Cuddly: Enchant Your Soft Objects with a Mobile Phone

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Abstract. Cuddly is a mobile phone application that will enchant soft objects to enhance human's interaction with the objects. Cuddly utilizes the mobile phone's camera and flash light (LED) to detect the surrounding brightness value captured by the camera. When one integrate Cuddly with a soft object and compresses the object, the brightness level captured by the camera will decrease. Utilizing the measurement change in brightness values, we can implement diverse entertainment applications using the different functions a mobile phone is embedded with, such as animation, sound, Bluetooth communication etc. For example, we created a boxing game by connecting two devices through Bluetooth; with one device inserted into a soft object and the other acting as a screen.

Keywords: Soft objects, mobile phone based computing, camera-based measurement, flash light.

1 Introduction

We are surrounded by soft objects such as plush toys, cushions, mattress, sofas and others in our daily lives. Soft objects act as a buffer between people and hard objects such as the floor or furniture. People often hug soft objects when they are feeling emotional such as while watching movies, or they tend to punch or throw soft objects when they are feeling frustrated. These actions show that there is a close emotional, physical interaction between soft objects and oneself. From the psychological point of view, soft objects can highly influence people's lives and behavior [1]. Research shows that it can help reduce stress as well as increase effectiveness [18]. Because of that, soft objects are often used in different fields such as medical therapy [25], communication [12], gaming purposes [19] etc. Our research group has also created FuwaFuwa, a sensing module that uses soft object as an interface in the past.

However, in order to develop and commercialize these soft interfaces and robots to the society, developers require users to purchase the device. When choosing a pet from a wide variety of animals or just choosing, for example, a pet dog based on its breed, people make their choices based on their own likes and dislikes. Similarly, when choosing soft objects, the same rules apply. Taking this into account, it can be seen that for the creations of a well-accepted and loved soft object, one needs to

D. Reidsma, H. Katayose, and A. Nijholt (Eds.): ACE 2013, LNCS 8253, pp. 138–151, 2013.

provide either many varieties, as with the case of ‘Furby’[6], or re-design repeatedly until universally accepted, as with the case of ‘Paro’[25]. This shows what huge leap there would be between the initial development stage and final manufacture for sales.

Currently, majority of our society is not aware of the usefulness of soft interfaces. Therefore, by providing a system which users can easily obtain and experience at low cost, we can spread the benefits of soft interfaces. We believe that this is important to discover new ways and playing methods to fulfill human needs. Based upon which, this research, entitle Cuddly, aims to utilize a device, which a majority of us are equipped with, to create interaction with soft objects which we already have in our home.

This research utilizes a smart mobile phone, which has had very high sales in the recent years, to create an application to enhance user’s interaction with their soft objects (Fig. 1). This is done by embedding the mobile phone into a soft object. Cuddly then utilizes the mobile phone’s camera and flashlight (LED) to detect the surrounding brightness values captured by the camera. When user inserts the mobile phone into a soft object and presses the object, the density of the material surrounding the mobile phone increases. This increase in density decreases the brightness of the material surrounding the camera. The camera captures its surroundings in the form of average RGB values and converts these values into brightness values. With this data of brightness change, Cuddly can return feedback by utilizing functions a mobile phone has, such as sounds, lights, or even the animation on the display. In addition, as a mobile phone is a tool for communication, we can connect two or more mobile phones together to create a multi-user interaction.

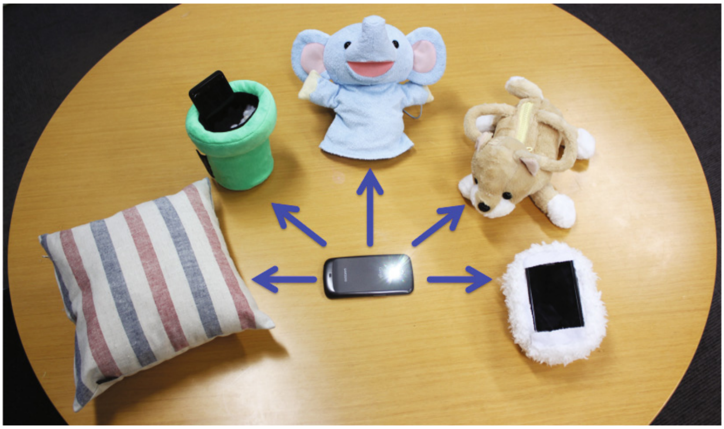


Fig. 1. Mobile phone can be placed in many soft objects to convert them to soft interfaces

2 Related Work

2.1 Soft User Interface

As soft interfaces stimulate emotional affection in people, there is much research created to incorporate soft interfaces to enhance the interaction between people and their devices. Marti et al. developed a user interface consisting of a small wireless animatronic device in an animal form to promote an interactive call handling agent by imitating animal behavior when a call is received [12]. Ueki et al. proposed Tabby, an alteration of a lamp by embedding sensors and covering it with soft fur, which shows to improve the interaction between people and their furniture [23].

Soft interfaces are also commonly used for entertainment or gaming purposes. Hiramatsu et al. created Puyocon, a throw-able, soft, ball-shaped controller consisting of sensors surrounded by sponges, which reacts when it is shaken, thrown or squeezed [9]. Anne created a pillow fighting game by inserting Wii remote controllers into 6 pillows and connecting them to a Macbook [19].

However, many of these devices require either sensors already embedded in their soft objects or they required getting a new object. As compare to that, Cuddly is a phone application and thus, users can utilize their own phone.

2.2 Soft Interface Detection

There are many attempts to create tactile sensors to be used on flexible or soft interfaces. Kadowaki et al. embedded LED and phototransistors into soft urethane foam; sensing different deformation gestures such as push, stroke, pinch etc., due to pressure applied [11]. Rossiter et al. created a novel tactile sensor by using a matrix of LED covered by a pliable foam surface – these LEDs act as photodetectors depending on its operation mode [16]. However, most of the sensors are to be attached on the surface of the devices, making it hard to be implemented with many soft objects.

Besides that, much research integrates soft surface with the use of a camera to detect the changes on the surface. Sato et al proposed PhotoElasticTouch; a novel tabletop system comprising of an LCD and an overhead camera, which detect deformed regions of the elastic materials [17]. Harrison et al. describe a technique for creating dynamic physical buttons using pneumatic actuation while accommodating a visual display and multitouch sensing [8]. Bianchi et al. proposed a bi-elastic fabric-based display for rendering softness when the fingertips interact with the display [2].

In addition, there are also studies that focus on inserting sensors into pillows or other soft devices to detect the behavior change. Yagi et al. developed a pillow inserted with an arduino, and 3 sensors -- which can control one's living environment depending on human's natural behavior [26]. Sugiura et al. proposed a method to detect density changes in the cotton material using photo reflective sensors [21]. Our concept is very similar to these research projects, but differs in that we use the mobile phone's in-built sensors, while these researches require separate sensors. These related researches show how important and advanced researches are heading in terms of soft-based interface.

2.3 Mobile Phone Based Computing

New interactions in mobile phones tend to leverage the device's built-in sensors or attached external sensors. Miyaki et al. proposed "GraspZoom", an input model using pressure sensing, sensed by a force sensitive resistor attached to the backside of a mobile phone [14]. Similarly, Goel et al. introduced GripSense, to detect hand postures by sensing the pressure exerted by the user, through observing gyroscope readings, and using it to facilitate interactions [7]. Iwasaki et al developed AffectPhone, a system that detects the user's emotional state using galvanic skin response electrode attached to the side of the handset and covert the data into warmth or coolness in a Peltier module attached the back panel of another device [10]. Our proposal leverages the device in-built proximity sensor, camera and flash light for interaction. Other sensors can be taken into account as well.

Many gadgets in the market can enhance the ability of a smart phone or protect the phone. For example, Fisher Price introduced Apptivity Case for iPhone and iPod devices, a sturdy case accommodated for babies, protecting the iPhone from dribbles, drool and unwanted call making. These allow babies to play and experience advance devices from a young age [5]. Cube-works released CocoloBear, an interactive teddy bear whereby users place their iPhone on the bear's stomach and the bear's mouth will move according to the frequency received [4]. This shows that innovations leveraging soft interfaces for mobile devices are gradually expanding in the market. This enhances the motivation to create soft user interface to increase hands-on experiences for younger generations with computing devices.

2.4 Computing Daily Objects

We are surrounded by objects that we use on a daily basis. Our gestures towards these objects are quite similar to our interaction with smart devices. Therefore, there is much research in enhancing the functions of existing daily objects by combining them with smart devices.

Cheng explored the approach of utilizing everyday objects as tabletop controllers, taking into account common computer gestures such as rotate, drag, click etc. [3]. Masui et al. proposed MouseField, a device that allows user to control various information appliances. This device consists of an ID recognizer and motion sensors, which sense the movement of objects placed onto it, and interprets it as a command to control the flow of information [13]. Sugiura et al. developed a skin-like user interface consisting of an elastic fabric, photoreflectors and phototransistors, to measure tangential force by pinching and dragging interactions on the interface [20]. His development can be used in daily wearable such as stockings. Sugiura et al. also developed a ring-like device that can be attached to any plush toys to animate the plush toys, converting it into a soft robot [22].

Seeing how important daily objects are to our lives, we are more attached to them than other random objects. Therefore, our proposal is to use our plush toys or pillow, an item that we have hold for a long time or have stronger memory, as the interface for the interaction.

3 Principle

Soft objects are usually encapsulated with soft, fluffy materials such as cotton, wool, feather etc. as their padding. These materials have many spaces in between the atoms allowing a flow of light to spread out.

Previously, our research group has created FuwaFuwa [21], a sensor module that uses photoreflectors sensors to detect the changes in brightness when integrated with soft objects. These sensors consist of an infrared emitter and a transistor side-by-side whereby the transistor detects the infrared light reflected back to it. From this concept, we discover that this measurement is possible even when the two components are at varied distance apart, until a maximum distance. As a note, the measurement method is the opposite of FuwaFuwa: the brightness sensed increases with compression for FuwaFuwa, while when the two components are apart for Cuddly, the brightness sensed decreases with compression.

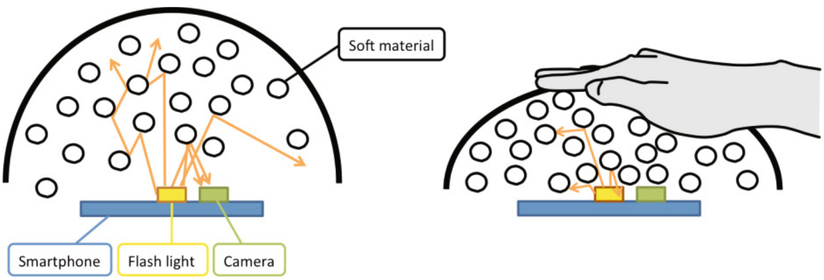


Fig. 2. Surrounding detected by camera is brighter at low density (left) than at high density (right)

We then implemented our test with a mobile phone by making use of its camera and flashlight. We integrate the mobile phone into soft objects and utilize the camera as a sensor to detect the brightness of the surrounding area; thereby distinguishing the change in density of the padding. In order to do so, the flashlight will act as the source of light and the camera will detect its reflection. In a mobile phone, the flashlight and camera are at a distance apart. When there is no pressure applied to the soft material, the surrounding is bright and numerous external light sources can enter the camera (Fig. 2 left). However, when the soft object is compressed, the density of the material surrounding the light source increases, reducing the light reflection – thus, reducing the surrounding brightness (Fig. 2 right).

The camera will capture the video of the surroundings and convert the pixels into average RGB values. These values will then be converted into brightness value using the equation below:-

$$Brightness = 0.3R + 0.59G + 0.11B \qquad [R = red; G = green; B = blue] \tag{1}$$

There are quite a number of equations for brightness that can be found. We chose to use the equation which best corresponds to the human perception [15]. The data of this brightness value is used to create different feedbacks such as sounds, lights, animation etc.

4 Experimentation

We conducted an experiment to investigate the relationship between the change in density of soft material and the brightness of the surrounding detected by a mobile phone. A mobile phone (nexus) was positioned at the bottom of a clear acrylic box (104 x 104 x 146 mm) covered by a cover that could be set at different heights (Fig. 3). This accommodates the calculation of the density of soft material. The box was filled with soft material, the cover height varied from 12 to 5.2 cm in intervals of 2 mm. The brightness detected by the camera was measured at each height. This experiment was repeated for four soft materials with different densities (Fig. 4): polyester cotton, natural cotton, sponge and feather.

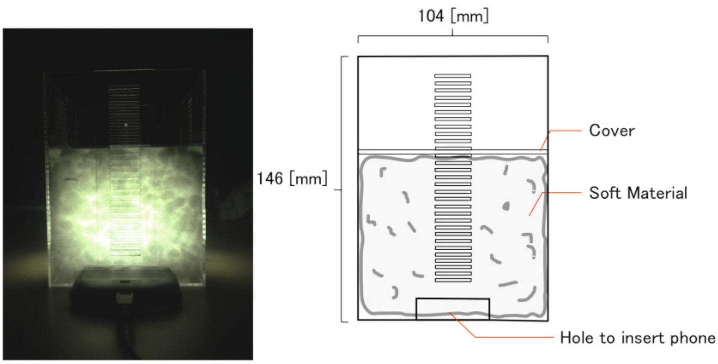
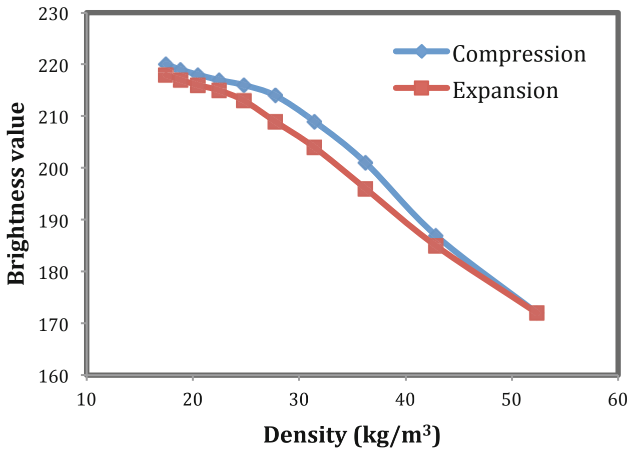


Fig. 3. Experiment Apparatus

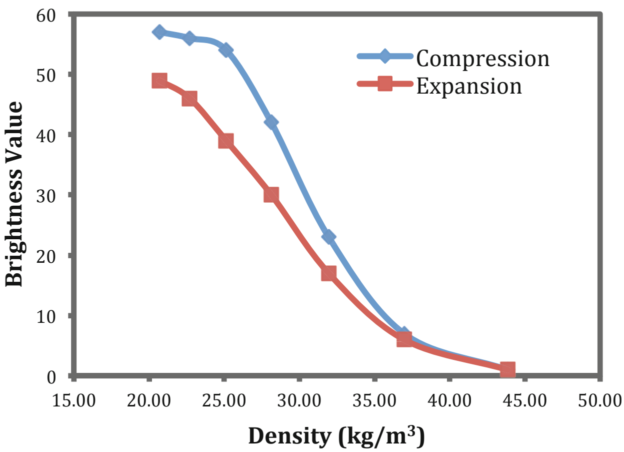
Fig. 4. Different materials tested

4.1 Experiment Result

Fig. 5 shows plots of the changes in surrounding brightness measured by the mobile phone's camera depending on the changes in density of the different materials used. Each graph represents an average of about 3 trials. The brightness detected decreases when density increases by pushing, and increases when density decreases by pulling. However, there is a certain level of hysteresis observed. Most soft materials have many holes in between their atoms. After undergoing push-pull activity, some does not return to its original state. Instead, they still remain in their compressed form. Therefore, the camera detects less brightness when it undergoes pulling activity than pushing activity. This is what causes the hysteresis. However, all the graphs show a significant decrease in brightness value when compressed. This proves that our proposal is capable to detect the change in brightness values.

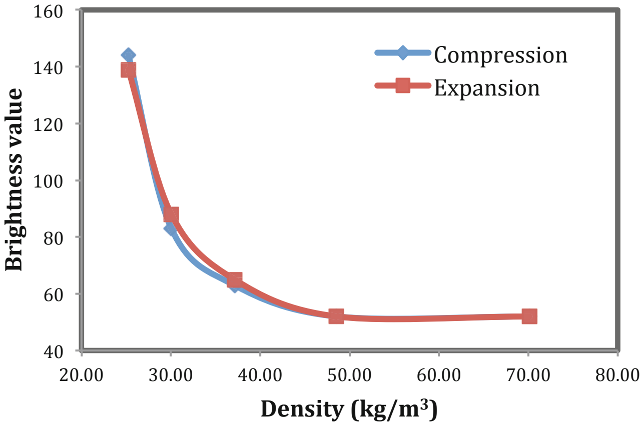


(a) polyester cotton

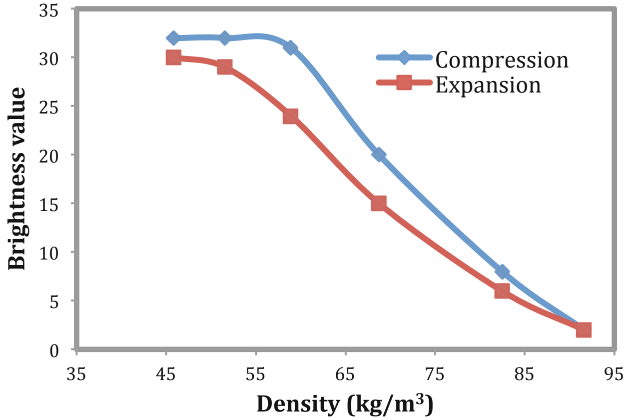


(b) natural cotton

Fig. 5. Average brightness value against density of materials



(c) sponge



(d) feather

Fig. 5. (*continued*)

4.2 Experiment Discussion

The RGB value changes according to the material color: with Black's RGB value [0,0,0] and White's RGB value [255,255,255]. This illustrates that brightness value reduce as brightness reduces. From our experiment, the values for three other colors are involved as well; natural polyester: brown and sponge: pink (back side) and blue (front side). The graphs also illustrates that all three RGB values also reduce when the material was being compressed. This shows that, the material color do not have a strong effect on the brightness level.

4.3 Implementation

For this proposal, we tested the application on Galaxy Nexus (API 4.1.1), HTC J (API 4.0) and Galaxy S SC-02b (API 2.3.6); making use of Android SDK and Eclipse.

Mobile phone's camera comes with auto-exposure function that automatically adjusts the aperture or shutter speed depending on the captured lighting condition. In order to prevent the readings from auto-adjusting itself, this auto-exposure function has to be locked. Therefore, by removing this function and setting the exposure compensation value, the camera can capture the data more accurately. However, as different material differs in density when being compressed, we adjusted the compensation level for each material: polyester cotton (-50), natural cotton (-10), sponge (-30), and feather (40). This allows a better range of values to be taken. For the applications, the proximity sensor was also utilized so that the feedback will only occur when there are materials surrounding the phone.

5 Application

5.1 Interactive Soft Toys and Puppets

Kids like to play as if their plush toy is alive, by giving them voices or moving their limbs [18]. We have designed a few applications by giving voices to different soft toys when the phone is inserted into the toy. For example, dog barking sound for a toy dog, a character voice for a cute character and playback of different recorded voices for a puppet. Besides that, using this application, we can animate a soft object by creating visual faces on the screen itself (Fig. 6). For this application, when the soft object is not pressed, the range of brightness value is about 100. When the object is pressed, it reduces to slightly below 50. Therefore, the brightness value chosen is 50. When the soft object is pressed and the brightness value reduces to 50 and below, the animated character will close its eyes.

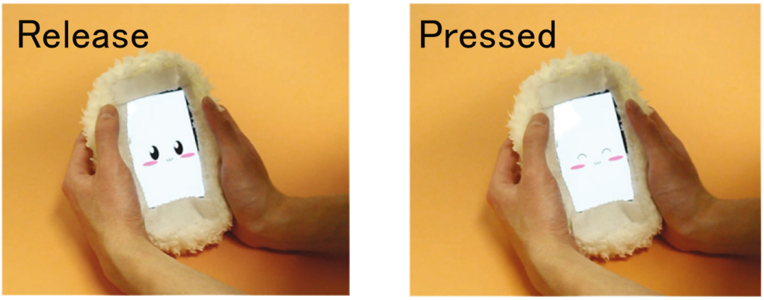


Fig. 6. Character

5.2 Game

We have also designed a gaming application that utilizes the screen while integrating part of the phone with a soft object. For example, depending on the brightness value, the character on the screen will jump at a different height (Fig. 7). For this game, as the brightness value decreases, the height increases and vice versa.

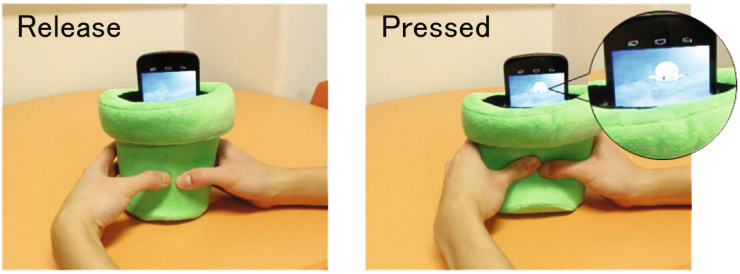


Fig. 7. Game

5.3 Music and Lighting

We have designed an application whereby when user insert the phone into a pillow and presses the pillow, music will flow according to the compression strength. At the same time, the screen color changes with the music. When this application is used in the dark with the pillow, it resembles the display of colorful lights (Fig. 8). The typical musical instrument notes were chosen. At the certain range of brightness value, it will play one note. And at another range, it will play another note and so on.

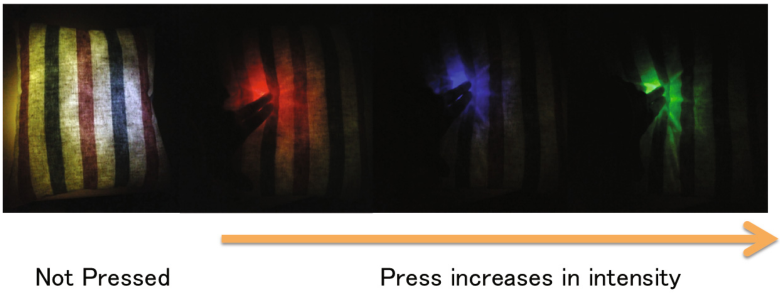


Fig. 8. Musical pillow

5.4 Alarm Clock

We have designed an alarm clock system whereby the user will set the time as a typical alarm clock and insert into the pillow. User will then lie on the pillow. At the designated time, the alarm will ring and vibrate. When user lifts his head up, the alarm will stop. However, when user lies back down, it will ring again.

5.5 Multiple Device Interaction through Bluetooth Communication

As mentioned in the introduction, as a mobile phone has a connectivity function to connect to other devices through Bluetooth, we can create a soft toy interaction with multiple devices. An example application as shown in Fig. 9, is a connection of a phone with a tablet. The phone is inserted into the pillow. When user applies pressure to the pillow, the character on the tablet will receive the punch. Through this, we can create soft controllers just by utilizing a mobile phone.

Fig. 9. Bluetooth connection with other device

Another interesting way of using Bluetooth is for storytelling. An example would be for multiple users to play together, such as creating a joint conversation between devices. When two people insert their mobile phones into their individual soft toy and one presses one's toy, both toys will play recorded script similar to telling a story. With this, users can create connecting stories with their soft objects.

6 Discussion

From both the experiment and test for application creation, a few points were brought up regarding its influence on the accuracy of the application.

- **Hysteresis:**
  Hysteresis differs by materials. However, many daily soft objects are filled with cotton, which has low hysteresis. From our test with different objects, many of the data shows that the readings do return back close to its original values before and after compression. Therefore, we can use optimum values for each interaction.
- **Ambient light from the surroundings:**
  We conducted the experiment in both a dark and bright environment. From observations, the results were similar as the light's reflection was too bright, that the ambient light does not highly affect its performance.
- **Movement of the phone in the object:**
  The phone is constraint by material in the object and thus, small movement may cause some glitches, but will not highly affect the application. However, Cuddly can detect harsh movements as the pressure does change and can generate versatile interactions. For example, when one pulls the soft object at both ends, there would be pressure change in the center of the object. Through this, other interactions such as pulling a part of the soft object can also trigger interactions.
- **Color of material:**
  In the experiment, we have tested with three different colored materials as well as each application presented uses a different colored soft objects. As the brightness value taken is an average, the colors of the material do not highly effect the application.

7 Limitation and Future Works

In this section, we will explain some of the limitations and possible future works to reduce these limitations. One of the limitations is the size of the mobile phone. Currently most mobile phones are rather long in size. Therefore, Cuddly can only be used in soft objects that are bigger than the size of the mobile phone. In addition, the hardness of the phone may be a challenge if the soft object does not have much stuffing in it. In this case, users may detect the phone when they press the soft object.

The compensation level and hysteresis are also some of the limitations as different materials have different compensation level and hysteresis level. As a future work, it may be possible to calibrate both accordingly using different algorithms.

Currently, Cuddly is only programmed to take an average value of the all the pixels captured by the camera – taking only readings in one dimension. However, by sing better image processing techniques, it may be possible to detect the areas of pressure – allowing to obtain readings in two dimension. Besides that, for an extra large interface, one may insert multiple phones and communicate the phone's data with each other to detect the brightness value at different spots. Besides that, another suggestion is to insert a few mobile devices into a big soft object (e.g. a bean bag) to detect the position where the interaction is taken place. This allows the object to act like a controller for different functions such as for gaming purposes. Currently, only the proximity sensor is being utilized – other sensors will be utilize as well in the future to create a more sensitive detection.

8 Conclusion

Cuddly is a phone application that allows users to integrate their mobile phone with soft objects found in the surrounding environment. This application works like a light sensor; making use of the mobile phone's camera and flash light. When the mobile phone is inserted into a soft object, the light from the flashlight will be reflected into the camera. This camera will capture RGB values of the surroundings and convert it into brightness value. When a soft object is compressed, the material's density surrounding the mobile phone will increase and reduces the light reflection. This causes the brightness value detected to decrease; thus, causing a range of value changes. Using these values, Cuddly can create feedback interactions with the soft objects. For example, sound feedback, light feedback, making a call, etc. Our experiment shows that Cuddly is capable of detecting the change in brightness.

In conclusion, this allows users to make use of their most common device, a mobile phone with soft objects from their surrounding environment. This may enhance their user experience with their objects.

Acknowledgment. This work was supported by the Strategic Information and Communication R&D Promotion Programme (SCOPE) of the Ministry of Internal Affairs and Communications, Japan.

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