# Stylus Knife for Paper-cutting: A System for Controlling a Knife

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## Abstract
We introduce a Stylus Knife that has a blade attached to the tip of a touch pen. This device can measure pressure when an artist cuts paper. In the past, we determined that knife pressure is important for creating paper-cutting designs. Therefore, we developed a device on a tablet computer to measure pressure when the user cuts paper. In an experiment, to confirm the effectiveness of our device, we compared it with a general utility knife that had a pressure sensor. Our test procedure was as follows: 1) our subjects cut paper with utility knife, and 2) each subject performs paper cutting using each device. For our experiment, we used seven subjects in each of three groups: G1 (practice using the Stylus Knife), G2 (practice using only the utility knife), and G3 (practice using the utility knife with a textbook). We compared the changes between Steps 1 and 2 exhibited by each group. As a result, group G1was able to apply sufficient pressure for a line pattern, while the others cut a line pattern with insufficient pressure. We confirmed that the novice subjects were able to cut paper with appropriate pressure by using our knife.

## Author Keywords
Stylus; Cutting; Knife interface; Supporting practice; Skill support; Creative activity support

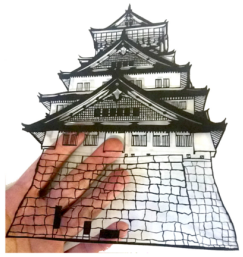

**Figure 1:** Examples of a paper-cutting.

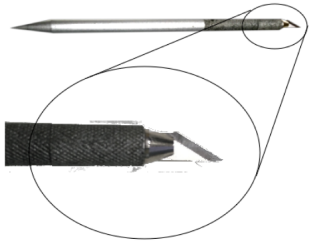

**Figure 2:** Example of an utility knife.

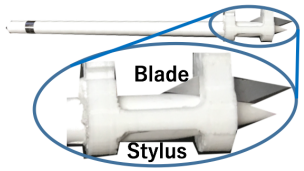


**Figure 3:** Stylus knife

## ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

## Introduction

Recently, artists have been designing their creations using practice creation through digital technology. This study presents improvements and attention points to the behavior of artists by reading the motion of the entire body using color and depth cameras [9]. For creative works such as paintings and sculptures, where handy usage is important, motion can be analyzed by attaching a sensor to the tool [6]. We have been researching the expert control of a utility knife. Paper-cutting is an art activity carried out using paper and a knife (Figure 1). Paper-cutting is greatly dependent upon control of the knife (Figure 2). A novice cannot easily conduct paper-cutting like an expert because it involves the application of many skills. In a previous study, we revealed that knife pressure is an important factor in controlling the knife [4]. In that study, we developed a system based on a stylus that learns an expert's skills of maintaining a suitable pressure on the knife.

Paper Cutting is one of the traditional arts, unlike the art of adding ink to paper such as Paint and Drawing, it is an art that expresses by removing unnecessary parts from paper. Therefore, the viewer can feel the picture of Paper Cutting with touch. From this feature, some blind people create with safe knives. However, cutting pictures can be easily produced due to the development of laser cutters, but there are few environments to support people making by manual work. Techniques to cut are difficult, some people practice during the period from several months to several years in the cutting course for beginners. Experts who practice many exercises and experiences can cut complex pictures. On the other hand, people who challenge Painting and Drawing are increasing due to the development of tablet devices and touch pen. Therefore, environments that support and nurture beginners also exist abundantly. In this study, we focused on Paper Cutting to develop an input device that allows the user to perform cutting using a new knife. This system measures pressure and cuts paper at two points, i.e., with the tip of the touch pen and the blade. Providing support is important, because it is difficult for the beginner to adjust the pressure during the cutting operation. Such improvements are envisioned to increase cutting performance, especially so for cutting opera- tions that require precise knife pressure. We propose a system whereby the user cuts paper with a knife by using the computer screen of a tablet on which the cutting pressure is displayed.

In this study, we focused on paper-cutting to develop an input device that allows the user to perform cutting using a new knife (Figure 3). Providing support is important, because it is difficult for the novice to adjust the pressure during the cutting operation. Thus, we created an input device operation that can positively perform the cutting operation. We focused on the adjustment of the pressure on the knife when cutting paper, and the development of a system to foster the dexterity of the fingertips. We propose a system whereby the user cuts paper with a knife by using a tablet computer screen that displays the pressure.

## Related Work

Many researchers present an approach to combining digital fabrication and craft. For example, this researcher developed a kitchen knife for minimizing cooking injuries by providing a skin color sensor [14]. In addition, the same researcher present the technology and explore several interaction methodologies for carving [17]. They research on production support by various devices such as The Free-D [15] and D-Coil [7] for the production of three-dimensional

modeling. Other researchers have developed dePENd to support sketches using regular pen and paper to aid drawing [13]. Many researchers support creative work for shaping and painting, and it is very important to support creative activities [16].

Many technologies exist that have the ability to drawing dexterity [11]. The motion of cutting using a tool requires dexterity in craftwork. This dexterity is present in manufacturing, which includes paper-cutting, and the ability to use the fingertips skillfully is important. For example, a user can color with a finger using a tablet computer by touching the input device with the finger [3]. Researchers focused on the coloring that children perform with ink on their own fingers, and intended to provide assistance using the motion of the eye and hand. Moreover, humans can indirectly stimulate dexterity using haptic information through a tool such as a pen in addition to their own hands. Because performing delicate movements with a tool requires a high degree of skill with greater control of the hand, the dexterity of activation can be expected. Therefore, researchers have been developing an input device such as a pen to promote the activation of the brain by drawing a picture or character.

Haptic studies using objects have resulted in the Tactile Augmented Kinesthetic IllusiOn Pen (TAKO-Pen), which uses suction pressure to stimulate a user's finger by adding the pressure to the pen [5]. This allows a user to learn the technique for controlling a tool with a delicate force. Thus far, for painting using a tablet computer, the user conducts a brush and spray-style input by using a pen-type device in the software. A new input device has been developed in the form of a brush for the tablet terminal [8]. In this study, the user can use the pen-type device to paint with a brush, thus experiencing the movement of the unique hand that cannot be experienced. A variety of input devices can increase dexterity by using haptic information in the child stage with the play. Another research is to support an ideal painting method in digital devices by incorporating various sensors into the input device [10]. In this research we have examined ways to increase the naturalness of digital pen table rendering using context sensing.

Many researchers have adapted the tablet computer and stylus for use in creating handmade crafts. One of the studies extracted feature information from a drawn image of a human face [2]. When drawing a sketch, it is difficult to draw a line, the system points out the balance of the user's line. Therefore, our system helps a novice to apply correct pressure with the stylus as an expert would. Each creative art has a technology component corresponding to a difficult skill. This research focuses on the movement of illustrators working on different levels of paper, expanding part of the drawing [12]. This improves paper productivity and enhances illustrator's creative work methods. We focused on the most important skills which are pressure in create paper-cutting. Pressure has been with the necessary technology component in some art, which includes ink painting [1]. Representation of pen pressure and pictures are related. Thus, we built a system that uses a tablet computer and stylus to simulate knife pressure, instead of using paper and an actual knife.

## Difference Between Novices and Experts

One of the differences between the novices and experts is cutting while maintaining suitable pressure. We examined a survey in which seven novices and seven experts cut the same picture. Each work was different depending on the user's skill at applying pressure. When paper is cut, the printed paper was overlaid on the colored paper. The novices cut coarse curves with stronger pressure to cut smooth curves because they were unable to main-

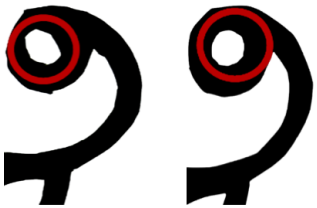

**Figure 4:** Circles which cut by novice (left) and expert (right).

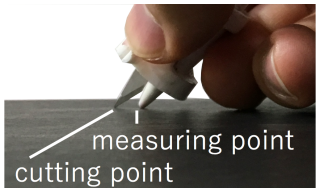


**Figure 5:** The user uses our Stylus Knife.

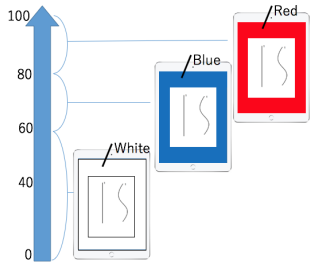


**Figure 6:** Color changes according to pressure.

tain the ideal pressure on the knife (Figure 4). The skill is also shown in courses and texts for paper-cutting. However, because words and letters cannot explain sufficiently, it is limited to making conscious with repeated experiences. Therefore, we developed a support system that displays the pressure applied by the user [4].

## Support System

*Stylus Knife*

Our Stylus Knife has a blade attached to the tip of the stylus (an Apple Pencil by Apple). This device has a blade at the tip of the touch pen, cuts paper at the blade point, and obtains the knife pressure at the stylus point. The user holds the connector and cuts the paper with the blade. At this time, the touch pen measures the pressure of the user by touching the tablet device (Figure 5). We have crafted a connector using a 3D printer to attach a blade to the upper side of the stylus. When a user uses operates the device, the connector secures the paper and blade at an angle of 40-degree. This device measures the knife pressure in steps of 100. The pressure cuts the paper when the value is higher than 60.

*Tablet Computer*

A user cuts paper as displayed on the screen of a tablet computer (an iPad Pro by Apple). In this system, the tablet device has two display covers. One is hard tempered glass with a Mohs hardness of 9. The other is a film that is softer than the knife. The glass protecting the display and the film reproduces the structure of a cutting mat. An actual cutting mat is made of soft vinyl chloride that sandwiches hard vinyl chloride. When using a cutting mat, the user cuts paper and the soft material of the surface.

This tablet computer has two pictures and a function. The user cuts certain patterns, and the tablet changes the color of the screen according to the pressure the user puts on the stylus. To indicate the pressure being applied, the display shows specific colors. When the user maintains a pressure of 60 to 80, the display changes to blue. When the pressure exceeds 80, the display changes from blue to red (Figure 6).

**Table 1:** Results of average angle.

| | Straight Line | | Wavy Line | |
|---|---|---|---|---|
| | average | variance | average | variance |
| Touch Pen | 40.5 | 0.5 | 40.6 | 0.6 |
| Stylus Knife | 40.2 | 0.7 | 39.0 | 0.4 |

Rouded to the first decimal place

**Table 2:** Results of average pressure.

| | Straight Line | | Wavy Line | |
|---|---|---|---|---|
| | average | variance | average | variance |
| Touch Pen | 61.5 | 9.1 | 64.6 | 12.9 |
| Stylus Knife | 62.8 | 11.5 | 64.2 | 9.1 |

Rouded to the first decimal place

## Measurement for Design

In designing our Stylus Knife, we measured the angle when using the utility knife. Our subjects were five male experts with an average age of 27.2 years, two of whom had three years of experience. The other three experts had two years of experience. All subjects were working as artists and teachers in paper-cutting courses. The purpose of this survey was to examine the angle at which experts use the knife. Subjects cut a straight line and a wavy line of 100 mm for a total of five times in a specified direction (Figure

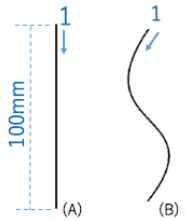


**Figure 7:** Experiment patterns: (A) Straight Line and (B) Wavy Line.

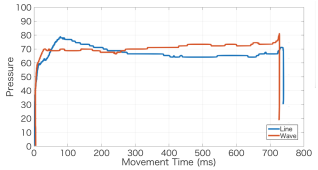


**Figure 8:** Process in average pressure using touch pen.

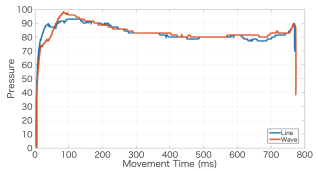


**Figure 9:** Process in average pressure using touch stylus knife.

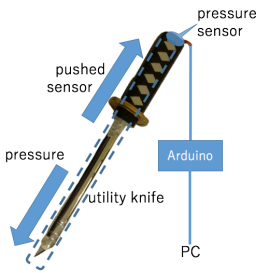


**Figure 10:** Utility knife with pressure sensor.

7). These patterns were simple designs and posted on the textbook for novices.

We installed a camera on the side of the user and measured the angle between the paper and the tool. As a result, experts use the knife as an angle of about 40 degrees. We designed the connector to touch the paper and blade at 40 degrees (Table 1). Moreover, the subjects used Stylus Knife designed at 40-degree with the same patterns fig7. They used the Stylus Knife at around 40-degree as well as the utility knife. By this inclination, the Stylus Knife reproduces the condition of cutting with a utility knife.

*Calibrating the pressure*

We measured the pressure when using the utility knife. The subjects are the same as our experts. The experts traced Fig7 with a stylus pen in the same way as the utility knife. This device measures the knife pressure in steps of 100. We adjusted the same as the pressure to cut paper when the measured value was 60. The experts maintained a pressure at an average of 65 out of 100 steps (Figure 8, 9 and Table 2). In this graph, the vertical axis represents pressure and the horizontal axis represents the vertical axis of the tablet computer. The subjects used a Stylus Knife designed at 40-degree with the same patterns, as shown in Fig7, with a pressure of approximately 70 as well as the utility knife.

## Experiment

*Experiment description*

We examined the effectiveness of our system by carrying out a user experiment. The purpose of this experiment was to verify whether our system enabled a novice to change the pressure they applied to the knife to more closely approximate that used by an expert. Our subjects (males, with an average age of 23 years) had never attempted paper-cutting. We investigated the pressure applied to the pen by each subject. Our experiment was straightforward: 1) a subject cuts paper without using the tablet computer and 2) each subject performs paper cutting with the same pattern (Figure 7). In Step 2, four groups consisting of seven subjects each practiced using different methods: G1 (practice using the Stylus Knife), G2 (practice using the utility knife) and, G3 (practice using the utility knife with a textbook). The textbook described the importance of knife pressure. G1 gets feedback from the tablet terminal, but G2 and G3 cut paper without getting feedback. All subjects cut in the same direction and in the same order. The patterns had been published in many textbooks for beginners. The figure displayed on the tablet was projected onto the paper, and the subjects cut this figure. We compared the changes between Steps 1 and 2 exhibited by each group.

*Measurement Pressure*

In our experiment, our Stylus Knife can measure the pressure applied by the subject. However, a common knife cannot do this. Therefore, we have developed a utility knife that measured pressure for this experiment (Figure 10). When a user held the device, the handle measured the pressure using a sensor. We have set the pressure sensor on the handle to the same sensing value as that of the Stylus Knife.

*Result of pressure*

Table 3 lists the results of extracting pressure when the knife is moving to cut paper. The subjects using a tablet terminal and knife changed the pressure to that suitable for a skilled person (Figure 11). In addition, we measured the average pressure of Steps 1 and 2 in the Mann = Whitney U test. The Mann = Whitney U test has a feature that allows two items of data to be measured independently. In straight line, the pressure differed significantly for the measurements performed on G1, with the test statistic (U) being

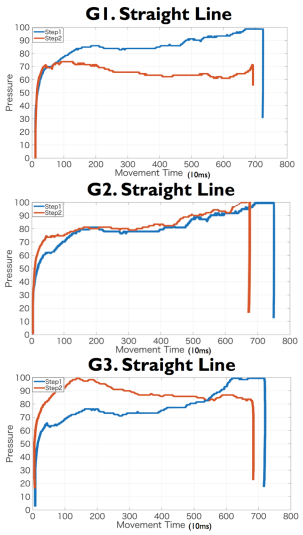


**Figure 12:** Results of pressure along a straight line.

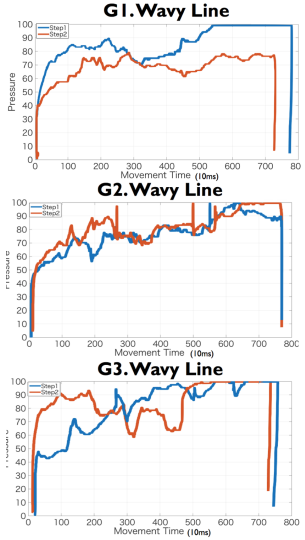


**Figure 13:** Results of pressure along a wavy line.

**Table 3:** Average pressure in experiment.

| | | G1 | | G2 | | G3 | |
|---|---|---|---|---|---|---|---|
| | | average | variance | average | variance | average | variance |
| Straight Line | Step1 | 86.3 | 12.5 | 89.4 | 8.6 | 80.0 | 13.3 |
| | Step2 | 64.9 | 10.8 | 83.3 | 11.9 | 81.8 | 11.4 |
| Wavy Line | Step1 | 87.7 | 21.4 | 88.1 | 17.8 | 89.6 | 15.5 |
| | Step2 | 68.5 | 12.5 | 83.8 | 15.5 | 80.2 | 19.3 |

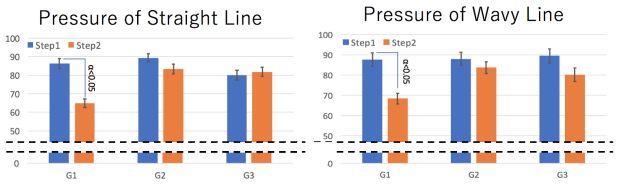


**Figure 11:** Change in the average pressure of Stylus Knife in Straight Line (up) and in Wavy Line (down).

0.01 for p-values of 0.05. However, no significant difference was observed for other groups: for G2, the value of U was 5.5 for p-values of 0.05, and for G3, the value of U was 4.5 for p-values of 0.05. The only group that showed a significant difference was G1. Only group G1 showed a significant difference. Similarly for the wavy line, the pen pressure of G1 was significantly different, and when the p value was 0.05, the test statistic (U) was 0.03. For G 2, the value of U was 5.0 for the p value of 0.05, and for G 3, the value of U was 5.5 for the p value of 0.05.

From the results for the line pattern, the members of G1 were able to apply a sufficient pressure. The others subjects cut the pattern using insufficient pressure (Figure 12, 13). The vertical and horizontal axes represent the average pressure of subjects and the changes in the knife movement time in 10 milliseconds intervals, respectively. Similarly, the subjects of G1 could cut stabilized at all the patterns. The measurements for G1 revealed that the system helps users improve their skill level. Thus, the pressure they applied during paper cutting approached that of the experts. By contrast, the other groups could not change the pressure between Steps 1 and 2. The subjects of G3 read a textbook and understood that a sufficient force was needed from the beginning. Therefore, they changed the pressure to become stronger during their initial movements; however, this was not the correct pressure.

## Conclusion and Future Work

In this paper, we proposed a support system to assist novices with controlling a knife like an expert. We developed a Stylus Knife, which is a system for learning proper knife pressure to be applied when cutting paper. This device can measure the pressure when the user cuts a piece of paper. Moreover, we carried out experiments with simple patterns in order to confirm the benefits of the Stylus Knife. As a result, subjects who practiced with the device could cut with a knife pressure close to that of an expert. In particular, major changes were observed in the force acceleration and in cutting curves such as a straight line or wavy line. In this paper, we focused on adjusting the pressure, which affects the quality of the work. In our future studies, we will

measure the state of the knife using characteristics such as coordinates, angle, and azimuth by using PHANToM. In addition, our Stylus Knife is separate between cutting point and measuring point. These points have a correlation, however they do not necessarily coincide. Therefore, we will improve those points. We aim to improve the novice's cutting behavior by measuring the state of the expert's knife.

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