VIRTUAL PAINTING: MODEL AND RESULTS

Abstract

While painting, artists use tools to apply a medium on a support. The visual effects depend on the properties of these materials and on the environment. Virtual painting is mostly bounded to a 2D model and a 2D representation. This paper presents a 3D model for virtual painting. In this model the picture generation and visualization can be 2D or 3D. The images generated with this model prove that it is particularly well adapted to impressionist rendering and can be easily extended to other styles of painting.

keywords: Non-photorealistic rendering, painterly rendering, paint simulation.

1 INTRODUCTION

In real painting artists apply brush strokes on a canvas. This is a 3D interaction between 3D objects. Usually, the simulation of this 3D interaction is modeled in 2D: for example, most related works present the canvas as a 2D surface and not as a weave volume. Our aim is to apply to painting on a canvas the ideas presented by Sousa[21][19] for the pencil drawing on paper sheet.

Moreover the subjective value of a picture depends not only on aesthetic aspects, but also on optical properties, viewpoint and lights. For example the ambient and direct lights of the Richelieu wing of Le Louvre have been extensively simulated[1][15] to obtain the best lighting quality on each picture.

Since the work of Haeberli[9], simulating painting has been one of the main field of the non-photorealistic rendering (see for example[13][12][11][10][16][4][21][19][5][8][7]). A chapter of the book Non-Photorealistic Rendering[6] presents this field and related works[23][2][24].
Most of these works focus on limited parts of the art of painting (for example watercolor effects for Curtis et al.\[2\]). The related works avoid a generalization of the simulation of painting.

We believe as discussed by Fredo Durand\[3\] that virtual painting is much more than a simple projection from a 3D scene to a 2D picture. Our aim is to model materials and processes involved in painting and to extend the possibilities of painting. This paper propose a global model of virtual painting and to validate these results through \textit{VPUP8}\[1\], a new kind of interactive paint box.

In the following we present some definitions, the new 3D model and VPUP8 as well as processed pictures.

\section{Definitions}

We define virtual painting as the activity of simulating painting on a computer. The results of virtual painting are called processed pictures. The tools refer to the objects (brush, palette knife...) used by an artist to apply paint paste on a canvas. The medium refers to the paint paste (pigments, oil...). The support refers to the object (canvas, paper...) the paint paste is applied on.

\section{Volumic Painting}

A painted surface is a volume therefore a processed picture has to be a 3D object. Virtual painting deals with describing the interaction between a medium and a support and with making a viewable result of this interaction: e.g. a 2D picture of a 3D rendered scene.

Tools have 3D shapes. For example the brush is composed of bristles and their arrangement and size give it its 3D shape. The medium is composed of pigments and a binding material. A pigment is a set of particles that has a coloring ability. Properties of the medium depend on the binding material used and the particles sizes. The support denotes the colorable material the medium is applied on.

Tools are 3D objects and can not be modeled efficiently through a 2D process. For a brush, the bristles volume and the contact with the support are modified all along the painting process. The support is not a plane surface but a 3D object. Even the material it is composed of may be rough or smooth. The medium may be viscous as acrylic or thin as watercolor, so that they spread differently on the surface of the support. To make a virtual painting system, we must create a 3D model for each material involved. Then we must apply physical laws to compute the interaction between materials and optical laws for the rendering process.

\section{Our Model}

Our model is designed to allow control of low level details and fast processing. It is inspired by both Curtis’ method\[2\] and Buchanan’s method\[20,22,21,19\].

The supports, the tools and the media are described with their characteristics. Then our model describes the interaction between support and media. It includes geometrical deformations and the coloring of the support.

In the following we present our model for the support, the medium and their interactions during the painting process.

\[Virtual Painting at University Paris 8.\]
Virtual Painting: Model and Results

4.1 The support

Supports are colorable material: wood, plywood, metal, glass fiber, paper, canvas... In our
model supports are described as: (1) an altitude map and (2) a set of physical characteristics
(absorption rate, maximal absorption). These characteristics can be valued to simulate any of
the above materials.

4.1.1 The altitude map

The painting process is composed of two steps:

1. to color the support,
2. to modify the altitude map.

As the support is discretized, its smaller part will be called a cell. Each cell will be defined
by its position \((i, j)\) and denoted \(c(i, j)\). For each cell \(c(i, j)\), an altitude \(A(i, j)\) is given. The
altitudes are normalized and are used to build a 3D triangular mesh as on figure 1. The altitude
map of a support is extended from a sample as in Li-Yi Wei and Marc Levoy’s method[25] and
Sobczyk et al.[18]. The support can be filled or a texture can be applied on it (see figure 2).

![Fig. 1](image1.png)

**Fig. 1.** the support as a 3D mesh with 129032 triangles.

![Fig. 2](image2.png)

**Fig. 2.** the support filled.

For each cell \(c(i, j)\) of the support a roughness factor \(R(i, j)\) is defined as the gradient of
the altitude map. This roughness factor is used to compute the amount of pigment set on the cell
by the medium. During the painting process, the support change dynamically (altitude, color).

4.1.2 Physical characteristics

The physical characteristics are given by:

1. an absorption rate, \(A_{abs}\) of the support \(s\),
2. a threshold \(Q_{max}(i, j)\) of coloring material that a cell \(c(i, j)\) can absorb. This value de-
pends on the material composing \(i\). If this value is exceeded, capillarity effects are applied
to neighbor cells,
3. a threshold $S_{\text{max}}(i, j)$ of coloring material that can settle on the cell. If this value is exceeded, the altitudes of the corresponding triangle vertices of the mesh are modified,

4. a current absorbed quantity of coloring material $Q(i, j)$,

5. a current settled quantity of coloring material $S(i, j)$.

4.2 Media and tools

This section presents the medium and the tools involved in virtual painting. A medium $m$ is defined by the following characteristics:

- a color $C_m$ (given in RGBA colorspace),
- a viscous factor $\mu_m$ used for capillarity effects. For example, watercolor has a low viscous factor,
- a settling rate $L_m$. For example $L_m$ is very high for pencil.

Tools are defined through their shapes and characteristics. For virtual painting, the main tool defined is the brush. A brush $B$ is defined as a collection of bristles $\{b_1, \ldots, b_n\}$. A bristle is defined as a 3D curve whose values are weighting coefficients. They can be seen as pressure factors when the bristle is in contact with the support. Each bristle $b_k$ has a hardness factor $H_k$. To simulate the quantity of paint on the bristles, $M$ the point of contact of the bristle $b_k$ has a quantity $q_k(M)$ of coloring material.

4.3 Interaction

The painting process results from the interaction between the medium and the support. When applying a medium on a support, there are three main consequences:

- the medium leaves coloring material on/in the support,
- the support may be altered according to the pressure applied by the media,
- the bristles move according to the brush strokes.

4.3.1 Coloring

The coloring of the support results from:

- the absorption of pigments by the support,
- the settling of pigments on the support.

Let $M$ be a contact point between a cell $c$ and a bristle $k$ of the medium. The pressure applied by the medium is $b_k(M)$. A total pressure $F$ which is a function of the bristle pressure and the roughness is given by:

$$F(M) = b_k(M) + R(M).$$

The potential quantity of coloring material that can be laid from the point of the bristle is:

$$q = F(M) \times L_m \times q_k(M).$$
Virtual Painting: Model and Results

The quantity of absorbed $q_a$ and settled $q_s$ material are:

$$q_a = A b_s \times q,$$

$$q_s = q - q_a.$$

These values are tested against $Q_{max}(c(n))$ and $S_{max}(c(n))$, and $Q(c(n))$ and $S(c(n))$ are dynamically updated.

### 4.3.2 Support deformations

Our model includes support deformations due to the pressure applied by the medium on the support. When applying a medium with too heavy a pressure, the support may be deformed. Let $F_{max}$ be this threshold. If $F(M) > F_{max}$, altitudes are modified.

### 4.3.3 Media deformation

Unlike real ones our bristles can not be eroded. Therefore the deformation of the media consists in moving the bristles according to the moves.

### 5 DIFFERENTIAL PROCESSING

As the images produced at this stage through VPUP8 have poor aesthetic qualities (it has not been tested by painters yet), we implemented filters to test the model. An input image and a support are given. The output consists in a 3D OpenGL scene and a 2D image.

#### 5.1 Partitioning

To make a virtual painting, we need to partition the input image into few regions. We define a region as a set of connected pixels with homogeneous colors. We consider that two colors are homogeneous colors if the Euclidean distance of their RGBA components is smaller than a value $\varepsilon$ given by the user.

Partitioning is first achieved with an edge detection on the input image. Two cases appear:

- if the detected edge is closed, e.g. the first point coincides to the last point, it determines a region of the image,

- if the detected edge is not closed, we determine the region so that:

1. the distance between two points of the region must be less than the maximum distance between two points of the edge,

2. the colors inside the region must be homogeneous.

The partition is then completed with the set of every unset pixels.
5.2 Brush strokes orientation

Once we have determined a region and its colors, we must determine the orientation and the length of the brush strokes. For each region $R$ we compute a maximum length $L_{\text{max}}$ for the brush strokes. This length depends on the size of boundary $B_R$ of $R$. For each point $P$ of $R$, we define a curve $C_P$ as follow:

- $C_P$ is a curve of $B_R$,
- $C_P$ has a length $L_{\text{max}}$,
- the middle point $M$ of $C_P$ is the closest point of $B_R$ to $P$. If few middle points $M$ are found, we choose one of them randomly.

A brush stroke is then given according to $C_P$.

6 RESULTS

Examples of visualization are given on figure 3:

- part (a) presents a 2D representation of the processed picture.
- part (b) shows a 3D representation of the processed picture. VPUP8 allows graphic designers to work on their compositions as in virtual reality.

Examples of processed pictures are given on figure 4 and figure 5. Figure 4(a) shows an original home made photography. This picture with sharp edges has been processed. The absorption rate of the support was set to a high value. The brushes strokes were given by little touches. Figures 4(b) and 4(c) show respectively an acrylic and a watercolor effect. The high absorption rate and the little touches produce some none-painted areas. Let's focus now on the TV behind the main character. One can see that the filter preserves mostly the shapes of the original picture. But more precise details as the child eyes or lips are too blurred.

To produce the figure 5 series, a landscape photography (figure 5(a)) was processed. It displays a river surrounded by trees. The regions are soft and there are a lot of details as the tree leaves and the stones around the water. To process this image, the absorption rate of the support was set to a medium value and the parameters of the media were set to produce a watercolor effect. We used brushes of small sizes in order to preserve the details. The brush strokes applied were also of small sizes. These parameters give the processed picture an impressionist effect. As one can see on figure 5(b), the far range vision of the processed picture is photorealistic and the brushes strokes are not visible. Figure 5(c) is a closed view of the center of figure 5(b). As in Impressionist pictures seen at close range, the vision is blurred and one can see the shapes of the brushes strokes.

For all the images presented above, the colored version is available at: www.ai.univ-paris8.fr/~dom/index.html.

With a 3D visualization tool, it is easy to change the ambient light, viewing perspective or farness of the picture. It is therefore easy to present different views of the same picture.
Virtual Painting: Model and Results

7 CONCLUSION

We proposed a 3D model for virtual painting. Based on the extension of the painting process, this model is particularly well adapted to Impressionist rendering and watercolor effects. It is adapted to any other kind of painting. This model can even be applied to sculpture. As modelization and visualization are no more bounded, we can use the OpenGL 3D library or a Ray Tracer to visualize the results. As OpenGL can not handle optical model such as Kubelka-
Munk model[14], a future work will consist in adding a better support for 3D visualization. As the computation of an image takes several minutes, another future work will consist in seeking a less time consuming implementation of the filters and some improvements of the interface of VPUP8. Then it will be possible to get better tests by artists.

REFERENCES


Fig. 4. “Family life”.
Virtual Painting: Model and Results

Fig. 5. “Bystra Woda”.

(a) the original image.

(b) the filtered image.

(c) the magnified center part of (b).