The Virtual Painting Paintbox

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Abstract

We present VPUP8 a new kind of paint boxes. It includes a model for the simulation of physic dynamics involved in the painting process and a human-machine interface to manage the position and the moves of the user. Usually digital painting is bounded to a 2D model and a 2D representation. Our 3D model is designed to accurately reproduce the painting process, stroke per stroke. To obtain the subtle details real painting provides, the model needs a very high resolution and the modeling of the picture as a 3D object thick with paint. In front of a real painting, any move brings new impressions. With VPUP8 the position of the user is the main factor of the viewpoint and of the scale of vision computation: from a whole view to a precise zoom-in well adapted to detail work. The position of the user is measured through a non-intrusive face tracker. The images generated prove that VPUP8 is well adapted to any style of painting.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Physically based modeling, Viewing algorithms, Display algorithms, Paint systems, Virtual device interfaces, Interaction techniques, Virtual reality

1. Introduction

Since the work of Haeberli[1] in 1990, non-photorealistic rendering (NPR)[2, 3] became one of the main fields in Computer Graphics. Most of related papers focus on: the representation of a 3D scene by a digital image with non-photorealistic aspects[4, 5, 6], stylized drawing[7, 8, 9] and image filters[10, 11]. Most of these works lead to artistic-like pictures (see for example the covers of[12, 13]). As other researchers[10] and even usual paint boxes[14, 15] we have been focused on impressionist rendering. Our purpose is to create a paint box with which a graphic designer could design artistic pictures[16, 17]. As noted by Gooch[2], this goal implies either a simulation of the physics involved or a reproduction of the feeling given by the style to be rendered. As Cockshott[18] we choose to simulate the physic laws of painting. This is only possible if the painting is not a flat but a 3D object. The visual impression declines with a flat model anytime brushstrokes overlap. For example, using the watercolor system included in Painter 7[15], one finds it realist until two strokes intersect. Then the flatness of the model causes problems on the outskirts.

In their work, Cockshott et al.[18] consider the canvas as a cell reservoir array. The main problems of this method are that the height of the reservoir is predefined and that the paint pigment flows as a liquid without viscosity. The works of Sousa and Buchanan[19, 20, 21, 7] are closer to our goal even if more oriented on the graphite pencil and paper interaction.

Our previous works conducted to the following remarks:

- To be able to produce an accurate impressionist rendering one must be able to accurately produce any kind of painting. The thickness of paint paste applied on the canvas has to be realistically simulated.
- The array of cells has to be of extended size in both three dimensions. It will be computed as a landscape with its valleys and peaks.
- To compute digital impressionist paintings cannot be done at the low resolution of the usual CRT or LCD visualization device.
- If the array of cells is large and the viewing possibilities low there needs to be a way to see the digital painting as a

whole and to work on details. We call this device a zoom-in / zoom-out system.

- A paint box must include a human-machine interface that allows the user to maintain the pose of a painter. In a near future any paint box will be a Virtual Reality tool.

We define virtual painting as the activity of simulating painting on a computer. VPUP8 is designed to accurately reproduce painting, stroke per stroke. The objects (brush, knife...) used by an artist to apply a paint paste (pigments, oil...) on an object (paper, canvas...) and their interactions are modeled. The human-machine interface manages not only the strokes of the pen on the tablet but also the moves of the graphic designer. The position of the user is the main input data VPUP8 uses to compute the viewpoint and the scale of vision: from a whole view to a precise zoom-in well adapted to detail work. If a close view is easily computed with one pixel per cell, an average zoom-out of the whole scene might hide some major feature of the picture, therefore zoom-in, zoom-out tools have been created to compute images without lost in quality. The user can also change the lighting of the image to obtain the best quality on each picture. VPUP8 works with an interactive pen display *Wacom Cintiq*[22]. It enables one to work directly with a pen on the full colored display and provides a hand eye coordination.

In the following, we present the model for the simulation of physic dynamics. Then we focus on the human-computer interface and we describe the techniques developed for zooms. Finally images produced with VPUP8 are presented.

2. Painting Model

This section presents the 3D painting model used. It is based on the model created by Sobczyk et al.[23]. This model is designed to reproduce accurately painting, stroke per stroke. To obtain the subtle details real painting provides, the model needs a very high resolution. This has been noted by Caillou[24] and Sobczyk et al.[25]. Our model is inspired by both Curtis' method for watercolor[8] and Buchanan's method for the interaction between paper and pencil[19, 20, 21, 7]. Note that this interaction is 3D modeled: thickness is the main factor of light's effects on the painting. Focusing on the sky in the *Église d'Auvers sur Oise* by Van Gogh[26] (see figure 3), one can see the dark side and the bright side, almost twinkling, of large brush strokes. On the contrary, one can see the texture of the support where lighter brush strokes have been applied. The painting can be viewed as a landscape with an altitude for each point (see the thickness of paint paste on the lawn of *Église d'Auvers sur Oise* by Van Gogh[26] on figure 5). Therefore in our work a digital painting is a three dimensional object. Our model includes the three elements involved while painting (the support, the tools and the medium) and their interaction with an adaptation of physical laws. They are presented in the following section.

- The support is a colorable material. We defined different supports used by artists: wood, metal, paper, canvas. The support is considered as a 3D object with characteristics as texture, absorption rate, hardness... As the support is discretized, its smaller part will be called a **cell**. The paint settled on a cell defines a layer. Layers overlayed produce thickness. At this stage of VPUP8, only the two highest layers with their altitude are considered. Without a sufficient number of cells a picture have not the quality of a painting. A scene must have 5×10^7 cells (6000x8000).
- The model includes different kinds of tools used by artists as brushes and knifes. Each tool is defined by its physical properties and the modifications it produces to the support (creation or destruction of layers). When used, a tool is applied on the support with a direction, a pressure and a quantity of paint.
- Medium corresponds to the coloring material applied: pencil's coal, paint paste, varnish, ink... It is defined by a color, a viscous factor, a reflectance and a transparency.

The toolbox includes interaction between the support and the medium. The support may be altered according to the pressure applied to the tools. The medium leaves coloring material in/on the support. When one brush stroke is applied on the support the bristles of the brush cross some cells of the support. The computation of how much medium is let to cover the upper layer of the cells depends on the pressure, the medium, the tool and the grain of the support. The paint layers increase the thickness of the cell and the altitude of the upper layer.

The painting is generated as a 3D *OpenGL*[27] object with vertices and facets. One can visualize the computed painting with different viewpoints and lightings. One can be satisfied to use common abilities of graphics card device to view the paintings, but with this method, lights effects are not accurately reproduced. Moreover as the object is discretized any attempt to move the viewpoint very close to the canvas produces polygon and viewable edges with *OpenGL*. With VPUP8, a global illumination system is used to obtain the view of the painting. Stochastic ray tracing seems to be an appropriate technic. It assumes that rays hitting a surface are reflected randomly in different directions, with probability distribution depending on the nature of the surface[28]. The main problem is to choose the right compromise between fast computing (in order to get real-time viewing) and improved quality.

Figures 1 and 2 present images produced with this model. As one can see on figure 1 the picture is seen from a low viewpoint. Figure 2 presents a very close view: the thickness of the paint is clearly visible.

3. Pacing to and fro

While at work a painter often walks to and fro the canvas. Brush strokes are done directly on the canvas while only a distant view can give the impression of the whole picture.

Figure 1: *Twisted Tree*

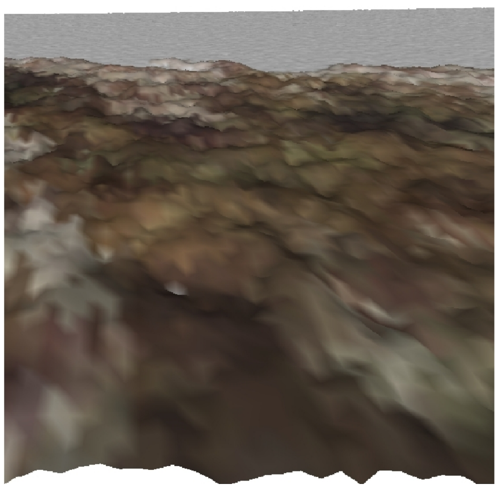

Figure 2: *Detail of Twisted Tree*

Sometimes one even leans to the side of the canvas to watch the sparkles of a detail.

In computer graphics the poor definition of pictures denies the use of such movements: all the pixels are still viewable at close or far range. As the model of the picture is flat, there is no sense on leaning to any side. With our model, the picture is a landscape, with its peaks and valleys. High where the brush let much paint, low where the brush was dry and one can see the canvas pattern. Moreover the landscape is deep with details and the canvas is a set of 50,000,000 cells. Look at it at far or close range is no more the same thing. Therefore we have developed a zoom system that adjusts the presented part on the distance between the viewer and the screen. When the user is close to the viewing device, a zoom-in is produced and a close range view is presented. When the user moves away a reduced view of the whole picture is computed.

3.1. Human-Machine Interface

A simple and intuitive human-machine interface is needed to use zooms. This interface is designed to reproduce accurately painter's movements. The zoom will be computed using the distance between the *Cintiq* interactive pen display and the user.

We have build a face tracker system that respects three constraints:

- it must be a non-intrusive face tracker,
- the tracking must be done in real time,
- no special lighting or mark on the user's face are needed.

Until now we use ultrasonic telemeters fixed on the *Cintiq* to determinate the distance between the user and the *Cintiq*. The telemeter emits ultrasonic sound waves. These waves are reflected hopefully by the face of the user and are sent back to the telemeter. The delay between emission and reception is linear to the distance between the telemeter and the reflecting object.

Some problems remain when using ultrasonic telemeters:

- precision. The distance measurements are not very precise.
- minimum. At very close range the part of the face reflecting the sound waves might be the forehead.
- interferences / obstacles. The only information obtained is the distance between the telemeters and an obstacle. The telemeters point to the face of the user, but this is not necessary the first obstacle (it can be his hand). It can even be a wall behind a too leaned head.

Before using this interface the user must calibrate the nearest and farthest position desired. To reduce the disruptions a set of five measures on two ultrasonic telemeters are realized and the average value is computed. Then the calibration and the distance measured are used to compute a distance ratio. This value is the input data of the zoom tool.

To improve this human-machine interface, the precision should be improved and interferences should be detected. We will try to use infrared telemeters which are more precise than the ultrasonic telemeters. An eye gaze tracking will also be developed, but the current eye gaze tracking methods basically rely on intrusive techniques. For example DeCarlo and Santella[29, 30] use an eye-tracking sensor monitor. Stiefelhagen et al[31] have realized a non-intrusive tracking eyes using a camera. But in this case the distance between the user and the monitor is not definite.

4. Zooms

Different kind of zooms have been developed. The input is always the value computed by the human-machine interface and the output is an image. This section presents the zoom-in / zoom-out system.

Generally zoom's techniques are based on an average computation and produce a smoothing effect. The advantage of this method is to reduce the aliasing, but it is not adapted to the impressionism painting. For example, a smoothing applied on the *l'Église d'Auvers sur Oise* of Van Gogh[26] modifies the painting. In this painting, blue is everywhere: dark blue for the sky that merges with blue-black; red blue on the roof of the church; reflection on the grass of stained glasses. Forms and colors intensify the uneasiness for the viewer. Using a classical zoom's technique, colors seems to be uniform and the brushwork disappears. The paint even appears "pretty" (see an average zoom-out (see figure 4)). To make the brushwork appear we have developed our own zooms. These are based on an analysis of the landscape treated with different color models (HSV, RGB…).

Figure 3: *Église d'Auvers sur Oise, original picture*

Figure 4: *Église d'Auvers sur Oise, average zoom*

5. Results

We present in this section an image of a tree. It's a complete demonstration of VPUP8. We have created a picture (see figure 6) with the model of painting. Then we have applied a

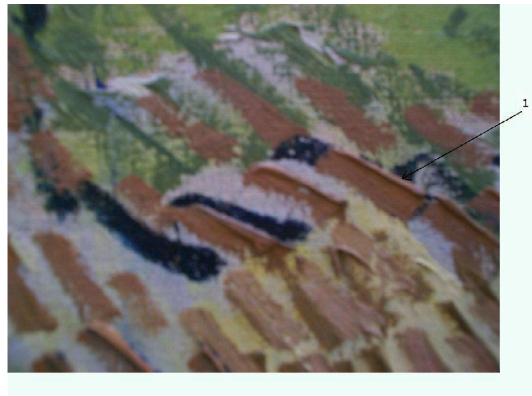

Figure 5: *Detail of Église d'Auvers sur Oise, original picture (1: thick brush stroke)*

zoom-out (see figure 7). A third picture is then presented: it is the second one resized to the original size (see figure 8). It is clearly visible that the impressionist effect generated with the model is preserved by the zoom. The main problem with our zoom algorithm is that it is too slow for an interactive system. Therefore, in a first approach of the system it is replaced by a preview with *OpenGL*[27] to which a proper zoom is applied. In this case we use a color-based, non average, zoom. For example, a distribution of the colors of the original picture, based on the hue value is computed. Then the most frequent and distant hues are selected to fill the zoomed picture.

Figure 6: *Picture produced with our model*

6. Conclusion

We have proposed a new kind of paint boxes designed to permit virtual painting, VPUP8. It includes a model for the sim-

Figure 7: *Zoom*

Figure 8: *Zoom (double size)*

ulation of physic dynamics involved and a human-machine interface to manage the position and the moves of the painter. 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 *OpenGL* can not handle optical model, 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. Zooms-out techniques have been developed and are well adapted to the impressionism. The zoom is computed using the distance between the *Cintiq* and the user. A simple and intuitive human-machine interface has been developed to use zooms. This interface is designed to reproduce accurately painter's movements. To improve this human-machine interface, an eye gaze tracking will be developed.

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