Computer-Augmented Stationeries for Human-Skill Support

Mayu M. Yamashita
Keio University
5322, Endo, Fujisawa,
Kanagawa 252-0882 JAPAN
t10554my@sfc.keio.ac.jp

ABSTRACT

We present an approach to support human skills of using common stationeries through computer augmentation. We focused on the features of materials being used in each stationery such as the conductivity of the scissors metal blades and clay erasers capability of mixing with carbon fiber and being molded into desired shapes. Our first system, enchanted scissors, is a digitally controlled pair of scissors. It restricts areas that can be cut while requiring the user's exertion of force and decision to execute each cut. It has varieties of usage from opening a letter to creating a complicated paper craft. Our second system is an eraser prototype with visual and haptic feedback to inform the users if they are erasing properly and the amount erased. Both of our systems provide real-time feedback thus allowing a comfortable connection of the user's physical input and the output implemented by the device.

INTRODUCTION

"Interactive fabrication" [?] is now a widespread concept as interfaces such as 3D printers and laser cutters have reached an affordable range. Users can conveniently transform their imaginations into high quality physical forms by utilizing computer-assisted machines. However, most of the existing fabrication tools require background knowledge and skills to operate or design models on software programs. It is challenging for beginners in digital fabrication to start from scratch. Even for advanced users, the preparation steps could be time consuming and stationary fabrication devices put limit to handiness. Our approach is to provide a gateway to interactive fabrication for the beginners and an easy-to-set up device for the professionals through a digitally controlled pair of scissors, a tool familiar to everyone.

We present an approach to support basic and complex cutting processes through an interactive fabrication experience. Our system, enchanted scissors[?](Figure 1), is a digitally controlled pair of scissors. It restricts areas that can be cut while requiring the users exertion of force and decision to execute each cut. Therefore, unlike a completely digitalized cutting device, the user can freely apply improvisations within the permitted areas in real-time. A pair of scissors is a common tool seen and used in everyday life; the user can instantly recognize its operation method. The device has varieties of usage from opening a letter to creating a complicated paper craft. While using scissors, it is common to cut unintended parts or difficult to control the blades for cutting intricate details. enchanted scissors prevents these errors in advance by using two switchable programs to restrict the areas that can be cut. Both programs provide real-time feedback to the user during the cutting process as regular scissors would, allowing a comfortable connection of the users physical input and the output implemented by the device.

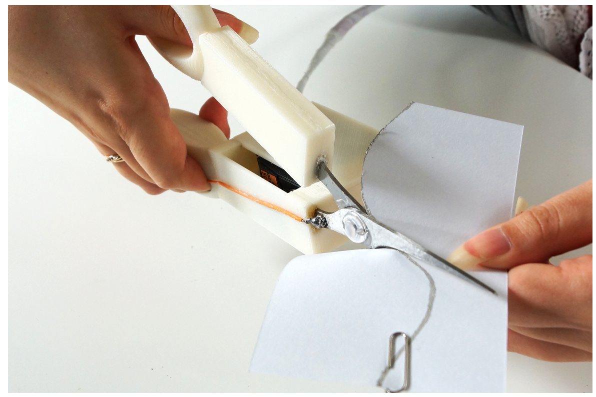

Figure 1. enchanted scissors.

In this paper, we discuss the enchanted scissorss hardware design and software composition, along with applications, user evaluations and future prospects. As an extension of enchanted scissors, we are starting a series of computer-augmented stationeries. We present an eraser prototype that allows the users to be aware if they are erasing on the line and how much they are erasing.

RELATED WORK

The FreeD [?] is a digitally controlled, mobile milling device. The computer adjusts the spindles speed or draws back the shaft as the bit approaches the 3D model which is based on the CAD model established beforehand. Although The FreeD allows the user to express creativity by developing unique textures or leaving particular areas of the model unfinished, the milling bit cannot exceed the boundaries set by the CAD model.

A computerized positioning approach to support 2D fabrication [?] has been explored. The user sets high resolution markers on a 2D material for localization, and by moving the cutting tool along a digitally specified path, the user is able to cut in precise motion over an unlimited range. enchanted scissors similarly aims to provide the user to enhance creativity while having computer-augmented accuracy in cutting, though without the need of localizing.

With immediate output process, Constructable [?] enables the user to experience personalized constructing with a laser cutter based tool. The user utilizes different proxy lasers to combine cutting patterns and designs actualized by the laser cutter to construct freely on a 2D platform. Our approach similarly accomplishes to display the results of the users actions in real-time, hence enabling the user to plan subsequent steps and modifications in designs.

Air-Hair [?] and The Haptic Scissors [?] superimpose forces of cutting hair and performing surgery respectively. Both works intend to establish virtual simulations with corresponding tactile displays. We reference the output methods of these interfaces to apply when controlling enchanted scissors feedbacks. ToolDevice [?] transforms familiar tools such as pinsets and droppers by adding multiple haptic feedbacks including force, firmness, and weight. The user can instantly recognize the affordance of the interfaces from past experiences as how we anticipate by using a pair of scissors. While ToolDevice implements dynamic digital control of the tools for virtual displays, enchanted scissors supports fabrication processes in the real-world.

There are various works focusing on enhancing hand-drawing [?] and bridging the gap between computer graphics and human capabilities [?] [?] [?]. Our eraser prototype outputs feedback to augment human skillset and rely mainly on the users decisions rather than almost entirely manipulating the outcome of the drawings.

ENCHANTED SCISSORS

Our objective is to have different types of users, from beginners to professionals, to incorporate enchanted scissors in multiple situations to improve their cutting performances (Figure 2). Some of the effects we anticipate include inexperienced users such as children learning how to properly cut on the line and handicapped users experiencing scissor handling almost effortlessly. With the real-time, immediate haptic feedback, even paper craft artists can utilize this device to prevent minor mistakes. Since the cutout templates do not need to be pre-made, users have the opportunities to customize the shape and thickness of the conductive line. Our system does not require any special tools; the cutout lines may be prepared using any ordinary writing/drawing utensil with conductivity such as pencils.

There are two switchable modes to enchanted scissors. The first mode prevents the blades from cutting the conductive line. This mode can be used to protect areas the user does not desire to cut. The user may choose to cut neatly along the line or apply additive or subtractive modifications such as for making paper cutouts. The second mode achieves the complete opposite of the first mode; it only allows the scissors to precisely cut on the line. This mode is suitable for practicing scissor handling. Users can start off with templates drawn in thick lines, and make transitions to templates drawn in thinner lines when their skills have improved. By combining the two modes with various lines and shapes, users are able to create personalized cutting experiences to fulfill different goals matched to their skillsets.

Figure 2. Improved cutting performance.

SYSTEMS ARCHITECTURE

Hardware

enchanted scissors was created using mostly the same parts as those of a regular pair of scissors; even without instructions, the user recognizes its basic usage from the prototype. We focused on the conductivity of the scissors metal blades. For the most stable distribution of electric current, we use pencils with lead softer than B, Techno Pen from Taniguchi Ink Corporation, and Bare Paint from Bare Conductive to mark the areas the user can cut or avoid to cut. Since the device reacts only when the blades come in contact with the drawn line, the user is able to predominantly control the lines design and the execution of each cut.

Wired Prototype

A capacitive sensor can be created when a conductive line or a shape is attached to the paperclip connected to a micro-controller (ATmega328P). This allows low electric current to flow into the line, thus forming a circuit. enchanted scissors has a wire connecting one of the blades with the inside of its handle where conductive tape is attached. This way, when the blades touch the the line, electric current extends from the surface of the paper to the interior of the handle where the user would hold. In other words, the user can indirectly touch the conductive line through the device (Figure 3). Since the human body contains electrostatic capacitance, it can function as a resistor when in contact with a conductive material. As the blades touch the circuit, the micro-controller reads a certain degree of capacitance within a few micro-seconds, and the servo motor contained in the device reacts according to that value. The motors torque strength is 13-16 kg-cm which is enough to pry apart the two handles even when the user is exerting counterforce. Considering the amount of body capacitance to vary depending on the surroundings, we must measure and calibrate the motors minimum trigger value each time we transport. Some inconveniences we encountered with this prototype are the restricted mobility of the device because of its separate power supply and the motors unintended function from direct skin contact with the conductive line.

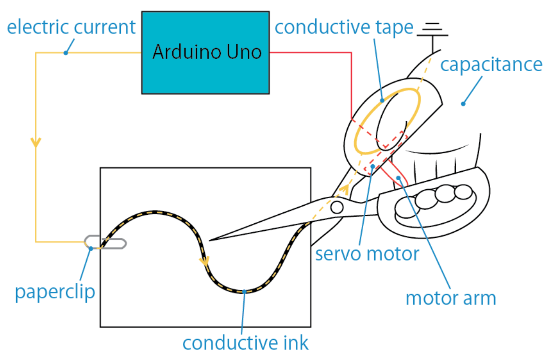

Figure 3. System diagram.

Wireless Prototype

We have succeeded in making the interface wireless in the later model. The basic functions remain the same, however there were slight alterations to the systems architecture. Instead of relying on the human capacitance, we now have a separate micro-controller specifically to send electric signals, via a wired paperclip, which would be received by a different micro-controller, via the blades, loaded on the device. Although this lead to increase in size and weight of the prototype, the wireless system solves the mobility problem and accidental function of the motor when the users hand comes in contact with the conductive line. With the wireless prototype, users have no restriction on the placements of the hand holding the paper while cutting. We attached a battery pack on the device for power source, and a button to immediately switch between the two modes.

Software

The device operates on two modes. The first program forbids the drawn line to be cut, thus the user can cut adjacent and/or nonadjacent to the line. When the user attempts to place the blades on the line, the angular position of the servo motors arm changes from the initial 0 degrees to 98 degrees, forcing the two handles apart from each other. In order to attach the paperclip, the drawing in conductive ink must be placed near the edge of the paper (Figure 4a).

The second program allows the user to cut only on the line drawn in conductive ink. The servo motors arm recedes when the blades touch the line, enabling the user to cut freely with the device. Likewise the other program, the drawing must be located within a range reachable for the paperclip attached to the paper. Additionally, it is necessary for a part of the drawing to touch the edge of the paper which would be the starting point for the user to cut (Figure 4b).

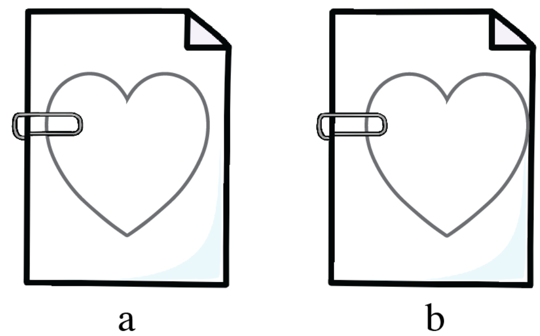

Figure 4. (a) the drawing must be placed within the paperclips reachable range, (b) the drawing must touch the edge of the paper.

APPLICATIONS

Those who are inexperienced with scissors such as children can practice their coordination as the device dynamically provides tactile restrictions if the blades go off track. By accomplishing to cut accurately with the device, they may be able to acquire the skills of using scissors and possibly continue to improve even when handling a regular pair. Rather than using practice worksheets for cutting, the dynamic feedback coming directly from the scissors may be a more effective way to guide children where to and where not to cut.

Changing the thickness of the conductive line allows the user more or less space to experiment with improvisation. The thinner the line, the more likely the chance of fabricating detailed papercrafts. It is suitable for advanced scissor users requiring assistance to prevent minor errors ahead. On the other hand, with thicker lines, the user can enhance creativity by cutting straight, in zig-zags or in curvy lines since there is a broader range to move the blades around. As seen in Figure 5, the three cutouts originate from an identical template (3cm-thick circles drawn in black conductive paint), despite resulting in the shapes of three different animals. It was based on the users judgment to add original arrangements within the painted area.

With further practice, enchanted scissors can be used with eyes closed (Figure 6). Even if cutting carelessly without visual information, the user may rely on the tactile feedbacks to guide the blades in the correct direction. The device protects the designated areas, therefore prevents undesirable accidents to happen such as cutting the contents inside envelopes (Figure 7). Attaching the paperclip to the folded edge of a letter outlined in conductive ink would forbid the user to unintentionally damage the letter. Moreover, enchanted scissors can be a supportive cutting tool for the visually impaired.

Exhibitions

enchanted scissors has appeared in several national exhibitions and an international conference. We organized materials that we encounter in everyday life such as newspapers, magazines, and postcards to promote its usefulness in varying scenes. Those who had experienced the demonstration of enchanted scissors made remarks on how the tool is useful in any typical situations involving 2D cutting.

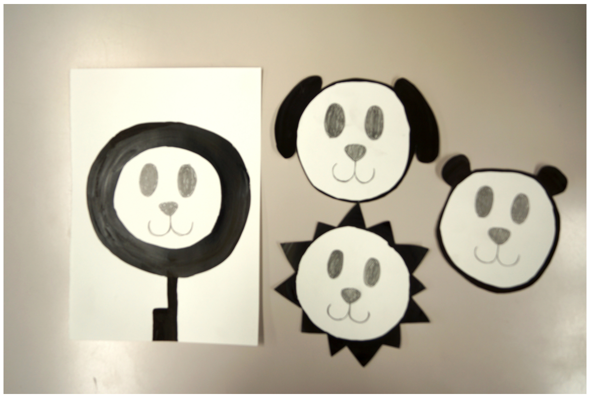

Figure 5. Three results from an identical template.

Figure 6. Cutting with eyes closed.

We participated in several events which targeted children to participate (Figure 8). Most of the young participants simply found the device to be entertaining due to the unusual movements it makes. The children were able to figure out the core purpose of enchanted scissors and attempted to cut carefully so the device will not get angry for cutting outside of the line.

One of the attendees was a teacher in a kindergarten school who happened to be using scissors everyday for making paper crafts. It was obvious her cutting skill was exceptionally advanced among all the visitors, however as she attempted to cut a more detailed part of the sample figure, enchanted scissors assisted by preventing her from cutting outside of the line. It is evident experienced scissor users can make slight mistakes, and the device can contribute to efficient workflow.

Another user who suffered from tumor confessed he cannot use a regular pair of scissors due to consistent convulsions. As the user held enchanted scissors in his hand, he was able to cut along the lines with minimal force. He commented on how the device is useful with handicapped users as himself.

Some visitors closed their eyes or turned the paper facedown to experiment if they can cut despite lacking visual information. The users who proceeded to cut more prudently were more likely to have better results. Those who cut hastily were able to roughly follow along the line, though ended up with

Figure 7. Prevent cutting unintended areas.

many tiny errors such as over-cutting (1 to 5 millimeters), struggling to set the blades on the line. With the wired prototype, some users accidentally touched the conductive line directly with their hands when holding the paper which generated the motor to malfunction. Those same users who also used the wireless prototype afterwards, all complimented on the systems improvement.

Throughout the exhibitions, we observed a slight time lag between the moment electric signal was sensed and the moment the motors arm started to rotate. This sometimes caused minor over-cut errors to occur. The increased size and weight of the wireless prototype also caused some children to struggle holding the scissors upright.

Figure 8. Workshop aimed for children.

FURTHER APPROACH FOR AUGMENTING STATIONERIES

We recently started out a secondary project pertained to enchanted scissors; we basically apply the same system to a different stationery. We developed a conductive eraser by mixing carbon fiber into clay eraser. We can embed actuators and LEDs in clay eraser before boiling the eraser into its final form, which enables us to maintain the same level of usability and appearance as regular erasers. In this approach, we present an eraser interface which roughly informs the users the locations they are erasing through visual or haptic feedbacks. The eraser device objectively outputs computer-augmented feedbacks such as lighting up or vibrating in certain patterns when in contact with pencil markings. Users may utilize the feedbacks as their guidance to decide where to or where not to erase. As enchanted scissors, the users act as the brain while the stationery is nothing more than a support tool. We provide applications for different situations involving the usage of erasers such as retaining unnecessary pencil marks and creating gradients for light and shadow effects. For example, we programmed the eraser to light up differently as the amount of graphite in contact with the eraser changes. The user may not be able to see how much is being erased underneath the eraser, however with the visual aid of the erasers glow, it would be easier to control the amount of rubbing until the desired color of shade is reached.

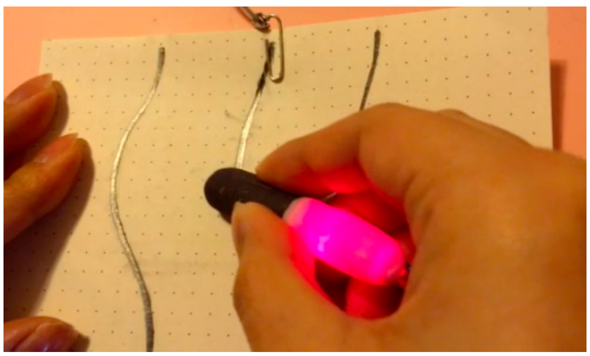

Figure 9. Computer-augmented eraser.

CONCLUSION AND FUTURE WORK

Each user may establish multiple applications to assist cutting processes using enchanted scissors. Once a cutting error happens, it is difficult to retract. Having computer-augmented aid, enchanted scissors would restrain such accidents from occurring in the first place. Users may produce quality 2D works in time efficient workflow. Beginners are able to improve scissor handling skills and users with more experience can utilize it to perfect each cut. Our aim is for the users to consequently develop more interest in interactive fabrication altogether.

In an attempt to quicken the reaction speed of the device preventing the users to cut unintended, we have replaced the servo-motor with solenoids. Since solenoids either push or pull in a vertical movement, the time from which the blades touched the conductive line to scissors opening or closing shortened. However, the strengths of the solenoids to hold in a certain position were not strong enough to withhold the users counterforce. Therefore, we conclude using servo-motors is currently the better method.

We are striving to make the wireless prototype smaller and lighter, taking into account the burden of the increase in size and the weight of the scissors compared to the wired model. It is desired to use a more compact servo-motor without much change in the torque strength from the current one. In the future, we intend to modify the device to output gradual haptic feedbacks depending on the distance between the blades and the conductive line. With the usage of command-type-servo-motors and their ability to have compliance control, it would be possible to express elasticity in the motors arm movements. For example, the scissors could open and close without constraint when the blades are precisely positioned on the conductive line and as the blades derail, the elasticity of the motors arm firms. This way, the user is able to physically feel how far or close the cutting line is through the firmness of the grip on the handles. Another potential application is to superimpose haptic textures. The user would perceive as if cutting a thick cardboard when actually cutting a thin sheet of paper.

The eraser prototype still lacks in manipulation compared to enchanted scissors. The users may recognize certain areas that can or cannot be erased from visual and haptic feedback, though they still have complete physical freedom. We hope to overcome these tasks by incorporating systems such as Traxion [**?**] for the users to feel an invisible force that segways the eraser away from certain areas. As the eraser, we anticipate to create series of augmented stationeries in the near future.

ACKNOWLEDGEMENTS

This research is supported by CREST, JST.

REFERENCES

1. Air-Hair. www.diginfo.tv/v/10-0106-r-en.php.
2. Hashida, T., Nishimura, K., and Naemura, T. Hand-rewriting: Automatic rewriting like natural handwriting. In *ACM SIGGRAPH 2012 Emerging Technologies*, SIGGRAPH '12, ACM (New York, NY, USA, 2012), 10:1–10:1.
3. Ikeda, Y., Sato, K., and Kimura, A. Tool device: handy haptic feedback devices imitating every day tools. In *Proc. HCI Int. '03* (2003), 661–665.
4. Kim, H., Kim, S., Lee, B., Pak, J., Sohn, M., Lee, G., and Lee, W. Digital rubbing: playful and intuitive interaction technique for transferring a graphic image onto paper with pen-based computing. In *CHI '08 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '08, ACM (New York, NY, USA, 2008), 2337–2342.
5. Lee, Y. J., Zitnick, C. L., and Cohen, M. F. Shadowdraw: real-time user guidance for freehand drawing. *ACM Trans. Graph. 30*, 4 (July 2011), 27:1–27:10.
6. Mueller, S., Lopes, P., Kaefer, K., Kruck, B., and Baudisch, P. constructable: interactive construction of functional mechanical devices. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, ACM (2013), 3107–3110.
7. Okamura, A., Webster, R.J., I., Nolin, J., Johnson, K. W., and Jafry, H. The haptic scissors: cutting in virtual environments. In *Robotics and Automation, 2003. Proceedings. ICRA '03. IEEE International Conference on*, vol. 1 (Sept 2003), 828–833 vol.1.
8. Rekimoto, J. Traxion: A tactile interaction device with virtual force sensation. In *Proceedings of the 26th*

Annual ACM Symposium on User Interface Software and Technology, UIST '13, ACM (New York, NY, USA, 2013), 427–432.

9. Rivers, A., Moyer, I. E., and Durand, F. Position-correcting tools for 2d digital fabrication. *ACM Transactions on Graphics (TOG) - SIGGRAPH 2012 Conference Proceedings 31*, 4 (2012), 88.
10. Willis, K. D., Xu, C., Wu, K.-J., Levin, G., and Gross, M. D. Interactive fabrication: new interfaces for digital fabrication. In *Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction* (2011), 69–72.
11. Yamaoka, J., and Kakehi, Y. dePENd: augmented handwriting system using ferromagnetism of a ballpoint pen. In *Proceedings of the 26th annual ACM symposium on User interface software and technology (UIST'13)*, ACM (2013), 203–210.
12. Yamashita, M. M., Yamaoka, J., and Kakehi, Y. enchanted scissors: a scissor interface for support in cutting and interactive fabrication. In *ACM SIGGRAPH 2013 Posters*, ACM (2013), 33.
13. Zoran, A., and Paradiso, J. The freed: a handheld digital milling device for craft and fabrication. In *Adjunct proceedings of the 25th annual ACM symposium on User interface software and technology (UIST'12)* (2012), 3–4.