Japanese Traditional Printing “Ukiyo-e” in a Virtual Space

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Abstract. We present an interactive CG (Computer Graphics) design system based on virtual woodblock printing, with the stress on an aspect of a tool to enjoy creation in a virtual space. This system is a simulation of real woodblock printing: generating a woodblock, spreading inks on the woodblock, putting a paper sheet on the woodblock, and rubbing the paper sheet with a Japanese squeegee “BAREN” in a virtual space. Using several virtual woodblocks with virtual inks of different colors, a multicolor print like a Japanese traditional print “Ukiyo-e” can be created. The user can enjoy printing a virtual “Ukiyo-e” with techniques of real printing without special knowledge of CG in this system.

1. Introduction

Synthesizing non-photorealistic images such as a painting created by computers has recently attracted much attention in the field of computer graphics (CG), and many techniques have been studied in the recent years, such as for oil painting (MEIER, 1996), pen and ink illustration (WINKENBACH and SALESIN, 1996; DEUSSEN *et al.*, 2000), pencil drawing (SOUSA and BUCHANAN, 1999), and so on.

As a way of synthesizing non-photorealistic images with CG, the authors have developed an interactive designing system using virtual printing (MIZUNO *et al.*, 1999, 2000a). In virtual printing, an image is synthesized by using “woodblocks”, “a paper sheet”, “inks”, and “a Japanese squeegee: BAREN” in a virtual space similar to real printing. A multicolor print like a Japanese traditional print “Ukiyo-e” is created with several virtual woodblocks and virtual inks.

There are two basic strategies to synthesize non-photorealistic images with CG: appearance based rendering and physics-based rendering. The virtual printing is a kind of physics-based rendering: it simulates the physical actions of printing in the real world. The user can print a virtual “Ukiyo-e” with the same techniques of real printing without special knowledge of CG. As a result, the created image also looks like a real “Ukiyo-e”.

2. Overview of Virtual Printing

A virtual woodblock print is created from printing woodblocks, a paper sheet, a “BAREN” (used like a squeegee in printing a silk screen) and inks prepared in a virtual 3D space. Figure 1 shows the outline and the structure of virtual printing.

A virtual woodblock is generated by interactive operations of a virtual sculpting system (MIZUNO *et al.*, 1999). The user of this system carves a virtual board with virtual chisels to create a virtual woodblock. The user can generate a virtual woodblock as if sculpting it in the real world. A woodblock is also generated automatically by the system, which is carved based on draft images or computer aided carving (MIZUNO *et al.*, 2000b). The shapes of the chisels are ellipsoidal, cubic or cylindrical. The surface of the virtual woodblock is similar to a real woodblock. Then the virtual ink is spread on the woodblock. A virtual paper sheet is expressed as a set of 2D lattice points, which is put on the virtual woodblock. Each lattice point can move only perpendicularly to the woodblock. The distance of this motion is controlled by the operation of a virtual “BAREN” with a mouse device.

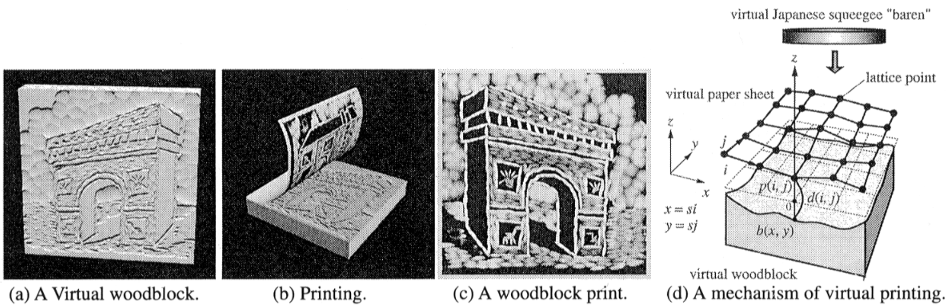
The darkness of the image is decided at each lattice point based on the distance of the paper sheet from the woodblock and properties of virtual ink. The distance expresses the pressure of the virtual “BAREN”. The more times, the user rubs the virtual paper sheet with the virtual “BAREN”, the closer the paper sheet approaches the virtual woodblock producing the thicker image.

Therefore, the operation of the virtual printing system is quite similar to real one. The system is usable for anyone without special knowledge about computers or graphics like children (Fig. 2).

3. Process of Virtual Printing

3.1. Outline of “Ukiyo-e”

“Ukiyo-e” is Japanese traditional multicolor printing (ULAK, 1995; SATO, 1999). It is created by using some woodblocks with inks of different colors. Each woodblock is pressed



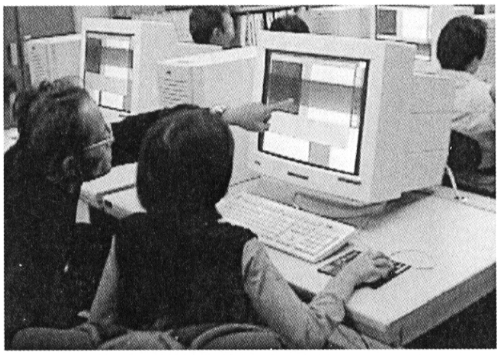
(a) A Virtual woodblock. (b) Printing. (c) A woodblock print. (d) A mechanism of virtual printing.

Fig. 1. Overview of virtual printing.

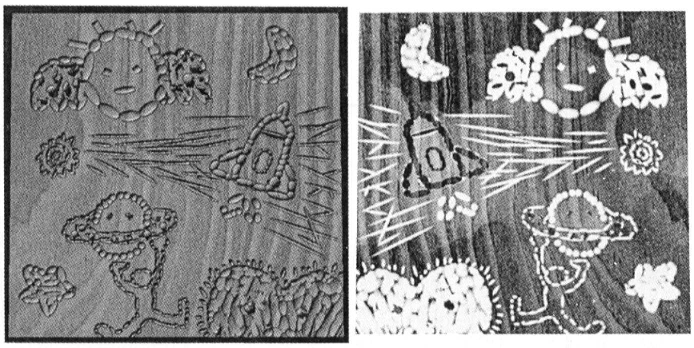
on the same paper sheet in succession and a multicolor print “Ukiyo-e” is completed. Figure 3 shows real one of the most famous “Ukiyo-e” created by Katsushika Hokusai in the 19th century. This kind of color gradations is often seen in “Ukiyo-e”. They are achieved at the printing stage by careful manipulation of the amount of ink applied to the woodblock and varying the hand-applied pressure. The surface roughness like the grain of the woodblock is sometimes used to give tonal variation in the print. Simulation of these real processes in woodblock printing is necessary for those representations.

3.2. Precise of virtual printing

In virtual printing, the user can create a virtual “Ukiyo-e” print in the same way as in the real case. The user carves virtual boards with virtual chisels to generate virtual woodblocks for each color. Applying a draft color image, the system also carves woodblocks for each color automatically (MIZUNO *et al.*, 2000b).



(a) Operating system with a mouse.



(b) A virtual woodblock and a print she created.

Fig. 2. Virtual printing by a girl (10 years old).

Fig. 3. “Clear Day with a Southern Breeze”, from the series Thirty-six Views of Mt. Fuji, created by Katsushika Hokusai in 1831–34.

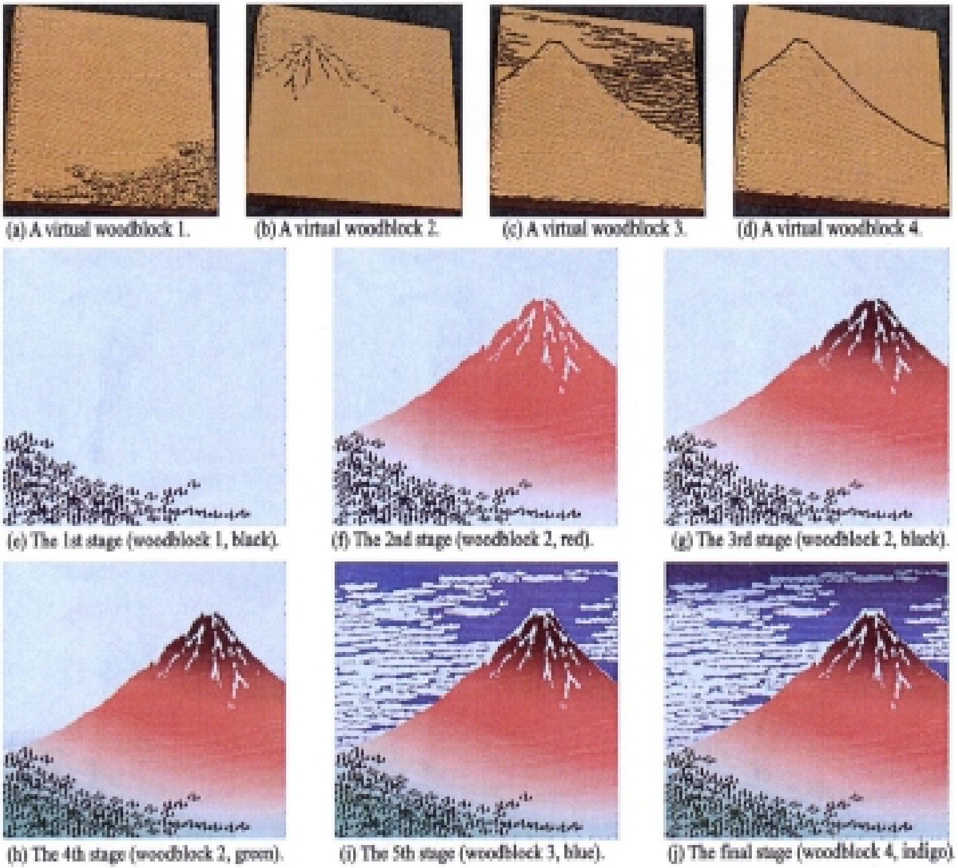


Fig. 4. Reproducing a Japanese print Ukiyo-e by virtual printing.

In multicolor printing, images from other woodblocks sometimes overlap each other. The former image is seen through the images printed after, which gives a special effect often seen in Japanese traditional prints "Ukiyo-e". In virtual printing, the virtual ink consists of two elements to decide its properties: a color and a degree of moisture. The degree of moisture controls the degree of transparency of the virtual ink. It is possible to change the ink on the same virtual woodblock.

In the previous study by the authors, we mixed virtual inks in a simple way in overlapped printing. So that the color of a print becomes opaque when the distance d from the paper sheet to the woodblock is small, or a moisture degree w of virtual ink is low. However, it was not based on any responsible physical phenomenon, and it was difficult to create gradations of transparency as are seen in "Ukiyo-e".

In this paper, we assumed the following new function f_{col} to calculate the color of the paper sheet at each point based on experimental results on real printing (MIZUNO *et al.*, 2001):

$$f_{col} = kI_{col} + (1 - k)P_{col},$$

$$k = w^2\{(d/t_d)^2 - 1\} - (d/t_d)^2 + 1, \quad (0 \le w \le 1,\ 0 \le d \le t_d),$$

where k is the degree of transparency, I_{col}, P_{col} are the color of the printing ink and the former color of the paper sheet, and t_d is the distance of the woodblock at the beginning of printing. With this printing model, the user can control the degree of transparency by changing virtual inks or the operation of the virtual "BAREN" to produce special effects such as gradation printing. This procedure is similar to the one of real "Ukiyo-e" printing.

4. Experiments

Figure 4 shows results of an attempt to reproduce the "Ukiyo-e" shown in Fig. 3 with virtual printing. Figures 4(a), (b), (c) and (d) are virtual woodblocks. They were generated in the computer-aided carving method (MIZUNO *et al.*, 2000b) by using an "Ukiyo-e" (Fig. 3) as a draft image, thus they are not necessarily the same at all with real woodblocks for the draft print. In the present printing model, it is possible to generate gradations in transparency by changing the degree of moisture of virtual ink and by "BAREN" operations (Figs. 4(f), (g), (h) and (j)). The reproduced image looks very much like the original image. It can even be asserted that the virtual printing is useful for creation of Japanese traditional prints. Figure 5 shows other examples of reproducing of "Ukiyo-e" by virtual printing. Mixing of ink and gradations of transparency and color has enough quality for reproducing "Ukiyo-e". However, it is difficult for the present computer-aided carving method to generate correct virtual woodblocks for original "Ukiyo-e" as seen from comparison of details of the printed image and real one.

5. Conclusion

In this paper, we showed an interactive designing system based on virtual multicolor printing. This system simulates operations and phenomenon of real printing process, so that

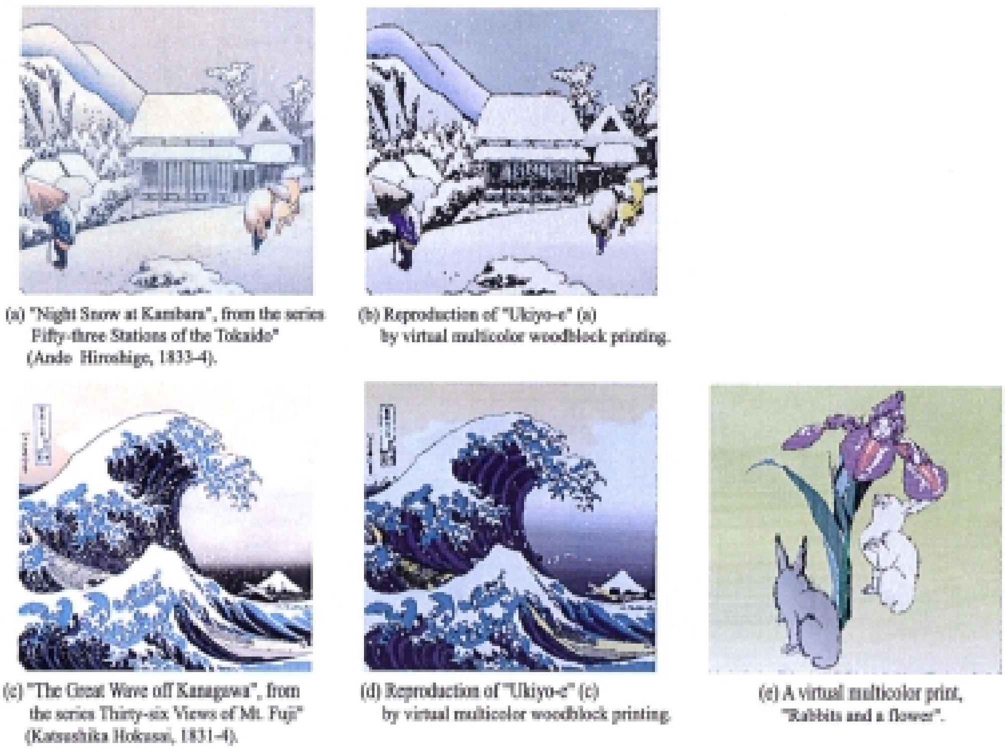


Fig. 5. Examples of reproducing Ukiyo-e.

the user can create a virtual "Ukiyo-e" as if printing it in the real world. The physics-based printing in this model enables the user to follow the special techniques of "Ukiyo-e" such as gradation of color and transparency created in the printing stage through manipulation of virtual woodblocks and virtual squeegee.

In the future we are going to express a variety of properties in printing according to the quality of the materials such as the woodblock and the paper sheet by modeling them in virtual space. Furthermore, we are going to preserve woodblocks of old Japanese "Ukiyo-e" in a virtual space with electronic technique founded on the virtual printing. In that trial, it is necessary to develop a method to generate accurate virtual woodblocks from an original "Ukiyo-e".

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