Stylus Knife: Improving Cutting Skill in Paper-cutting by Implementing Pressure Control

Takafumi Higashi

Japan Advanced Institute of Science and Technology
Nomi, Ishikawa, Japan
htakafumi@acm.org

Hideaki Kanai

Japan Advanced Institute of Science and Technology
Nomi, Ishikawa, Japan
hideaki@acm.org

ABSTRACT

In this paper, we propose an interactive system for controlling the pressure while cutting paper with a knife. Our system supports skill improvement for novices by measuring and evaluating their cutting pressure in real time. In this study, we use a knife with a blade attached to a stylus with a pressure sensitive sensor, which can measure the pressure, coordinates, and cutting time. We compare the cutting pressure values of novices with those of artists and thereby observe the difference in their cutting skills. We have also developed a practice system that guides the novices on controlling the pressure by providing information on the cutting pressure values of experts. This system shows the difference in pressure between novices and experts using a synchronous display of color and sound. Using these functions, novices learn to adjust their cutting pressure according to that of experts. The purpose of this research is to improve the cutting skill of novices learning the art of paper-cutting. Instructors typically teach the novices how to control the cutting pressure during paper-cutting workshops, as novices tend to cut paper with an unstable and higher pressure than necessary. Determining the right cutting pressure is a critical skill in the art of paper-cutting, and we aim to improve the same with our system. We verify the effect of our system by practicing paper-cutting in various methods and comparing the cutting pressure values obtained. It is evident from the results that novices who practice with our system show progress on the average and variance of cutting pressures.

CCS CONCEPTS

• **Software and its engineering** → **Software system models**; *Inheritance*;

KEYWORDS

Cutting, Knife interface, Stylus, Drawing display, Supporting practice

ACM Reference Format:

Takafumi Higashi and Hideaki Kanai. 2019. Stylus Knife: Improving Cutting Skill, in Paper-cutting by Implementing Pressure Control. In *The 34th ACM/SIGAPP Symposium on Applied Computing (SAC '19)*, April 8–12, 2019, Limassol, Cyprus.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

SAC '19, April 8–12, 2019, Limassol, Cyprus

© 2019 Association for Computing Machinery.

ACM ISBN 978-1-4503-5933-7/19/04.

<https://doi.org/10.1145/3297280.3297348>

Figure 1: Paper-cutting is the art of cutting paper with a knife (A). User cuts with a knife on the tip of a stylus on a drawing display (B).

Limassol, Cyprus. ACM, New York, NY, USA, 8 pages. <https://doi.org/10.1145/3297280.3297348>

1 INTRODUCTION

The creation of craft art is appealing to all generations because it helps with concentration and has a relaxing effect. However, as many crafting activities cannot be undone, it is necessary to develop various skills, such as hand dexterity, through repeated practice. In this paper, we focus on the skill of paper-cutting, which involves creating art by cutting paper with a knife (Figure 1-A).

Anyone can learn to craft art designs from books and the internet. However, it is difficult for novices to adapt motifs created by other artists, because of the skill gaps between them. Novices find it difficult to cut smoothly when they learn paper-cutting. They tend to cut the paper with excessive pressure. Therefore, some paper-cutting instructors instruct novice students to practice tracing the paper with a pencil. When a novice traces the paper with excessive pressure, the pencil tip wears down or breaks. The purpose of this instruction is to make the novices learn how to maintain the appropriate pressure for paper-cutting through practice. However, cutting and tracing are different from each other and therefore, novices must practice constantly in order to improve their cutting skills.

We aim to improve the cutting skills to create cutting pictures. In this paper, we focus on the cutting pressure that many lecturers instruct novices at the workshop. We develop a device to measure cutting pressure and a system to support pressure control for novices by measuring pressure controlled by experts (Figure 1-B). The pressure was invisible information, so it could only be learned

by training repeatedly. This system can measure the amount of applied pressure, and we believe it will lead to an improvement in cutting skills.

We have developed a practice system that measures the cutting motion by attaching a blade to the tip of a stylus [9], while some have come up with a system for pressure control by tracing motion [8, 10]. [8] and [10] are for users aiming to improve skills through stylus movement. Therefore, their system does not require cutting paper. Our system supports to improve the cutting operation by measuring the pressure when the user cuts the paper. [9] measures the cutting pressure as well. However, as the measuring point and the cutting point are in contact with the paper, this device takes the direction of the pressure into account.

In this paper, we describe the support system that has been developed and its effect on the ability of novices to control the cutting pressure in chapter 3. In chapter 4, we experiment to determine the difference between the cutting pressure values of novices against those of experts. Based on the results of this experiment, we implement the correct range of pressure and create a display, which is described in chapter 5. In chapter 6, we compare the cutting pressures of novices who have practiced using different patterns of pressure control. We verify the effect of the system from the results to confirm that it improves the skill of the novices to control the cutting pressure. We present the discussion and the conclusion in chapters 7 and 8.

2 RELATED WORK

Observation and imitation of an expert is one way to improve the creative skills of novices [22]. The use of technology, as a means of assisting users drawing, has been explored in modeling applications. Studies [17], [5], and [4] assist users in drawing faces and eyes. These studies rely on a face and a set of sketch recognition algorithms to generate domain-specific instructions and textual or on-canvas feedback. Studies [1, 25] present an image-guided pen-based suggestive interface for sketching 3D wireframe models. Studies [12, 14] support 2D/3D drawing practice and promote correction and improvement by comparing the user's imitation of a picture with the original.

In a study to improve the novices' movement, actions performed by the experts are measured and the novices are instructed according to the differences observed. Many studies visualize the measurement and expression of movement and promote practice and support of creation through various imitations [27]. The system provides appropriate instructions to the user by measuring the coordinates and the pressure of the stylus at the time in creation. Some researchers support art creation by controlling the pressure on tools through sketch [24] and calligraphy [21]. These studies are evaluated based on input pressure. Studies [26] and [2] use an intuitive "ghost" metaphor and a first-person viewpoint for effective motion training. The result is an image of the subject performing gestures with the accuracy of an expert [3, 20]. Study [15] compares the movement of the user's arm with that of an expert using a camera during pottery modeling. It then uses a projector to provide instructions to users on arm movements. These studies compare the behavior of the users with that of the experts. The systems in these studies instruct the user appropriately in real time to improve the

Figure 2: A blade is attached to the tip of the stylus (A). The gap is covered with ultraviolet resin (B).

motion. Similarly, our system improves the user's control of cutting pressure by comparing the cutting pressure values of users with those of experts in real-time.

Various support systems provide guidance using a projector, a monitor, and a tablet device. Study [19] supports performing paper-cutting by cutting along a line projected on paper. Projector-Guided Painting [7, 13] decomposes the target painting into coarse-to-fine layers. Users paint over the projection of each layer, following the guidance to orient individual brush strokes or paint all the strokes of a given color. Similarly, study [16] allows users to trace over a 3D scene projected on paper. Study [23] supports sculpting work using a projection of three-dimensional objects. Moreover, study [23] improves the accuracy of tracing by displaying instructions on a head-mounted display. Study [18] corrects tracing by comparing the drawings with those on a database in a tablet device. Study [6] allows expert users of sketching software to generate tutorials for novice users. This system offers on-canvas guidance and feedback so that users can replicate experts' strokes along each step of the tutorial. These systems allow novices to imitate the behavior of experts. Our system aims to allow the user to cut paper with the amount of pressure used by experts. This is achieved by displaying the difference between the pressure applied by the user and that applied by experts.

3 CUTTING DEVICE

In this chapter, we discuss the design of our system which consists of a drawing display and an attached stylus. A blade is attached to the tip of the stylus. The purpose of our system is to measure the pressure with which the user cuts the paper as well as the cutting time.

3.1 Stylus with Blade

Our device is designed to measure the cutting pressure. We have modified the stylus to collect data by attaching a blade (NT BDC-200P) to the tip of the touch pen (Wacom PenPro2) (Figure 2-A). We have glued the tip of the knife and the stylus with ultraviolet resin (Figure 2-B). In our system, this stylus has a pressure sensor. It recognizes the cutting distance from 0.1 mm and the pressure from 0 to 500 g from 7000 degrees at a response speed of 250 ms.

Figure 3: User cuts paper with our knife device on a drawing display.

3.2 Display Unit

The drawing display (Wacom Cintiq Pro16, 3860×2140 pixels, 275 dpi) shows pictures (Figure 3). The system only responds when the stylus is in contact with the screen. Although the tip of the stylus and the surface of the screen are not in contact, the display can recognize the stylus's coordinates. It can obtain the location and angle data for the stylus via electromagnetic induction. Paper is fixed on the screen, which is protected with tempered glass. The user cuts the paper with the device, and our system measures pressure, coordinates, and moving time.

3.3 Cutting Patterns

The system provides four patterns for practicing paper-cutting (Figure 4). These are plotted in a square measuring $100 \text{ mm} \times 100 \text{ mm}$. Some experts use these patterns during paper-cutting workshops to instruct users on how to practice cutting. Figures 4-A and 4-B show simple patterns. In addition, the participants divide these patterns into three parts. Figure 4-C shows a pattern in which the margins gradually decrease in size. The participants start from the wide left side and cut only vertically. The pattern in Figure 4-D consists of circles that gradually become smaller, and it is cut from the outside of the circle with the smallest curvature.

4 EXPERIMENT 1: DIFFERENCE IN CUTTING PRESSURES BETWEEN NOVICES AND EXPERTS

4.1 Objective

In this chapter, we present our experiment for measuring the pressure applied by novices and experts. The purpose is to compare the pressure applied by novices with that of experts and determine the pressure range of experts. We measure the pressure, time, and coordinates when novices, as well as experts, cut paper using our knife device.

4.2 Experiment Configuration

20 participants are asked to cut paper with our knife on the drawing display. There are 10 novice participants (seven males and three

Figure 4: Tablet device shows patterns for practicing. Users cut in the order specified and do not cut on portions with the x mark.

females with the average age of 27.4 years) who have never done paper-cutting and 10 expert participants (six males and four females with the average age of 32.5 years) who are artists and instructors. The participants are asked to cut the borders between the white and black portions for all of the four patterns in Figure (Figure 4). They are made to repeat this process ten times.

4.3 Result

We compare the average pressure and the variance for all the four patterns together as well as the average pressure and cutting trace for each pattern.

4.3.1 Average and Variation of Pressure from Experiment 1. Table 1 shows the average pressure when participants cut all the four patterns 4). Novices performed the cutting with 1.4 times more pressure and spent 1.3 times longer than the experts. The experts quickly cut the lines with an average pressure of approximately 300 g.

Figure 5 shows the variation of pressure maintained for more than one second to be within 1 g in all the patterns. In this box-and-whisker plot, the left and right line segments show the maximum and the minimum value of pressure, and the center line of the box shows the median pressure. Novices cut the paper with a wide range of pressure ranging from 320 to 480 g. On the other hand, the pressure range of experts is from 250 to 350 g, which is half of the intervals of the novices' pressure range. The average and median values for the experts are similar while the average value for the novices was much lower than their median value.

4.3.2 Cutting Trace of Pressure in the Patterns. We have plotted the average coordinates and the pressure when the participants cut each of the four patterns 6). As shown in Figure 6-A, the novices cut the entire straight line with higher pressure than that applied by the experts. Figure 6-B shows that the novices cut the curved pattern with stronger pressure than that applied for the straight

Table 1: Average pressure and moving time in for the pattern in Figure 4.

	Pressure (gram)		Time (second)	
	Average	SD	Average	SD
Novices	437.7	23.9	58.9	6.6
Experts	303.3	14.8	44.8	3.9

Note: Rounded to one decimal place

Figure 5: Variability of pressure maintained while cutting the four patterns. The x marks shows the respective average values.

Figure 6: Our system plotted average pressure and coordinates when novices and experts cut the patterns.

line. On the other hand, experts cut paper with similar pressures regardless of the pattern. As can be seen in Figure 6-C, the novices cut the boundaries with higher pressure as the margins narrowed. They also cut the pattern in Figure 6-D with higher pressure as the curvatures became bigger.

The cutting trace performed by the novices is very different from that of experts, particularly with regard to the smallest circle in Figure 4-D (diameter 10 mm). Figure 7 shows the difference between the cutting performed by one representative participant from each group. One of the novices cuts a rough circle by applying a pressure that is too high (Figure 7-A). However, one of the experts can cut a circle smoothly by appropriately adjusting the pressure applied (Figure 7-B).

4.4 Conclusion of Experiment 1

During experiment 1, we measure the average and variation of pressure when the novices and the experts cut the same pattern. It

Figure 7: A novice cuts the circle as protruding from the prescribed line (A), an expert cuts along the original picture accurately (B).

is observed that the novices cut with stronger pressure compared to the experts. Furthermore, the cutting time and the pressure of novices are higher for thin lines and small circles. When we interviewed the participants after the experiment, we observed that the experts tried to maintain uniform cutting pressure in all the lines. Cutting the paper with excessive pressure makes it difficult to operate the knife. Therefore, the experts cut with pressure ranging between 250 and 350 g. On the other hand, novices cut the more difficult patterns with higher pressure. They cut carefully and have been unaware of maintaining the pressure. We found that the novices cut with higher pressure as the difficulty of the patterns increased. From the above results, we have confirmed that there is a difference in cutting pressure between novices and experts.

5 DRAWING DISPLAY

Our drawing display has a function called ‘Displaying Applied Pressure.’ This function synchronizes with the pressure of the knife and produces the corresponding color on the drawing display along with sound alerts. It is confirmed from experiment 1 that the experts cut paper with a pressure ranging from 250 to 350 g. Therefore, we have designed the color and alert threshold according to the pressure difference between the user and an expert. The evaluation is provided based on a comparison of the user pressure with the pressure applied by the experts (Figure 8). The user cuts the paper fixed on the Drawing Display with a knife that measures the pressure. Our system measures the cutting pressure of the user and displays how different it is from that of the expert, thereby supporting the acquisition of his / her cutting skills.

When the pressure applied by the user is 350 g or less, the display is white. When the applied pressure is in the range 250 to 330 g, the display color gradually changes to dark green. In the range of 330 to 350 g, the display changes to yellow to alert the user about the use of excessive pressure. At pressures greater than 350 g, the display color turns red. When the color changes from green to yellow or red, the system produces an alert from the speaker. The user can control their applied pressure based on the display and alerts.

Figure 8: Color and noise are synchronized with pressure.

Figure 9: Participants cut as per step 1 and step 3 (A). Wavy lines composed of various curvatures (B).

6 EXPERIMENT 2: CUTTING WITH THE RIGHT PRESSURE

6.1 Experiment Configuration

In this chapter, we present an experiment on the effectiveness of the ‘Displaying Applied Pressure’ function. The purpose of this experiment is to compare the practice effect of our system with that of the conventional practice methods. We measure the pressure, time, and coordinates when the participants cut in the pattern shown in Figure 9-A twice. This picture is drawn on a 100 mm square and published in a textbook as a design for novices. The wavy line in the picture is especially complex and involves several changes in cutting angle, as shown in Figure 9-B. We compare the changes in cutting behavior when the participants cut these complicated patterns.

6.2 Experiment Procedure

In this experiment, 30 novices, who have never done paper-cutting, perform the following tasks.

- Step 1. Cut picture (Figure 9-A) with our knife that measures the pressure.
- Step 2. Practice cutting on the patterns (Figure 4) using various methods.
- Step 3. Repeat step 1.

As all the participants cut the same pattern in step 1, we divide the participants into three groups of 10 based on the average pressure applied in step 1. Then, the participants practice using different methods, as mentioned in step 2. During step 3, they repeat step 1. During step 2, the participants who are divided into Gr 1, Gr 2 and Gr 3 perform the following tasks using the picture in Figure 4.

- Gr 1. Practice with the ‘Displaying Applied Pressure’ function.
- Gr 2. Practice without pressure presentation.
- Gr 3. Trace the patterns using a pencil.

Some paper-cutting instructors instruct novice students to practice by tracing the paper with a sharp pencil. Our experiment uses an instructor working on tracing practice with a pencil. Gr 3 traced the cutting line with no.2 pencils (uni, Mitsubishi). We compare their pressure values with those of the participants who cut the pattern in Figure 9 twice. We verify the difference between the effect of the system and that of the existing practice method by comparing the average pressure of each group during their cutting in step 1 with the same in step 3.

6.3 Results

We have compared the average pressure applied by each group and the variation of the maintained pressure in step 1 with those in step 3. The pressure values of each group are compared against the average pressure across the whole task, and the cutting traces of complex wavy lines performed by the three groups are compared against each other.

6.3.1 Average Pressure. Figure 10 shows the average pressure for step 1 and step 3. In step 1, the pressure applied by all the groups has exceeded 400 g. In step 3, Gr 1 has the highest reduction ratio of 77.2%. On the other hand, the reduction of Gr 2 is 93.5%, and that of Gr 3 is 88.2%.

In addition, we have tested the normality of the average pressure between step 1 and step 3 for each group. From the test results, it could not be concluded that the pressure follows a normal distribution. Therefore, we evaluated our results using Mann-Whitney U test, which is a non-parametric test method. The U test is a test method for two independent groups. However, it is based on homoscedasticity, which leads to lower accuracy in case of heteroscedasticity. We have confirmed that the pressure values for all the groups are equally dispersed at $F_{0.05}$ by an F test. As per the results of the U test, only the pressure of Gr 1 has significantly dropped at $p < 0.05$, but the pressure values of Gr 2 and Gr 3 are not significantly different.

6.3.2 Variation Pressure. Figure 11 shows the pressure variations maintained for more than one second during step 1 and step 3 to be

Figure 10: Average pressure applied by each group while cutting the pattern shown in Figure 9-A.

Figure 11: Variability of pressure maintained by tracing and cutting the pattern shown in Figure 9-A. The x marks show the average values.

within 1 g. In step 1, all the groups cut paper with a wide range of pressure values from 300 to 500 g. Furthermore, their average values (x in Figure 11) are lower than the median. This figure shows the average pressure variation of each group. Gr 1 learned about the range of appropriate pressure through the system in step 2. As a result, they cut with a lower range of variation in step 3. Moreover, the difference between the average value and the median has declined. However, the fluctuation of pressure is lower between step 1 and step 3 for Gr 2. For Gr 3, as with Gr 1, the difference between the average value and the median has decreased, as compared to that in step 1.

6.3.3 Cutting Trace with Wavy Lines. Figure 12 shows the cut traces of one participant from each group, as mentioned in step 3. The red line is the original one. Gr 1 has cut along the original line. However, the cut line of Gr 2 is protruded from the red line for each curve. In the lines traced by Gr 3, the low curvature (the base of the curve) part follows the original image while the high curvature (tip of the curve) part protrudes at an acute angle.

Figure 13 shows the average coordinates and pressures when the participants cut the pattern shown in 9-B. Gr 1 has maintained an average pressure that is indicated by a yellow line. However, the average pressure of Gr 2 is indicated by red or dark red. Gr 3 shows red at high curvature and orange at low curvature.

Figure 12: Wavy lines (Fig.9-B) cut by one of the participants from each group.

Figure 13: Our system shows the average pressure and coordinates for step 3 with wavy lines (Figure9-B).

6.4 Conclusion of Experiment 2

In experiment 2, we have examined the effect of practice using the function of indicating the pressure with color display and sound alerts. We have compared the average pressure and the pressure variation in step 1 with those in step 3. Using Gr 1 and Gr 2 outputs, we have confirmed the improvement in pressure control using our system. We have also found that our system is more effective than the existing pencil tracing practice system.

The pressure applied by Gr 1 has significantly reduced as they used our system during step 2 and learned pressure control techniques. The range of pressure variation also has declined due to this effect. Gr 1 has learned to cut smoothly by stabilizing the pressure during the time of cutting. On the other hand, the outputs from Gr 2 have not changed significantly as this group was not supported by our system. The pressure variation is also small owing to the difference between the average value and the median value. This shows that there has been no improvement in the cutting skill of Gr 2 participants. It is not possible for them to operate the knife along the high curvature in the wavy line, as well. Outputs from Gr 3 participants, who have practiced tracing using pencils, are not significantly different, except for a decline in the cutting pressure. Similarly, the strength of the pressure to be maintained has not reduced as much as the one with Gr 1. However, the range of the

variation in pressure is less than that of Gr 2. Moreover, Gr 1 has shown a dominant change in $F_{0.05}$.

7 DISCUSSION

The purpose of this research is to improve the skill of adjusting cutting pressure to create paper-cutting. One of the cutting skills required for creating paper-cutting is controlling the cutting pressure. Therefore, we have developed a cutting practice system consisting of a drawing display and a blade on the tip of the stylus. In experiment 1, we have compared the pressure values of novices with those of artists and found that the novices cut papers with 1.4 times stronger pressure than that of experts. We interviewed the participants after the experiment. The novices were very careful to cut along the line, cut with stronger pressure, and unable to adjust the power. On the other hand, the experts had tried to maintain uniform cutting pressure along all the lines. Therefore, curves with higher curvature were rougher for novices compared to those of experts. In experiment 2, we have compared the improvement of cutting pressure achieved with our system against that achieved with conventional methods. The average cutting pressure of novices has declined by 77.2% with support from our system. We have also compared the improvement in values with those obtained using the pencil tracing practice method as this is one of the existing practices for novices (pressure reduction of 88.2%). The group that employed our new system has shown more improvement compared to the one using the previous system. We interviewed the participants after the experiment. The novices who used our system have learned how to adjust pressure like experts do by constantly evaluating their own pressure values. On the other hand, it is found impossible to acquire sufficient skills with just one exercise to handle minuscule changes in pressure with practice methods using pencils. This research aims to improve the cutting skill in paper-cutting. However, cutting skill includes several elements other than pressure such as the position of fingers, fixing the paper, and so on. In this paper, we focused on pressure which is a primary element of instruction during workshops. In the future, we aim to improve the cutting skills more effectively by developing systems that correspond to various factors.

8 CONCLUSION

We have developed a cutting practice system consisting of a blade on the tip of the stylus and a drawing display. Our knife measures the pressure applied by the user, and the drawing display has a function to present the difference between the knife pressure of the user against that of the experts using respective color and sound. The purpose of this paper is to improve the cutting skills of novices to cut pictures. Cutting paper with appropriate pressure is an important skill for artistic and craft artistic expression. First, we have measured the cutting pressures of novices and experts. Next, based on the results, we have compared the changes in the pressure across groups practicing pressure control using the new system, groups practicing without the system, and those practicing with existing pencil method. The group using our system has shown more improvement compared to the one that used the existing practice method. The average pressure used as well as the pressure variation has reduced as a result of using our system. Our

system has the effect of enabling the novices to adjust their cutting pressure on par with the pressure range applied by experts.

This paper supports the improvement of cutting skills for beginners. During future research, we will measure the skill level of users and accordingly provide practical practice support covering various elements of cutting skills. Moreover, we are currently analyzing measuring the cutting skill level and difficulty level of cutting pattern [11]. This study aims to adjust the level of difficulty of the task in order to improve the skill level of the user. Our goal is to support the optimal improvement of cutting skills for novices. By combining these studies, we can bring great fulfillment and happiness for novices by matching their skills against the tasks.

ACKNOWLEDGMENTS

This work was supported by JSPS KAKENHI Grant Number JP16K00269 and The Okawa Foundation for Information and Telecommunications. I would like to thank Sidney Fels and HCT group at the University of British Columbia.

REFERENCES

- [1] Seok-Hyung Bae, Ravin Balakrishnan, and Karan Singh. 2009. EverybodyLovesSketch: 3D Sketching for a Broader Audience. In *Proceedings of the 22Nd Annual ACM Symposium on User Interface Software and Technology (UIST '09)*. ACM, New York, NY, USA, 59–68. <https://doi.org/10.1145/1622176.1622189>
- [2] J. C. P. Chan, H. Leung, J. K. T. Tang, and T. Komura. 2011. A Virtual Reality Dance Training System Using Motion Capture Technology. *IEEE Transactions on Learning Technologies* 4, 2 (April 2011), 187–195. <https://doi.org/10.1109/TLT.2010.27>
- [3] Philo Tan Chua, R. Crivella, B. Daly, Ning Hu, R. Schaaf, D. Ventura, T. Camill, J. Hodgins, and R. Pausch. 2003. Training for physical tasks in virtual environments: Tai Chi. In *IEEE Virtual Reality, 2003. Proceedings.* 87–94. <https://doi.org/10.1109/VR.2003.1191125>
- [4] D. Cummings, F. Vides, and T. Hammond. 2012. sha. In *Proceedings of the International Symposium on Sketch-Based Interfaces and Modeling (SBIM '12)*. Eurographics Association, Goslar Germany, Germany, 97–106. <http://dl.acm.org/citation.cfm?id=2331067.2331082>
- [5] Daniel Dixon, Manoj Prasad, and Tracy Hammond. 2010. iCanDraw: Using Sketch Recognition and Corrective Feedback to Assist a User in Drawing Human Faces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. ACM, New York, NY, USA, 897–906. <https://doi.org/10.1145/1753326.1753459>
- [6] Jennifer Fernquist, Tovi Grossman, and George Fitzmaurice. 2011. Sketch-sketch Revolution: An Engaging Tutorial System for Guided Sketching and Application Learning. In *Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology (UIST '11)*. ACM, New York, NY, USA, 373–382. <https://doi.org/10.1145/2047196.2047245>
- [7] Matthew Flagg and James M. Rehg. 2006. Projector-guided Painting. In *Proceedings of the 19th Annual ACM Symposium on User Interface Software and Technology (UIST '06)*. ACM, New York, NY, USA, 235–244. <https://doi.org/10.1145/1166253.1166290>
- [8] Takafumi Higashi and Hideaki Kanai. 2016. Instruction for Paper-cutting: A System for Learning Experts' Skills. In *Proceedings of the 2016 ACM on Interactive Surfaces and Spaces (ISS '16)*. ACM, New York, NY, USA, 457–460. <https://doi.org/10.1145/2992154.2996872>
- [9] Takafumi Higashi and Hideaki Kanai. 2017. Stylus Knife for Paper-cutting: A System for Controlling a Knife. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '17)*. ACM, New York, NY, USA, 2638–2645. <https://doi.org/10.1145/3027063.3053224>
- [10] Takafumi Higashi and Hideaki Kanai. 2017. Tracing Practice System for Developing Paper-Cutting Skills. In *Proceedings of the 12th International Conference on Knowledge, Information and Creativity Support System (KICSS '17)*. Springer Berlin Heidelberg, 173–178.
- [11] Takafumi Higashi and Hideaki Kanai. 2018. Impact of Practice Effect on Each Difficulty of Cutting Skill. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction (NordiCHI '18)*. ACM, New York, NY, USA, 904–909. <https://doi.org/10.1145/3240167.3240236>
- [12] Emmanuel Iarussi, Adrien Bousseau, and Theophanis Tsandilas. 2013. The Drawing Assistant: Automated Drawing Guidance and Feedback from Photographs. In *Proceedings of the 26th Annual ACM Symposium on User Interface Software and*

- Technology (UIST '13)*. ACM, New York, NY, USA, 183–192. <https://doi.org/10.1145/2501988.2501997>
- [13] Hark-Joon Kim, Hayoung Kim, Seungcho Chae, Jonghoon Seo, and Tack-Don Han. 2013. AR Pen and Hand Gestures: A New Tool for Pen Drawings. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13)*. ACM, New York, NY, USA, 943–948. <https://doi.org/10.1145/2468356.2468525>
 - [14] Yongkwan Kim and Seok-Hyung Bae. 2016. SketchingWithHands: 3D Sketching Handheld Products with First-Person Hand Posture. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology (UIST '16)*. ACM, New York, NY, USA, 797–808. <https://doi.org/10.1145/2984511.2984567>
 - [15] Paraskevi Kritopoulou, Sotiris Manitsaris, and Fabien Moutarde. 2016. Towards the Design of Augmented Feedforward and Feedback for Sensorimotor Learning of Motor Skills. In *Proceedings of the 3rd International Symposium on Movement and Computing (MOCO '16)*. ACM, New York, NY, USA, Article 38, 4 pages. <https://doi.org/10.1145/2948910.2948959>
 - [16] J. Laviolle and M. Hachet. 2012. PapART: Interactive 3D graphics and multi-touch augmented paper for artistic creation. In *2012 IEEE Symposium on 3D User Interfaces (3DUI)*, 3–6. <https://doi.org/10.1109/3DUI.2012.6184167>
 - [17] Yong Jae Lee, C. Lawrence Zitnick, and Michael F. Cohen. 2011. ShadowDraw: Real-time User Guidance for Freehand Drawing. *ACM Trans. Graph.* 30, 4, Article 27 (July 2011), 10 pages. <https://doi.org/10.1145/2010324.1964922>
 - [18] Alex Limpaecher, Nicolas Feltman, Adrien Treuille, and Michael Cohen. 2013. Real-time Drawing Assistance Through Crowdsourcing. *ACM Trans. Graph.* 32, 4, Article 54 (July 2013), 8 pages. <https://doi.org/10.1145/2461912.2462016>
 - [19] Lijuan Liu, Yang Chen, Pinhao Wang, Yizhou Liu, Caowei Zhang, Xuan Li, Cheng Yao, and Fangtian Ying. 2018. Papercut: Digital Fabrication and Design for Paper Cutting. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18)*. ACM, New York, NY, USA, Article LBW078, 6 pages. <https://doi.org/10.1145/3170427.3188522>
 - [20] Tsutomu Terada Minoru Fujimoto and Masahiko Tsukamoto. 2012. A Dance Training System that Maps Self-Images onto an Instruction Video. In *Proceedings of the 5th International Conference on Advances in Computer-Human Interactions (Achi 2012)*, 309–314. http://www.thinkmind.org/download.php?articleid=achi_2012_12_30_20280PDF
 - [21] Noriaki Muranaka, Takafumi Yamamoto, and Shigeru Imanishi. 2003. A Calligraphy Mastering Support System Using Virtual Reality Technology and its Learning Effects. *IEEE Transactions on Fundamentals and Materials* 123, 12 (2003), 1206–1216. <https://doi.org/10.1541/ieejfms.123.1206>
 - [22] Michael Polanyi. 1973. *Personal Knowledge-Towards a Post-critical Philosophy*. University Of Chicago Press.
 - [23] Alec Rivers, Andrew Adams, and Frédo Durand. 2012. Sculpting by Numbers. *ACM Trans. Graph.* 31, 6, Article 157 (Nov. 2012), 7 pages. <https://doi.org/10.1145/2366145.2366176>
 - [24] Masato Soga, Shota Kuriyama, and Hirokazu Taki. 2009. Sketch Learning Environment with Diagnosis and Drawing Guidance from Rough Form to Detailed Contour Form. In *Learning by Playing. Game-based Education System Design and Development*. Springer Berlin Heidelberg, 109–109.
 - [25] Steve Tsang, Ravin Balakrishnan, Karan Singh, and Abhishek Ranjan. 2004. A Suggestive Interface for Image Guided 3D Sketching. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04)*. ACM, New York, NY, USA, 591–598. <https://doi.org/10.1145/985692.985767>
 - [26] Ungyeon Yang and Gerard Jounghyun Kim. 2002. Implementation and Evaluation of "Just Follow Me": An Immersive, VR-based, Motion-training System. *Presence: Teleoper. Virtual Environ.* 11, 3 (June 2002), 304–323. <https://doi.org/10.1162/105474602317473240>
 - [27] A. Zoran, R. Shilkrot, P. Goyal, P. Maes, and J. A. Paradiso. 2014. The Wise Chisel: The Rise of the Smart Handheld Tool. *IEEE Pervasive Computing* 13, 3 (2014), 48–57. <https://doi.org/10.1109/MPRV.2014.59>