ChromicCanvas: interactive canvas using chromic fiber

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Abstract. This study aims to realize a simple and flexible method of expression by combining chromic materials and digital fabrication tools. Focusing on UV embroidery thread among chromic materials, we propose "ChromicCanvas," an interactive drawing system that allows users to draw with various colors and drawing patterns. The prototype consists of canvases created with embroidery thread and pen and stamp-type devices for switching the shape and color tone to be drawn. This paper describes the preliminary verification of UV embroidery threads, the prototype device developed, and evaluation experiments.

Keywords: Photochromism · Embroidery · Canvas · Drawing.

1 Introduction

In recent years, considerable research has been conducted on wearable computers, in which the computer functions are built into clothing to support people's daily lives. In particular, research on e-textile, which incorporates sensors and electronic circuit functions into the fabric itself, is being actively pursued. Much of the previous research on e-textiles has focused on the electrical characteristics of the materials [2, 6, 7]. This study focuses on applying chromic materials to e-textiles. Chromic materials reversibly change their color in response to changes in the environmental conditions or other stimuli [1]. Goods and materials for manufacturing that change color with heat or ultraviolet (UV) light are sold as products, such as mugs and nails that change color with temperature, and yarn and beads that change color with UV light. These materials can be used to create fascinating works of art with interactive color changes. Nevertheless, many of these materials have limitations, such as allowing only transitions between two colors (e.g., from colorless to red), and once a pattern is determined, it cannot be changed, making it difficult to achieve flexible expression in conjunction with e-textiles. In this study, we aim to create a simple and flexible expression method by combining chromic materials and digital fabrication tools such as a CNC embroidery machine. Focusing on the UV embroidery thread among other chromic materials, we propose "ChromicCanvas," an interactive drawing system that allows users to draw with various colors and drawing patterns (Fig. 1 a).

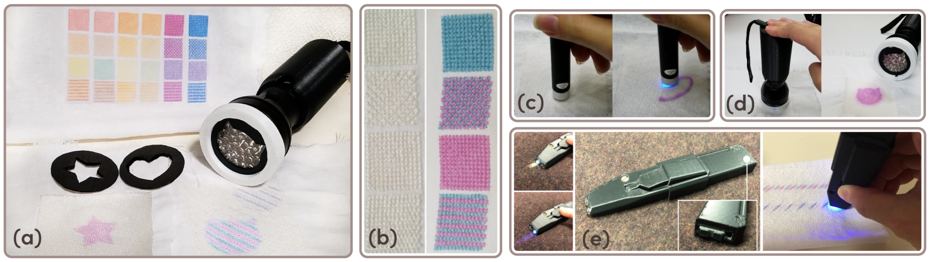

Fig. 1. (a) Overview of ChromicCanvas. (b) Trial of a new color by mixing two colors of threads in embroidery (top to bottom: blue, mix1, pink, mix2). (c) Drawing with a UV laser pointer. (d) Drawing with a UV stamp prototype. (e) Drawing with a UV pen prototype.

2 Related Work

2.1 Interaction method using chromic materials

Interactive systems have been proposed to control the color of a work using a material that changes color upon heating. Kaiho et al. [5] proposed a method for controlling the color of origami paper by applying thermochromic and conductive inks. Mosaic Textile [11] is a system that changes the color of cloth dyed with liquid crystal ink by means of heat generated by conductive threads and is proposed for use in clothing and other applications. Okazaki et al. [8] developed a method of knitting using wool dyed with an ink, whose color is fixed when a certain temperature is applied, and a special knitting rod to control the discoloration of any part of the yarn. Systems for drawing pictures on a single-color canvas coated with photochromic ink have also been proposed. Photochromic Canvas [3] allows drawing lines using a pen with a built-in projector, while Photochromic Carpet [10] permits drawing patterns as footprints by walking on it. In this study, we explored a simple method of creating canvases with color variations using a commercially available UV embroidery thread and an embroidery sewing machine. We also developed drawing devices, aiming for a system that allows users to draw pictures while easily switching color tones and patterns.

2.2 Printing technology using chromic materials

Many photochromic compounds that cause color changes due to UV rays change between specific colors and colorless, or between two specific colors. To increase the number of colors that can be represented, the following techniques have been proposed: ColorMod [9] changes the color of an object later by coloring a multicolor voxel pattern with photochromic inks during 3D printing; Photo-Chromeleon [4] improves the color tone and resolution, which can be expressed by mixing multiple colors of chromic ink into a single solution. These methods require the expertise and skill of the producer because the ink must be applied to the object, and the production procedure is complicated and difficult. Instead of dyeing with chromic ink, this study used a UV thread to facilitate the creation of canvases. In addition, we focused on the possibility that different wavelengths of UV light-emitting diodes (LEDs) can change the color of lines drawn on a single-colored canvas, and we fabricated and verified prototypes of the drawing device.

3 Materials used in this study

3.1 Material selection and characteristics of UV threads

There are many types of chromic materials, for example, thermochromic materials, which change color depending on temperature; photochromic materials, which change color with light; and electrochromic materials, which change color with electricity [1]. We focused on photochromic materials because of their availability and ease of handling. After reviewing products with threads, fabrics, and other forms applicable to e-textiles, we obtained a "UV thread 7-color set" [1] (hereinafter referred to as UV thread). These threads are typically white and change to a unique color when exposed to UV light (Fig. 1 b), after which they gradually return to white over time. We confirmed that the UV thread could be used stably with Brother's PR655 commercial embroidery sewing machine owned by our laboratory.

The duration of coloration and effect of UV wavelength on the color tone of these UV threads were examined. We prepared embroidery samples and observed the color changes when exposed to UV light. Box-type (EKO-UV36W, 365 nm) and handheld-type (Vansky 51LED, 395 nm) UV lights were used (Fig. 2 left).

Duration of coloration. After exposure to UV light for 30 s with the box light to activate color, the change back to white was captured on video. Under 20.9°C, the color almost disappeared after 5 min, whereas under 10.3°C, the color remained pale even after 10 min. Thus, the color duration tended to vary with temperature.

Color tone and UV wavelength. The results of UV irradiation of the embroidery samples using the box (365 nm) and handheld (395 nm) UV light are depicted in Fig. 2. The embroideries in blue, pink, and purple had almost the same color, but those in red, orange, yellow, and green had different color tones.

4 ChromicCanvas

We propose an interactive canvas called "ChromicCanvas," which utilizes UV threads and a sewing machine. The goals are to enable expression of a variety of colors and to achieve a flexible drawing method. To realize the former, we

[1] Nakamura Shoji Co. Ltd., https://angelking.co.jp/SHOP/wagon-uv-thread.html

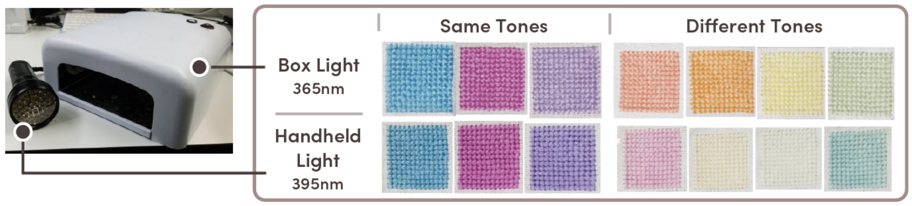

Fig. 2. UV lights used and results of UV irradiation of the embroidery.

attempted to create a variety of colored canvases by mixing multiple colors of UV threads and embroidering them. Color expression utilizing the difference in coloration according to the UV wavelength was also considered. To realize the latter, we applied devices such as laser pointers and stamped- or pen-type devices that can switch the shape and color of the drawing.

4.1 Implementation of canvas

Single-color canvases made with a single embroidery thread and multicolor canvases made with multiple embroidery threads were created. To create a multicolored canvas, we first mixed and embroidered two colors of threads from the basic seven-color thread. We tried several stitch settings available in the sewing machine software and several patterns by sending their data to the sewing machine. As a result, it was found that the "cross stitch" and "diagonal stripe" pattern with a width of 1.5 mm blended the colors better (Fig. 1 b-mix1). Fig. 3 displays 21 types of color samples mixed with two colors. Canvases with four and seven colors were also created using the same settings (Fig. 4). Although the mixed color was not as good as the two colors, it was used to validate the drawing device.

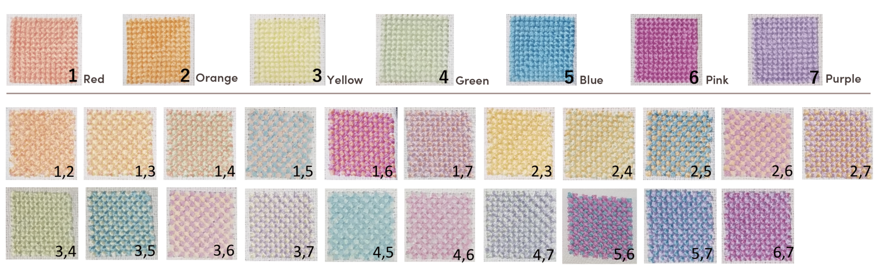

Fig. 3. Embroidery samples in seven primary colors and 21 mixed colors.

The single-color canvas was created using the "Tatami fill" stitch setting, which produces a cloth-like finish. Tatami fill can create a canvas on both sides of the fabric by using UV threads as the upper and lower threads on the sewing

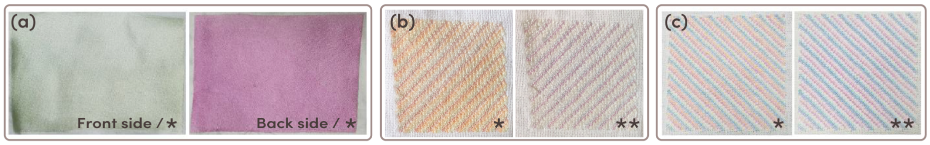

Fig. 4. Examples of canvas: (a) single-color, (b) seven-color, (c) four-color. *: Result of UV irradiation with box light. **: Result of UV irradiation with hand-held light.

machine. We used it to create a single-color double-sided canvas with different colors on the front and back sides. Fig. 4 (a) shows a canvas created with the upper thread in green and the bobbin thread in pink.

4.2 Drawing on canvas using a laser pointer

Using a UV laser pointer (HTPOW Ltd., 405 nm), we confirmed that lines could be drawn freely on the canvas, similar to writing with a pen on paper (Fig. 1 c). The color density of the lines depends on the speed at which the laser pointer moves. The written lines also disappear over time.

4.3 Implementation of stamp and pen type devices

The stamp-type input device (hereinafter referred to as the UV stamp) was implemented by attaching parts created by 3D printing to a handheld UV light. When the UV stamp is pressed against the canvas, UV rays are emitted (Fig. 1 d). These are partially blocked by the attached plate, and irradiated onto the canvas in the shape of holes in the mold. This allows the user to draw stamps of various shapes on the canvas. A spring was used to fix the battery of the original handheld UV light, which was modified to emit UV rays only when the holding part is pushed all the way to be stamp-like in its usability. Flexible filaments were used for the mold cap to allow easy attachment and detachment of the stamp mold. The stamp mold was cut from a 2mm-thick black acrylic plate using a laser cutter. By exchanging the stamp mold, a stamp of any pattern can be drawn on the canvas.

A pen-type device (hereinafter referred to as the UV pen) that can switch between two UV LEDs of different wavelengths was implemented (Fig. 1 e). This allows the user to freely draw lines on the canvas. Using different UV LEDs, we aimed to control the colors that emerge on the canvas. Two types of UV LEDs were set as pen tips, and the LED used by the slide switch on the back of the pen was switched. The LED was lit only when the switch was pressed. The voltage was 4.5 V (three 1.5 V button batteries), and four types of UV LEDs with different wavelengths (375, 385, 405, and 415 nm) were used.

5 Evaluation

This section describes the usability evaluation of ChromicCanvas and the performance investigation of color drawing using the UV pen.

5.1 Usability evaluation

We conducted a hands-on workshop using the single-color canvas, laserpointer [2], and UV stamp, and investigated the impression on the expression of the drawn pictures as well as the usability of the drawing devices through questionnaires/observations of the subjects.

Method. The experimenter verbally instructed the subjects on how to use the UV stamp, and the subjects painted on the canvas approximately 10 times without practicing, changing the stamp mold. The experimenter also instructed the subjects on how to draw using the laser pointer. The subjects practiced, and then drew a free-drawing artwork. They were then asked to complete a questionnaire. Ten subjects aged between 21 and 22 years (including four females) participated.

Result. The results of a 5-point scale for the "ease of stamping" of the UV stamp and the "ease of changing" the stamp mold showed that the average for the former was 4, while the average for the latter was 2.8. In the free description, some respondents answered that the cap was somewhat hard and difficult to remove.

Regarding free-line drawing using the laser pointer, the average scores were 4.3 for "ease of line drawing" and 4.3 for "degree of freedom in line drawing." In the free description, some users answered, "I want it to be possible to draw thin lines," and "Colors disappear faster than I expected." Fig. 5 shows examples of drawings using the laser pointer.

The question asking for "examples or places that could be used" was answered with "patch," "children's playgrounds," and "schools." In the question "How do you feel about the phenomenon of colors disappearing while drawing?" respondents answered "No problem for simple drawings" and "Can express a variety of color intensities." During the experiment, when the device colored the canvas, the subjects often exclaimed, "Oh!" and "Wow!" when the device colors the canvas. After the experiment was completed, the subjects were free to draw pictures or create complex drawings that they had not drawn during the experiment.

5.2 Performance study of UV pen

As discussed in Section 3.1, there are differences in the coloration when the wavelengths of the UV light used are different. To confirm whether this characteristic

[2] Since it was before the UV pen was implemented, the laser pointer was used.

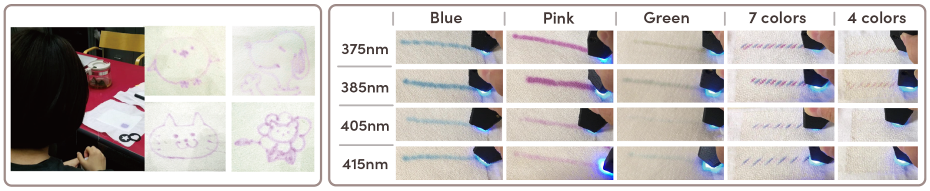

Fig. 5. Results of evaluations 5.1(left) and 5.2(right).

can be reproduced with UV pens, we compared the color outputs of LEDs with different wavelengths attached to the UV pen.

Method. The task of drawing a line on the canvas with the UV pen of approximately 5 cm for 6–7 s was performed for the single-color canvas (blue, pink, and green) and multicolor canvas (seven and four colors). LEDs with wavelengths of 375, 385, 405, and 415 nm were attached to two UV pens. The experiment was conducted in a room with a temperature of 20.5 – 21°C and fluorescent lighting, and it was filmed on video, which was used for color comparison.

Result. The color and density of the drawn lines differed depending on the UV LED wavelength. Fig. 5 illustrates the lines immediately after drawing using the UV pen.

The color tone of the lines varied according to the color of the canvas. The lines drawn on the green canvas were yellow-green at 375 nm, bluish-green at 385 nm, and light blue at 405 nm and 415 nm. The lines drawn on the seven-color canvas were strong pink and blue stripes at 375 nm and 385 nm; at 405 nm and 415 nm, the pink faded, so the overall stripes appeared cold. The lines of the four-color canvas were orange/red/green at 375 nm and 385 nm but not visually visible at 405 nm and 415 nm. The blue and pink canvas did not show any differences in the color tone of the lines.

The color intensity of the lines was darker at 375 nm and 385 nm and lighter at 405 nm and 415 nm for all canvases. The yellow UV threads in the seven- and four-color canvases were difficult to confirm visually. For the aforementioned four-color canvas, the entire line was extremely thin for visual confirmation.

6 Discussion

Regarding the color duration, the positive response from 5.1 subjects suggests that the disappearance of color over time can be used for shading expression or for trial and error in expression. On the other hand, there was a comment "colors disappear faster than I expected." Because color duration is extended at low temperatures, as mentioned in Section 3.1, we considered adding a canvas temperature control feature to avoid interfering with the user's drawing.

For the control of the color shade/tone with the UV pen, the results in Section 5.2 showed that the LEDs of different wavelengths were able to switch the color tones of the green, four-color, and seven-color canvas. In all canvases, the colors were darker with 375 nm and 385 nm LEDs and lighter with 405 nm and 415 nm LEDs at the same drawing speed. In the future, we would like to improve/verify devices that can adjust the intensity of UV light and attempt to control shading and color tone.

7 Conclusion

We proposed ChromicCanvas, an interactive canvas that can express various colors and drawing patterns using a UV thread and a CNC sewing machine. New color canvases were created by combining seven colors of commercially available threads. We implemented a UV stamp that can instantaneously stamp a specific shape and a UV pen that can freely draw using UV LEDs of different wavelengths. The basic performances were verified and discussed based on the findings. In the future, we plan to pursue the improvements described in the discussion and seek applications that take advantage of the system features.

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