Interaction Technique Combining Gripping and Pen Pressures

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Abstract. We propose an interaction technique called "gripping" to improve the operation of input with pen-based interfaces. This operation involves a strong grip when holding a pen. It can provide new input operations while maintaining the usability of the pen because users can grip it without having to lift their fingers off it. There is an interaction technique called pen pressure that users can use without having to lift their fingers off the pen. We introduce a novel interaction technique that combines gripping and pen pressures. This combination enables users to simultaneously input new two values in addition to common pen interactions like those with tapping or stroking. By applying this technique to a paint tool, for instance, novel drawing operations become possible and artists can create new artworks. Two experiments were conducted to investigate whether users could perform an operation that combined gripping and pen pressures. As a result, they confirmed that combined interaction was possible and there was an optimal range of pressures that enabled combined interaction. We also implemented an application software for this combined interaction.

1 Introduction

Pens are one of the most familiar tools for creative activity because almost everyone has used them from an early age. Therefore, a pen-based interface, which is a pen-shaped device, would be more suitable for creative activities than devices only used for computers (like mice and keyboards). However, current pen-based interfaces have limited operability due to their lack of input operations. Therefore, we developed "gripping" [7], which is an interaction technique that can increase the number of input operations without users having to lose the usability of the pen. Gripping is an operation that involves a firm grip when holding a pen. It can maintain the usability of the pen because it maintains the pen idiom, which simply means that the pen is being physically gripped.

There is an interaction technique called pen pressure that users can use without having to lift their fingers off the pen. This pen pressure is used in commercial software and is useful for our pen-based interface. We considered combining gripping and pen pressure. This combination provides a pen-based interface with multi-stream input operations. That is, users can carry out common pen interactions like those in tapping or stroking while inputing two values simultaneously.

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Applying this technique to a paint tool would enable them to undertake novel drawing operations and would offer new perspectives for artwork.

However, it is not clear whether users can independently apply gripping and pen pressure, and combine both operations. We attempted to answer this question by conducting two experiments that concerned the relationship between gripping and pen pressure.

2 Related Work

There have been many researchers who have improved the operability of pen-based interfaces. Here, we review some studies that have dealt with multi-stream input operation by using these interfaces.

We previously developed [6] an interaction technique using hand motions in the air. We used three motions; rolling, shaking, and swinging. Bi et al. [1] also conducted research that used rolling interactions. These researchers succeeded in increasing the number of input operations while maintaining the usability of the pen. Miura et al. [2] developed an interaction technique in which the stylus was rotated and slid. Siio et al. [5] proposed an interaction technique using the metaphor of a paperweight. The status of the user's palm — whether it was touching the bottom of a PDA or not — determined how modes were switched. A tablet developed by Wacom could detect not only the coordinates of a pen but also the pressure and tilting applied to it. Some research[3], [4], [8] that has used pen pressure and tilting has been conducted.

These researchers aimed to increase the number of input operations of pen-based interfaces. This aspect is common to our research. We accomplished multi-stream input by using pen gripping, which is a crucial motion when using pen-based interfaces.

3 Combining Gripping and Pen Pressure

3.1 Basic Idea

Gripping [7] is an interaction technique, which we proposed for a pen-based interface, that utilizes essential motion when using a pen. Gripping is a simple and easy operation that involves a strong grip when a pen is held. Pen pressure, on the other hand, is a common interaction technique in pen-based interfaces. Humans can control pen pressure naturally when using a pen. For instance, they can control line strength by varying pen pressure. A common aspect of both interaction techniques is to apply them without having to lift onefs fingers off the pen. Therefore, we came up with the idea of combining gripping and pen pressure.

3.2 Advantages of Combining Gripping and Pen Pressures in Creative Activities

A pen-based interface has recently been used and found to be suitable for creative activities like painting. However, the only change in creative activities by using the pen-based interface is that the canvas has been changed from paper to an LCD screen. Because the functions of the pen-based interface are basically the same as those with a pen, the role of the pen does not essentially change. Thus, creative activities using the pen-based interface do not receive favors of using it.

By combining gripping and pen pressure, we can achieve multi-stream input and simultaneously control two parameters. In other words, pen-based interfaces provide new modality for inputs. For instance, this can be applied to line-drawing operations while simultaneously changing the widths and colors of lines. Therefore, this combined interaction technique would enable users to benefit from pen-based interfaces during their creative activities.

3.3 Implementation

We developed a pressure-sensitive (PS) stylus that could detect gripping pressure [7]. The PS stylus was equipped with three pressure sensors to detect three degrees of finger strength. We designed the PS stylus to detect gripping pressures from 30 to 500 g, which was the average for the three sensors. The PS stylus recognized gripping pressure in 1024 steps. An application could attain a value from 0 to 1023 (the higher the value, the greater the strength). The relation between the output value of the sensor and the actual pressure was not linear but logarithmic. Hence, we modified the logarithmic characteristics to be linear through software.

We used a tablet made by Wacom to detect pen pressure.

4 Experiment 1: Range of Gripping and Pen Pressures for Simultaneous Control

4.1 Purpose

The combination of gripping and pen pressures could provide a novel interaction style. However, humans cannot always simultaneously control gripping and pen pressure. For instance, although it is clear that we cannot exert strong pressure on the pen by using weak gripping pressure, we still need to find the maximum strength of pen pressure exerted by weak pen pressure. Thus, we did an experiment to investigate what range of gripping and pen pressures could be used to enable simultaneous control.

4.2 Participants and Apparatus

Six male volunteers whose ages ranged from 22–26 participated in the experiment. Five of them were right-handed and one of them was left-handed. All of them correctly grasped the pen with their two forefingers and thumb. We adjusted the positions of the sensors according to the length of their fingers and asked them to grip the PS stylus naturally. The participants could use the PS stylus without having to worry about the sensors because of this adjustment.

We used a pressure sensor, which was the same as the ones attached to the PS stylus, to measure the pen pressure. We measured the pen pressure by placing the sensor on a desk and getting the participants to press it with the tip of the PS stylus. We used a pen tablet to measure the pen pressure. However, it was difficult to analyze the relationship between gripping pressure and pen pressure because the sensing specifications of the pen tablet were not clear. We could match the sensing specifications by using a sensor that was the same as that attached to the PS stylus.

The participants in this experiment sat down on a chair and pressed the sensor on the desk by using the tip of the PS stylus. The experimental software was run on an Intel Core 2 Duo 3.16-GHz PC with Windows Vista.

4.3 Tasks and Measurements

We measured the maximum value of pen pressure exerted with minimum pen pressure. First, participants held the pen lightly. Measurement began when participants touched the tip of the pen onto the pressure sensor. They exerted slight gripping pressure and pressed the pen with maximum pressure. Then, they increased the pen pressure step by step until it reached the maximum value (1023). This experiment was used to find the strength of the range of gripping and pen pressures that humans could simultaneously control because gripping pressure intensifies depending on increasing pen pressure. Participants repeated this trial five times. We measured both the gripping and pen pressures in this experiment.

4.4 Results

Fig. 1 is a scatter diagram where all the measured values have been plotted. The X-axis represents the gripping pressure and the Y-axis represents the pen pressure. A–F represent the six participants.

The results from analyzing all the measured values revealed that the regression relationship between gripping and pen pressures was not linear but logarithmic ($R^2 = 0.754$). Participant F had a tendency to hold the pen with the strongest grip. The regression curve of participant F was expressed by $y = 168.4 \log x - 283.97$.

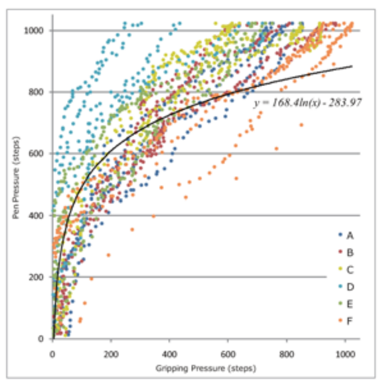


Fig. 1. Scatter diagram. X-axis represents gripping pressure and Y-axis represents pen pressure. A–F represent six participants.

4.5 Discussion

As participant F tended to hold the pen with the strongest grip, we decided to use the measured values to obtain the relation between gripping and pen pressures. When the gripping pressure was equivalent to x, the maximum value of pen pressure y could stand for $y = 168.4 \log x - 283.97$. Therefore, we found that it was possible for humans to simultaneously control gripping and pen pressures if the pressure range was $y >= 168.4 \log x - 283.97$.

We also found that there was a correlationship between gripping and pen pressures, which indicates that gripping can be an alternative to pen pressure. For instance, users can carry out continuous inputs like those with pen pressure when using devices that cannot detect pen pressure.

5 Experiment 2: Simultaneously Independent Control of Gripping and Pen Pressures

5.1 Purpose

We observed the relationship between gripping and pen pressures from the previous experiment and we could specify the pressure range that could be obtained. However, it was not clear whether humans could easily perform both operations simultaneously throughout all the available pressure range. We investigated what range could easily attain simultaneous control of gripping and pen pressures in this experiment.

5.2 Participants and Apparatus

The participants were nine volunteers (seven males and two females), who were 22–26 years old. Eight of them were right-handed and one of them was left-handed.

We used a pressure sensor that was the same as that attached to the PS stylus in Experiment 1 to measure the pen pressure. We measured the pen pressure by placing the sensor on a desk and getting participants to press it with the tip of the PS stylus.

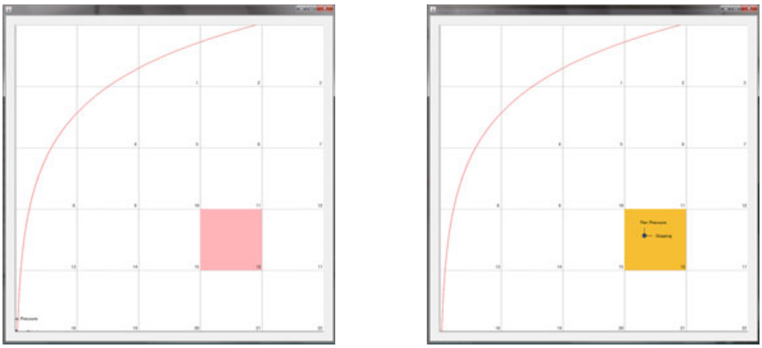
The participants in this experiment sat down on a chair and pressed the sensor on the desk by using the tip of the PS stylus. We used a 20-inch LCD with a resolution of 1280×1024 pixels. The experimental software was run on an Intel Core 2 Quad 2.83-GHz PC with Windows Vista.

5.3 Tasks

One task was where participants simultaneously controlled gripping and pen pressures and then selected a target.

A pressure map (Fig. 2) was presented to the participants, which represented the pressure range. The X-axis represented the gripping pressure and the Y-axis represented the pen pressure. A blue cursor represented the pressure exerted by a participant. The point of origin of the pressure map was the bottom left corner. The cursor was located on the point of origin when both the gripping and pen pressures were 0 (Fig. 2(a)). The pressure map was 800 × 800 pixels. There were 1024 steps of output for gripping and pen pressures that were mapped uniformly to 800 pixels. There were 25 rectangles because the horizontal and vertical lines on the pressure map were divided into five. That is, the pressure range was divided into 25 partial ranges. These rectangles were targets that the participants selected. The target rectangles were pink. When the cursor was inside the target, the target changed to orange. A red curve was plotted on the pressure map in experiment 2, which represented the relation between gripping and pen pressures that humans can simultaneously control.

We excluded three rectangles because rectangles outside the curve were difficult to select. Over half the area of the excluded rectangles were outside the curve. We assigned ID numbers from 1–22 to the rest of the rectangles in the left top corner. These IDs were used when displaying the results.



(a) Screenshot when cursor is located on point of origin.

(b) Screenhost when cursor is inside target.

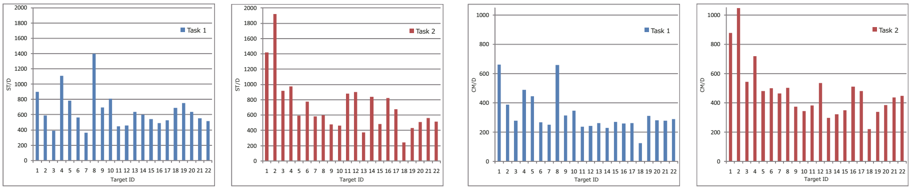
Fig. 2. Screenshot of pressure map. Cursor is blue circle and target is pink rectangle. Target changes to orange when cursor is inside target.

There were two kinds of tasks. The main difference was in the position of the cursor when the trial began. The initial position of the cursor in task 1 was the point of origin and the initial position in task 2 was the top right corner, i.e., where gripping and pen pressures had maximum values. When gripping and pen pressures were applied simultaneously, the initial strength of these two pressures was not always constant. Therefore, we prepared the two tasks to simulate the effects of the difference in initial pressures.

The nine participants started the experiment by moving the cursor to the initial point. Then, a target was presented and they moved the cursor to the target by exerting gripping and pen pressures. The target was selected by using the *Keeping* operation inside the target. Each participant selected the target 22 times to match the number of targets. The order in which targets were presented was balanced using a Latin square. Participants repeated this target selection three times. In summary, 1188 correct target selections (9 participants $\times$ 22 partial pressure ranges $\times$ 3 repetitions $\times$ 2 tasks) were performed in this experiment.

5.4 Performance Measurements

We evaluated performance from two points of view, i.e., target selection time (ST) and cursor movement distance (CM). We used ST as an index of rapidity



(a) ST (task 1) (b) ST (task 2) (c) CM (task 1) (d) CM(task 2)

Fig. 3. Results for target selection time (ST) and cursor movement distance (CM)

and CM as an index of ease. We could not use ST and CM without modifications because the distance between the initial cursor position and target varied from the target. Therefore, we defined the distance, D, between the cursor position and the target. Then, we minimized the effects of distance by dividing ST and CM by D. We adopted a Euclidean distance in task 1 from the point of origin to the bottom left corner of the target as the distance. We adopted a Euclidean distance in task 2 from the top right corner of the pressure map to the top right corner of the target as the distance. Then, we defined distance D as the Euclidean distance when the length of the target rectangle was one, plus one. For instance, the distance for target 14 in task 1 was $D = 1 + \sqrt{2}$ and that for target 20 in task 1 was $D = 3$.

5.5 Results

We removed 61 measurements that were beyond two standard deviations from the mean value.

Figs. 3(a) and 3(b) show the results for ST, which indicate that the participants took a lot of time to select targets 1, 4, and 8 in task 1. They also took a lot of time to select targets 1 and 2 in task 2.

Figs. 3(c) and 3(d) show the results for CM, which indicate that participants took a lot of time to select targets 1 and 8 in task 1. They also took a lot of time to select targets 1, 2, and 4 in task 2.

5.6 Discussion

Our analyses of ST and CM revealed that it was difficult to select targets 1, 2, 4, and 8. Fig. 4 shows these four target positions on the pressure map, where these four targets are located along the curve that we obtained from experiment 1. This indicates that areas along the curve are difficult to select. We only examined two initial cursor positions in this experiment and areas that were difficult to select were biased. Therefore, we concluded that areas along the curve were difficult to select independently of the initial cursor position. That is, it was not optimal to use the pressure ranges of the areas for interaction. In contrast, participants could select other areas easily and quickly on some levels. Therefore, we concluded that it was possible for them to use these areas for interaction.

We set the selection equation at $y = 0.667x+1.333$ to divide the pressure map into areas that were easy and difficult to select. This equation was an expression connecting the bottom right corners of targets 2 and 8. The gripping and pen pressures were equivalent to x and y, and areas that were easy to select could be defined as $y < 0.667x + 1.333$. We believe that this definition would work well as a guide in design applications. Multi-stream input operations that combine gripping with pen pressure can be accomplished by using this pressure range optimally.

It is clear that gripping and pen pressures are in a proportional relation in our setup because we used the same sensors for measuring both pressures. Hence, every designer can apply our results when he or she uses other sensors whose specifications are known.

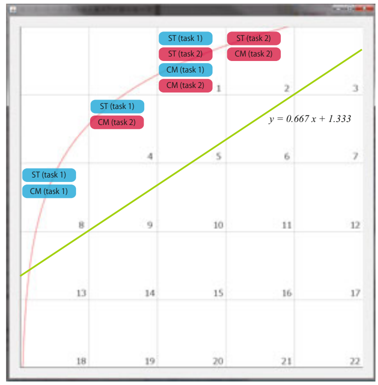


Fig. 4. Four difficult targets to select on pressure map. All four targets are along curve we obtained from experiment 1.

6 Applications

We found that gripping and pen pressures could be used simultaneously from the experiments. By combining gripping and pen pressures, a user can simultaneously change two parameters without interrupting operations. Here, we discuss applications using a combination of gripping and pen pressures.

Gripping Brush. Some paint tools support pen pressure, where a user can change the line width by varying pen pressure while drawing a line. The line width in in our paint tool could also be changed by varying pen pressure. The stronger the pen pressure became, the thicker the line became. In addition, the color of the line could be changed by gripping. The color saturation decreased when the pen was grasped strongly and increased when the pen was grasped weakly. Various kinds of lines like those in Fig. 5 could be drawn by combining gripping and pen pressures. The upper line in Fig. 5 was drawn while only controlling pen pressure, the middle line was drawn while only controlling gripping pressure, and the lower line was

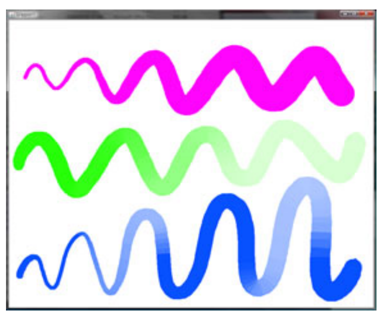


Fig. 5. Screenshot when using gripping and pen pressures. Upper, middle, and lower lines are drawn while only controlling pen pressure, gripping pressure, and both gripping and pen pressure, respectively.

drawn while controlling both gripping and pen pressures. The user could freely change pressures in all assignments like they did in controlling gradation or transparency.

Drawing operation while simultaneously changing two parameters have not been achieved in current pen-based interfaces. However, the combination of gripping and pen pressures should enable users to draw novel representations of lines. In addition, this combination should also enable users to create new drawing techniques because they can freely assign functions to the modality of input. This combination would be useful for creative activities like those in painting because it can help artists create novel artworks.

7 Conclusions

We proposed an interaction technique combining gripping and pen pressures, which enabled users to carry out common pen interactions while simultaneously inputting two parameters. That is, this combination provided users with four DOFs in input operation combined with two-dimensional input of X-Y coordinates. We conducted two experiments to investigate whether or not users could do operations with combined gripping and pen pressures. As a result, we found that combined interaction was feasible and there was an optimal pressure range.

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