Interactive Rendering Technique for Realistic Oriental Painting

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Abstract

Interactive and realistic rendering of various effects which are appeared in the real world paintings can be used for several applications such as animation or education. For Western paintings, watercolor or oil paintings have been main subjects for representation and model-based approaches have been researched. In case of Oriental paintings, numerous studies have focused on model-based approaches. In this paper, a new model-based approach for Oriental paintings is described. To represent the diffusion effects, we propose local equilibrium model(LEM) which is a method to calculate the movement of water and ink effectively. With LEM, the diffusion of water and ink can be processed interactively and realistic diffusion effects can be generated. In addition, we propose a layer model. With this layer model, overlapped strokes can be well represented. Conclusively, we show several results of Oriental paintings drawn with proposed methods.

Keywords

Interactive, Oriental Painting, Layer Model, LEM

1 Introduction

Oriental painting rendering is non-photo realistic rendering which stands in contrast to conventional computer graphics rendering methods. It is even distinct compared to general non-photo realistic rendering such as digital painting or illustration. Oriental painting typically consists of just a few simple strokes intended to convey the artist's deep feelings regarding the painted object. In other words, simplicity of objects and beauty of space are a key concept. The feelings are expressed by the speed, placement, pressure, and movement of the brush[Lee99, Lee01, ZST$^+$99, WHCS01]. Fig.1 shows two examples of original Oriental paintings, plum and landscape.

Until now, most studies simulating Oriental paintings have been generally based on the modeling of brush, diffusion and paper. The diffusion effect is a special feature of Oriental painting. Although watercolor paintings have the diffusion effect, it is very different from the one in Oriental painting due to the ink and paper to be used. Modeling paper, brush and diffusion has influenced the simulated-image quality of Oriental painting[Lee99, Lee01, ZST$^+$99, WHCS01]. In this paper, a model based approach is also proposed to generate Oriental paintings. For calculating the state of each cell on paper more accurately, layer structure and equilibrium property are considered. And local equilibrium model(LEM) is proposed for fast calculation of the state of each cell at each time step. With LEM, an user can draw Oriental painting interactively.

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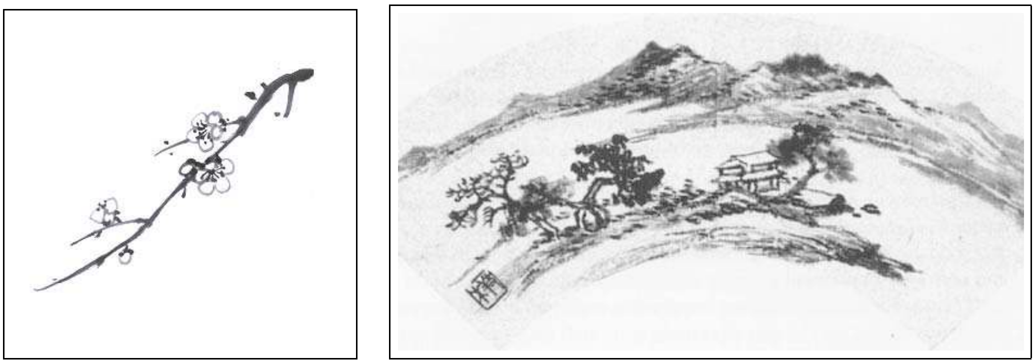


(a) plum (b) landscape

Figure 1. Two examples of original Oriental paintings.

2 Related Work

Recently, there have been concerned about generating NPR images such as paintings, illustrations and caricatures. Western paintings, watercolor and oil painting which use complicated and varied effects, are the main subjects of NPR research[Cur97]. Oriental painting is also a subject to which NPR technique can be applied. The method for simulating Oriental painting is divided into a modeling technique and texture based synthesizing. Modeling is the main method of simulating basic materials and tools of Oriental painting. Most proposed models are for brush, paper and diffusion effect.

Curtis *et al.*[Cur97] propose a simple paper model to simulate watercolor painting. They propose three layers model for each cell on paper. A paper model with fiber structure is shown by Kallmes and Corte[KC60, Ran82]. The model assures us that the water and ink of the initial cell on paper move to the neighboring cells by way of the fiber structure. As a paper model for generating Oriental painting, Guo and Kunii[GK91] propose a 2D fiber structure. Lee[Lee99, Lee01] improves the Kunii's model, and generates paper with fiber structure using sin curves.

Brush models studied by numerous researchers are classified into two approaches, an outline-based approach and a flat-brush-based approach. The flat-brush-based approach generates strokes using various shapes, sizes and patterns of brush. Strassmann[Str86] proposes a rendering model to describe a stroke which is generated by a spline curve which allows control points. The model has a difficulty in simulating brush pressure and rotation effects. In the outline-based approach, the outline of brush strokes is described as a sequence of connected Bézier or B-spline curves with mouse or pen input and scaling/editing control points. Lee[Lee96, Lee99] proposes a 3D brush model which is an elastic model, to calculate the position of bristles. The model, however, requires a great deal of time to calculate the elastic equation.

Kunii *et al.*[KNH95] propose a multidimensional diffusion model to animate complicated phenomenon of diffusion on the surface of paper. Zhang *et al.*[ZST^{+}99] present a behavioral model of water and ink particles based on a 2D cellular automaton computational model known as "tanks" model. Lee[Lee99, Lee01] develope a "wave" schema for representing how ink flows through a fiber mesh. Diffusion is considered to originate from the "boundary points" of strokes, being analogous to the outward-moving circular waves produced when an object is thrown into a lake.

Simulating ink decreasing phenomenon is proposed by Strassmann[Str86], Zhang[ZST^{+}99], and Wong[WI00]. Strassmann[Str86] introduces the method that ink quantity of bristles was reduced. Wong[WI00] decreases number of bristles to represent decreasing effect of ink. Simulating shade on an Oriental painting is proposed by Strassmann, Lee, and Zhang. Strassmann[Str86] and Lee[Lee99] represent the shade effect by interpolating ink quantity of each bristle. Zhang[ZST^{+}99] represent the shade effect by controlling ink quantity of each bristle.

Way *et al.*[WHCS01] propose two novel methods capable of synthesizing rock textures in Chinese landscape painting and synthesizing portraits in Chinese figure painting. Jinhui *et al.*[YYP01] propose a method to animate water in Chinese painting.

In this paper, several models are proposed for paper, brush and diffusion. The proposed paper model is based on Lee's fiber mesh structure[Lee01] and uses layer structure for each cell of paper. For the diffusion of water and ink, an equilibrium property is considered. In Section 3, we describe our method for rendering of Oriental painting. We propose a modified layer model for simulating the overlapped strokes. In addition, we propose an equilibrium model for diffusion phenomenon. Section 4 gives experimental results of our method.

3 Rendering

A model-based approach is a method to represent Oriental paintings. We propose a model for diffusion, LEM(Local Equilibrium Model), to generate Oriental paintings interactively. In addition, a layer model is proposed to represent the diffusion effects when strokes are overlapped.

3.1 Paper and Brush

In our paper model, paper is composed of cells which are minimal components. It is assumed that a cell has eight neighboring cells. Neighboring cells are connected by fibers. The number of fibers which connect two neighboring cells is determined by the density of the generated paper. Fig.2 shows an example for the relationship between neighboring cells on the paper. We assumed that ink and water is transferred along the fibers for easy computation.

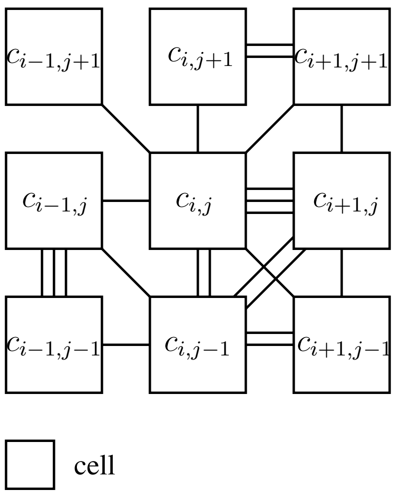


Figure 2. The relationship between neighboring cells on the paper.: each neighboring cell is connected by zero or more fibers.

When two or more strokes are intersected, the shape of the strokes in the intersected parts is different from that in the other parts due to the moisture included in each cell. To simulate this phenomenon, each cell on the paper is divided into three layers: surface layer, absorption layer, and deposition layer. Details for the operation of each layer will be described in Section 3.3.

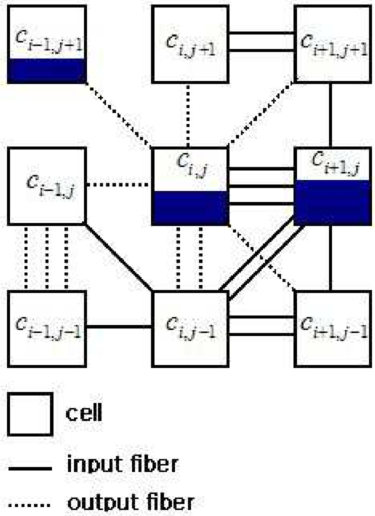


Figure 3. The relationship between a front cell $c_{i,j}$ and neighboring cells.

In our brush model, bristles are distributed within a circular form. There are three types of bristles: inner, boundary, and center bristles. Boundary bristles are placed on the boundary line of the circular form and used to represent the stroke boundary. Inner bristles are distributed within the circular form randomly. A center bristle is used to determine the stroke path.

3.2 Local Equilibrium Model

When a stroke is drawn, cells which are placed along the stroke path are filled with water and ink. We call this cells as initial front cells. Water and ink within initial front cells is diffused to neighboring cells at the next time step. For diffusion, the quantity of water and ink in each cell must be determined at each time step. In the ideal case, the quantity of water and ink in each cell may be determined considering the state of all cells on the paper[ZST$^+$99]. This method need much computational time and can not be processed interactively.

We propose LEM to determine the state of each cell at each time step interactively. LEM is a method for the movement of ink and water between neighboring cells on the paper. Let a cell $c_{i,j}$ denote a front cell if $c_{i,j}$ has water and ink moving to neighboring cells. Let $c^k_{i,j}$ denote the k'th neighboring cell of $c_{i,j}$ and $W_{i,j}$ and $I_{i,j}$ denote the quantity of water and ink of the cell $c_{i,j}$, respectively.

Fig.3 shows the relationship between a front cell $c_{i,j}$ and neighboring cells. A fiber connecting neighboring cells is defined *input* or *output* fiber according to the quantity of water in each cell. If $W_{i,j} >$

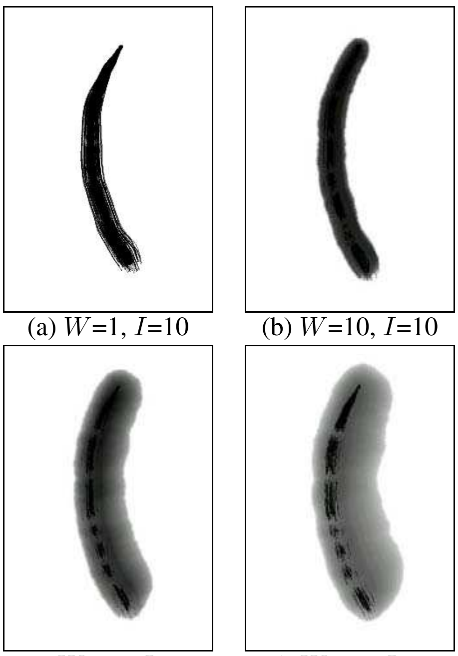
$W^k_{i,j}$, then fibers connecting $c_{i,j}$ and $c^k_{i,j}$ are regarded as output fibers. Otherwise, those are regarded as input fibers. If fibers connecting $c_{i,j}$ and $c^k_{i,j}$ are output fibers, water and ink in $c_{i,j}$ is moved to $c^k_{i,j}$. In Fig.3, fibers connecting $c_{i,j}$ and $c_{i+1,j}$ are input fibers and other fibers are output fibers. Let f_{out} and f_{in} denote output and input fiber, respectively. In the time step t_i, the quantity of water and ink moving from $c_{i,j}$ to $c^k_{i,j}$ is determined by the following equations.

$$W^k_{i,j} = \frac{\epsilon \cdot f_k \cdot W_{i,j} \cdot N(f^k_{out})}{N(f_{out}) \cdot p_{average}}, \ \ if \ p_k > 0$$

$$I^k_{i,j} = \frac{\epsilon \cdot f_k \cdot I_{i,j} \cdot N(f^k_{out})}{N(f_{out}) \cdot p_{average}}, \ \ if \ p_k > 0$$

$$p_{average} = \frac{\sum_k p_k}{N(f_{out})},$$

where p_k denotes the difference of water pressure between $c_{i,j}$ and $c^k_{i,j}$ and $N(f_{out})$ denotes the number of output fibers which is connected to the cell $c_{i,j}$. $N(f^k_{out})$ denotes the number of fibers which connects $c_{i,j}$ and $c^k_{i,j}$. Fig.4 shows the diffusion effect of a stroke according to the quantity of water.



(a) W=1, I=10 (b) W=10, I=10

(c) W=20, I=10 (d) W=30, I=10

Figure 4. The diffusion result in case that the quantity of provided water is varied.: W and I denote the initial quantity of water and ink, respectively.

3.3 Layer Model

LEM is a model to describe the movement of water and ink between neighboring cells on the paper. However, to represent the diffusion phenomenon, we also need to model the evaporation and absorption of water and ink. For this, a layer model is proposed. In the layer model, each cell on the paper is divided into three layers: surface layer, absorption layer, and deposition layer. Fig.5 shows the layer structure of a cell. Water

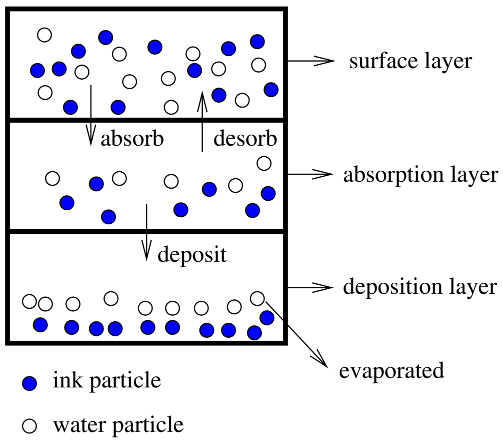


Figure 5. The layer structure of a cell.

and ink in the surface layer are moved to neighboring cells or absorbed in the absorption layer. In the absorption layer, the water and ink are desorbed to the surface layer or deposited in the deposition layer. Water in the deposition layer evaporates over time.

During the time interval Δt, water and ink in the surface layer is moved to the neighboring cells or absorbed in the absorption layer. The movement of water and ink follow the LEM. The quantity of water and ink absorbed is determined by the following equations.

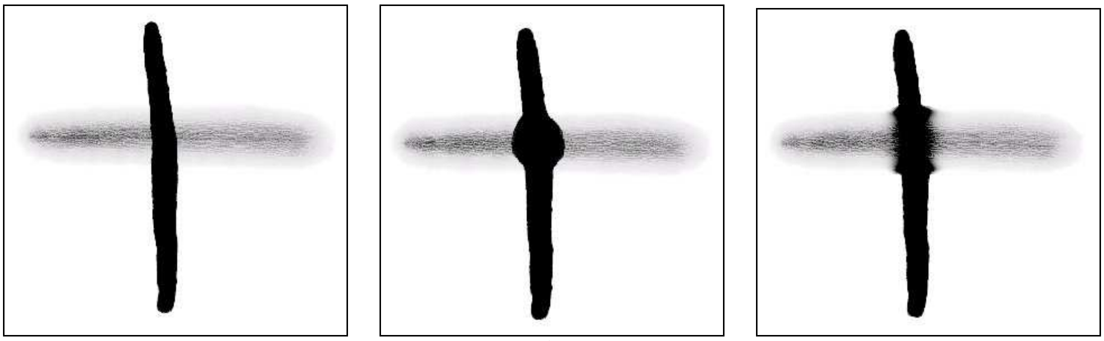
$$W^a_{i,j} = W_{i,j} \cdot (\alpha - (\alpha - \beta) \cdot \frac{W^d_{i,j}}{W_t})$$

$$I^a_{i,j} = I_{i,j} \cdot (\alpha - (\alpha - \beta) \cdot \frac{W^d_{i,j}}{W_t}),$$

where $W^a_{i,j}(I^a_{i,j})$ denotes the absorbed quantity of water(ink), 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 $W^d_{i,j}$ denotes the water quantity which remains in the deposition layer.

The absorbed water and ink is desorbed to the surface layer or deposited in the deposition layer in the next time step. The desorbed quantity to the surface layer is determined by the following equations.

$$W^{ds}_{i,j} = W^a_{i,j} \cdot (\gamma + (\rho - \gamma) \cdot \frac{W^d_{i,j}}{W_t})$$



(a) (b) (c)

Figure 6. The diffusion effects generated in the intersected region due to the proposed layer model.

$$I^{ds}_{i,j} = I^{a}_{i,j} \cdot (\gamma + (\rho - \gamma) \cdot \frac{W^{d}_{i,j}}{W_t}),$$

where $W^{ds}_{i,j}(I^{ds}_{i,j})$ denotes the desorbed quantity, γ and ρ denote the minimum and maximum desorption ratio, respectively. The quantity deposited in the deposition layer is determined by the constant ratio d given by a user.

$$W^{d}_{i,j} = W^{a}_{i,j} \cdot d, \;\; if \; W^{a}_{i,j} > W^{d}_{min}$$

$$I^{d}_{i,j} = I^{a}_{i,j} \cdot d, \;\; if \; W^{a}_{i,j} > W^{d}_{min},$$

where $W^{d}_{i,j}(I^{d}_{i,j})$ denotes the quantity of water(ink) deposited and d is the deposited ratio.

Fig.6 shows the diffusion effects generated in the intersected region due to the proposed layer model when two strokes are intersected. In Fig.6(a), the vertical stroke is drawn after the horizontal stroke is dried completely. Therefore, overlapped diffusion effects are not appeared in the intersected region. Fig.6(b) and (c) show the results when the vertical stroke is drawn on the wet horizon stroke.

4 Experimental Results

The proposed models were implemented with Pentium III 600MHz PC and Visual-C++ 6.0. Our system can be used as a drawing tool for Oriental paintings. In this Section, several experimental results are presented.

Fig.7 shows an example when the initial quantity of ink is decreased. This effect is implemented by decreasing the quantity of ink within each bristle over times.

The shading effect in the Oriental painting is an important characteristic which can be discriminated with Western paintings. In the original paintings, the shading effect is generated due to the difference of ink density in a bristle. To do this, we use a spline curve with several control points which represent the ratio of ink density in a bristle. Fig.8 shows strokes with various shading effects.

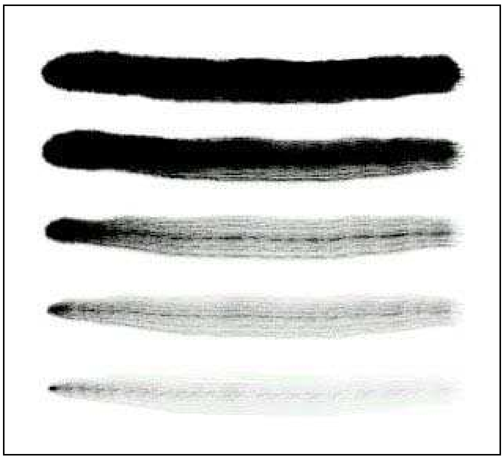


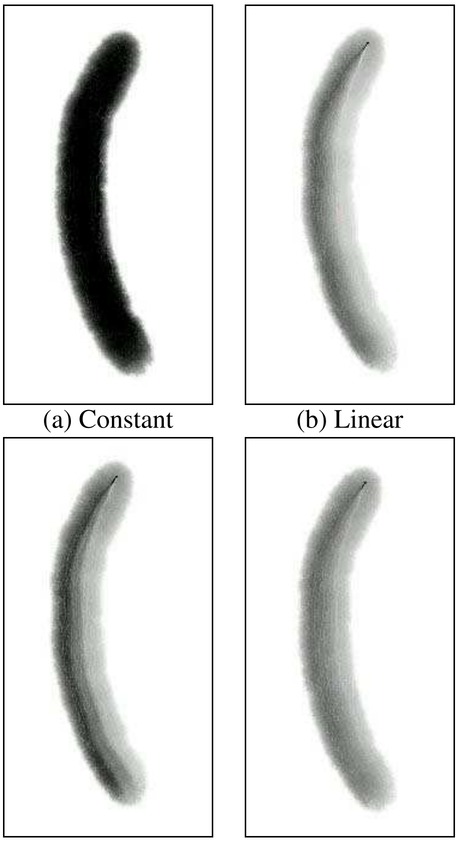
Figure 7. A simulated ink decreasing effect by the proposed method.

Fig.13 are generated images of the Four Gracious Plants, traditional material of Oriental paintings. Those plants have been considered appropriate to represent a main characteristic of Oriental paintings, simple strokes and beauty of space. These results show natural simulated images. The degree of ink quantity and diffusion effects are shown in Fig.9, 10, 12. Fig.11 shows the background landscape using simple strokes.

5 Drawbacks

Our system have several drawbacks. The followings are drawbacks of our system.

- In our system, a mouse or a pen can be used as an input device. Both a mouse and a pen require



(a) Constant (b) Linear

(c) Piecewise linear (d) Random

Figure 8. Shading effects of a stroke by simulation.

extensive trial and error to produce an Oriental painting because both a mouse and a pen have different characteristics with a real brush. To address this drawback, a method is needed so that an user feels input from a mouse or a pen like that of a real brush.

- To represent more realistic diffusion phenomenon, it may be better to consider the physical process of the diffusion phenomenon.
- The drawing speed gradually decreases with the complexity of the painting because the number of front cells is increased.

6 Conclusion

The purpose of this paper is to describe how to generate interactive and realistic Oriental paintings. To do this, we proposed several models for paper, brush, and diffusion. The proposed paper model is based on Lee's fiber mesh structure and uses layer structure for each cell of paper. In the layer structure, each cell on the paper was divided into three layers: surface, absorption, and deposition. We determine the degree of moisture of each stroke and generate the various phenomenon in the intersected regions using the proposed layer structure. For fast computation of bristle position, a two dimensional brush model is proposed. For the diffusion of water and ink, equilibrium properties were considered. A local equilibrium model is proposed for fast computation. We acquired realistic diffusion effects with LEM. Whereas the models proposed in this paper do not coincide with real models accurately, we generate realistic Oriental paintings. However, much work is still needed to generate more realistic Oriental paintings.

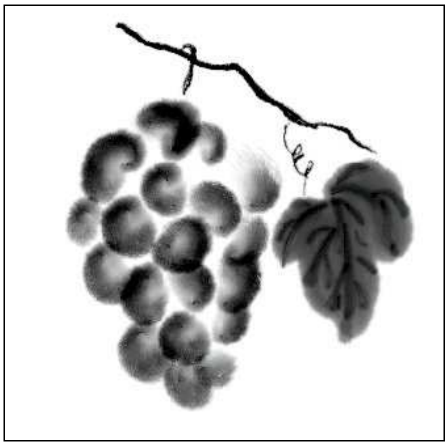


Figure 9. Grape.

Figure 10. Tree.

Figure 11. Mountain.

Figure 12. Rock.

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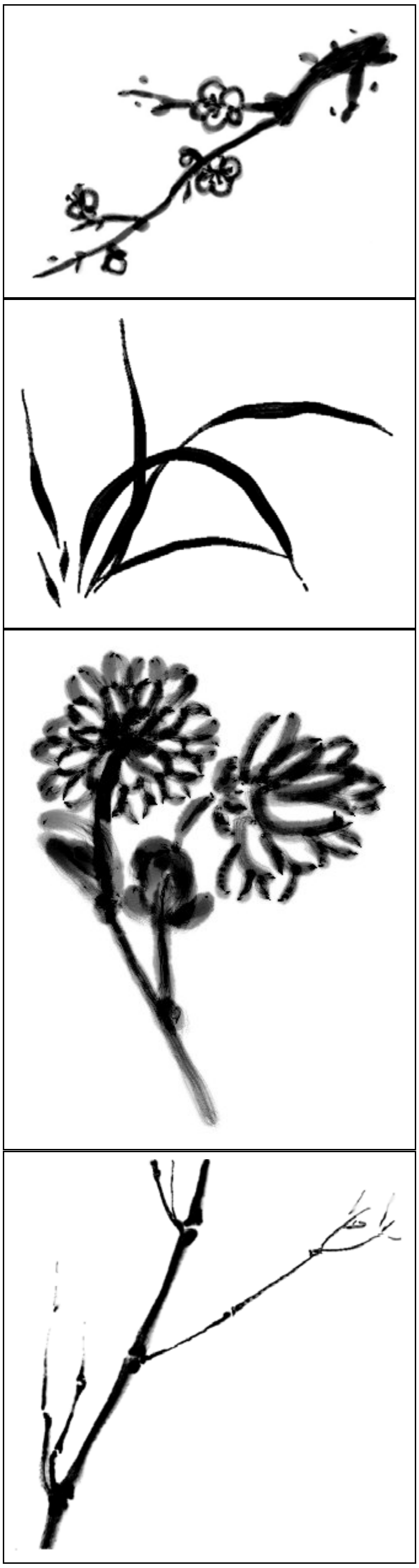

Figure 13. The Four Gracious Plants: plum, orchid, chrysanthemum, bamboo.