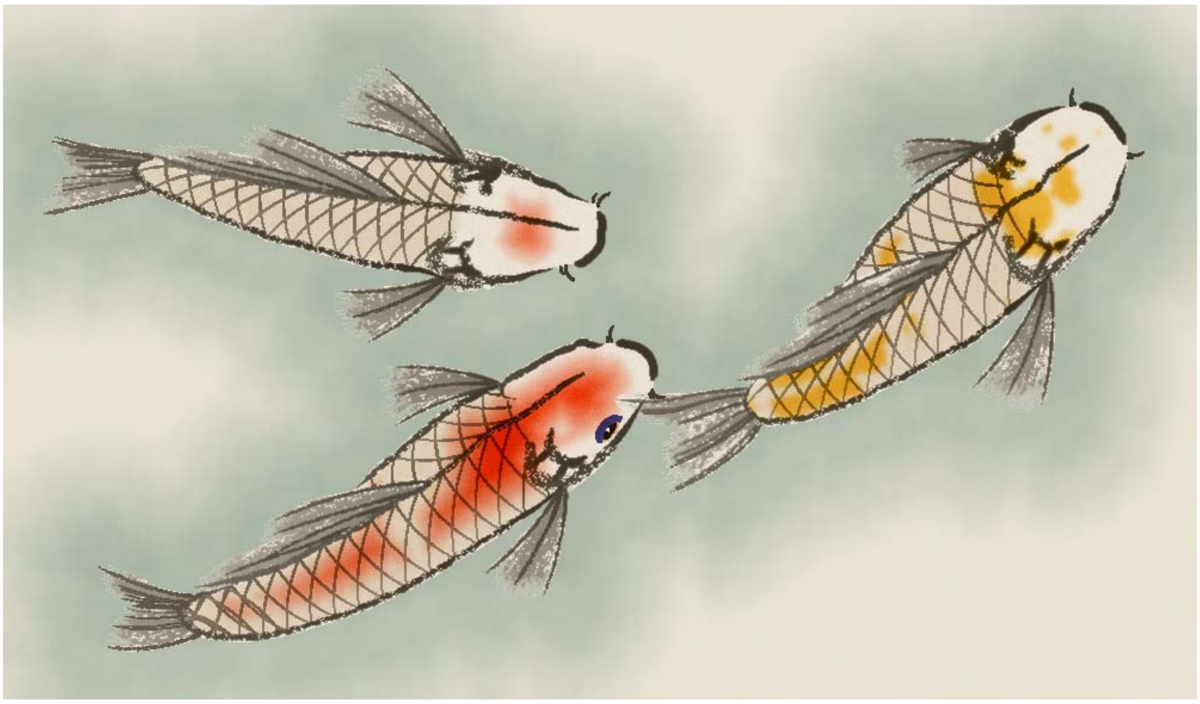


Figure 6.8 The final result of example 2

Example 3 is an 800×800 image as shown in Figure 6.9. Figure 6.10 shows the results of contour sketching. Figure 6.11 shows the result of washing. The final result of this example which already applies background is shown in Figure 6.12.

Figure 6.9 The original image of example 3

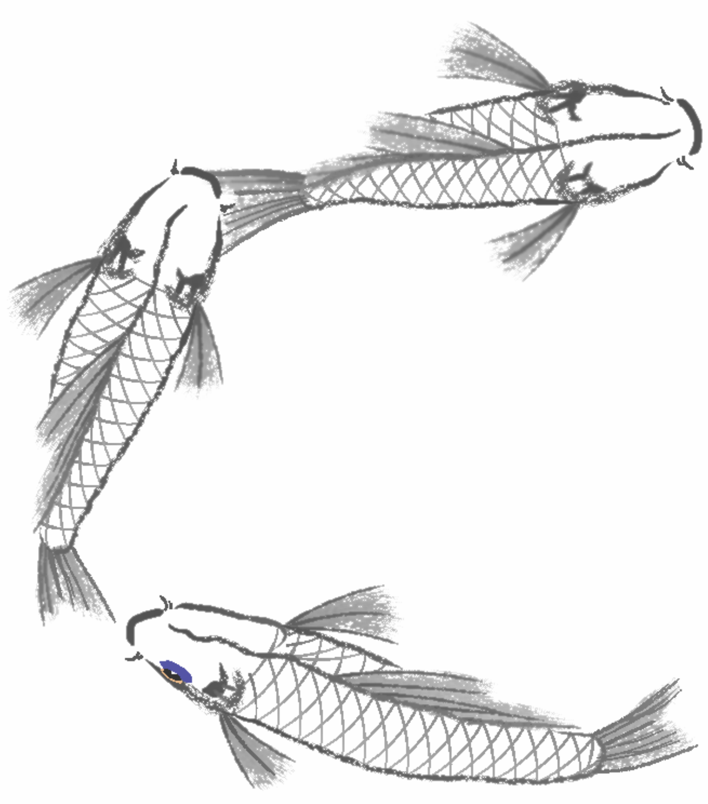


Figure 6.10 The contour sketching of example 3

Figure 6.11 The washing result of example 3

Figure 6.12 The final result of example 3

CHAPTER 7

Conclusion and Future Works

In this thesis, we propose a method to synthesize Lingnan School Painting on Embroidered Fish. We simulate this style by two processes: contour sketching and coloring. In the former process, we design a brush model to simulate Horse Hair Brush. In coloring, we propose a washing model to simulate the effect of dyeing. The whole process is semi-automatic. Users just input several parameters and draw the fish spine. The rest of work is done by the computer. Therefore, users my generate Lingnan style Painting easily by using our proposed system without any painting skill.

However, there are still some issues left to be solved in the future.

1. The extracted region of washing is not fine. The border of fishes is darker than the rest part. Our system decides it as the part of black. So we hope to use better algorithm to find out the region.

2. Our proposed system uses the basic Subtractive Color Mixture method. This

method simulates the traditional Chinese color mixture roughly but not exactly. Moreover, the other advanced methods focus on the color mixture of Western Painting, such as KM model. We hope to find a suitable or integrate several color mixture methods for traditional Chinese colors.

3. Our system is not entirely automatic, users still need to draw a spine. Although it is not difficult to draw, the produced results could be different. So we hope our system generate spine stroke automatically in the future.

4. Fish belly and scales would be further processed to emphasize three-dimensional effect. And we recommend that contour sketching should be more similar to the style of painters.

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