Carving, Painting, and Printing with a Pen Tablet

S. Mizuno, D. Kobayashi†, M. Okada††, J. Toriwaki††† and S. Yamamoto†††

Information and Medhia Center, Toyohashi University of Technology, Toyohashi, Japan
†NEC Corporation, Tokyo, Japan
††Graduate School of Information, Production and Systems, Waseda University, Kitakyushu, Japan
†††Graduate School of Computer and Cognitive Sciences, Chukyo University, Toyota, Japan

Abstract

We discuss on an interactive CG system with a pressure sensitive pen tablet. This system is based on the virtual sculpting and printing method which are simulations of real sculpting and woodblock printing. In the sculpting process, the user operates virtual chisels with a pen to carve a virtual wooden object which has a 3D shape. The user can control the carving depth and the carving angle to the surface of the object with the pressure applied to the pen. In the painting process, the user paints ink with a pen on a 3D virtual sculpture created in the sculpting process. The painting result is determined by the surface shape of the sculpture and the pressure to the pen. In the printing process, a pen is used to operate a Japanese printing squeegee, Baren. The user can control the thickness of the print by changing the thickness of ink on the virtual woodblock and the pressure of printing operation.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 [Computer Graphics]: Computational Geometry and Object Modeling

1. Introduction

The virtual sculpting and printing system is an interactive CG creating system which anyone can use without special knowledge of computers and CG by adopting carving and printing techniques of the real world [MOT 99, MOTY 02]. In virtual sculpting, we can form a solid object by carving a virtual workpiece with a virtual chisel. Virtual printing is a method to synthesize a woodblock print by simulating real process for it with virtual items such as woodblocks, a paper sheet, ink, and a Baren. In the previous virtual sculpting system, the user utilizes a mouse to operate a chisel. It is difficult to give parameters of the carving depth and the carving angle to the surface only with the mouse. In the previous virtual printing system, a Baren is also operated by a mouse and it is considered to be operated with fixed pressing pressure.

A pen tablet is one of the most popular pressure sensitive hardware devices. It is widely used for 2D drawing [XLTP 03] and in other various fields [RB 03]. We consider a pen tablet can improve the operation of our virtual sculpting and printing methods, and we are developing a user interface using this device. The pressure value of the operation is converted to the carving depth and angle dynamically in the same way as carving in the real world. The new interface enables the system to take into account the concept of the hardness of the workpiece that results from the shape of the surface and the grain of the wood. In virtual printing, the user can control the pressure pressing the paper sheet against the printing block to make gradations on the printed image. This is an important technique in printing a real Ukiyo-e. Painting ink on a 3D shape is also an important factor in creating a sculpture and many methods have been studied [JTKNC 99]. We are studying a method to paint a 3D shape with a pen tablet which considers the interaction of the operation pressure and the surface shape.

2. Outline of virtual sculpting and printing methods

In the virtual sculpting system, an original workpiece and virtual chisels are prepared in a virtual space. The workpiece is polyhedron by curved surfaces. Each virtual chisel is defined by an ellipsoid, a cube and a cylinder, and the shape of a carved solid object is expressed with a CSG. While carving, the user can remove or attach pieces of the shapes of virtual chisels from or to the workpiece, and then the workpiece is deformed at once. By performing these operations repeatedly, the user can form a complex solid object which looks like a real wooden sculpture.

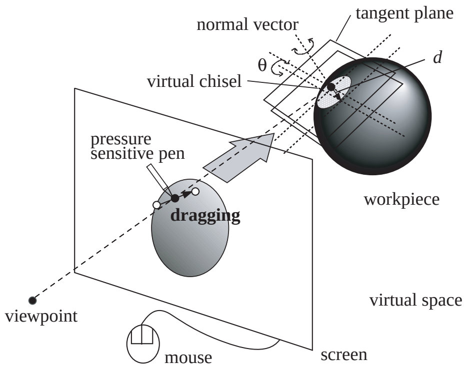


Figure 1: *Placing a virtual chisel on the workpiece.*

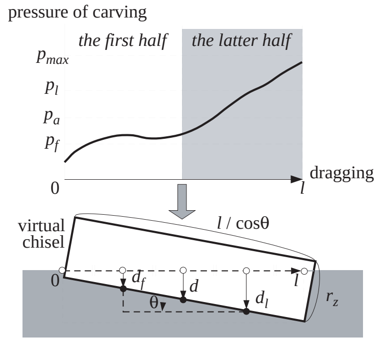


Figure 2: *Getting the carving depth and the carving angle from the pressure applied to the pen.*

Using a board as a workpiece in virtual sculpting, a printing block can be generated. In the printing stage, a user synthesizes a printing image from the printing woodblock, a paper sheet, a Baren (disk-shaped squeegee pad), and ink in the virtual space. A virtual paper sheet is expressed as a 2D lattice. It is put on the virtual woodblock, and the operation of the virtual Baren decreases the distance from the printing block to the virtual paper sheet interactively. This distance determines the wetness of the ink at each point on the paper sheet, and an image is synthesized one after another.

3. Carving a virtual wooden object with a pen tablet

We use a dragging operation for carving a wooden object with a chisel. One carving operation is done with one dragging. The length of the chisel, the point on the surface of the workpiece, and the rotation on the normal vector at the point can be obtained from the position and the direction of dragging (Figure 1). A virtual chisel is put at the designated position, and the chisel deforms the workpiece immediately.

We improve a user interface with a pressure sensitive pen tablet instead of a mouse [MKOTY 03]. The user can give the values of the carving depth and the carving angle to the surface dynamically only with the pen. The user drags the pen to carve the virtual workpiece. The pressure applied to the pen is transferred to the carving depth and the carving angle to the surface (Figure 2). The carving depth is decided based on the average of the pressure: p_a, in one carving. The carving angle to the surface is decided based on the average of the first half pressure: p_f, and the latter half: p_l.

Grain is produced with seasons, and the portion which grows in autumn is harder and darker than the portion which grows in summer. Fibers grow along grain, thus it is easier to carve along grain than to carve against the grain. We consider the hardness of the virtual wooden workpiece by analyzing its grain texture. The average of the gray value on the carving line: g_a, shows the ratio of the hard portion. To analyze the frequency of crossing fibers of wood, the system counts the number n of the gray value crossing the threshold: g_t on the carving line whose length is l, and calculates a value: $f = n/l$.

The carving depth: d is defined as follows.

$$d = \frac{r_z p_a}{p_{max}} \cdot C_0 \frac{g_a}{g_{max}} \cdot C_1 \frac{(f_{max} - f)}{f_{max}}, \tag{1}$$

where, r_z, p_{max}, g_{max}, f_{max}, and C_0, C_1 are the height of the virtual chisel, the maximum sensitive pressure, the maximum gray value of the texture ($0 < g_a < g_{max}$), the maximum frequency of crossing fibers ($0 < f < f_{max}$), and coefficients (change with the kind of wood), respectively. The carving angle to the surface: θ, is decided based on the average of the first half pressure: p_f, and the latter half: p_l, in the operation. It also considers the grain.

$$d_{\{f,l\}} = \frac{r_z p_{\{f,l\}}}{p_{max}} \cdot C_0 \frac{g_{a\{f,l\}}}{g_{max}} \cdot C_1 \frac{(f_{max} - f_{\{f,l\}})}{f_{max}}, \tag{2}$$

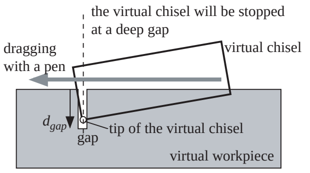
$$\theta = \tan^{-1}\left(\frac{d_l - d_f}{0.5l}\right), \tag{3}$$

where, g_{af} and g_{al} are the first and the latter half of the average of gray values in the carving area respectively. f_f and f_l are the first and the latter half of the frequency of crossing fibers on the carving line, respectively. To carve deeply, the user should operate the pen strongly like real operation of a chisel. The transition of the pressure during one carving operation decides the carving angle to the surface. A long curved carving operation is divided into short straight operations automatically, and each carving mark is connected with ellipsoids and cylinders.

In real wooden sculpting, we sometimes carve an outline of a figure narrowly and deeply with a knife to make a gap, and cut out the outside of the figure next called *Kirimawashi* in Japanese. If we carve with moderate pressure, we will feel

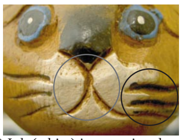
(a) Carving a wooden board with a knife to make gaps along with the outlines of the figure.

(b) A generated printing woodblock for Japanese Ukiyo-e.

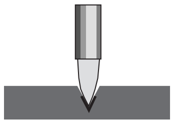


(c) A method to realize *Kirimawashi* in the virtual sculpting.

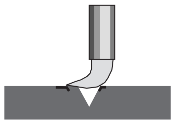
Figure 3: *Kirimawashi: a technique to generate a clear outline of a figure.*



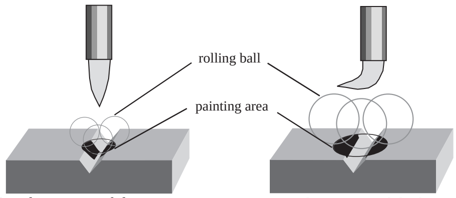
(a) Ink (white) is not painted on the area thinly carved. However, if the penpoint is used, it is possible to paint it (black ink).



(b) Painting on a sculpture with low pressure.



(c) Painting on a sculpture with high pressure.



(d) Virtual painting with low pressure.

(e) Virtual painting with high pressure.

Figure 4: *Painting result of a real sculpture with a brush and a method for virtual painting.*

that the wood is harder at the gap, and the chisel will stop there, thus a clear figure will be created. We implement this technique in the system by analyzing the shape of the surface of the virtual workpiece. The carving operation will be stopped at a gap when the gap is deeper than the position of the tip of the virtual chisel as shown in (Figure 3(c). If the user operates the virtual chisel strongly, the carving mark will cross the gap.

4. Painting ink on a virtual sculpture with a pen tablet

We implement interactive painting in the system by generating a 3D texture for ink in addition to the grain texture. The system has 700^3 arrays for the 3D texture. Each array has four values: three color values and a moisture value, and corresponds to a point in the space for virtual sculptures. The moisture value controls transparency for a grain texture and a printed image in multicolor and multi-woodblock printing.

We use a pen tablet for the virtual brush, and consider the operation pressure and the surface shape. We pay attention to small irregularities on the surface of the sculpture. In real painting on a sculpture, the painting result changes by the interaction of the operation pressure and the surface shape, and generates a unique style (Figure 4 (a)(b)(c)). We realize this phenomenon by modeling a virtual brush using balls (Figure 4 (d)(e)). When the user operates the virtual brush with a pen, a painting area is decided based on the position and the pressure of the pen. The painting area is circular, and it extends in proportion to the pressure. In the area, the system rolls the ball on the surface of the sculpture. The size of the rolling ball is also changed proportional to pressure. The attainment points of the rolling ball are calculated in the operation. They are considered to be painted and corresponding pixels of the 3D texture are updated immediately. We decided that the radius of the rolling ball was the same as the radius of the carving area experimentally.

5. Virtual printing with a pen tablet

In real woodblock printing, the user uses a Baren to push the paper sheet against the printing block. The pressure applied to the Baren can control the printed image and is a factor to generate gradations of color and density. This technique is very important to synthesize a Japanese print Ukiyo-e, and the printing process is done by specialists.

Figure 5 shows our virtual printing method. The z coordinate of the bottom of the Baren is determined based on the average value of the z coordinates of a virtual paper sheet under the Baren, z_{Ba}. Lattice points under the Baren which have z coordinates larger than that of the Baren are considered to be pushed. As the user operates the Baren repeatedly, the paper sheet approaches the surface of the virtual printing block gradually, and virtual ink painted on the block adheres to the paper. The displacement value Δz_B expresses the pressure of the virtual Baren. In the former system, a mouse was used to operate the virtual Baren, and the value Δz_B is fixed. We adopt a pen tablet instead of a mouse to operate the virtual Baren. The value Δz_B is decided based on the pressure applied to the pen in printing operation. Not only the frequency of the operation, but also the pressure can change the wetness of the ink printed on the paper, and the new interface enable a user to generate smooth graduations on the printed image.

6. Experiments

We implemented the system on a Windows PC (Pentium4, 3GHz, 2GB) with a LCD pen tablet (Wacom CintiQ C-1700SX) (Figure 6(a)). In the sculpting process, we confirmed that the carving depth and the carving angle to the surface changed with the pressure of the operation. It is possible to carry out direct operation to the object displayed on the screen as if carving in the real world. Figure 6(b) and (c) show virtual reliefs created in the system. In creating a

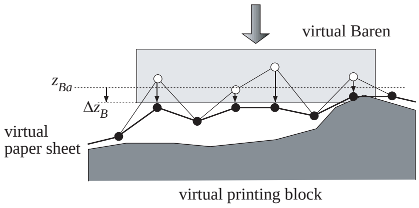
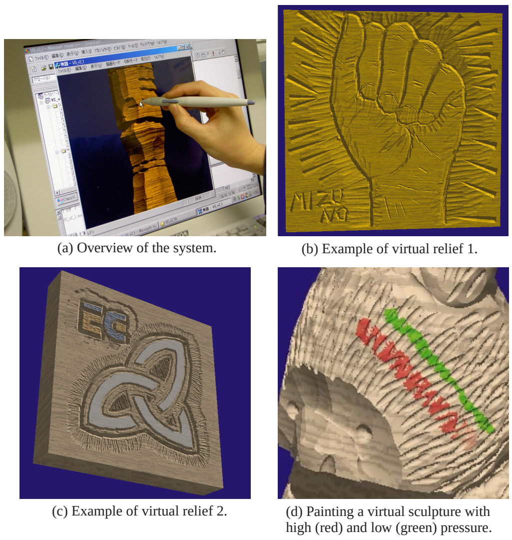


Figure 5: *Movement of lattice points of the virtual paper sheet by operating a virtual Baren.*

virtual relief 1, the outline of the hand is carved deeply and widely by high pressure operation, and wrinkles are carved shallowly by low pressure. Figure 6(d) shows an experiment of painting ink on a 3D sculpture with a virtual brush interactively. The painting varies by the interaction of the operation pressure and the surface shape as painting in the real world, and it has a handmade style. Figure 7 shows an experiment of creating Ukiyo-e with our system. Here, using the system with a pressure sensitive pen, the user can create virtual woodblocks with the same technique of *Kirimawashi* to carve clear outlines. A little gradation was attached to the background of the woman in the printing process by painting ink with gradation and changing the pressure of operating a virtual Baren. This technique is similar to the real one.



(a) Overview of the system.
(b) Example of virtual relief 1.
(c) Example of virtual relief 2.
(d) Painting a virtual sculpture with high (red) and low (green) pressure.

Figure 6: *Virtual sculpting and painting with a pen tablet.*

7. Conclusions

In this paper, we developed a new user interface with a pressure sensitive pen tablet for the virtual sculpting and printing system. We also developed a method to paint on a 3D virtual sculpture which considers the interaction of the operation pressure and the surface shape. We confirmed that the interface with a pressure sensitive pen tablet is useful for our system to make the operation more similar to real sculpting and real printing.

(a) A virtual printing woodblock for the green area.
(b) A virtual printing woodblock for the yellow area. Ink on the block has gradation.
(c) A virtual printing woodblock for the black and glay area.
(d) A virtual Ukiyo-e printed after five printing operations.

Figure 7: *Carving virtual woodblocks and printing a virtual Ukiyo-e using same techniques of real Ukiyo-e creation.*

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