CONSTRUCTING AN ELASTIC TOUCH PANEL WITH EMBEDDED IR-LEDS USING SILICONE RUBBER

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ABSTRACT

This paper presents a technique for the construction of an elastic touch panel using silicone rubber. The technique is similar to that of the frustrated total internal reflection-based method for multi-touch sensing, but the surface of the touch panel is made of transparent silicone rubber rather than acrylic. Moreover, we embedded infrared LEDs within the rubber for multi-touch sensing. In tests, our touch panel had better sensitivity than one made of acrylic. Furthermore, unlike acrylic panels, it readily detects contact by styluses and other stiff objects. We implemented a touch panel based on our technique and tested it through experiments.

KEYWORDS

Multi-touch, FTIR, user interface.

1. INTRODUCTION

Multi-touch sensing technology based on frustrated total internal reflection (FTIR) (Han 2005) is widely used in the HCI research community because of its various advantages, one of which is its low cost of construction. One can readily construct a multi-touch panel from scratch with an acrylic panel, USB cameras, and some infrared LEDs (IR-LEDs), all of which are readily available. Another advantage is the flexibility of its sensor (i.e., cameras). By analyzing the shape of a contacted area, which can be captured with cameras, it is possible to gather various types of information (e.g., pressure (Hennecke et al. 2011, Augsten et al. 2010) and the orientation of touching fingers (Wang et al. 2009)) can be possible and has been explored. Extensions of this concept have also been explored, such as FLATIR (Hofer et al. 2009), Inverted FTIR (Echtler et al. 2009), and Scanning FTIR (Moeller and Kerne 2010). Hereafter, we call those touch panels which use acrylic panels as the surfaces as acrylic touch panels.

However, there is still room for improvement of such systems for casual use. Specifically, acrylic touch panels tend to require the user to touch relatively forcefully with her/his fingers because the surface is hard. If the user touches the surface with a fingertip, the system may not be able to detect it because the area of contact is too small. Similarly, touching with a hard object, such as a stylus, may not be detected for the same reason. To address this problem and to improve the usability of touch panels, the idea of pasting an elastic material on the surface of an acrylic panel has been proposed (Han 2005) and applied (e.g., Smith et al. 2007, Hennecke et al. 2011, Augsten et al. 2010, Fukumoto 2009). Pasting such elastic material increases the area of contact with hard objects; thus, the sensitivity of the touch panel increases. Other related work includes the use of deformable materials for detecting rich interactions (Vlack et al. 2005, Vogt et al. 2004). Such research has involved embedded markers within deformable materials to detect deformation of the materials caused by the user. However, due to these markers, these systems use a front-projected display, which always suffers from occlusion.

In this paper, we describe a novel type of multi-touch panel, Silicone Touch, which has better sensitivity than acrylic touch panels. This technique is similar to the FTIR-based method for multi-touch sensing, but the surface of the touch panel is made of transparent silicone rubber rather than acrylic. Moreover, we embedded IR-LEDs within the rubber for multi-touch sensing. Furthermore, unlike acrylic panels, it readily detects contact by styluses and other stiff objects.

2. SILICONE TOUCH

This section describes the technique for constructing an elastic touch panel with embedded IR-LEDs using silicone rubber.

2.1 Hardware

Technique to construct an elastic touch panel with embedded IR-LEDs using silicone rubber

Silicone Touch consists of a transparent silicone rubber panel, an acrylic panel as its base, and an LED module. We used approximately 3 kg silicone rubber (RTV-2 SLJ 3220 of Wacker Asahikasei Silicone, 4200 JPY per kg) to form a silicone rubber panel, and an acrylic panel (960 mm × 720 mm × 6 mm) to construct our prototype Silicone Touch device. We constructed the LED module by connecting 32 IR LEDs (Toshiba TLN231(F), half-angle value: ±15°) in 3 cm intervals. To form the silicone rubber panel, we first attached a wooden frame to each of the four sides of the base, and then placed the LED module along the longer side of the base. Next, we poured the rubber from a low height to avoid creating air bubbles in the rubber (Figure 1). We made the thickness of the silicone pane approximately 10 mm. It took a whole day for the rubber to cure.

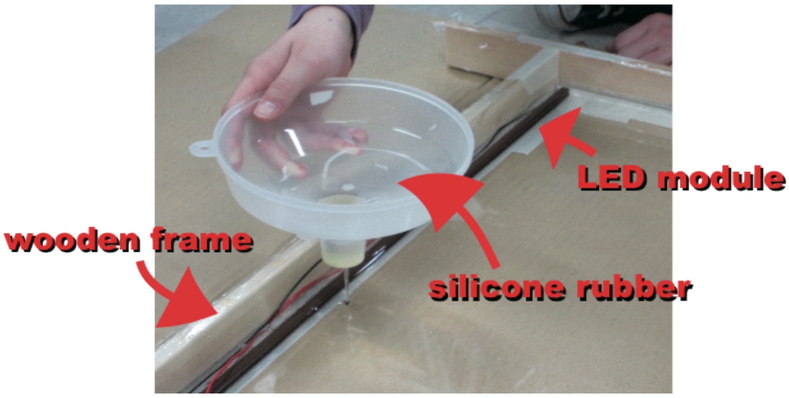

Figure 1. Embedding IR-LEDs into silicone rubber by casting.

The panel cost approximately 25000 JPY, including the wiring, a frame to form the LED module, silicone

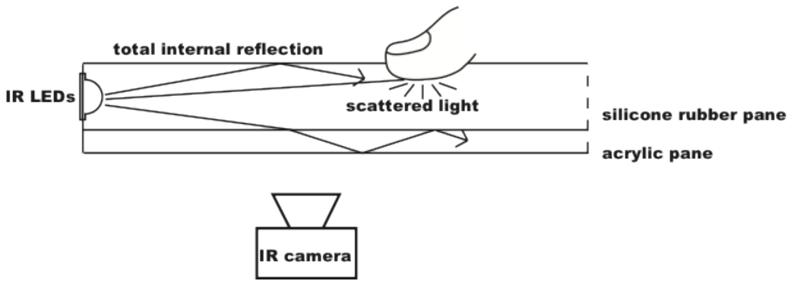

Figure 2. Schematic overview of Silicone Touch.

rubber, an acrylic panel, and the IR-LEDs.

Principle

Figure 2 illustrates how the light from IR LEDs travels through the silicone rubber pane and the acrylic pane with reflection and refraction.

Assume that the IR LEDs have a high degree of directivity. In such case, most of the light from the IR LEDs remains in Silicone Touch, because the angles of incidence are much smaller than the critical angle (Table 1) in both cases (i.e., in the case where the light hits the interface between air and the silicone rubber pane, and in the case where the light hits the interface between the acrylic pane and air).

Table 1. Critical angle θ_m at each interface.

	θ_m
Silicone rubber → air	45.59
Silicone rubber → acrylic pane	-
Acrylic pane → air	42.16
Acrylic pane → silicone rubber	69.99

Once an object touches the surface of Silicone Touch, the light is frustrated in the area of contact. And as the object goes deeper into the silicone rubber, more light from the IR LEDs directly hits the object, thus the scattered light becomes powerful. By optically processing the images from an IR camera under the surface, the contacted areas can be detected.

Although most of the light that hits the interface between the silicone rubber pane and the acrylic pane penetrates the interface and remains in the acrylic pane because the refractive index of silicone rubber is lower (1.4 in our case) than that of acrylic (1.49), most of the light from the IR LEDs remains in the silicone rubber pane due to the high degree of directivity of the IR LEDs.

Silicone Touch Prototype

We built a tabletop system as a Silicone Touch prototype (Figure 3). We used aluminum frames to form the table, with Silicone Touch as the tabletop. Below the panel, we placed an IR camera to detect contacted areas. To form a rear-projected display, we placed a sheet of tracing paper as a diffuser on the undersurface of the acrylic pane, to serve as the screen for the projector, mounted below the panel.

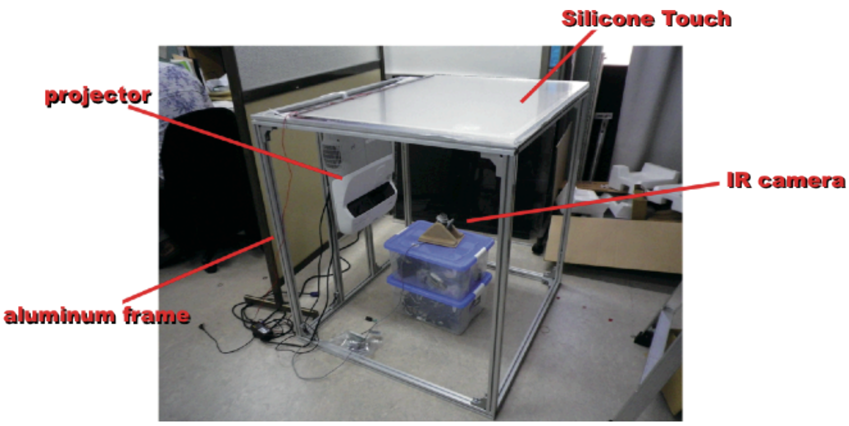

Figure 3. Silicone Touch prototype.

Software

We built a software driver for the detection of contacted areas. The driver first captures images from the IR camera, frame by frame. Then, it labels blobs, each of which corresponds to a contacted area. For each labeled blob, the driver calculates the shape, center, area, and average brightness. Finally, the driver transmits the result to the application with the ID of the blob. To make the driver application-independent, we used Open Sound Control (http://opensoundcontrol.org/) as the communication protocol of the driver. That is, developers can make their own applications using their favorite frameworks, by making the applications communicate with the driver via a network.

3. EXPERIMENT

We conducted an experiment to examine the difference in sensitivity between our Silicone Touch and an acrylic touch panel. For this experiment, we first developed an acrylic touch panel of the same size as our Silicone Touch prototype. Then one of the authors placed various objects, including fingers, on both panels and observed the images captured from the IR camera in both conditions.

Figure 4. Blobs caused by fingers on the panels. Left: the fingers' posture in this experiment. Center: blobs by the fingers on Silicone Touch. Right: blobs by the fingers on the acrylic panel.

Figure 5. Stylus and blobs by the stylus touched on the panels. Left: stylus of a graphics tablet. Center: blob by the stylus on Silicone Touch. Right: blob by the stylus on the acrylic panel.

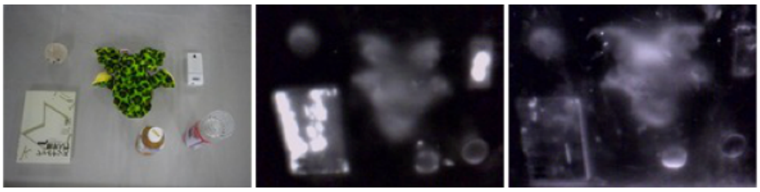

Figure 6. Objects and blobs by the objects placed on the panels. Left: objects (a ball of yarn, a stuffed animal, a cell phone, a book, a PET bottle, and a can from top-left to bottom-right). Center: blobs by the objects on Silicone Touch. Right: blobs by the objects on the acrylic panel.

Figure 4 shows the resulting images captured when both panels were touched with fingers. In both conditions (i.e., Silicone Touch condition and the acrylic panel condition), clear and bright blobs appeared, each of which corresponded to the contacted area with a finger. Figure 5 shows the resulting images captured when we pushed both panels with a stylus of a digital tablet. In contrast to the finger contact (Figure 4), the results differed between the two conditions. Touching the stylus to Silicone Touch diffused much IR light, causing a bright blob in the image of the IR camera, while touching it to the acrylic panel resulted in dark and unclear imagery. Figure 6 shows the resulting images when we placed various objects on both panels. Some objects, which did not produce any bright blobs on the acrylic panel (e.g., a book and a cell phone), made bright blobs on Silicone Touch.

These results demonstrate that Silicone Touch has better sensitivity than the acrylic panel. Moreover, blob brightness increased according to the weight, i.e., pressure placed on the surface. Furthermore, our results suggest Silicone Touch can be used to recognize objects placed on the surface if each object has a uniquely shaped bottom surface. Thus, Silicone Touch may be useful for developing a SLAP Widget (Weiss et al. 2010) with no marker attached to the bottoms of objects.

4. APPLICATION

As an application to test Silicone Touch's capability to sense pressure of touched areas, we implemented an entertainment application Fly Swatter (Figure 7). The goal of players in this game is to remove all of the targets, which are the small flies moving around the field (i.e., the display), as quickly as possible. Each target initially has a certain hit point. After the game begins, each player uses a swatter to hit the targets. If the swatter hits one or more targets, then the hit point of each swatted target decreases according to the force (i.e., pressure) with which the swatter hits the surface. When the hit point of a target decreases to zero, the target is removed from the field.

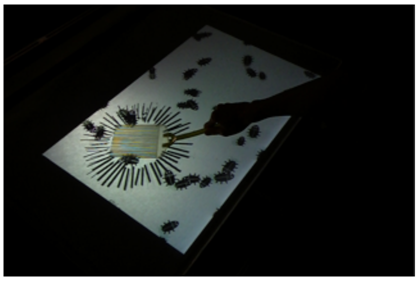

Figure 7. Using the Fly Swatter application to test Silicone Touch's capability to sense pressure of touched areas.

In this implementation, we used the average brightness of a touched area within the image from the IR camera, as the pressure. This is based on the observation that as the strength in which the swatter hits the surface increases, the swatter goes into the silicone pane more deeply, scattering more light.

5. DISCUSSION AND FUTURE WORK

The results of the experiments with Silicone Touch were promising. However, we also found some interesting issues regarding the material and its structure.

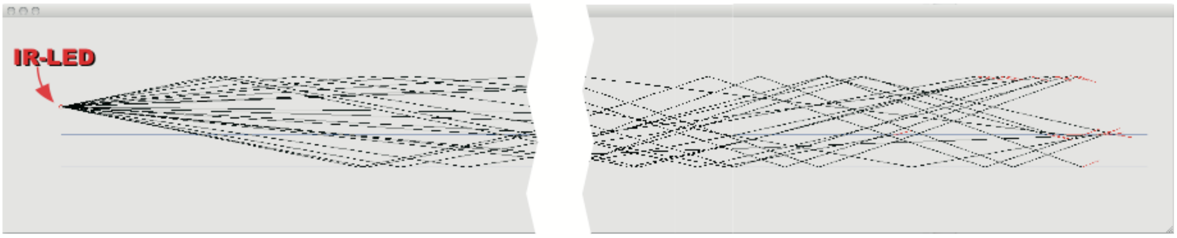

Figure 8. Result of simulation using material with a higher refractive index than acrylic (e.g., urethane rubber) as the material of the upper panel.

In this implementation, we used an acrylic panel as the base. As a result, the light penetrating the interface between the silicone rubber pane and the acrylic pane remained in the acrylic pane, because the refractive index of silicone rubber is lower than that of acrylic. However, this also means that sensing performance can be improved if we can use an elastic material with a higher refractive index than acrylic (of course, it is also possible to use a material with a lower refractive index as the base, instead of acrylic). We tested this idea with our own optical analysis simulator, based on a ray tracing technique. Figure 8 shows the result of the simulation. In this simulation, instead of silicone rubber, we used a material with a higher refractive index (the value was 1.5) than acrylic (e.g., urethane rubber) for the panel. The size of the panel was the same as our prototype Silicone Touch. In this figure, the light from the IR-LED, which is placed on the left edge of the panel, travels across the inside of the two panes, reaching the left side of the panel. Although we have to investigate this issue further by actually constructing such touch panels because the algorithm of the simulation is very simple, this result suggests that FTIR-based touch panels can be constructed using an elastic material.

In addition, we used an acrylic panel as a base, but this does not itself contribute to detection. Hence, we can construct a touch panel with only a silicone rubber panel and embedded IR-LEDs, without a base. We plan to develop such a prototype in a future study, and explore its characteristics and applications.

6. CONCLUSIONS

This paper describes a novel type of elastic touch panel, Silicone Touch. The system embeds IR-LEDs within transparent silicone rubber, which forms the surface of the touch panel. We built a tabletop system as a prototype of Silicone Touch. Results of comparative experiments showed that our touch panel had better sensitivity than one made of acrylic and was able to detect contact by fingers as well as stiff objects including a stylus of a graphics tablet.

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