TransPen & MimeoPad: A Playful Interface for Transferring a Graphic Image to Paper by Digital Rubbing

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1. Introduction

Frottage and rubbing are drawing techniques that allow interesting visual expression through simple rubbing actions revealing a texture or a pattern hidden in the background. Specifically, frottage is a drawing technique where one puts a textured surface, such as wooden planks, metal sheets, wire nets, and hemp cloth, under a sheet of paper and rubs over it with a charcoal or a colored pencil to make appear various strange images [Simpson 1989]. Frottage has been loved by many artists since it enables them to add incidental textured effects to an intentional drawing (Fig. 1(a)). With rubbing, on the other hand, one transfers a carved image by putting a sheet of paper on an object with a carved pattern and rubbing on it with a pencil, a charcoal, or a colored pencil. Putting a piece of paper over a coin and then rubbing over it with a pencil to copy the image of the coin can be regarded as a type of rubbing (Fig. 1(b)). This activity is done for visual amusement itself or for a primitive means of copying graphic information.

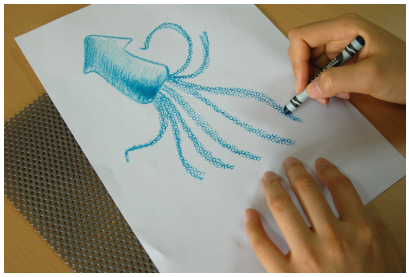
Frottage and rubbing both are a method of visual expression that uses a simple rubbing action to copy a texture from a surface. While these methods are distinguished, depending whether the texture on the surface is a textual pattern or a certain form, transcription of a pattern and a form both provides an interesting method for drawing. One can make partial drawings by copying a pattern or a form, and then make up a finished work by arranging the partial drawings into a composition. The playful attribute of these drawing methods is due to the simple action of rubbing, which allows complex images and patterns to appear. Moreover, different hand gestures can express different feelings.

What enables frottage and rubbing is a physical pattern on a physical surface; people copy graphic information carved in a physical surface by rubbing on it with tools like a pencil. Our question then is "Are frottage and rubbing only possible with physical engravings?" "Can we copy an image on a PC screen by placing a sheet of paper on it and rubbing over it with a pencil?" This question led us to propose *digital rubbing*, a new drawing method of copying a digital image straight onto a sheet of paper in the same way as in frottage and rubbing.

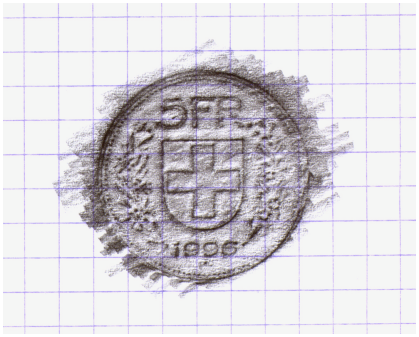
2. Digital rubbing

Ho [1998] and Neustetter [2005] have presented works under the title digital frottage. Ho used a three-axis milling machine and a plotter to engrave fractal lines into maple wood, and then put a piece of paper on it to copy the textured pattern with graphite lead. In other words, a digital image was transformed into a physical object, which in turn is transferred to paper with the traditional method of frottage. Neustetter used a method similar to screen capture followed by the surrealist process of frottage, "got away," thereby completing a work in two stages. First, he scanned animations and abstract icons on his computer screen. Then he used a monitor displaying the scanned images as an enlarger in the darkroom, and placed photo emulsion paper on it to print the image onto printing paper.

The digital rubbing technique proposed in this research is different from the methods stated above. Digital rubbing in this research has almost an identical process of completing a drawing as the traditional frottage method of the surrealists'. One can simply place paper on top of an image to copy, and then rubs the paper with a pencil. The biggest difference between the traditional method and digital rubbing, as illustrated in Figure 2, is that with digital rubbing you can copy a pattern or an image without a physical pattern. Instead, you place a sheet of paper on the surface where a two-dimensional digital image is stored and rub on it to

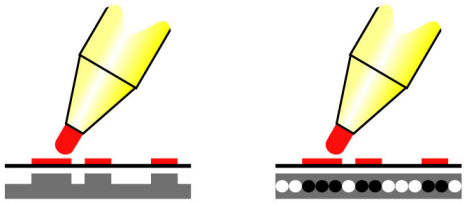


(a)



(b)

Figure 1: (a) Drawing by a frottage technique. (b) Drawing by a rubbing technique.



(a) (b)

Figure 2: (a) Traditional frottage. (b) Digital rubbing.

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copy the image.

3. TransPen and MimeoPad

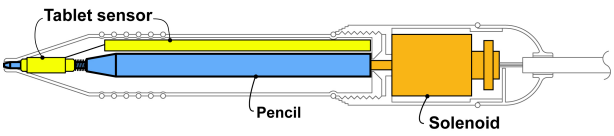
To realize digital rubbing, we designed TransPen and MimeoPad. TransPen, just as the name implies, is a pen that copies an image onto paper, and MimeoPad is a flat object that stores a digital image to be copied. MimeoPad detects the location of TransPen and sends appropriate signals to TransPen to print the image. TransPen is a tool that receives signals from MimeoPad to print an image on paper. MimeoPad should be able to detect the location of TransPen as it can detect that of a tablet stylus. At the same time, TransPen should be able to print on paper while held in the hand like an ordinary writing tool. It can be regarded as a type of hand-held plotter.

Devices similar to TransPen exist, such as the HapticPen [Lee et al. 2004], the PrintBrush™ [PrintDreams 2005] and PixelRoller [rAndom International 2005]. The Haptic Pen is an interesting device that gives tactile feedback by using a solenoid when operating on a stylus-based touch-screen display. TransPen has similar form factors to the HapticPen but is different in that it is a drawing device. PrintBrush™ is an incredibly innovative product, which you can hold in your hand and print onto paper directly. It is similar to TransPen in the way of printing on paper with a handheld device, but is different in that TransPen prints a graphic image depending on its coordinates. PixelRoller is a paint roller that paints pixels, designed as a rapid-response printing tool specifically to print digital information such as imagery or text onto a great range of surfaces. The biggest difference of TransPen from other similar devices is that it interacts with MimeoPad and is aware of its location, which is the unique attribute of TransPen that makes digital rubbing possible.

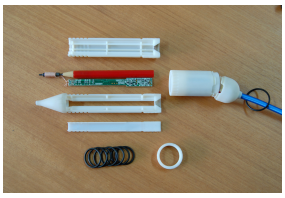
4. Implementation

4.1. TransPen

TransPen consists of a tracker circuit, a mechanical drive, and a pencil. The tracker circuit is for tracking the location of the pen, and the mechanical drive is for converting image information to the linear motion of the pencil. The tracker circuit (tuning circuit) was taken from a tablet stylus (Wacom Intuos 3), and the mechanical drive is a small solenoid available off the shelf. The pencil is a mechanical one that can maintain the pencil tip at a constant length automatically (Fig. 3(b)). TransPen, in response to a signal from MimeoPad, actuates the solenoid, which in turn moves the pen back and forth to produce an image (Fig. 3(a)).



(a)



(b)

(c)

Figure 3: (a) Structure of TransPen. (b) Components of TransPen. (c) MimeoPad.

4.2 MimeoPad

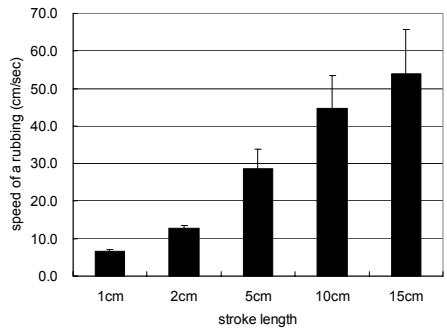
The MimeoPad consists of a tablet, an RFID reader, an interface board, and a PC. When a drawing board with an RFID tag is placed on MimeoPad, the RFID reader recognizes the tag ID and the PC loads a corresponding pattern or an image for digital rubbing. A user places a sheet of paper on the drawing board and rubs with TransPen. The embedded tablet detects the location of the pen and sends corresponding signals to the pen (Fig. 3(c)).

4.3 Compensating the system delay of TransPen and MimeoPad

When the TransPen and MimeoPad was first built and tried out to copy an image, severe discordance was observed between the copy and the target image (Fig. 4(a)). The main cause seemed to be the system delay between the detection of the position and the actuation of the pen. To quantify the problem, we measured the speed of rubbing movements for different stroke lengths by an experiment with 10 university students (Fig. 4(c)). For short strokes of around 1~2cm (for a detailed part of a drawing), it was about 10cm/sec on average. However, for long strokes of around 10~15cm (drawing in a large area), it turned out to be unexpectedly high: around 50cm/sec on average.

The built-in tablet in the MimeoPad detects the locations of the TransPen at the speed of approximately 100 pps (points per second). Every time the system measures the location of TransPen, the hand can move as much as 5mm. In addition to the possible time delay by the tablet, the system requires time for reading an event from the tablet, processing graphic image data, and actuating the solenoid. The inertia of the mechanical structure of the pen is

(a) (b)



(c)

Figure 4: (a) Pencil traces before system delay compensation. (b) Pencil traces after system delay compensation. (c) Analysis of rubbing speed.

also a significant factor in the total system delay. The resultant system delay caused the discordance in the drawing shown in Figure 4(a).

A basic dead-reckoning technique was used in order to overcome the system delay problem [Gutwin et al. 2000]. Because rubbing is a regular and periodic movement, it is possible to predict the location of TransPen for a short amount of time. Using the algorithm shown below, we could take the system delay (Td) into account to predict the coordinates (X, Y) of the pixel to print out given the current location of the pen (X_0, Y_0). The velocity and the acceleration of the pen were estimated using the last three location samples.

```
X = X0 + Velocity_X * Td
     + 0.5 * Acceleration_X * Td * Td
Y = Y0 + Velocity_Y * Td
     + 0.5 * Acceleration_Y * Td * Td
if (Image(X,Y) = 0) then
       Solenoid_Output(0)
else if (Image(X,Y) = 1) then
       Solenoid_Output(1)
end if
```

5. Various Methods of Digital Rubbing

5.1 Digital rubbing using MimeoPad

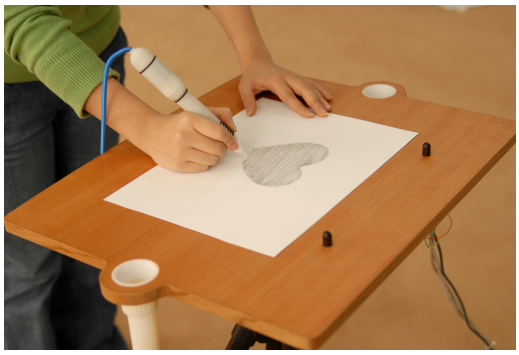
MimeoPad is a drawing board with a built-in tablet. If you put a paperboard with an image printed on it, cover the board with a sheet of paper, and rub it with TransPen as shown in Figure 5(a) just as in the traditional method of rubbing, you can obtain a physical copy (Fig. 5(d)) of a digital image stored in MimeoPad (Fig. 5(b)). Similarly, if you place a film with a textural pattern (Fig. 5(c)) on MimeoPad, and make a sketch on it, you can produce the same effect as in the traditional frottage (Fig. 5(e)).

Most young children draw random scribbles to learn how to express themselves visually. Since TransPen can provide them with a stimulating drawing experience even through random rubbing actions, it can be a helpful educational tool to evoke their interests in drawing.

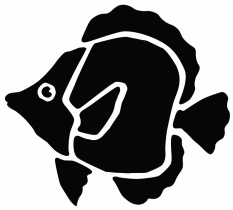
5.2 Digitally physical image transfer using a tablet monitor or a tablet PC

It is possible to copy an image drawn and edited on a tablet monitor or a tablet PC with TransPen by placing the paper on the screen and going over it physically. Going one-step further, as Neustetter [2005] mentioned, one can perform digitally physical image transfer using TransPen. First, one places an image on the tablet, and copy the image onto the screen using TransPen (Fig. 6(a)-(b)). Next, on a clean piece of paper, one can paste the drawing on the monitor back to paper (Fig. 6(c)-(d)). During this process, an artist alternates between the physical real world and the virtual computing world, copying images and adding ideas to create a new piece of work. Using TransPen with a tablet monitor or a tablet PC, one can perform the action of copy-and-paste of real images easily in the physical world.

A tablet PC, which is now popular, also has a built-in tablet. It can be used in place of MimeoPad to make it possible to create a digital rubbing using TransPen. One can draw on a tablet PC, place a sheet of paper on top of it, and use TransPen to copy various images and texts on the screen back to physical paper. We anticipate that TransPen as an output device may create a new style of human-computer interaction, different from the usual one with a tabletop printer.



(a)



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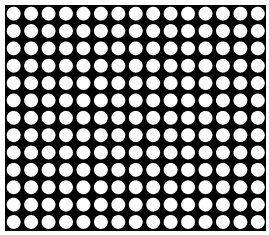
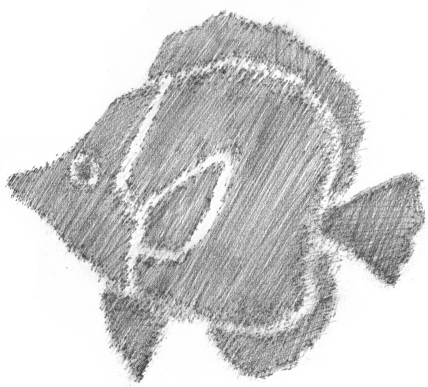
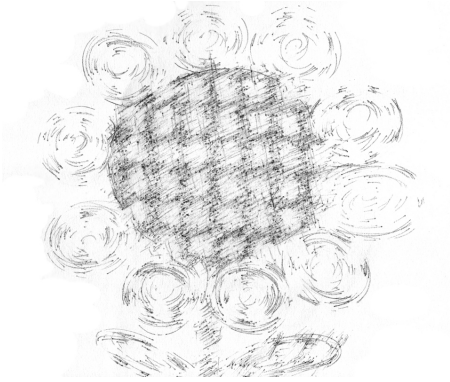


(c)



(d)

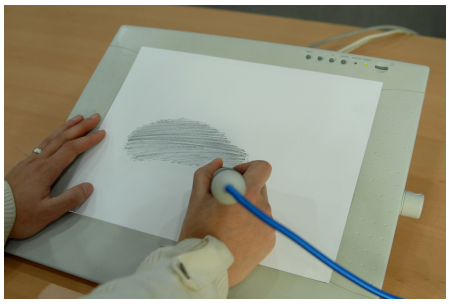


(e)

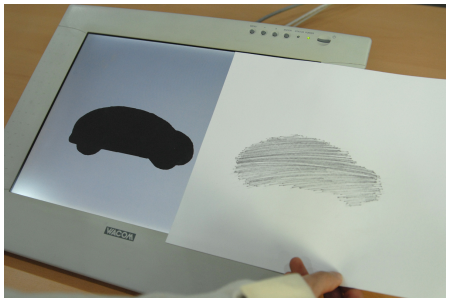
Figure 5: (a) Digital rubbing using TransPen and MimeoPad. (b) Original graphic image of a fish. (c) Circle array pattern. (d) Transferred image of the fish on paper through a simple rubbing technique. (e) Drawing of sunflower by a frottage technique on the circle array pattern.

(a)

(b)



(c)



(d)

Figure 6: (a)-(b) Copying a drawing to the screen with TransPen. (c)-(d) Copying an image on the screen back to paper with TransPen.

6. Conclusion

The components and the working mechanism behind TransPen and MimeoPad proposed in this research are not very new except that TransPen is a special stylus with a hand-held plotter. However, this small difference has made digital rubbing possible, and enabled a different approach to the act of drawing. As is the case with the traditional methods of frottage and rubbing, we could observe that people were strangely amused while using the technique, which is in-between drawing and copying. We expected that TransPen and MimeoPad would be useful in arts and design as a new medium of expression in the process of drawing and editing ideas. In addition, we expect that it have the full potential to become a drawing toy for children.

The current prototype, especially its hardware, requires a lot of technical improvement. The problem of the system delay was treated with a dead reckoning method in the current prototype, but it should have been avoided as much as possible in the design of the hardware, e.g., by using a low-latency data channel and a low-inertial mechanical drive. In addition, a more accurate and rugged printing tip than a mechanical pencil, a smaller form factor of the pen, and a wireless connection between TransPen and MimeoPad are desired in order to extend the application scope of TransPen and MimeoPad.

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