FuwaFuwa: Detecting Shape Deformation of Soft Objects Using Directional Photoreflectivity Measurement

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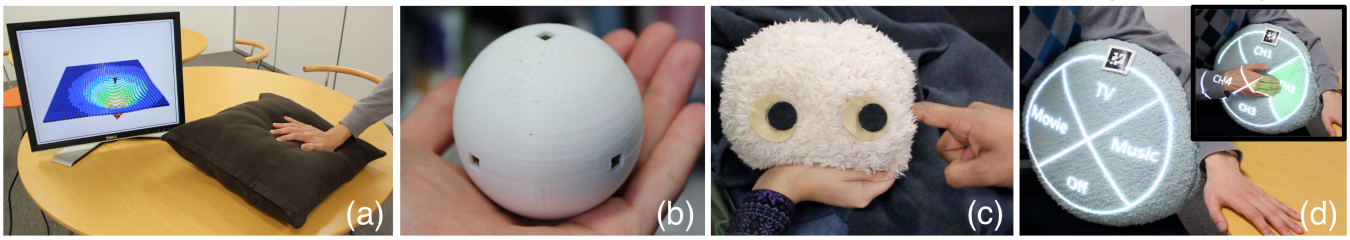

Figure 1: *a: Detecting touch location. b: Sensor module. c: Soft Interactive Robot. d: Cushion changes into a remote controller.*

1. Introduction

Soft objects are widely used in our day-to-day lives, and provide both comfort and safety in contrast to hard objects. Also, soft objects are able to provide a natural and rich haptic sensation. In human-computer interaction, soft interfaces have been shown to be able to increase emotional attachment between human and machines, and increase the entertainment value of the interaction. We propose the FuwaFuwa sensor, a small, flexible and wireless module to effectively measure shape deformation in soft objects using IR-based directional photoreflectivity measurements. By embedding multiple FuwaFuwa sensors within a soft object, we can easily convert any soft object into a touch-input device able to detect both touch position and surface displacement. Furthermore, since it is battery-powered and equipped with wireless communication, it can be easily installed in any soft object. Besides that, because the FuwaFuwa sensor is small and wireless, it can be inserted into the soft object easily without affecting its soft properties.

2. FuwaFuwa Overview

Soft objects such as stuffed toys and pillows usually consist of light materials such as wool, hair or cotton as padding. The random arrangement and grainy structure of such materials scatter incident light, resulting in a diffused energy pattern. However, when these materials are tightly packed, (i.e. when the density is increased), the amount of directed and specular reflected light increases considerably (Figure 2). The FuwaFuwa sensor consists of five pairs of IR photo sensors, with IR light emitters positioned in five directions perpendicular to each other (Figure 1-b). Each sensor measures the reflected light intensity from each direction. When a user interacts with the soft object, its shape changes, resulting in a change in density of the padding material. This changes the amount of reflected light as described above. In this way, the FuwaFuwa sensor can derive the direction and depth of deformation according to the five sensor measurements of reflected IR intensity.

Furthermore, by installing multiple modules in a larger soft object, collective sensor measurements can be used to interpolate the point of touch on the surface. Therefore with these modules, we can convert any soft object into a touch-sensitive surface. Additionally, it gives a measurement of the depth of touch to a higher depth than hard touch surfaces. Since the object is soft and sensing is contactless, the natural soft haptic sensation of the object is preserved.

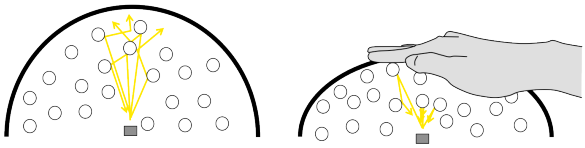

Figure 2: *Directionality of reflected light is lower at low density (left) than at high density (right).*

We have developed a software driver to connect the FuwaFuwa sensor to a PC as an input device. The software allows the user to detect sensor locations, calibrate the sensors, and visualize the sensed data (Figure 1-a). Once sensor locations are defined and calibrated, any application can use the FuwaFuwa sensor's data as input.

3. Applications

Home Media Controllers. Soft objects are commonly found in the home environment. With this in mind, we created a media control application for the living room, converting a cushion into a remote controller for a digital home theatre system. Three FuwaFuwa sensors were installed inside the cushion, and a media control menu is projected onto the cushion. The user can manipulate the cushion to browse, play and control the home theatre system (Figure 1-d). In addition to this, we also created a music composer with a stuffed toy. The user can select different tones by pressing at different points, and change the pitch according to the depth of deformation. We believe that this will be promising as a future musical instrument.

Gaming Peripherals. We installed the FuwaFuwa sensor in a small spherical soft object to create a game controller for a simple game. By manipulating the surface of the sphere, the user can control the game character. Different actions such as squeeze, hit, push and rub can be used as different action triggers.

Soft Robots. We developed a soft pet robot using our sensor. The robot can detect user interaction and react accordingly (Figure 1-c). The robot is designed to move its eyes towards the location of the user's touch, and change its voice according to the depth of touch.

4. Future Work

We plan to develop a finer filtering algorithm to improve the sensor's reading accuracy, and increase the number of sensors to enable multi-touch on soft objects. We are also in the process of developing games and music creation applications to utilize the multi-dimensional sensor data with the sensing technology.

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