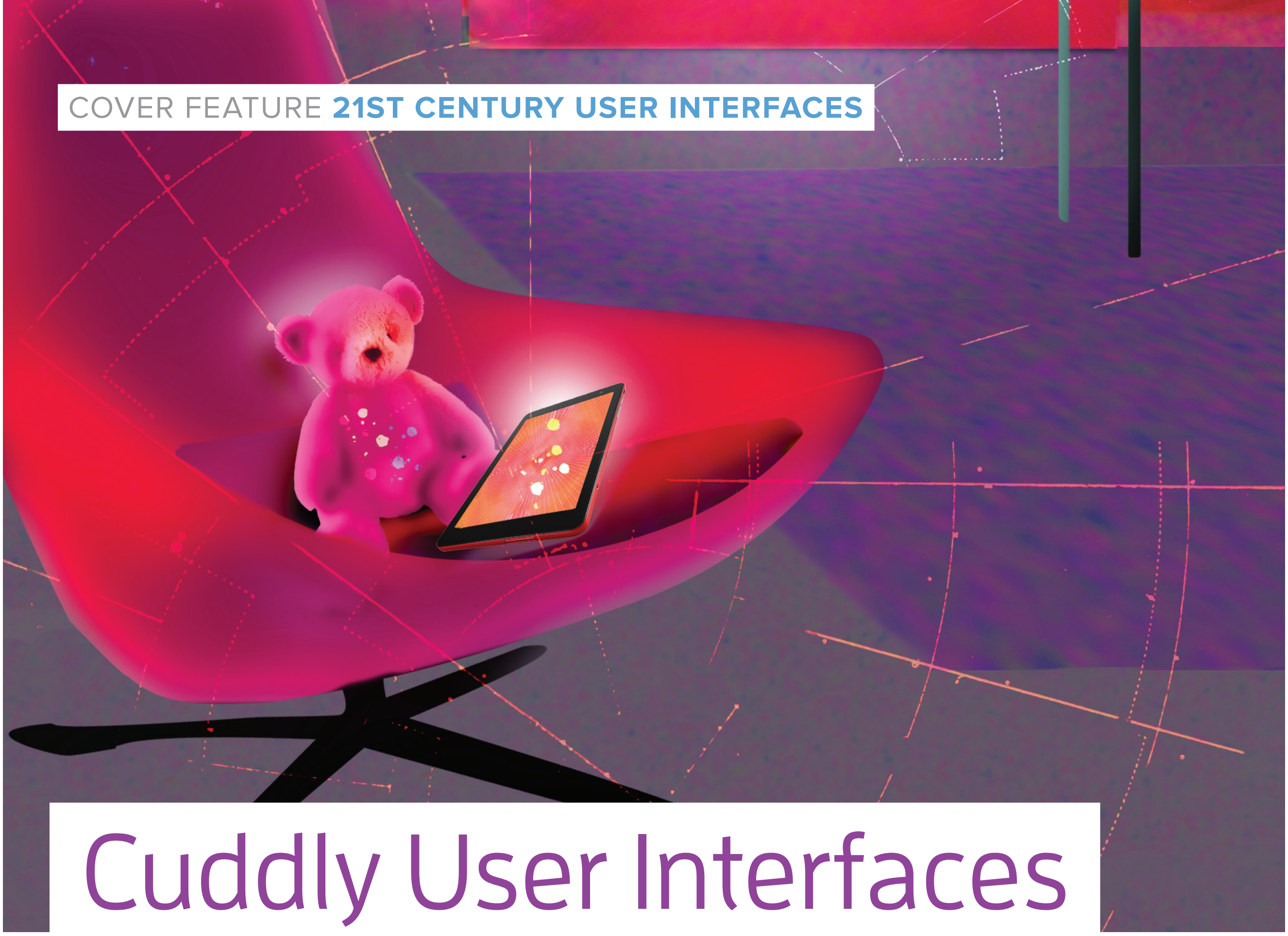

Cuddly User Interfaces

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Cuddly User Interfaces employ soft objects as interfaces between people and smart systems. They can contribute to the realization of ubiquitous computing because soft objects are familiar to us and induce a low psychological burden.

In 1991, Mark Weiser proposed the vision of ubiquitous computing to blend computers into our daily lives beyond conventional desktop interaction.[1] He imagined that the connection between the virtual world and physical world would soon be transparent. Human–computer interaction researchers have made many attempts to address this vision. In particular, researchers have proposed user interfaces (UIs) that manipulate the virtual world.[2]

Humans have developed virtual worlds through hard interfaces, similarly to how early humans used stone tools to develop the real world. These UIs are intuitive, but users must grasp them explicitly. People are often reluctant to use such tools in daily life.

We need to move beyond these hard tools to provide natural interaction between humans and smart environments while maintaining a familiar lifestyle. Toward that end, researchers have developed *organic UIs*, which are deformable and allow natural interaction such as pressing and bending. However, these interfaces are still far from blending into people's daily routines.[3]

So, we developed *Cuddly UIs*, which employ soft objects that are already familiar to users—for example, pillows, carpets, and stuffed toys. These objects connect people with smart systems providing services and applications. Cuddly UIs are a step toward implicitly merging the information world with our everyday environment.

INTERACTING WITH SOFT OBJECTS

A typical home has many soft objects—for example, clothing, stuffed toys, and beds. Because these objects

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serve diverse roles and are personal belongings, people tend to keep them a long time. Soft objects are often heat insulated and thus can serve as shock and heat absorbers. Also, because the shape and feel of some soft objects are similar to those of living animals, they can easily lead to emotional attachment, potentially offering their owners lasting comfort.

Soft objects can positively affect humans' psychological state. Joshua Ackerman and his colleagues investigated how touching soft objects influences social judgment and decisions.[4] In their study, participants who had touched a hard block judged another person as being more rigid or strict than did participants who had touched soft objects.

As we all are aware, young children like soft objects and touch them frequently. As they grow independent from their parents, they recognize soft objects as transitional objects and treat them as alternative representations of their parents.[5] Soft objects provide comfort and therefore can reduce children's stress and fear.

People interact with hard and soft objects differently (see Figure 1). Hard objects are grasped by the user's hand and manipulated explicitly as tools for short periods of time. Soft objects come close to the body, interact with the whole body, and are often kept in contact with humans for long periods of time.

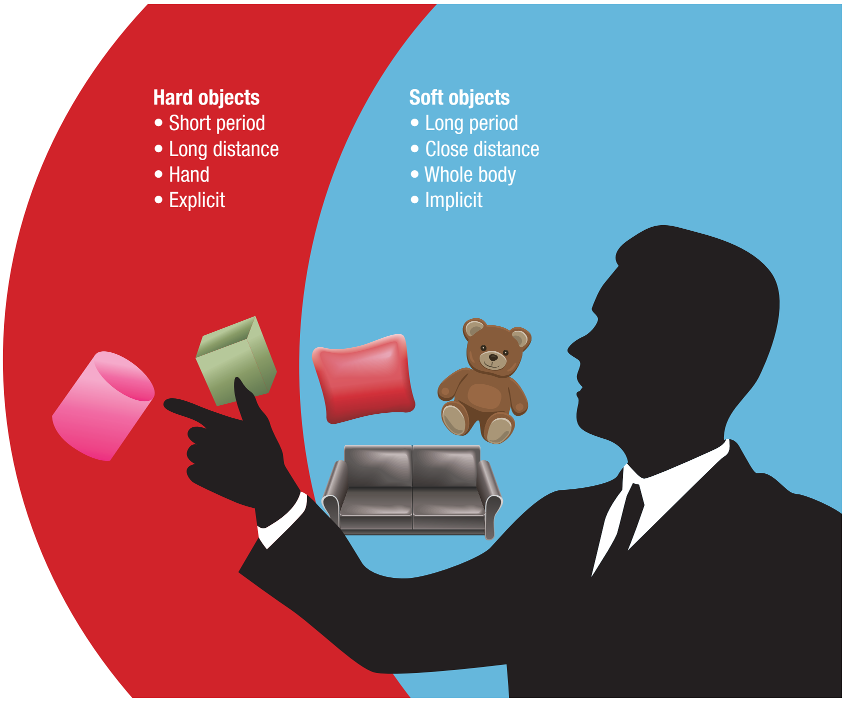

FIGURE 1. The differences between interacting with hard objects and soft objects.

DESIGNING CUDDLY UIs

Imagine lovers sitting close together. They can sense each other's state by observing each other's physiological behavior, such as breathing, heartbeat, and skin temperature, at close range. They can also better comprehend the overall situation by being physically close. Cuddly UIs can provide a similar experience.

To design such Cuddly UIs, we follow these guidelines:

- We use soft objects people already have, to avoid disturbing their lifestyles.
- Cuddly UIs must support easy installation and removal of the computing device for user customization, in accordance with the particular soft object's properties, such as shape and size.
- I/O should be based on natural interaction with everyday objects. For example, with a pillow, hugging could be the interaction.
- The computing device should mesh harmoniously with the soft material, to maintain the original object's softness.

Cuddly UIs have some limitations compared with conventional hard UIs. For example, Cuddly UIs are not suitable for precise manipulation and have difficulties presenting high-resolution information. However, we believe Cuddly UIs will be useful in situations in which people constantly change their posture and move around. Cuddly UIs will blend into the environment; users will not have the explicit feeling they are using an interface (see Figure 2).

For Cuddly UIs to meet our guidelines, we need an appropriate measuring system and display mechanism for the soft objects. Next, we show how we have fulfilled these requirements when transforming various soft objects into Cuddly UIs.

FIGURE 2. A future ubiquitous environment with Cuddly User Interfaces. The sofa and pillows have embedded sensors that recognize users' posture and emotional state. The carpet and curtain change their pattern according to the user's mood. Interactive stuffed toys monitor children. Grandparents can transfer a hugging sensation to their grandson through deformable cloth. ("Pi" is the sound made when the user presses a button.)

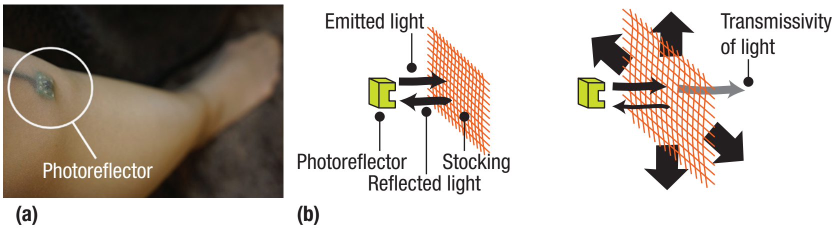

FIGURE 3. Cloth as a sensing system for body shape change. (a) Our sensor can be attached to a nylon stocking. It measures the foot's movement over a long period of time without constraints on the body. (b) The photoreflector detects the ratio of expansion and contraction of the stocking on the basis of changes in the transmissivity of infrared light passing through the stocking.

CLOTH AS A SENSING SYSTEM FOR BODY SHAPE CHANGE

Cloth is perhaps the daily commodity most closely connected with people. If we can convert cloth into a sensing system, it can measure not only our dynamic body movement but also changes in our body shape.

We created a way to convert stretchable cloth to such a sensing system (see Figure 3a).[6] The system contains several photoreflectors consisting of an infrared (IR) LED, a phototransistor, and elastic fabric such as a nylon stocking. The sensing method is based on our observation that photoreflectors can measure the ratio of expansion and contraction of a stocking by observing changes in the transmissivity of IR light passing through it (see Figure 3b). Conventional sensors such as strain gauges require glue on the cloth, which decreases the cloth's softness. Our sensor can be easily attached to the cloth without special tools and does not affect softness. So, our system does not induce any constraints on the user's body.

Our method is suitable for wearable-interface applications. Some intended applications are medical—for example, continuous monitoring of muscle movement and body volume changes (as in cases of edema). Also, it is possible to log dynamic body movement (for example, exercising, working, and eating). Because our method is adaptable to rubber, we can create interactive training tools to monitor how much an exerciser pulls on a resistance band. Our method also works with various material densities.[6]

PILLOWS AS EMOTIONAL SENSORS

Pillows can serve as a shock absorber when people want to relax. Also, people sometimes emotionally interact with pillows—for example, hugging one while watching TV or punching one when under stress. If pillows can become a sensing system, they could help measure not only a user's posture but also his or her emotional state.

FuwaFuwa converts a pillow into a sensing system (see Figure 4a).[7] The FuwaFuwa module is a round, hand-sized, wireless device that measures the shape deformations of soft objects such as pillows. It can easily be embedded in soft objects without spoiling their softness because it requires no physical connection. Six LEDs emit IR light in six orthogonal directions, while six corresponding photosensors measure the reflected light energy (see Figure 4b). People can easily convert almost any soft object into a touch-input device that detects both the touch position and surface displacement.

Using FuwaFuwa, we converted a pillow into a remote control for a home theater system. The user pushes the pillow in the appropriate places to select the desired functions. This remote control can also be a game interface; behaviors such as squeezing, hitting, pushing, and rubbing trigger different actions. FuwaFuwa also works with health-related games that incorporate body movement. In addition, it can monitor emotional states in a natural manner. For example, one application estimates a movie scene's emotional impact by measuring the viewer's hugging of the pillow (see Figure 4c). This deformation measurement technique can measure the density of not only cotton but also feathers and sponge.[7]

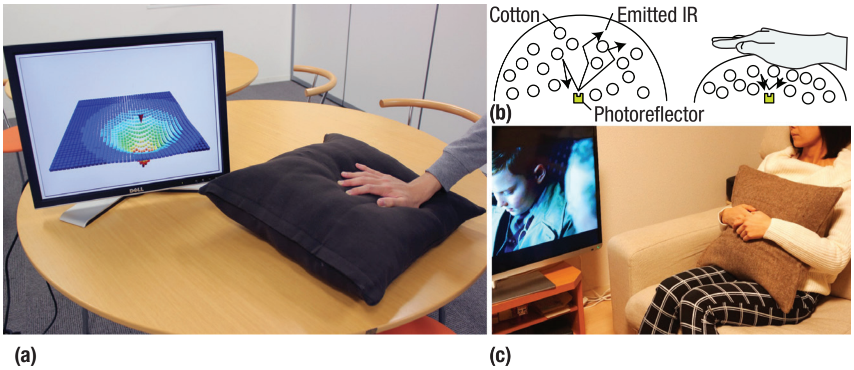

FIGURE 4. Pillows as emotional sensors. (a) Using infrared (IR) emitters and sensors, FuwaFuwa detects the user's touch position and amount of pressure. (b) The reflected light's directionality is lower at low density (left) than at high density (right). (c) The Fuwa-Fuwa sensor monitors the emotional state of a user watching a movie.

SOFT SURFACES AS DISPLAYS

People use soft surfaces to cover large spaces in homes—for example, carpets typically cover floors. If we can convert these surfaces into displays, they can present information that blends into the environment. They can also function as canvases for artwork.

Graffiti Fur is a display technology that exploits the phenomenon in which fur's shading changes as the positions of its fibers change.[8] To draw images on fur, a person raises the fibers by moving his or her finger in the opposite direction of their growth. To erase the images, the user flattens the fibers by sweeping the surface by hand in the fibers' growth direction.

These material properties also occur in objects such as carpets. We have developed three devices that draw patterns on such material: a roller, a pen, and a pressure projection device (see Figure 5). Our technology can turn ordinary objects into rewritable displays without the objects needing nonreversible modifications.

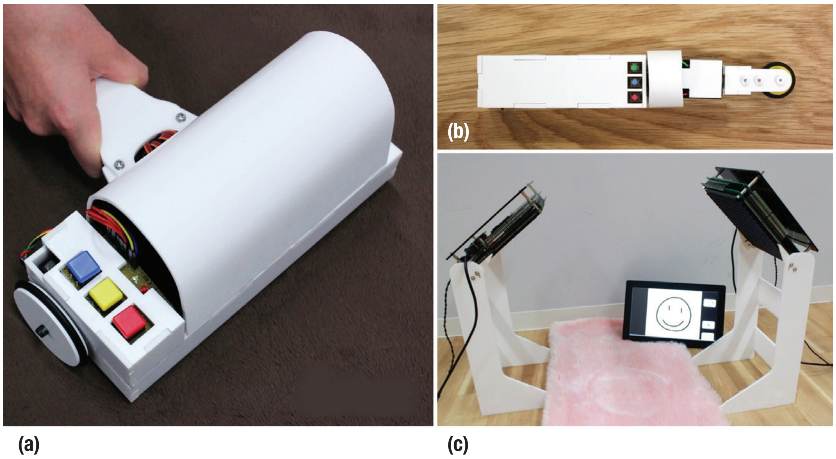

FIGURE 5. Three prototype devices that draw patterns on soft surfaces. (a) A roller. (b) A pen. (c) A pressure projection device. To draw, these devices move some surface fibers in the opposite direction from the other fibers.

Graffiti Fur can be used in daily living—particularly on large spaces such as floors or walls and on objects such as toys, clothes, and curtains. For example, users can draw special pictures for their loved ones on their birthday or write messages to visitors (see Figure 6a). Children can play storytelling games using the pictures they have drawn (see Figure 6b) and can easily modify their drawings in accordance with a game. Users can create patterns on carpets and can change the patterns according to their mood (see Figure 6c). Hotels can display information for guests—for example, a welcome mat showing the direction to the entrance (see Figure 6d). Custodians can indicate that they have cleaned a carpet by leaving a message (see Figure 6e).

Figures 6f through 6h illustrate uses on everyday objects other than carpets. Users can draw on a curtain so that it shows different images when open or folded (see Figure 6f). Many people like to dress up their stuffed toys to give them individuality. With Graffiti Fur, users can easily draw patterns on stuffed toys without modifying them (see Figure 6g). Finally, users can draw different patterns on their clothing every day (see Figure 6h).

FIGURE 6. Soft surfaces as displays. (a) Birthday greetings. (b) Having a toy follow a drawn path. (c) Art on the floor. (d) Visitor navigation guides. (e) Greetings on a carpet. (f) Changing patterns. (g) Pattern on a stuffed toy. (h) Temporary drawing on clothing.

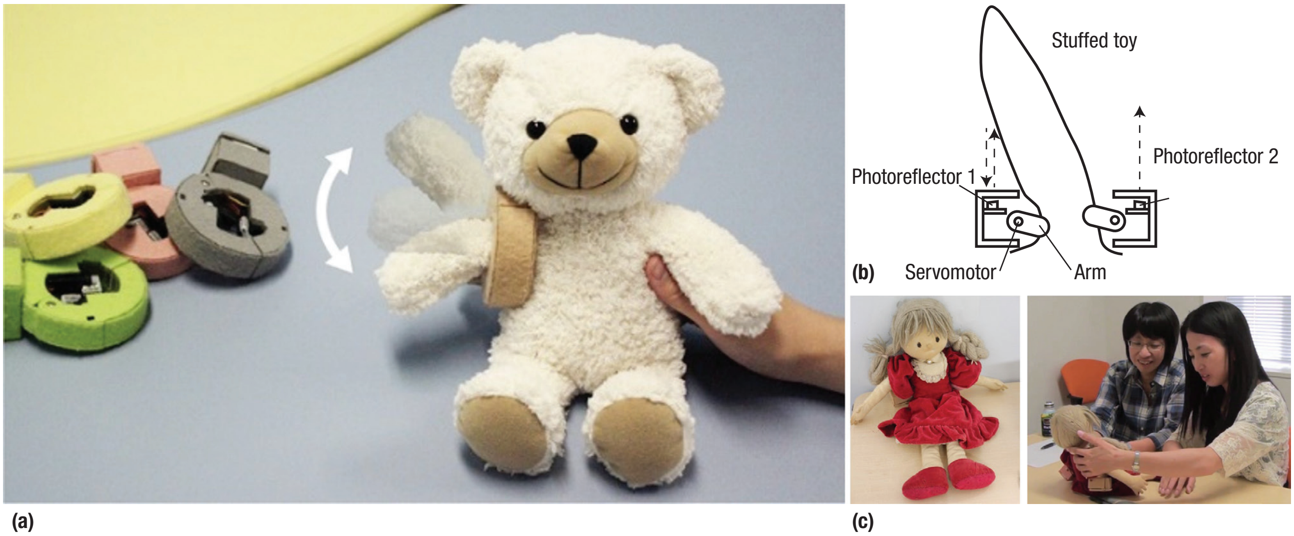

FIGURE 7. PINOKY. (a) The ring device animates stuffed toys. (b) A pair of DC servomotors push on the toy's cover, and two photoreflectors sense the joint angle by measuring the distance between the sensor and cover. (c) A pilot study involved two users and their doll.

We performed a user study with 18 visitors at a local science museum: 6 parent–child pairs and 6 children. Overall, the participants figured out how to use the roller within five minutes.

STUFFED TOYS AS ROBOTS

Most people have had a positive relationship with stuffed toys since childhood, and some adults still own stuffed toys.

We administered a questionnaire to 30 participants aged 14 to 70 (the average age was 34.7, with a standard deviation of 13.7 years).[9] Eleven were male and 19 were female. Approximately 70 percent of the participants owned more than one stuffed toy. The average number of toys owned was 13.6 (with a standard deviation of 14.5); the family configuration affected this number.

The participants frequently remembered the circumstances in which they had received the toys, and they had some memory associated with approximately 76 percent of those toys. (For example, approximately 58 percent of the toys had been gifts on a special occasion such as a birthday.) Approximately 73 percent of the stuffed toys were placed at easily visible locations, such as around the bed (approximately 34 percent), on a shelf (approximately 16 percent), or on the sofa (approximately 9 percent). So, we believe that if a stuffed toy that a user already has a positive relationship with served as an interactive robot, it could provide services and comfort to the user at close range.

PINOKY gives life to a user's favorite stuffed toys.[9] PINOKY is a wireless ring-like device that users externally attach to any stuffed toy to animate it—for example, by moving its limbs and sensing their angle (see Figure 7). Users can control the toy remotely or input the desired movement by moving the toy and having the data recorded and played back. Unlike other methods for animating stuffed toys, PINOKY is nonintrusive, so the toys do not require alterations.

PINOKY can also enhance the relationship between a toy and its owner. For example, we attached PINOKY to a doll that the owner had carefully kept for 20 years. In our study, a mother and daughter played with the doll (see Figure 7c). Afterward, the daughter said the experience brought back memories of when her grandmother gave her the doll. This shows that PINOKY can trigger memories related to a toy. Also, the mother said she discovered new things about doll—for example, how the face and clothes were neatly made. This shows increased engagement with the toy.

Our vision is that eventually every soft object in contact with us becomes an interface that implicitly connects us to the information world. We hope the designs we presented here inspire other researchers developing computing systems that support and enhance people's daily lives. Achieving that goal will require further exploration of how to efficiently use soft materials to create UIs for smart systems.

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