Heat Sensation in Image Creation with Thermal Vision

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ABSTRACT
We introduce how to involve the heat sensation in image creation by using thermal vision. We develop "ThermoTablet" which can detect touch regions of physical input objects on a sensing surface using changes of a temperature distribution of the surface when those objects are hotter or colder than the surface. Image creation applications of painting, image modifications are implemented on it. In the painting application, users can directly use physical paintbrushes and airbrushes with hot water in spite of paint, and even use their own fingers, hands, and breaths directly. "ThermoInk" transforms the temperature information into a variation of painting. Image modification application aims an intuitive user interface for color saturation modification, hue modification, shape modification and CAD model deformation which are strongly related to heat sensations.

Categories and Subject Descriptors
H.5.2 [**Information Interface and Presentation**]: User Interface—*Input devices and strategies*

General Terms
Experimentation, Human Factors

Keywords
Heat sensation, Thermal Vision, Image Creation, Heat Metaphor

1. INTRODUCTION
Heat sensations are accessible feelings like people use heat for cooking, perceiving neighboring objects, changing conditions of objects and so on. Some of them are strongly related to image impression like warm/cold color. Therefore, when such heat sensations are involved into image creations, users can easily form appropriate mental models of them and intuitively manipulate them.

In this paper, we propose ThermoTablet which can detect touch regions of physical input objects on a sensing surface and temperature information of them using thermal vision. Their touch regions are detected as a temperature distribution of the surface which is captured by a thermo-infrared camera located behind the surface. In addition, a canvas-like display is combined with the sensing surface.

We introduce heat sensation interactive applications for entertainment on ThermoTablet. A painting application is that users can directly use physical paintbrushes and airbrushes as we use in the real world with hot or cold water in spite of paints, and even use their own fingers, hands, and breaths because of their own body heat. In an image modification application, users can intuitively change image properties which is strongly related to heat sensations.

2. RELATED WORK
In EnhancedDesk[2], hand gestures are recognized robustly since human bodies can be detected separately from the background in thermal vision which is not suffered from a lighting condition. However, there are difficulties of detecting touches between the surface and their hands. In contrast to EnhancedDesk, ThermoTablet can detect touch regions of physical input objects on a sensing surface.

I/O Brush[3] lets children explore colors, textures, and movements found in everyday materials by picking up and drawing with them. This system looks like a regular physical paintbrush but has a small video camera. Outside of the drawing canvas, the brush can pick up color, texture and movement of a brushed surface. On the canvas, children can draw with the special ink they just picked up. In contrast to I/O Brush, the proposed painting application allow users to paint with anything hotter or colder than the sensing surface which can be found around them.

DAB[1] is a painting system with an intuitive haptic interface. The force feedback enhances the sense of realism and provides tactile cues that enable users to better manipulate the paintbrush. In contrast to DAB, ThermoTablet does not have to have a force feedback framework since users can directly use physical paintbrushes to draw. Users can use not only paintbrushes but also airbrushes, their own fingers, hands and breaths in ThermoTablet.

3. THERMOTABLET
In this section, we describe the sensing principle, system overview and several unique advantages of ThermoTablet.

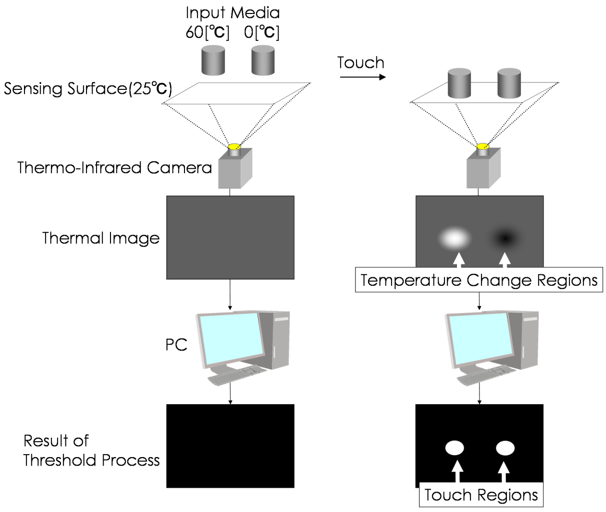

Figure 1: Principle of touch sensing

3.1 Sensing Principle

Figure 1 shows the sensing principle of ThermoTablet. The interface consists of the sensing surface(e.g. a paper) and a thermo-infrared camera located behind the sensing surface. When objects hotter or colder than the surface touch it, the temperature of the touch regions of the sensing surface are changed. We can capture these temperature changes by thermo-infrared camera and measure the touch regions using brightness changes of the thermal image(high: white, low: black).

We assume the sensing surface is quite thin. In this case, heats quickly transfer from the front side of the sensing surface to the back side and the temperature distribution of the back side becomes the same one of the front side. ThermoTablet can selectively detect the touch region between the sensing surface and input objects since the thermo-infrared camera locates behind the sensing surface.

3.2 System Overview

A video projector behind the canvas displays the result images of the interaction on the sensing surface(Fig. 2). In this manner, we use the sensing surface as the projecting screen. Because of the rear projection, there is no occlusion of the projective light due to users' fingers or hands. The process of the measurement of touch regions and the display of images are separated since thermal image is not affected by the projective light.

The homography is exploited for the calibration. The sensing surface is regarded as a 2D world coordinate. Four points of a projective image corresponded with the four corner points of the surface are manually detected and the homography matrix between the projector and the world coordinate is calculated. Touching the four corner points of the surface by a finger, the coordinate values of the four points of the thermo-infrared camera coordinate are obtained by capturing the temperature distribution and the homography matrix between the thermo-infrared camera and the world coordinate is calculated.

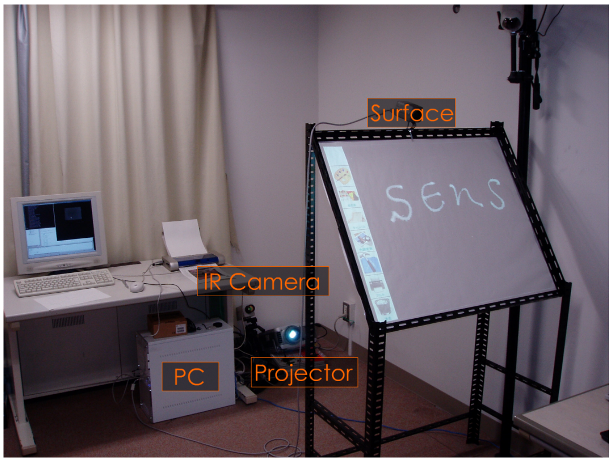

Figure 2: ThermoTablet

3.3 Advantages

In ThermoTablet, users can use anything hotter or colder than the sensing surface for input objects from their immediate environment. Therefore, users can directly use physical paintbrushes and airbrushes with hot water, and even use their own fingers, hands, and breaths because of their own body heat, since the sensing surface is kept in room temperature(25[deg]).

When there are multiple touches, ThermoTablet can separately detect these all simultaneously since there are multiple regions where temperature changes in thermal images. Therefore, multiple users can use ThermoTablet at the same time.

ThermoTablet can also measure the temperature information of input objects as attribute information of them in every pixel of the thermo-infrared camera. Temperature changes on the sensing surface are both low and high. Therefore, in ThermoTablet, some interactions strongly related to the heat sensations can be implemented.

4. HEAT SENSATION INTERACTIVE APPLICATIONS

We develop heat sensation interactive applications of painting, image modifications on ThermoTablet. In this section, we describe interaction techniques used on the applications.

4.1 Painting Application

Creating visual arts such as paints, illustrations and calligraphy with a computer become widespread and the data tablet is in heavy usage. Yet users cannot control a stylus like they turn or twist a physical paintbrush in the real world. And also users cannot see shape transformations of bristles and feel elastic force feedbacks. In the case of an airbrush, users have to touch the tablet surface while physical airbrushes are used without touching canvas. These are quite unnatural especially for artists who have trained to use these painting tools. Therefore they have to train again to use it in order to create art works as they wanted.

At this point of view, we propose a novel painting applica-

Table 1: Image modifications strongly related to the heat sensations

	Color Saturation	Hue	Shape	Stiffness
High	colorful	warm color	expansion	solid
Low	monotone	cold color	contraction	soft

tion on ThermoTablet. In the proposed application, users can directly use physical painting tools since it can detect touch regions on the sensing surface and painting results are projected as a projective pattern to touch regions.

We also propose a heat sensation graphics, ThermoInk, which transforms a temperature information into a paint variation. In ThermoInk, an alpha value of paint graphics is defined as an intensity of the thermal image. A variation of temperature on the sensing surface determines the thickness of the virtual ink.

4.2 Image Modification Application

In this section, we describe interactive applications using heat sensations. In these applications, users can easily form appropriate mental models of heat phenomena, and intuitively manipulate image modifications based on the heat sensations.

In the preliminary experiment, we have found image modifications which are strongly related to the heat sensations as shown in Table 1. Therefore a color saturation modification, a hue modification, a shape modification and a CAD model deformation applications are implemented on ThermoTablet. In these applications, users can modify images by heat. As an example of the first three applications, in the color saturation modification, when users warm a projected image on the surface, color saturations of this part of the image increase. On the contrary, users can decrease color saturations of the image by cooling it.

In a CAD model deformation application, we use the thermal plasticity and users can intuitively deform CAD models as making glassworks. While something hotter than the sensing surface touches a part of a CAD model which is projected to the sensing surface, the thermal plasticity of this part of the model becomes soft and is deformed according to an additive mouse drug operation.

5. EXPERIMENTS

In this section, we describe experimental implementation of ThermoTablet.

5.1 Implementation

Figure 2 shows the overview of ThermoTablet. It is composed of a thermo-infrared camera(MITSUBISHI IR-SC1, 320×240[pixel]), a PC(CPU: Pentium4 2.4GHz), a video projector and a thin film of paper material as the sensing surface. In experiments, we keep that hot water temperature is 60[deg], cold water temperature is 0[deg], and the room temperature is 25[deg].

The reason why we adopt paper for the sensing surface is following. Thermal images respond to the radiation from physical objects. The radiation is determined from both the temperature and the emissivity of the sensing surface. In general, metals have low thermo-infrared emissivities while they have high thermal conductivities. On the contrary, paper is a suitable material which has higher emissivity than metals and in the case of thin film realize fairly good conductivity.

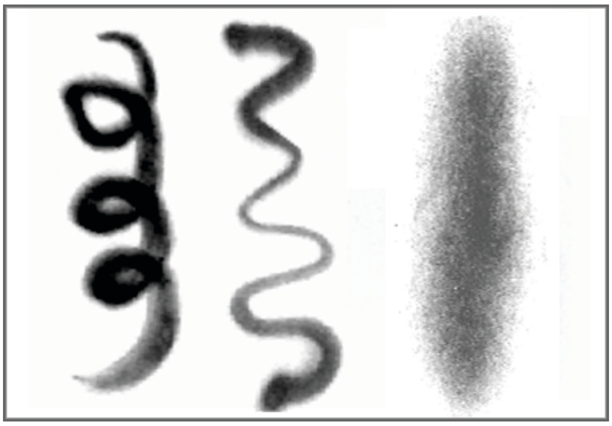

Figure 3: Paint example(left: paintbrush, middle: finger, right: airbrush)

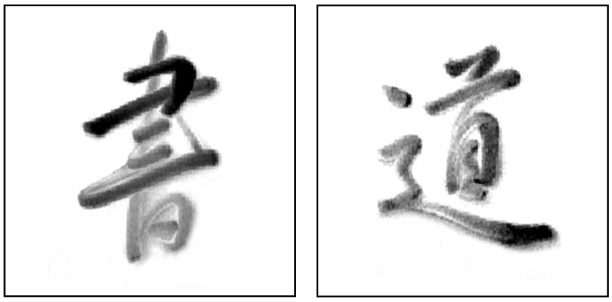

Figure 4: Art work by calligrapher

5.2 Painting Application

Figure 3 shows that the result of painting with a physical paintbrush, a finger and an airbrush. We use a paintbrush with hot water and an airbrush with cold water. In this figure, we can see that the stroke of the paintbrush and the airbrush is precisely reproduced. In the case of finger painting, we can observe a line which has various widths in a stroke, thus users can easily draw lines of various widths only by controlling the touch pressures to the surface. The paintbrush with hot water and the finger can produce watercolor effects by ThermoInk.

A master of Japanese calligraphy created art works. He had experience of data tablet drawing. In experiments, he was able to draw several types of art works without any trainings(Fig. 4). After finishing the experiment, he argued that he could as usual create art works which he could not create using the data tablet. We believe that this calligrapher's experience indicates that ThermoTablet can support graphical artists.

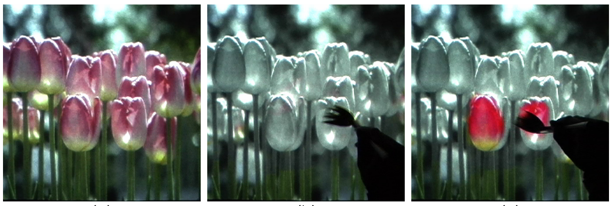

Figure 5: Color saturation modification: (a)original, (b)reducing color saturation by paintbrush with cold water, (c)increasing color saturation by paintbrush with hot water

Figure 6: Hue modification: (a)original, (b)becoming warm color by dryer, (c)becoming cold color by paintbrush with cold water

5.3 Image Modification Application

Figure 5, 6 and 7 shows results of image modification applications. In color saturation modification, we use paintbrush with cold water for reducing and hot water for increasing color saturations. In hue modification, we use dryer for warm colored and paintbrush with cold water for cold colored modifications. In shape modifications, we use two transparent circular plate and hot or cold water is in them each as input objects.

In CAD model deformation application, a mouse is used. In this application, a user's hand is used as a heater to change thermal plasticity of a part of the model. Figure 8 shows the results of this application. The image(a) shows the original model and a part of this model become red color because of the high temperature change in this part(image(b)). In the image(c), only red colored part of the model is affected by the mouse drugging the model and move.

6. CONCLUSION

We have presented heat sensations in image creation with thermal vision. We developed an interactive image creation system, ThermoTablet, which consists of a thermo-infrared camera and a video projector. It can detect two dimensional distribution of the touch regions between the sensing surface which is a thin film of paper material and input objects. At the present time, ThermoTablet is quite expensive because of a thermo-infrared camera. But the price of the camera is decreasing.

In the painting application, users can directly use physical painting tools as they use in real world and paint intuitively on a virtual canvas. In experiments, we proved that precise reproductions of physical painting tools' strokes were available, and this application was able to be used by graphical artists. We implemented image modification application on ThermoTabet. Through the experiments, we proved that users could intuitively modify images using the heat sensations.

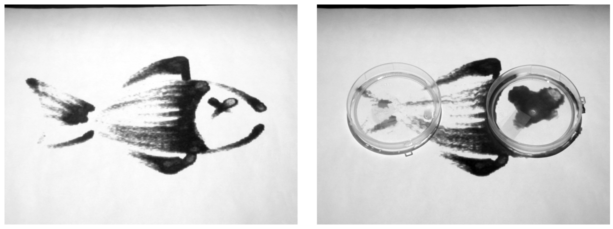

Figure 7: Shape modification: (a)original, (b)contraction/expansion by cold/hot water in plates

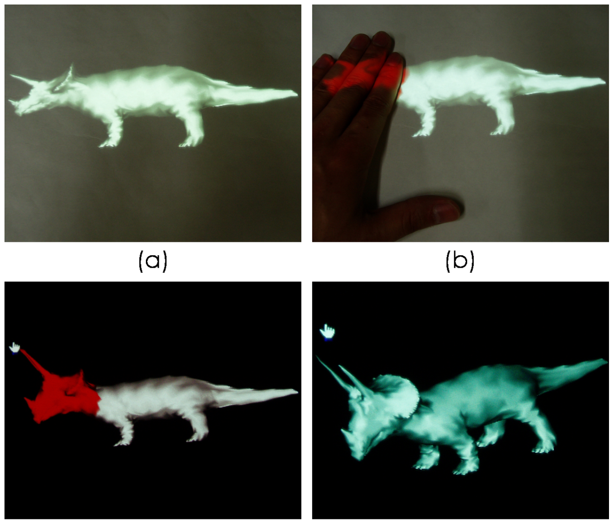

Figure 8: CAD model deformation: (a)original model, (b)warm model by hand, (c)deformation by mouse moving, (d)result

7. REFERENCES

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