Oriental Brush Simulation using 3 Dimensional Action

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ABSTRACT
Calligraphy is an art of beautiful handwriting seen widely in Oriental countries. The principle tool for oriental calligraphers is the oriental brush which has characteristics different from a pen. The purpose of this paper is to realize a simulation of the expressive oriental brush with a pen tablet and a web camera. Especially we have focused on the effects of the pressure that the calligrapher gives to the oriental brush. The information from the tablet such as the xy-coordinates, pressure, altitude, and azimuth of the pen can be utilized to simulate the oriental brush. However the pen pressure values obtained from the pen tablet are not suitable for an elaborate simulation of the oriental brush in that the calligrapher cannot closely control the pressure. In our system, the calligrapher uses a device brush, i.e., a device pen with attached hairs, as a substitute for the oriental brush. The system measures the z-coordinate of the brush, i.e., the height from the surface of the tablet to the center of gravity of the brush bristles, by using a web camera and utilizes it as a parameter for the brush pressure. The aerial movements of the brush are reflected to the various aspects such as the shape and size of the droplet, ink consumption, ink diffusion, and ink scratchiness, which enables users to write calligraphy with the device brush with a feeling that they use a real oriental brush and to make more delicate expressions.

CCS Concepts
• Human-centered computing → Graphics input devices; User interface programming; • Computing methodologies → Image processing;

Keywords
Oriental Brush; Calligraphy; Pen Tablet

1. INTRODUCTION
In Oriental countries, there is a culture called "Calligraphy". In Calligraphy, people write characters on the paper with an oriental brush and ink mainly, which is considered as an oriental art to express the beauty of the characters. In Japan, the calligraphy is an important culture that is learned and practiced today. Therefore, many systems for the calligraphy simulation are developed. There are simulation systems using a pen tablet among them. The device pen of the pen tablet is used as a substitute of the oriental brush, but it is a pen type device.

The oriental brush has characteristics different from the pen. The pen such as a pencil, a ballpoint pen and a fountain pen is a writing tool whose tip is hard, while the oriental brush is a writing tool whose tip is a soft bundle of hairs. Therefore the pressure of the oriental brush is different from the pressure of the pen. The pen pressure is the power that the writer gives to paper through a pen. Because the head of the pen is hard, the pressure of the pen base and that of the pen tip are the same as shown in Figure 1. However, because the head of the oriental brush is soft, the pressure of the brush base and that of the brush tip are different as illustrated in Figure 2. Therefore the pressure of the oriental brush should be treated in the light of that point.

One of the aims of our research is to realize a simulation system where users write calligraphy with a feeling that they use a real oriental brush even though they write it with a device pen on a pen tablet in fact. The information necessary to the simulation, such as the xy-coordinates, pressure, altitude, and azimuth of the pen is basically acquired from the tablet. We can get the xy-coordinates of the pen close to the tablet even when the pen does not touch the surface of it. However the pen pressure values obtained from the tablet are not suitable for an elaborate simulation of the oriental brush in that the calligrapher cannot closely control the pressure. In our system, the calligrapher uses the device pen with the attached hair as a substitute for the oriental brush. We call it device brush. The system measures the z-coordinate of the device brush, by using a web camera and utilizes it as a parameter for the brush pressure.

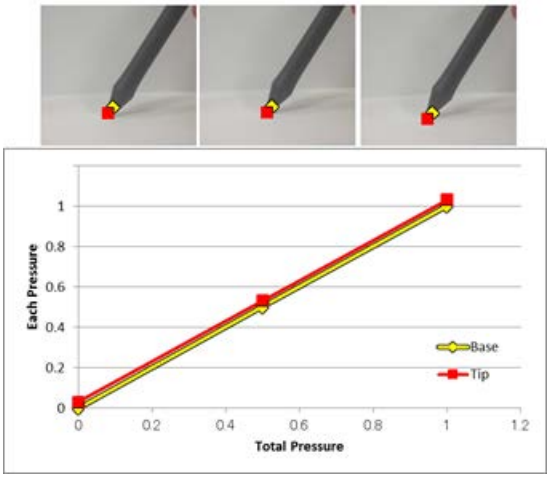

Figure 1. Pressure of the pen

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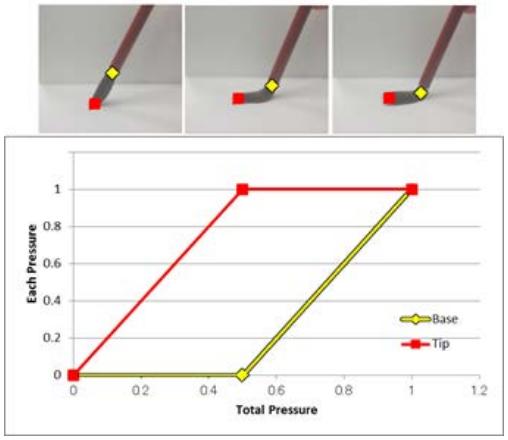

Figure 2. Pressure of the oriental brush

The remainder of this paper is organized as follows. Section 2 describes the related works briefly. Some details of the proposed simulation system are presented in Section 3. After discussing the experimental results in Section 4, we conclude in Section 5.

2. REVIEW OF PAST STUDIES

There have been various studies on the oriental brush. In [1, 2, 3], the calligraphy papers were researched. The shape change of the head of an oriental brush was researched [4, 5, 6] and the shape of the head of the oriental brush was expressed as a droplet model. The brush ahead rotation was researched [7] and the scratchiness was expressed in connection with the model of the head of the oriental brush [7]. The scratchiness and the diffusion were expressed by ink [8]. The studies allow the simulation systems to enable the calligrapher to nobly express the scratchiness and the diffusion occurred when using the oriental brush. However, they did not carefully consider the z-coordinate of the brush enough to lead the calligrapher to feel so real and to give more granular control over the brushing effects when writing calligraphy. In our research, the z-coordinate of the oriental brush is measured as a parameter of the brush pressure.

3. BRUSH WRITING SYSTEM

The main purpose of our research is to realize a simulation of the oriental brush in consideration of the real time brush pressure that calligraphers can maintain fine grained control over. In our simulation system, a pen tablet is used as a calligraphy paper and a device brush as an oriental brush. The xy-coordinates, pressure, azimuth, and altitude of the device pen are obtained from the pen tablet (WACOM Intuos4 PTK-640). The z-coordinate of the device brush is extracted from the image given by a web camera (Logicool TV Cam for Skype).

3.1 Z-Coordinate

Our droplet model decides the shape and size of each droplet to be drawn on the paper by reflecting the brush pressure, which is calculated as a value in the range of 0 to 1 from the pen pressure and the z-coordinate of the device brush. The former is given by the tablet and the latter is calculated as a result of the analysis of the image obtained from the web camera. The z-coordinate of the device brush is conceptually the height from the surface of the tablet to the center of gravity of the bristles of the device brush.

The tablet used in our study can recognize its device pen over it if the pen is within a certain height. Moreover, we can get the xy-coordinates of the pen tip from the tablet even though it does not touch the surface of the tablet. We call such area over the surface of the tablet pen detection area. By tracking the real time three dimensional movements of the pen tip with attached hairs in the area, our system enables the users to write calligraphy on the tablet with a feeling that they do it with a real oriental brush on the paper and to make more delicate expressions.

The roots of the hairs of the device brush are attached around the tip of the device pen and the length of them is less than the height of the pen detection area. Therefore the xy-coordinates of the device brush can be obtained from the tablet while the user writes calligraphy because the pen tip is in the detection area provided that the tip of the device brush tip, i.e., the point where all the ends of the attached hairs meet, touches the surface of the tablet.

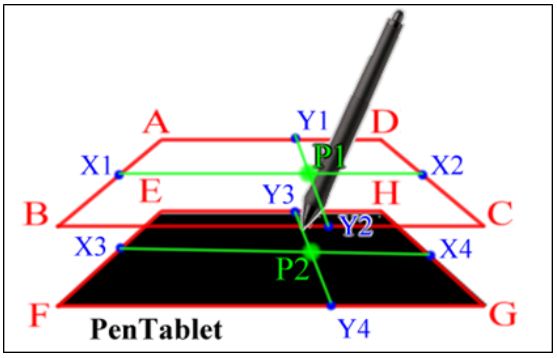

Figure. 3 Device brush in the acquired image

Our system calculates the z-coordinate of the device brush as follows. First, the dynamic objects in the image from the web camera are detected through background subtraction. If the hand of the user is detected as a dynamic object, it is filtered out. Second, the system locates the base points in the image that are necessary to calculate the z-coordinate of the device brush in the light of its depth. The parallel planes ABCD and EFGH shown in Figure 3 are two planes that the pen detection area is defined as the area between. The xy-coordinates of the points A through H in the image are initialized at the time of the simulation setup. Both the point P_1 on the plane ABCD and the point P_2 on the plane EFGH are on the same line perpendicular to the planes where the pen tip lies. The system uses the points P_1 and P_2 as the base points described above because they have the same depth as the device brush in the image. The point P_1 is the intersection of the lines X_1X_2 and Y_1Y_2 and the point P_2 is that of the lines X_3X_4 and Y_3Y_4. So the xy-coordinates of the points P_1 and P_2 can be calculated if the xy-coordinates of the points X_1 through X_4 and Y_1 through Y_4 are found. By using the xy-coordinates of the device brush acquired from the tablet and Equations 1 and 2, we can get the xy-coordinates of the point X_1.

$$X_1(x) = \big(B(x) - A(x)\big) * \left(\frac{INPUT(x)}{MAX(x)}\right) + A(x) \qquad (1)$$

$$X_1(y) = \big(B(y) - A(y)\big) * \left(\frac{INPUT(y)}{MAX(y)}\right) + A(y) \qquad (2)$$

Here, *INPUT(x)* and *INPUT(y)* are the x and y coordinates of the device brush acquired from the tablet respectively. *MAX(x)* is the

maximum x-coordinate of the tablet and *MAX(y)* is the maximum y-coordinate of the tablet. The xy-coordinates of the points X_2, X_3, X_4, Y_1, Y_2, Y_3, and Y_4 can be calculated the same way as the point X_1.

Finally, the z-coordinate of the device brush is calculated by Equation 3 where *G(y)* is the center of gravity of the bristles of the device brush.

$$Z = \frac{(G(y) - P_1(y))}{(P_2(y) - P_1(y))} \qquad (3)$$

3.2 Droplet model

To simulate oriental calligraphy, it is necessary to express the footprints of the oriental brush based on the data acquired from the pen tablet and the web camera. The footprints can be defined with the xyz-coordinates, pressure, altitude, and azimuth of the device brush. We model the oriental brush based on a droplet model. The droplet model basically defines the shapes and sizes of the droplets of the oriental brush that is drawn on the paper when the user put the brush on one point of the tablet. In the droplet model, the shape and size of the droplet are decided by the pen pressure, z-coordinate, and pen altitude. The calligraphers can rotate the droplet and change its size by controlling the direction, pressure, and z-coordinate of the device brush. And they can draw a stroke by moving the device brush. The stroke is expressed by drawing the droplets in succession according to the movement direction of the device brush.

3.3 Ink Color and Ink Tank

In our system, each droplet is colored gray. The level of the gray is decided by the density of ink and the amount of water that the brush takes and somewhat influenced by a random factor for the realistic simulation. The gray levels of the parts of a droplet may be different from each other, e.g. when the ink scratchiness occurs or when the effects of light and shade are expressed.

The oriental brush takes some amount of ink, which corresponds to the value of ink tank in the system. The value of ink tank is initialized by the density of ink and the amount of water and decreased whenever a droplet is drawn. The decrement rate of the value of the ink tank is not constant. It changes depending on the size of the droplet drawn.

3.4 Diffusion and Scratchiness

When the calligrapher writes calligraphy, the ink spreads on the paper. Such phenomenon is called ink diffusion. It occurs mainly when droplets are drawn with the oriental brush containing a large amount of ink. We extend the ink diffusion droplet model. As a main factor for determining the range of ink diffusion, the size of the regular hexagon changes with the pen pressure and z-coordinate of the device brush, and the amount of the water.

Another phenomenon occurred in calligraphy is ink scratchiness. When it occurs, the locations where remarkable decreases of ink smeared into the paper can be observed in a stroke. The phenomena are caused by the fast writing speed or the little amount of ink held in the oriental brush. Our droplet model basically determines the shape and size of each droplet to be drawn and the initial amount of the ink. Then, the amount of the ink was conceptually managed point by point. We have designed the system to randomly go into the state where the amount of the ink held in some randomly selected points decreases remarkably, which makes the ink scratchiness occur naturally.

Both the density of ink and the amount of water are in the range of 1 to 10 in our system. While little scratchiness and much diffusion are expressed when the density of ink is 1 and the amount of water is 10, much scratchiness and little scratchiness are expressed when the density and the amount are 10 and 1 respectively, When both the ink density and the water amount are 5, the diffusion and scratchiness are occurred occasionally. Such things occur the same way that they do in the real calligraphy

4. EXPERIMENTAL RESULT AND DISCUSSION

The pen tablet users have difficulty in maintaining the fine-grained control over the pen pressure. Practically the users are able to maintain only several levels of the brush pressure as desired. So the simulation systems using only the pen pressure acquired from the tablet as the factor of brush pressure cannot effectively support for delicate expressions by the brush pressure control. Our system enables the users to write calligraphy with changing naturally and easily the level of the brush pressure by reflecting the z-coordinate of the device brush. Figure 4 shows the comparison of two characters written by a calligrapher. The left one was written when the z-coordinate of the brush is reflected in simulation and the right one when not reflected. We can find that the strokes of the left one is much more delicate than those of the right one.

The width of the z-coordinate level corresponds to the number of pixels from the surface of the tablet to the root of the brush bristles in the image from the web camera. The higher resolution the web camera used has, the more pixels that part of the image has. In the case of the web camera used in our experiments, the width is in the range of 46 to 50. The reason why it is not constant is that the number of pixels changes according to the depth of the device brush in the image.

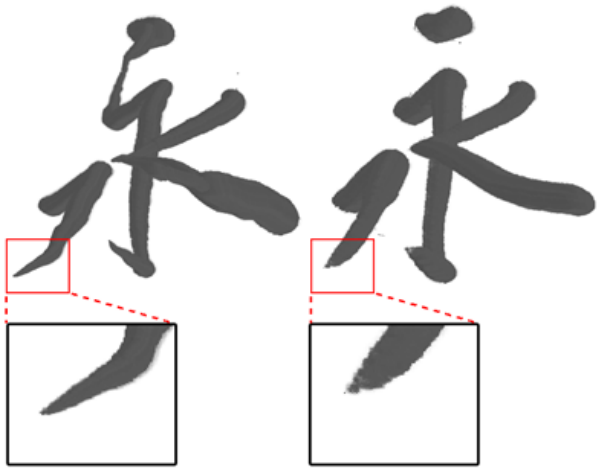

Figure 4. Left: calligraphy with z-coordinate, Right: calligraphy without z-coordinate

Figures 5 and 6 show some results of the brush simulation. We can see a result of ink wash painting in Figure 5 where the effects of the ink diffusion are observed here and there in the picture. Figure 6 shows the effects of the ink scratchiness in calligraphy.

Figure 5 Ink diffusion in an ink wash painting simulation

Figure 6. Ink scratchiness in a calligraphy simulation

5. CONCLUSIONS AND FUTURE WORK

In this research, we propose how to realize a more realistic simulation of an oriental brush with a pen tablet and a web camera. As a substitute of the oriental brush, we use a device brush that has hairs attached around the tip of the device pen as the oriental brush has hairs attached to the base of its handle. Our system enables the users to write calligraphy with changing naturally and easily the level of the brush pressure that reflects the pen pressure from the tablet and the z-coordinate of the device brush. We calculate the z-coordinate of the device brush based on the xy-coordinates of the device pen from the tablet and the image from the web camera. The aerial movements of the device brush are reflected to the various aspects such as the shape and size of the droplet, ink consumption, ink diffusion, and ink scratchiness, which enable users to write calligraphy with the device brush with a feeling that they use a real oriental brush and to make more delicate expressions.

The studies on the expression of the effects of light and shade and the method for applying the proposed simulation system to the calligraphy education are our future works.

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