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Master's Thesis

Academic Year 2013

Cuddly:
Enchant Your Soft Object with a Mobile Phone

Graduate School of Media Design,
Keio University

Suzanne D'Bel Khin Su Low

A Master's Thesis
submitted to Graduate School of Media Design, Keio University
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Suzanne D'Bel Khin Su Low

Thesis Committee:

Professor Masahiko Inami	(Supervisor)
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Abstract of Master's Thesis of Academic Year 2013

Cuddly:
Enchant Your Soft Object with a Mobile Phone

Category: Science / Engineering

Summary

Cuddly is a mobile phone application that will enchant soft objects to increase the interactivity of 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 integrates 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. The mobile phone application we proposed utilizes the inbuilt functions for audio recording and playback, where users can record their voice, place the phone into the soft objects and when they press the object, their recorded sounds will be played at random. Thus, users can give their soft objects different voices and speeches. With this application, we aim to improve the communication between people and their soft objects as users can use their own mobile phone without the need to purchase a new device.

Keywords:

Soft Objects, Mobile Phone Based Computing, Camera-based Measurement, Flash Light

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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, 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 [34]. Because of that, soft objects are often used in different fields such as medical therapy [43], communication [17] or for gaming purposes [33] etc.

However, in order to develop and commercialize these soft interfaces and robots to the society, users are required 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. This same rule applies when people choose soft objects. Taking this into account, it can be seen that for the creation of a well-accepted and loved soft object, developers need to provide either many varieties, as with the case of "Furby" [12], or re-design repeatedly until universally accepted, as with the case of "Paro" [43]. This shows what huge leap there would be between the initial development stage until the final manufacturing stage for sales.

Currently, majority of our society are not aware of the usefulness of soft interfaces. There is a strong assumption that soft objects such as soft toys are mainly

Figure 1.1: Commercialized products [12] [43]

for kids. Therefore, by providing a system which users can easily obtain and experience at low cost, we aim to spread the benefits of soft interfaces to everyone. We believe that this is important to discover new ways and playing methods that fulfill human needs. On this premise, this research, entitled Cuddly, aims to utilize a device, which a majority of us are equipped with, to create an interaction with soft objects that we already have in our home.

There are many sensors such as FuwaFuwa [36] which aims to increase the interactivity of soft objects when embedded with the object. However, Cuddly aims to take that step to a higher level, by integrating the functions of a mobile phone. With this, users are not required to obtain a new device or to embed their soft objects with various components.

Cuddly utilizes a mobile phone, which has had very high sales in the recent years, to create an application which enhances users' interaction with their soft objects (Figure 1.2). This is done by embedding the mobile phone into the soft objects. Cuddly will utilize 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 starts preventing the light from flowing out and thus, decreases the brightness of the material surrounding the camera. The camera captures its surroundings and the pixels from the camera preview will be converted into RGB values and finally be converted into brightness values. With this data of brightness change, Cuddly can return different feedbacks by utilizing functions a mobile phone has, such as sounds, lights, or even the animation on the display. This is not only limited to the mobile phone's flashlight and camera. We can also utilize other sensors in the phone such as the accelerometer sensor, proximity sensor and others to detect different gestures. 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.

Figure 1.2: Cuddly: mobile phone application to be used in any soft objects

2.
Related Works

2.1. Soft User Interface

As soft interfaces stimulate an emotional affection in people, there is much research and many products created to incorporate soft interfaces in order to enhance the interaction between people and their device. Marti et al. developed a physically embodied and animated user interface consisting of a small wireless animatronic device in the form a squirrel, bunny, or parrot to promote an interactive call handling agent. The device will imitate animal behavior depending on whether there is an incoming call or not [17]. Ueki et al. proposed Tabby, an alteration on the design of a lamp by embedding sensors and covering it with a soft fur cover which has been tested to improve the interaction between humans and their furniture [40].

Figure 2.1: Animatronic device (Marti ei. al) [17]

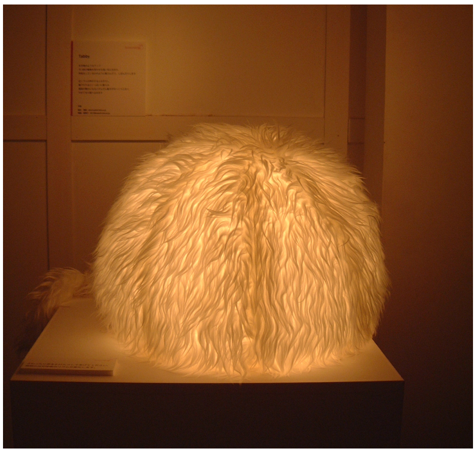

Figure 2.2: Tabby (Ueki et.al) [40]

Soft interfaces are also commonly used for entertainment or gaming purposes as these reduce harm to both the device and the user. Hiramatsu et al. created Puyocon, a throw-able, soft, ball-shaped controller that reacts when it is shaken, thrown or squeezed, in order to replace traditional button type devices such as Wii etc. The device consists of a 3 way acceleration sensor and 14 pressure sensors surrounded by sponges, to detect the pressure applied on the device [13]. Sorensen created a pillow fighting game by inserting Wii remote controllers into 6 pillows and connecting them to a Macbook. The rules of the game are simple, hit each other and the score will appear on the screen. Her design is mainly to use technology for the common human-to-human interaction [33]. Our proposal can be applicable to both applications; by converting the mobile phone into a soft controller or inserting into the pillow to initiate the games.

Figure 2.3: Puyocon (Hiramatsu et. al) [13]

Besides that, although many children are shy, they do love communication especially with their parents. However, most technologies do not accommodate this need, as the targeted users are mainly adults. There are also several studies to learn more about child-parent interaction using common devices. Vaananen et al. did a user study for the communication of parents and their children using a mobile phone connected to their children's soft toy so that any gestures done by the child to the toy will be conveyed to the parents' phone [41]. Their finding shows that soft toy-like communication device has an opportunity to connect both parents and children.

2.2. Soft Interface Detection

There are many attempts to create tactile sensors that can be used on flexible or soft interfaces. Kadowaki et al. embedded LED and phototransistors gapped within a distance from each other, into soft urethane foam; sensing different types of deformation gestures such as push, stroke and pinch etc. This sensor senses the change in gap when pressure is applied [16]. Ohmura et al. suggested a tactile sensing sheet consisting of a micro-controller, 4 serial bus terminators and a 32 tactile sensing circuit, each consisting of a photoreflector covered by urethane foam. These photoreflectors detect the changes in light scattered by the urethane foam when it is deformed [25]. Rossiter et al. created a novel tactile sensor by using a matrix of LED covered by a pliable foam surface, where they found out that LED can act as photodetectors depending on its operation mode [29]. Murakami et al. had developed a device that enabled one to intuitively manipulate 3D CG models [21]. A block of non-conductive urethane foam was cut into a cube, and 90 pieces of conductive urethane foam were attached to it. The resistance of the foam pieces changed in accordance with the deformation of the cube, and the relationship between the resistance and length of the foam pieces was calculated beforehand. In accordance with the lengths recorded for 90 points, the user was able to manipulate the 3D object by de-forming the cube. 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 camera to detect the changes on the surface. Sato et al proposed PhotoElastic Touch; a novel tabletop system comprising of an LCD and an overhead camera, which detect deformed regions of the elastic materials in order to create a touch-based interaction using objects made from transparent elastic material [31]. Cassinelli et al. proposed Khronos Projector, an interactive art installation that allows user to alter the time-space dimension of a portion of an image projected when the user touches and deforms the projection screen [4]. Harrison et al. describe a technique for creating dynamic physical buttons using pneumatic actuation while accommodating a visual display and multitouch sensing [11]. Bianchi et al. proposed a bi-elastic fabric-based display for rendering softness when the fingertips interact with the display. When pressure is applied, the contact area acquisition is based on a RGB image binarization [3]. Similar to these projects, our proposal relies heavily on the camera on the mobile phone to detect the changes of the surrounding surfaces.

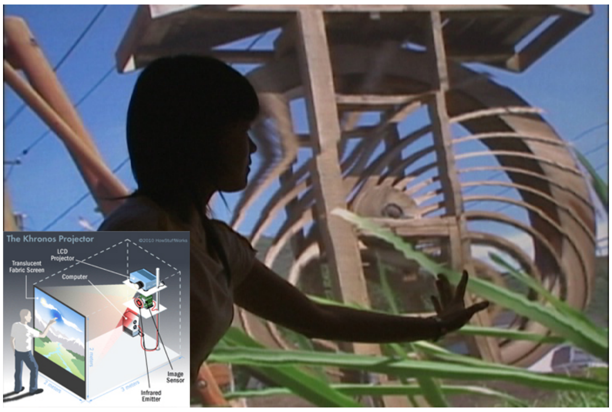

Figure 2.4: Khronos Projector (Cassinelli et al.) [4]

In addition, there are also studies that focus on inserting sensors into pillows or other soft devices to detect behavior change. Yagi et al. developed a pillow which is inserted with an arduino, and 3 sensors: acceleration, photoreflector and capacitive touch sensors, that can control one's living environment depending on human's natural behavior such as hugging, pillowing, laying one's back and others [45]. Our concept is very similar to this research projects, but differs in that we use the sensor features already in a device that most people have, while a majority of people do not bring around 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 use of the device's built-in sensors or external sensors attached to the mobile device itself. 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 [20]. Similarly, Goel et al. introduced GripSense, leveraging the mobile device touch-screens, built-in sensors and vibration motor to detect the hand postures when one uses the mobile device. It senses the amount of pressure exerted by the user by observing gyroscope readings and using it to facilitate interactions such as zoom-in and zoom-out [10]. 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 [15]. Thiel et al. presented a method that uses inaudible sound patterns to detect the proximity between mobile phones by leveraging Bluetooth communication and sound beacons in an inaudible spectrum [39]. Goel et al. introduced WalkType, a text entry system which detects the finger-touch location and distance traveled on the screen, leveraging the use of a mobile device's built-in tri-axis accelerometer to increase typing accuracy [9]. Yoshida et al. proposed a mobile application which converts image edge features and distance-to-edge maps to sound in order to help visually impaired people recognize basic object shapes in an image form [46]. Our main principle leverages the device in-built proximity sensor, camera and flash light for interaction. For other applications, other sensors are taken into account as well.

There are many gadgets in the market which can enhance the ability of a mobile phone or to protect the mobile phone. For example, Fisher Price introduced Apptivity Case for iPhone and iPod devices, a sturdy case accommodated for ba-

Figure 2.5: GraspZoom (Miyaki et al.) [20]

bies which can protect the iPhone from dribbles, drool and unwanted call-making. These allow babies to play and get a hands-on experience with the advance devices from a young age [28]. Wiz. Co. Ltd sells several products which are made for certain gaming applications such as: AppBaseball for a baseball game and AppCopter to control a remote-control helicopter etc. [44]. There are also many innovations which focus on using soft object as their interface to be used together with a mobile phone. Cube-Works released CocoloBear, an interactive teddy bear whereby user places their iPhone on the stomach of the bear and the mouth of the bear will move according to the frequency received. For example, when music is playing or when one receive a phone call etc. [6]. Ishiguro created Hugvie, a plushy pillow shaped of a mono-legged human form that allows user to embrace the person they are talking to over the phone. Hugvie consists of a microcontroller and two vibrating discs that stimulate the user's heartbeat according to their voice tone. The way it works is where users will place their phone into a pocket inside the head of Hugvie and hug the robot as they talk [42]. Acoustic-Sheep created SleepPhones, a headband earphone which user can wear to listen to music while they are sleeping without getting disturbed [2]. This shows that innovations leveraging soft interfaces for mobile devices are gradually expanding in the market.

Figure 2.6: Hugvie (VStone) [42]

2.4. Computing Daily Objects

Our lives are surrounded by objects which we use on a daily basis; we cannot live without them. 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 bringing them in combination with a smart device.

Cheng explored the approach of utilizing everyday objects as tabletop controllers, taking into account common computer gestures such as rotate, drag, click etc [5]. Masui et al. proposed MouseField, a device which 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 interpret it as a command to control the flow of information [18]. Siio et al. proposed IconStickers, to convert computer icons into bar code to be used in the real world in order to manage and classify those files [32]. Sugiura et al. developed a skin-like user interface which consists of an elastic fabric, several photoreflectors and phototransistors, to measure tangential force of the interface generated by pinching and dragging interactions [35]. His development can be used in daily wearable such as stockings. Sugiura et al. also developed a ring-like device which can be attached to any plush toys to animate the plush toys, converting it into a soft robot [37].

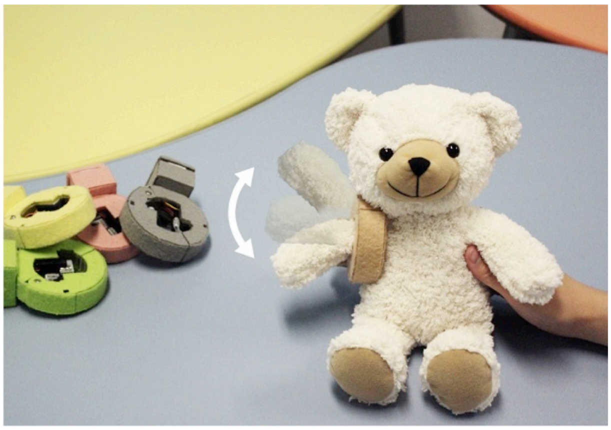

Figure 2.7: Pinoky (Sugiura et al.) [37]

Seeing how important daily objects are to our lives, we are more attached to them than to some random objects around, especially if the object is soft. Therefore, our proposal is to use our plush toys or pillow, an item which we have hold for a long time or have stronger memory compare to a new object, as the interface for the interaction.

3. Principle

3.1. Concept

Soft objects are usually encapsulated with soft, fluffy materials such as cotton, wool or feather etc. as their padding. When light waves are flashed towards these materials, the waves can propagate through it. As soft materials have many spaces in between their atoms, the waves can easily transmit through and spread out.

In this project, we utilized the camera and flashlight of the mobile phone to detect the surrounding brightness. Flashlight releases visible light waves, which are energies composed of a continuous range of wavelengths [27], that will propagate through the soft materials. When these waves propagate from one medium to another, the waves will undergo different processes depending on the properties of the materials. Some of the common processes are absorption, reflection and transmission. Absorption mainly occurs when the materials absorb waves frequencies that coincide with the natural frequency of the material, and convert these energy into heat energy. On the other hand, waves frequencies that do not match the natural frequency of the object will either be reflected (scattered) or transmitted (refraction). Reflection occurs when the object is opaque, where energy cannot be passed from one atom to another in the material. Thus, the energy will be re-emitted as a reflected light wave. Transmission is the opposite; it occurs when the object is transparent, allowing energy to pass from one atom to another until it is re-emitted on the other side of the material. Figure 3.1 illustrates how the processes take place.

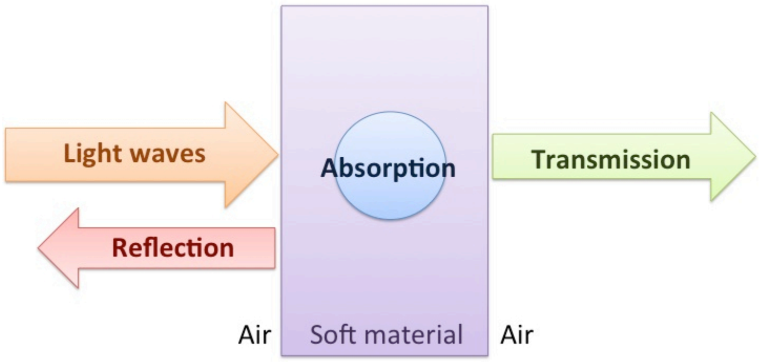

Figure 3.1: Propagation of light through different medium

When light waves are transmitted through a medium, the speed of the waves changes. This change in speed can be reflected by the refractive index, n [23], which are influenced by the properties of the materials. For example, the refractive index for cotton at normal state is 1.53 [22]. However, when the density of the material increases, it takes a longer time for the waves to transmit through and thus, the refractive index increases. When this happen, more light waves will be reflected back from the material due to lack of energy to transmit through.

One common theoretical equation to detect the percentage of transmittance of light waves is the Beer-Lambert Law [8]. This law shows the change in light intensity through a medium depending on the depth of the medium. The equation for Beer-Lambert Law is explained below and Figure 3.2 numerically represents this theory.

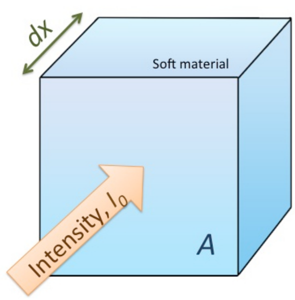

Figure 3.2: Explanation of Beer-Lambert Law

$$-\frac{dI_x}{I_x} = \frac{\sigma C A}{A} dx$$

[dI_x = change in intensity over I_x; I_x = Intensity of incoming light; σ = cross section; C = concentration of molecules; A = area of material; dx = thickness of material]

For detecting the change in soft materials, σ, C and A are assumed to be constants. Summarizing the equation shows that the intensity of light decreases exponentially with the depth of the medium. In other words, less light waves will be able transmit through as the depth reduces. The summarized equation is as follow:

$$I = I_0 e^{-\sigma C x}$$

There is a lot of research and practical experiments which utilize this concept of capturing the light propagation through different materials. For example, to detect the concentration of microbial cells using optical density [38], or to detect the turbidity of water [30]. A few researches also focus on the propagation of light through textile material [47]. Zhou et al. examined the changes in the intensity of backscattering light when the light passes through non-woven fabric of different area density. Their research shows that the backscattering intensity increases exponentially as the area density of the fabric increases, which also coincides with the theoretical equation above [47].

In a mobile phone, the flashlight and camera are at a distance apart. Therefore, the camera can be approximated to detect the transmission of light through the material instead of the reflection, as the material will block the reflection from reaching the camera. Figure 3.3 gives a clearer picture on how the light propagates to the camera.

In this project, we integrated 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. The difference in the density of the material will determine the percentage of waves that will transmit through or

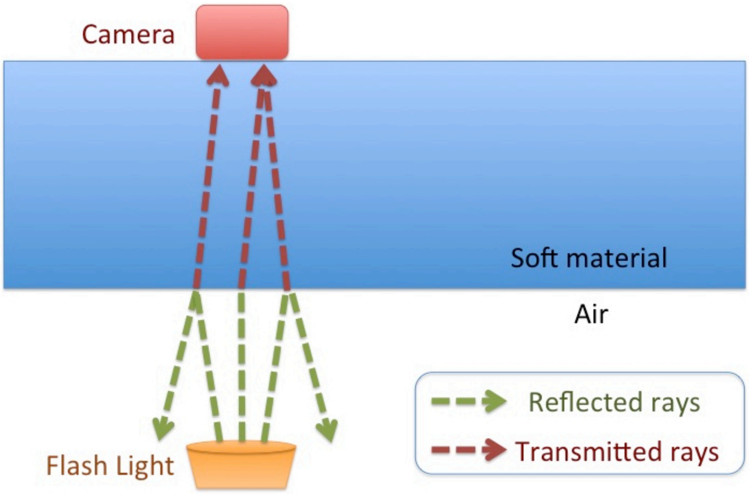

Figure 3.3: Concept model of Cuddly

reflect away from the material; which will then determine the brightness detected by the camera.

When no pressure is applied to the soft material, light can easily be transmitted through the material and numerous external light sources can easily enter the camera. Thus, the surrounding captured by the camera is bright (Figure 3.4). However, when pressure is applied to the soft material, the density of the material will increase, reducing the light transmitting to the camera and thus, reducing the brightness detected (Figure 3.5). The camera will capture the preview of the surroundings and convert the pixels into average RGB values. These values will then be converted into brightness value using the equation below:-

$$Brightness = 0.3R + 0.59G + 0.11B$$

$$[\ R = \text{red};\ G = \text{green};\ B = \text{blue}\ ]$$

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 [7]. The data of this brightness value is used to create different feedbacks such as sounds, lights, animation etc.

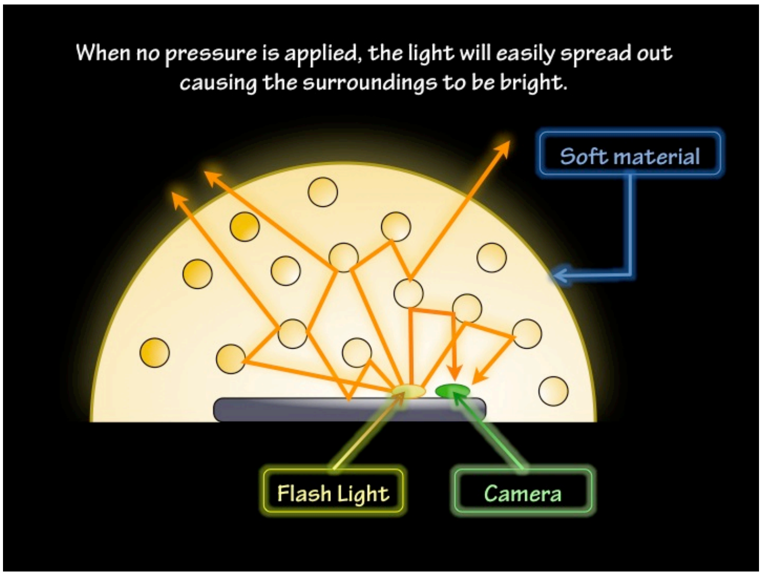

Figure 3.4: Surrounding is bright when no pressure is asserted

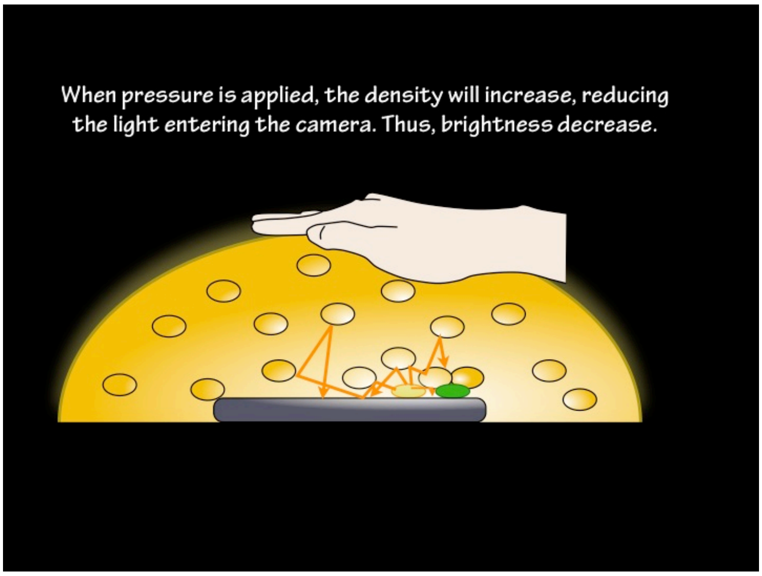

Figure 3.5: Surrounding is dark when pressure is asserted

The principle of Cuddly is relatively similar to the principle of FuwaFuwa (Figure 3.6) [36], a sensor module that is integrated into soft object to detect the deformation on the object. This module consists of several photo-reflector sensors that detect the change in brightness when pressure is applied on the object. A photo-reflector sensor consist of an infrared emitter and a transistor side-by-side whereby the transistor detects the infrared light reflected back to it. Similarly, measuring the light change is possible even when the two components are at varied distance apart, until a maximum distance. As a note, the measurement method for Cuddly is the opposite of FuwaFuwa: the brightness sensed increases with compression for FuwaFuwa, while when the two components (camera and flashlight) are apart for Cuddly, the brightness sensed decreases with compression.

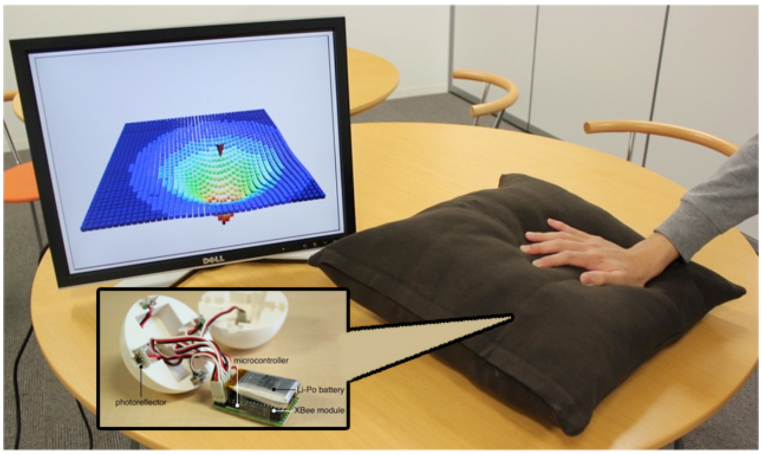

Figure 3.6: FuwaFuwa (Sugiura et. al) [36]

3.2. Experiment

3.2.1 Experiment Procedure

We conducted an experiment to investigate the relationship between the change in density of soft materials and the brightness of the surrounding detected by a mobile phone. A mobile phone (Nexus) was positioned at the bottom of a clear

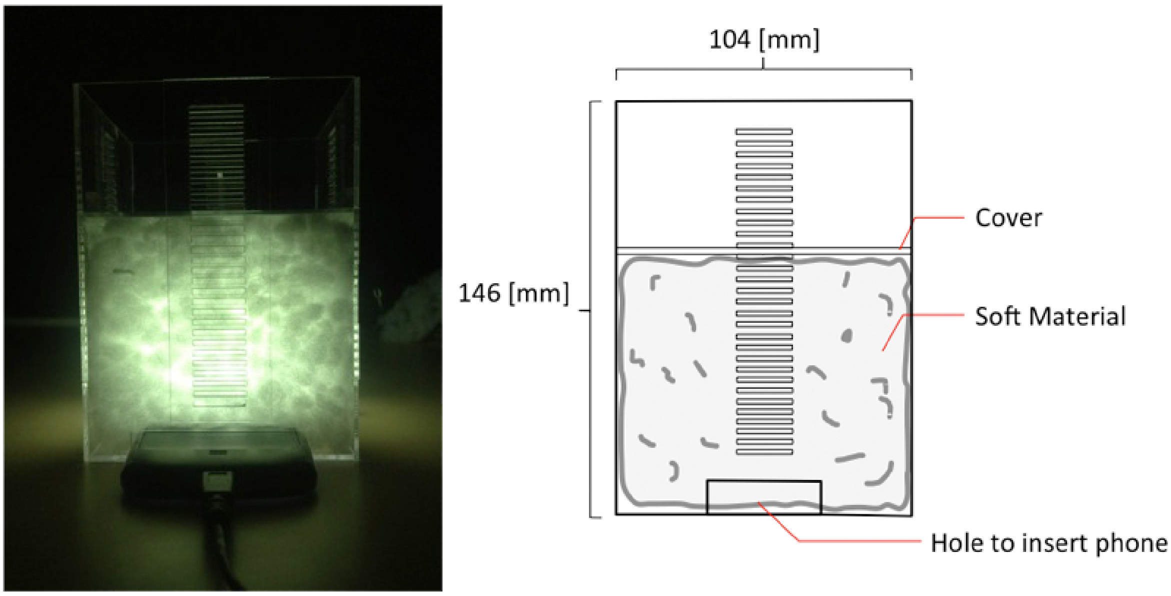

Figure 3.7: Experiment apparatus

acrylic box (104 x 104 x 146 mm), which was covered by a cover that could be set at different heights (Figure 3.7). This accommodates the calculation of the soft materials' density using the equation [19]:

$$Density = Weight/Volume$$

The box was filled with soft materials and the height of the cover was varied from 12cm to 5.2 cm in intervals of 4 mm. The brightness detected by the camera was measured at each height when the materials were compressed, followed by when the materials were released back until it reaches its original height. This experiment was repeated for four soft materials with different densities (Figure 3.8): polyester cotton, natural cotton, sponge and feather.

To be more specific, these are the steps for the experiment conducted:

1. Turn on the application and insert the phone into the bottom of the box.
2. Place 20.0 g of polyester cotton in the box.
3. Set the cover to be on top of the material and record the height value.

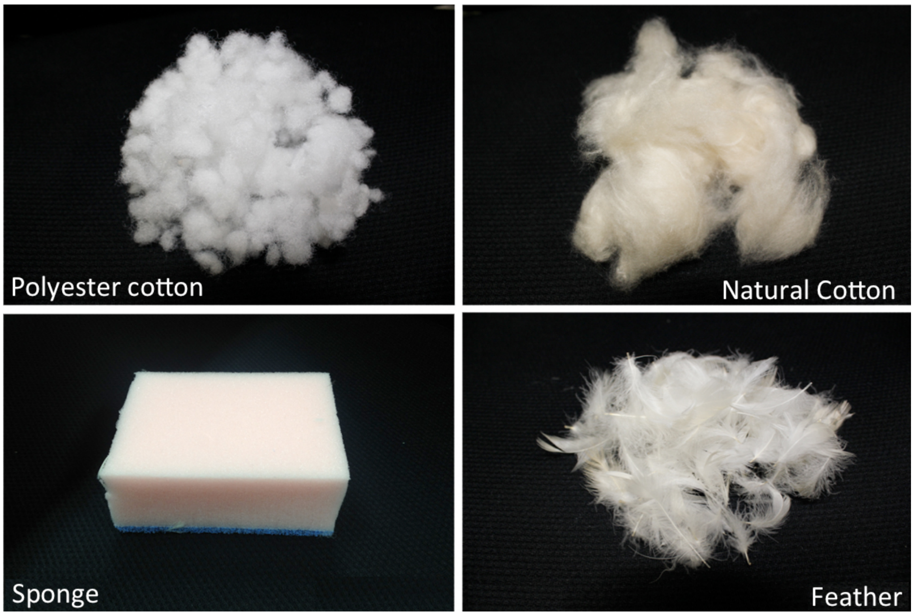

Figure 3.8: Experiment materials

4. Record the values of R, G, B and brightness (in average) detected by the camera, averaging about 10 sets of records.
5. Lower the cover by 4mm.
6. Repeat steps 4 and 5 until the compression is at its limit.
7. Reverse back by raising the cover by 4mm.
8. Record the values of R, G, B and brightness (in average) detected by the camera, averaging about 10 sets of records.
9. Repeat steps 7 and 8 until the cover reverse back to its original height the experiment had started from.
10. Repeat steps 1 to 9 for 20g of natural cotton, 35g of feather and 10g of sponge.

3.2.2 Experiment Results

Figure 3.9 shows plots of the changes in surrounding brightness measured by the mobile phone's camera depending on the changes in density of the different

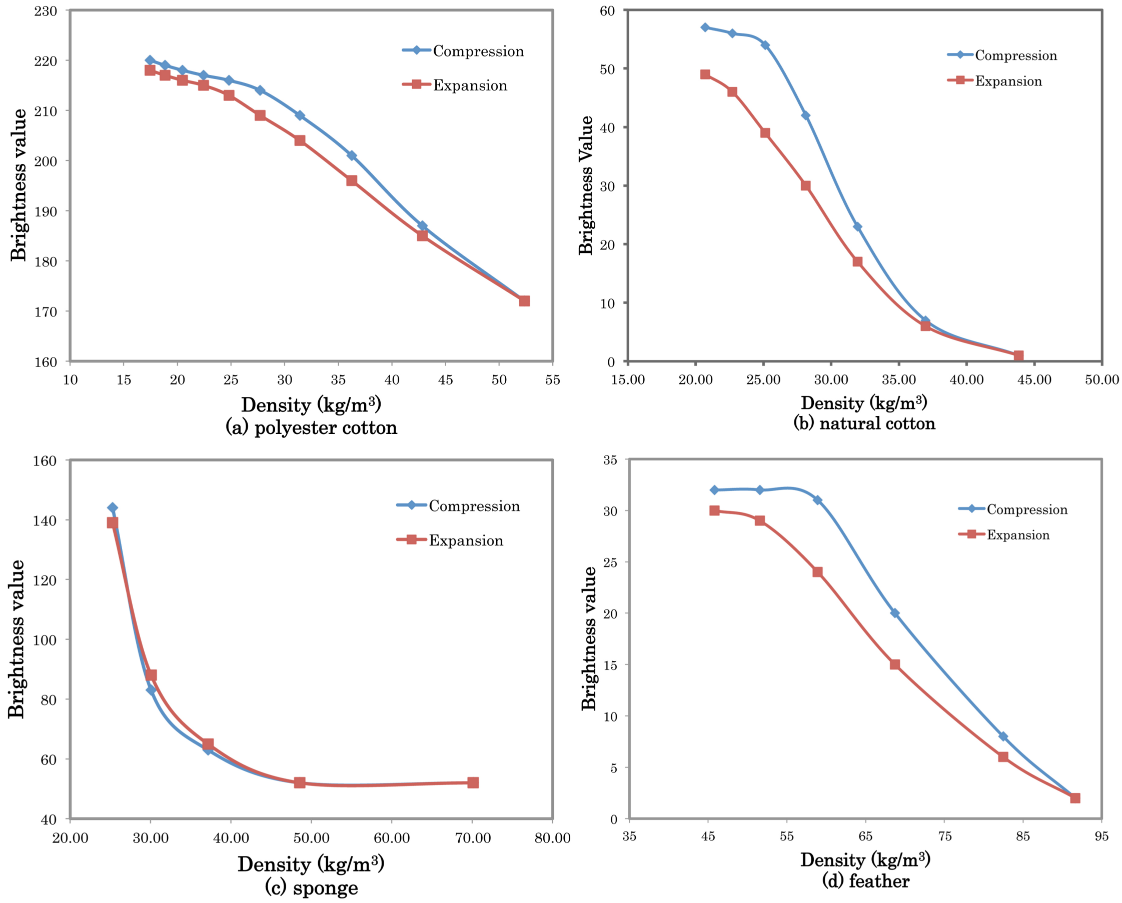

Figure 3.9: Experiment results

materials used. These readings are taken from an average of three trials. From the results, we can observe that the brightness detected do decreases when density increases by pushing and also increases when density decreases by pulling.

3.2.3 Experiment Discussion

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 an auto-exposure function that automatically adjusts the aperture or shutter speed depending on the captured lighting condition. This function hinders the accuracy of the application, and therefore, in order to prevent the readings from auto-adjusting itself, this function has to be locked. However, when this function is removed, the light reflected will be very bright. Therefore, the lighting conditions has to be manually adjusted by changing the compensation value. In other words, by removing the auto-exposure function and changing the exposure compensation value, the camera can capture the data 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 during experimentation. For the applications, the proximity sensor was also utilized so that the feedback will only occur when the phone is surrounded by materials.

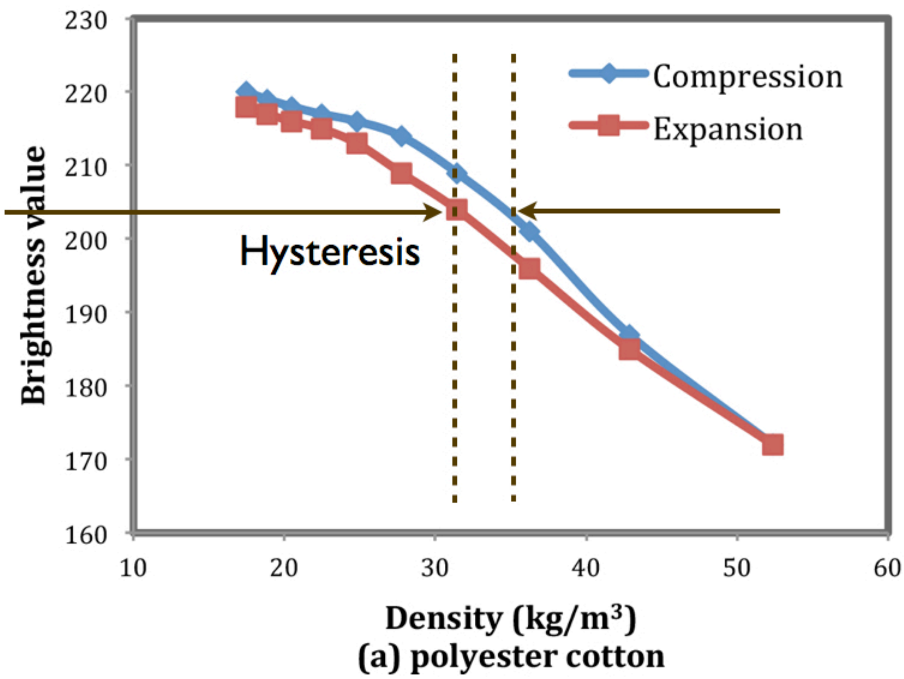

Figure 3.10: Hysteresis example

Another point to be taken into account is the hysteresis. Most soft materials have many holes in between their atoms. After undergoing the push-pull activity, as soft materials are not elastic, it do not immediately return to its original state. Thus, some of the materials still remain in their compressed form. Because of this effect, the camera will detects less brightness when it undergoes pulling activity than when it undergoes pushing activity. This difference cause a small gap between the results taken during compression and expansion as illustrated in Figure 3.10. From the experiment results, we can see that hysteresis differs by materials. However, many daily soft objects are filled with cotton, which has rather low hysteresis. From our test with different objects, majority of the data shows that the readings do return back close to its original values before and after compression. Therefore, the hysteresis effect is almost negligible on the application.

4. Implementation

To implement Cuddly, there are a few points that we have to take into account in order to create the better and more accurate interactions:

1. Calibration
2. Interaction Sensing
3. Movement of the phone in the object
4. Color of material
5. Ambient light from the surroundings

4.1. Calibration

Different soft objects have different brightness values. Therefore, we have to calibrate to obtain the range of brightness values for different type of soft objects. Our method of calibration is to get the maximum and minimum brightness values after mobile phone is embedded into the object. Our calibration method is to press and release the object repeatedly for 5 seconds, as though the user is giving a heart massage to the object. Figure 4.1 illustrates an example of a graph during calibration. This graph is obtained when calibrated with a puppy soft toy.

From Figure 4.1, we can observe that the maximum value is 210 and the minimum value is 2. Therefore, the calibrated brightness value range is 208 using the equation:

$$Range = MaxValue - MinValue$$

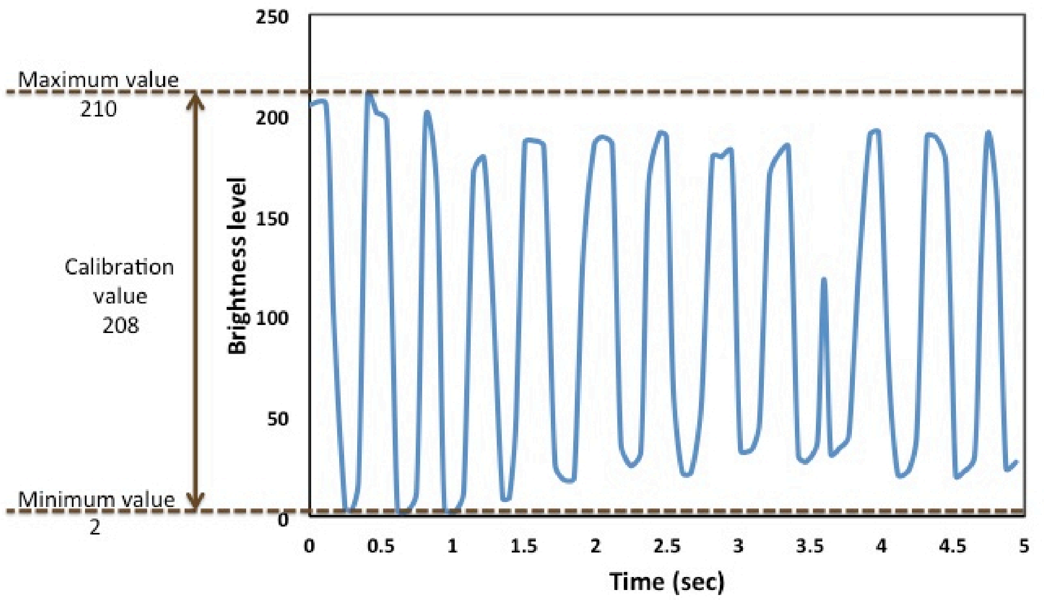

Figure 4.1: Graph taken during calibration

[$Range$ = Calibrated Brightness Range; $MaxValue$ = Maximum Calibrated Value; $MinValue$ = Minimum Calibrated Value]

Then, we utilize these values to detect different interactions.

4.2. Interaction Sensing

We created an application where user can record three different voices (For more information, please refer to Section 5.2). These voices will come out randomly when the soft object is pressed. However, the playback rate of the sound will change depending on the speed of the user's press. This is done by collecting the gradient of the graphs. Figure 4.2 and Figure 4.3 illustrates an example of the difference in gradient at fast and slow speed.

We utilize the camera preview of the mobile phone to continuously capture the surrounding brightness. This camera preview recaptures the scene at a very rapid rate. Therefore, our method is to put the captured values in an array to

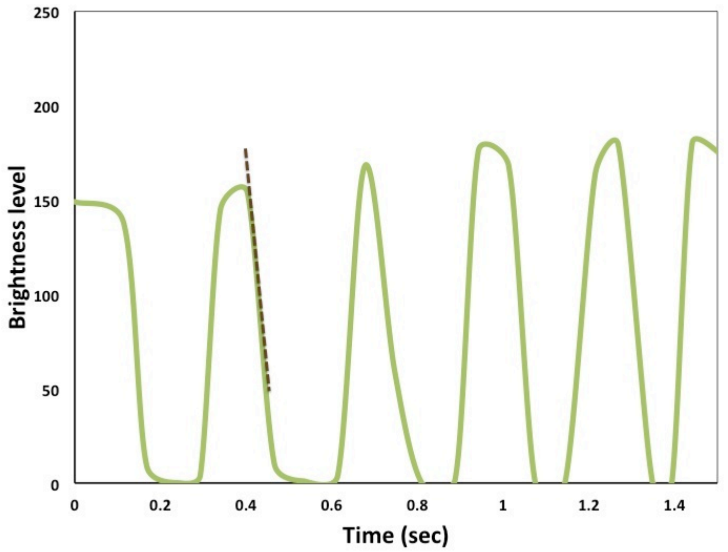

Figure 4.2: Graph when pressed at fast speed

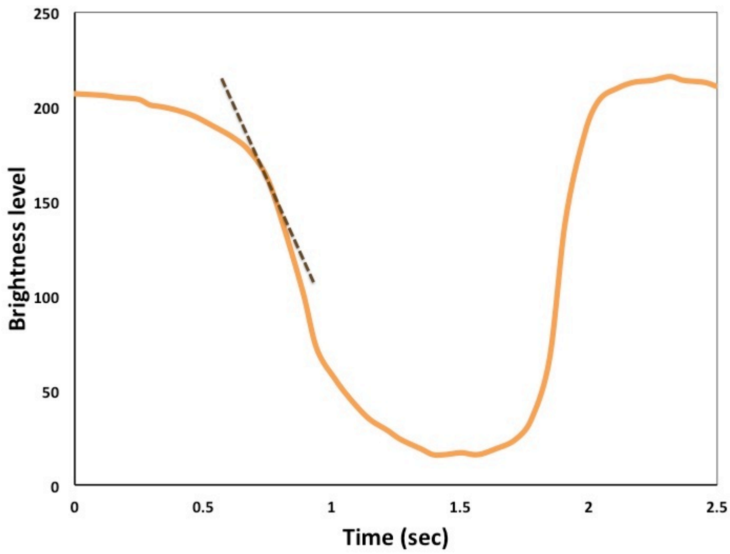

Figure 4.3: Graph when pressed at slow speed

continuously compare the 1st and 5th stored value. As the time is rapid, these comparison can be approximated as a straight line. From Figure 4.2 and Figure 4.3, the difference in gradient when the pressing is fast and slow can be observed (the brown line). We then compare these gradient values with the calibration values to detect the difference in speed. The equations used are as follows:

Fast speed:

$$Array[5th - 1st] > (MaxCal - MinCal)/2$$

Normal speed:

$$Array[5th - 1st] > (MaxCal - MinCal)/4$$
$$\& \, Array[5th - 1st] < (MaxCal - MinCal)/2$$

Slow speed:

$$Array[5th - 1st] > (MaxCal - MinCal)/8$$
$$\& \, Array[5th - 1st] < (MaxCal - MinCal)/4$$

[$Array[5th - 1st]$ = gradient comparison of the 1st and 5th values, $MaxCal$ = maximum calibration and $MinCal$ = minimum calibration]

4.3. Movement of the phone in the object

The movement of the phone within the object differs for two cases:

1. **When the phone is inserted into the object**

   When the phone is inserted into the object, the phone is constraint by the materials which surrounds it. Therefore, small movements may cause some glitches, but will not highly affect the application. However, when harsh movement are applied on the objects, Cuddly can detect these movements as they do cause a change in pressure. 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.

2. **When the object is placed on top of the phone**

For the case when the object is placed on top of the mobile phone, the phone may easily slip off from the object when harsh movements are applied, as the phone is not constraint by anything.

4.4. Color of material

During the experiment, we have tested the application with three different colored materials. We also have conducted different tests with many materials and soft objects. From this, we found out that colored material do not highly effect the application, except for two different situations:

1. **When material color is too dark or close to black color**

   When the color of the material is black or rather close to black, it will absorb the the flash light, preventing the light from transmitting to the camera. Therefore, in this case, the application could hardly detect any change in brightness values. This case is also similar when the mobile phone is placed on a flat dark surface, below the object. Due to the darkness of the surface, the light can hardly be reflected back to the camera as well. Though some dark materials may work when the compensation level is set at a higher level.

2. **When the material is too white**

   Another problem is if the material is too white. In this case, the light reflected is too bright from the start, preventing much change even when the material is pressed. One method, is to adjust to a lower compensation level to capture a darker surrounding.

4.5. Ambient light from the surroundings

We conducted the experiment in both a dark and bright environment, and found that the results for both conditions were similar. This is because the light from the flashlight has a higher magnifying effect as compare to the ambient light of the surrounding, causing the ambient light to be negligible. Thus, the ambient light do not highly affect the application's performance.

5. Application

5.1. Prototyping Applications

By implementing Cuddly's principle, we created several prototype applications to create interactions with soft objects. These applications utilizes the different functions which a mobile phone is embedded with, such as utilizing the sound, screen, sensors, wireless connection and many others. This section will describe a few of the applications.

5.1.1 Interactive Soft Toys and Puppets

Kids like to play as if their plush toy is alive, by giving them voices or moving their limbs [34]. 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 inputted voices for a puppet.

Besides that, using this application, we can animate a soft object by creating visual faces on the screen itself (Figure 5.1). For this application, the calibration values were not yet utilized and therefore we fixed the values accordingly. 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.

Figure 5.1: Character

Cuddly can also be utilize with soft objects that does not contain any holes to insert the phone. The method of play with these object is to place the mobile phone under the soft object with the flash light facing towards fluffy side of the object. Figure 5.2 illustrates how this can be done with a character known as "momo" .

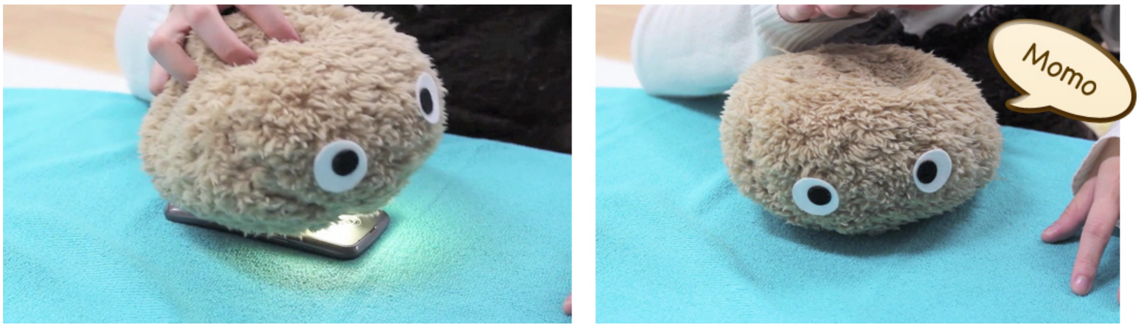

Figure 5.2: Put under soft object

5.1.2 Jumping mario

Mario is one of the famous widely known character of Nintendo's Super Mario Brothers games [24]. We often see Mario on the screen when playing the game. However, similarly, it will be interesting if one can mix Mario with a real life soft object as well. We have designed an application that utilizes the screen while

Figure 5.3: Jumping Mario

integrating part of the phone with a soft object from Mario, Mario's pipe. When the pipe is pressed, Mario will jump up and when the pipe is released, it will fall back down. The height of Mario's jump depends on the brightness detected.

5.1.3 Musical and Lighting Pillow

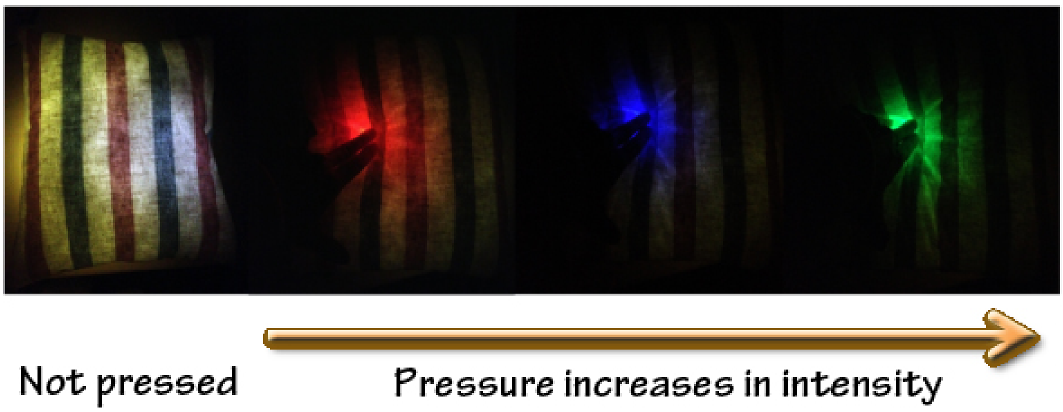

Figure 5.4: Musical pillow

We created 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 certain range of brightness value, it will play one note. And at another range, it will play another note and so on. The music here used is a typical piano sound

“Do Re Mi Fa So La Ti Do” . At the same time, the screen of the phone can be used as a light source in a dark environment. Therefore, for this application, the screen color will change according to the musical instrument sound. When this application is used in the dark with the pillow, it resembles a display of colorful lights (Figure 5.4).

5.1.4 Alarm Clock

It is quite common for one to use their phone as an alarm clock. We prototyped 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.

5.1.5 Multiple Device Interaction through Bluetooth Communication

Figure 5.5: Connectivity with other devices to create a soft controller

A mobile phone has connectivity function to connect with other devices using Bluetooth or Wi-fi. By using this function, we can create a soft toy interaction by connecting multiple devices. For example as shown in Figure 5.5, we connected the phone with a tablet. The phone is inserted into the soft pillow while the tablet is left outside to be used as a screen. When user applies pressure to the pillow, the character on the tablet will receive the punch. There are many other possible games to be created with this application. The main aim is that we can create soft controllers just by utilizing a mobile phone.

5.2. Application Release on Google Play

From the different prototypes, we decided to release an application which everyone would be able to use easily. The aim for the release is to give access to anyone to download the application for free so that they can play with their soft objects. In addition, we hope to get feedback from different people regarding their thoughts about the application.

5.2.1 Application: Record and Play

After testing out with different applications, one of the interesting application observed is for users to "record and play" their voices. As compare to the other prototype applications, "record and play" allows users to play the application with any of their soft objects at home without the need to get a special soft object for the application (as such in the case for Mario in Section 5.1.2). This is also more beneficial over automatically inputted voice, as users can insert different scripts, or voices of their parents and friends. This function gives more flexibility to the application. Hence, we have released the first beta version of Cuddly on Google Play featuring the function of "record and play".

The procedure to play is as follows:-

1. Record three recordings.
2. Click “Let’s Play” to start.
3. Insert mobile phone into soft objects within the first five seconds. (when you hear a beeping sound)
4. Press and release multiple times within the next 5 seconds. (when you hear a chime sound)
5. Press to play with your soft objects.

Extras:

- There are three type of playback speed depending on how fast you press.
- Tap on the screen again to restart.
- If the camera video is too dark when inserted into objects, you can adjust using the seekbar. (darker to lighter)

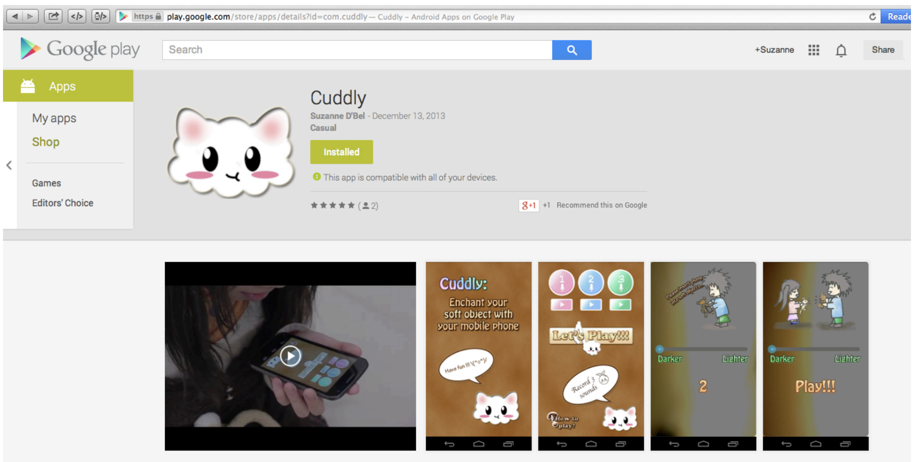

Figure 5.6: Release on Google Play

Here is a better illustration on how to play the application.

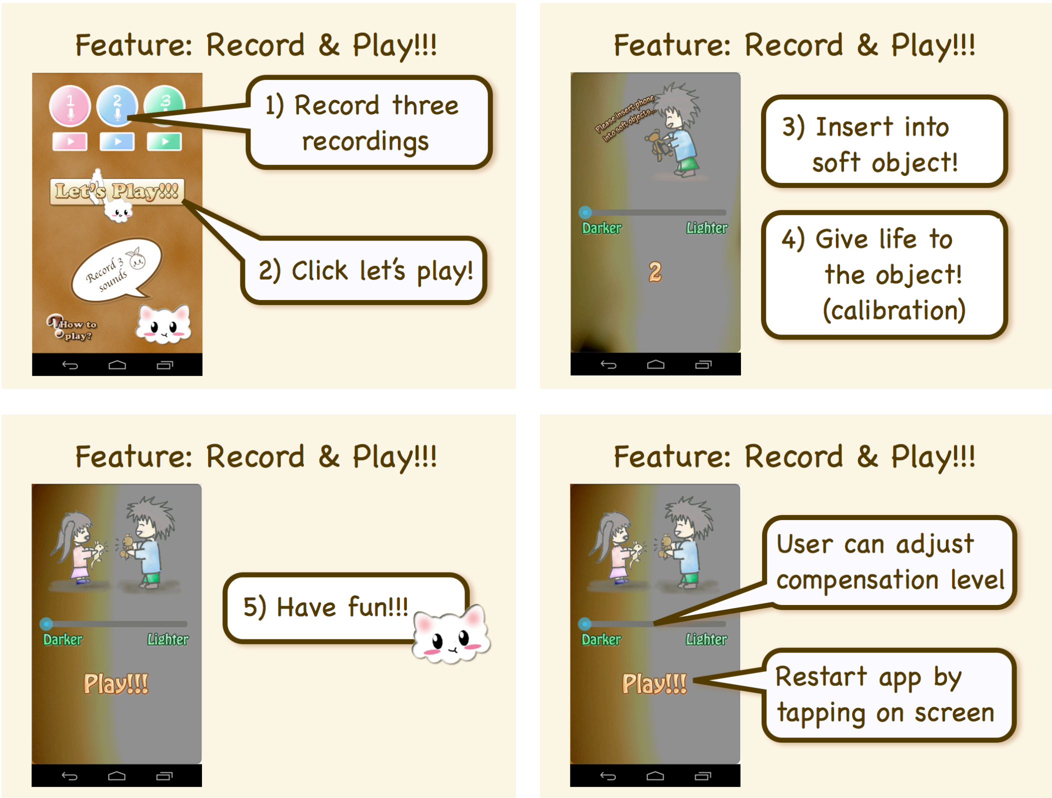

Figure 5.7: Steps to play the application

5.2.2 Webpage for Cuddly

After the demonstration (which will be mentioned in Section 6), many visitors requested for a webpage to learn more information on the application. Therefore, we created a simple site explaining the basic information on how the application works.

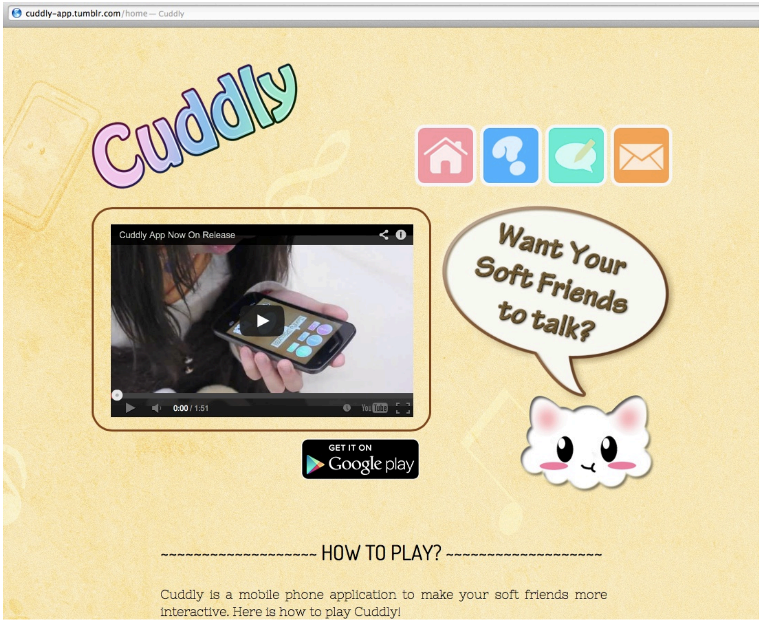

Figure 5.8: Screenshot of Cuddly's Webpage

5.2.3 Feedback on the application

Since we have just released the application on Google Play, we are hoping to get further feedbacks from people who have downloaded the phone application. We have also gotten many feedbacks from the demonstration and the user study which were held right after the release. More discussions will be explained in Section 6.

6. User experience

6.1. Parent-Children Playing Observation

As children communication using soft objects is also another aim of our project, we wish to observe the usability of the application when parents and children play together, as well as when the child plays alone. We conducted a study with 6 pairs of parents *(age range 40 - 51)* and children *(age range 8 - 14)* and 5 individual children *(age range 6 - 10)*. This study was conducted in conjunction with two other studies *[Graffiti Fur by Koki Toda and MyRin by Natsuki Sakamoto]*. And, each pair are allocated with a time slot of 20 minutes. After 20 minutes, each pair will switch between these three studies. The main aim of our study for Cuddly is to observe how would parent and child play the application together and how would the child play the application individually.

We conducted the study with the procedure as follows:

- **First:** We did a brief description on what the application is about, and questioned the participants about their connectivity with soft toys such as "Do they have soft toys?", "What kind of soft toys do they have?" and "What would they feel if their soft toys talk?"

- **Next:** We explained on how to use the application while involving the participants to experience the application step-by-step during the explanation. After the explanation was done, we let the children to play with their parents if they were in teams, or we let the child play individually. At the same time, we gave some ideas on different playing methods such as the child can sit on the pillow or the soft toy.

Here, we would like to discuss 2 main points about the flow of the study as well as the observations observed:

1. Different playing methods
2. Playing with parents and playing individually

6.1.1 Different playing methods

In this study, we observed many different types of playing methods.

Figure 6.1: Mother and son creating conversation

A mother-son (Figure 6.1) pair played whereby each of them holds a phone and put under a big and a small "momo". The mother recorded three questions; "How did you score in your test?", "What sweets do you want?" and "Have you finish your homework?", while the son recorded his answers on the other phone; "85 points", "Curry rice" and "There's no way I have finished". They were trying to create a conversation between the mother "momo" and the son "momo". However, as the voice comes out randomly, the answer played has a higher chance to be different from the question. When the answer comes out wrongly, both the mother and son burst into laugher. However, when the answer coincides with the question, both of them went "ohhh". This shows that it is more interesting when things do not go according to plan.

Figure 6.2: Sitting on the pillow to make weird sound

One of the favorites where a majority of the boys played was to place the phone under the soft toy or pillow and sit on them to make them sound with weird or funny sounds like “fart sound” or sentences such as “You have gained weight!” (Figure 6.2). It reminds them of a whoopee cushion (a joke device which produces noise that resembles a human flatulence) which many used to play when they were much younger. This shows that Cuddly is not just limited to soft toys, but can be used with different soft objects from the home environment.

Figure 6.3: Father and son playing together

Not just with the soft pillow, one pair played by sitting on the soft toy as well. A father (Figure 6.3) recorded his voice with “Nice to meet you”, “Morning, morning. It’s morning!” and “I’m hungry! Ah, after eating, my stomach hurts! I am going to the toilet.” and put in under a fox toy. Then, the son sat on the toy and the voice came out in high pitch sound. It really sounds like the fox was talking. This similar pair were also really interested in learning the principle of the application.

Figure 6.4: Played with two objects, each placed on top of a mobile phone

One of the individual participant (Figure 6.4) played with two mobile phones; placing one mobile phone under a pillow and the second phone on top of the pillow. Finally, he placed a "momo" on top of the second mobile phone. When he pressed, both mobile phones will sound. He mentioned that it really does sound like the toys were talking. This shows that one player can even use multiple phones to give an interesting interaction.

Figure 6.5: Playing with two soft objects to create a conversation

Another individual participant (Figure 6.5) did a similar play by placing the two mobile phones into two different soft toys. He then pressed both soft toys to make sound and to create a conversation. However, instead of questions, he recorded the same voices in the phone.

One mother-daughter pair played where the mother recorded her voice and the phone was inserted into a soft shoe. Then, the daughter took the shoes and jump around her mother and on her mother's head. Since the shoes were soft, it does not injure either participants, but instead it was fun as they can get really close to the objects.

6.1.2 Playing with parents and playing individually

We observed that the playing methods between parent-child pair and individual quite differs from each other. Here is a further explanation on the differences:-

Individual

Among the children, 8 were boys and 3 were girls. All of them were very shy from the beginning. However, after starting to play with the soft toys, each of them started opening up. Boys were playing more actively compare to girls. A few of them were playing a bit rough with the soft toys. Figure 6.8 shows a boy participant who was really shy at the beginning but soon opened up when he starts playing with the soft toy. However, as parents are not around, he can be a bit rough on the toys which is a typical act when children plays with soft objects.

Figure 6.6: Shy boy opened up after playing with soft objects

Girls were more shy when playing with soft toys. They tend to stay at the same spot from the start till the end of the time slot. For the individual participants, one of the participant was a girl. She really likes soft toys, but she was really shy. Figure 6.7 shows the soft toys she played with during the 20 minutes study.

Figure 6.7: Individual girl participant playing

Many of the participants prefer their parents to record something in the phone. For example, Figure 6.8 shows a boy participant who participated in the workshop alone. However, as his mother was sitting somewhere nearby, he asked his mum to record her voice and to join him to play with Cuddly. His mother then recorded; "Faster go to sleep!", "You are still awake?" and "Hey, don't touch me!". Then the boy placed the fox on top of the phone. It was really funny when the voice "Hey, don't touch me!" came out in a high pitched voice.

Figure 6.8: Individual boy participant called his mother to play with him

Parent-child pair

A father-daughter pair (Figure 6.9) played together where whenever the girl records a voice, she would pass the phone to her father for him to record as well. During the observation, this was a very common act. A high percentage of the users were not quite sure on what to record and eventually they will pass it to their parents to record for them. From these observations, it may be best to put an example in the application itself on how to use.

Figure 6.9: Father and daughter playing together

A mother-son pair (Figure 6.10) played with the toy shoes together, where each will place a phone into a shoes and each will play step by step to make a continuous sound. Another method of playing the toy shoes is to make it walk without the need to press the shoes. Once the shoes are made to walk, pressure is asserted onto the shoes when it hits the ground causing the sound feedback.

Figure 6.10: Mother and son playing together

Summary of parent-children study

A majority of the children still likes to play with soft toys where boys favors "Pokemon" and girls favors toy bears such as "Rilakkuma". Most of them mentioned that it was either scary or surprising if their own soft toys talk. However, after playing with the soft objects, many mentioned that it may be fun if their soft toys can talk in a similar manner. A few also suggested that they would really like to try use the application to play a trick on their siblings, such as to insert in their sibling's bolster etc.

At first, we were worried about two points; will the children be able to understand how to use the application and will the flash light gives any problem as children may look straight into it. However, during the study, we observed that the children could easily understood how to use the application without the need to understand the concept. They easily understood that they have to just place the flash light to the direction of the object when placing the phone under or in the toy.

However, as this study was conducted together with another two projects and the room was slightly crowded, many participants were shy and were reluctant to record their voices. In addition, one of the parent was a bit strict on the child and do not allow the child to record any impolite sound. For a future user study, it may be best to have a study to observe children playing at home with their parents without anyone around.

6.2. Presentation and Demonstration

We presented and conducted a half-day demonstration at ACE 2013 held at the University of Twente, Netherlands on November 14th, 2013 and a 3 days demonstration at Siggraph Asia 2013 held at the Hong Kong Convention and Exhibition Center on November 20th - 22nd, 2013. The age range of the visitors to these conferences were about 16 - 70 years old. During these demonstrations, we observed the reactions of the visitors as well as obtained their feedbacks about the application, to further improve the application. Many visitors find the application really interesting, not only in terms of the experience but also the simplicity of the application and the advantage of not requiring external sensors. Below are several pictures of the demonstration which took place.

Figure 6.11: Demonstration at ACE 2013

Figure 6.12: Demonstration at Siggraph Asia 2013

We will discuss about a few of the feedbacks obtained.

1. **What is the difference between using Cuddly's principle and using the pressure or light sensor in the phone?**

    - In the phone, the pressure sensor is to detect the atmosphere pressure, rather than the pressure applied on the phone. When inserted into soft objects, the atmosphere pressure does not change and thus, it cannot be utilized for this application.
    - Similarly, once inserted into the soft objects, the light sensor can detect the change in light only at very obvious change. It does not detect a full range of values when pressure is asserted. Therefore, Cuddly's principle has much better sensitivity compare to a light sensor when utilized with soft objects.

2. **What is the difference between Talking Tom?**
    During the demonstration, we were not really aware of this application. Talking Tom [26] is an application by Outfit7 whereby users own a cat character which will repeat what users say in a high pitch voice. In addition, users can touch, hit and play games with it. After giving Talking Tom a try,

the application is quite different from Cuddly. The difference are in terms of:

(a) Cuddly aims to enhance the interactivity of soft objects while Talking Tom is an interactive pet to be played on the phone.

(b) The voice detection function from Talking Tom was tested in the soft objects. However, the phone can only detect voices from a short distance away from the objects. Therefore, Cuddly has better sensitivity in terms of detecting gestures.

(c) Cuddly uses pre-recorded voice and therefore, user can always repeat the voice continuously. This goes the same for recording parents or friends voices. Talking Tom does not utilize the recording function and thus, it only repeats what was said once.

(d) However, Cuddly still lack of advertising needs and gaming application as compare to Talking Tom and thus, one of the future works is to advertise it.

3. **The alarm clock application is interesting. However, it is not recommended to place your phone beside your pillow when you sleep.**
   Though, many people do still sleep beside their phone, to use it as an alarm clock.

4. **Can you detect other gestures as well?**
   Current detection can detect how fast you press. Depending on the speed, the pitch of the sound will change. To increase the interaction of the application, we are planning to use other sensors to detect other motions as well.

5. **What is our motive of the future? Are you planning to sell it?**
   We have released the application for free on Google Play. Our aim is to

increase the interaction between people and their soft objects; to let people know the capability of their soft objects and their mobile phone. Therefore, we are not planning to sell it.

There are also other suggestions to improve the application such as:

- To off the flashlight when the application is at rest and re-light it when it is in used. Through this, we can reduce the power consumption as well as prevents the phone from heating up.
- To use other sensors for other interactions.
- To create an Iphone version and a website to explain the application in details. From our observations, there are not many Android users as compare to iPhone users.

Overall, there were quite good rating during the demonstration as many visitors really enjoyed the application. It was a fun experience to hear laughters from many visitors. From our observation, many visitors enjoyed the sound playback at a fast rate with a squeaky voice, especially when the recordings were in different long, funny sentences. However, a majority were quite shy and thus, many recorded just "hello" or similar quotes during the demonstration. We released the application on Google Store right before the demonstration at the conference. However, as the internet connection at the conference hall was not available, not many visitors were able to download the application. Thus, our next aim is to advertise the application to get more feedback from different people.

7. Limitation and Future Works

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. Another limitation is that Cuddly would not work with materials which color is too dark as most of the light waves will be absorbed by the material.

In addition, a pre-long use of the application may cause a drainage in the battery life as the flash light has high battery consumption. Furthermore, children tend to forget that the phone is left on continuously in the soft objects. Therefore, from a suggestion at Siggraph Asia, it may be best to put the phone at rest when it does not detect any movement and resume the app again when it detects movement. This way, it reduces the power consumption of the battery when not in used.

For the current "record and play" application, user has to adjust the compensation level according to the material (if the material is too dark or light). For a future work, it is best to create an auto-adjustable compensation level. This can be a concept to allow others to create their own application as well, not just limiting to "record and play". One interesting suggestion was to publicize a general library for the application in order for others to be able to use the codes.

Currently, Cuddly is only programmed to take an average value of all the pixels captured by the camera. However, by using a different algorithm it is possible to divide the pixels into a matrix form to capture the brightness pixel at each position and compare to get the position where pressure is asserted.

As the workshop was conducted in an open space, where there were many people around, the children were quite shy. Therefore, we should conduct a user study with parents and children playing in their home environment or at a less crowded place. This way, the children will be less shy to try out different playing methods.

8. Conclusion

Cuddly is a phone application that allows users to integrate their mobile phone with soft objects found in their 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 or placed below 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.

We implemented this concept into different applications and created an application with the feature of audio recording and playback of the user's voice in the soft objects. With this, users can make use of their most common device to play with any of their one toys without the need to purchase a new item. Through this, we aim to enhance their user experience with their objects. We also conducted a user test to observe how parents and children will play the application together and to observe how children will play the application individually. From our observations at demonstrations and user study, a majority really enjoyed the experience playing with the application. We aim to further improve the application to give users a better playing experience.

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Appendix

A. Pressure Detection on Mobile Phone By Camera and Flash

A.1 Principle

Not just limiting to soft objects, this principle can also be used for other interactions. An example is to detect pressure exerted on the mobile phone. Many research has been focusing on creating new interaction methods with the mobile devices such as shaking, finger print detection or other dynamic actions. This includes pressure detection.

The concept here is to utilize the mobile phone's camera and flashlight to detect the change in pressure applied on the phone. When the phone is placed on the palm, there is a gap between the palm and the camera. This gap allows the flashlight to reflect back to the camera, causing the camera to detect a bright surrounding (Figure 8.1). When pressure is applied, the gap will reduce, preventing the light from reaching the camera and thus, reducing the brightness detected (Figure 8.2). Figure 8.3 gives a better illustration of the camera preview when the screen is not pressed (left) and when the screen is pressed (right). Using this method, there are two pressure interactions that can be detected. One is the pressure applied on the surface of the mobile phone when the phone is placed in the palm and another is when user squeezes the mobile phone.

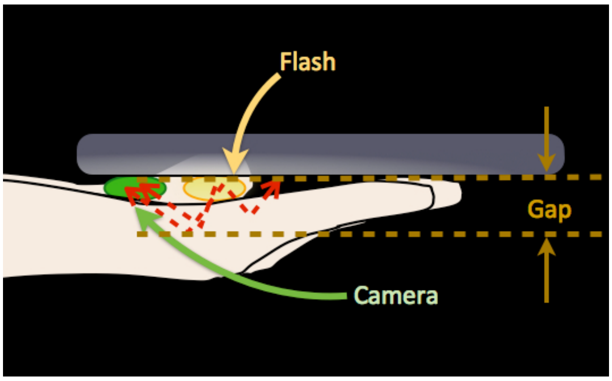


Figure 8.1: When no pressure is applied, there is a gap between the palm and the camera

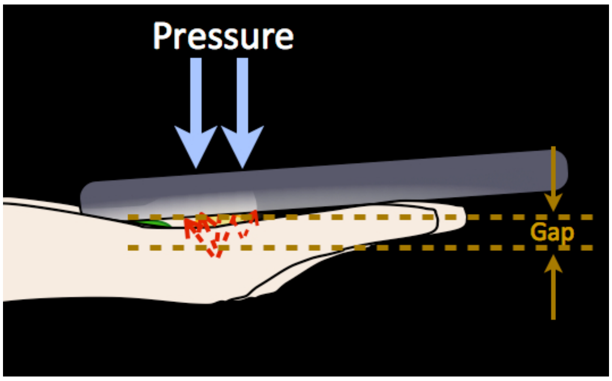


Figure 8.2: When pressure is applied, the gap will reduce causing the camera preview to be dark

A.2 Experiment

An experiment was conducted to illustrate the brightness change when force is applied on the surface of the phone. The phone was placed on the palm in two directions: (a) parallel to the palm and (b) perpendicular to the palm (Figure 8.4). This two placing are used to imitate the two gestures: (a) for when pressure is applied on screen and (b) for when pressure is applied by squeezing. The camera was positioned on the center of the palm. We used a force gauge (AD-4932A-50N by AD) to detect the force asserted on the screen, and checked the brightness level at regular force intervals. Each reading was taken at an average of 3 readings. In order to reduce error, the initial starting point for each reading was taken at the same value; (a) at 96 and (b) at 101.

Figure 8.3: Screen illustrates brightness (left: not pressed, right: pressed)

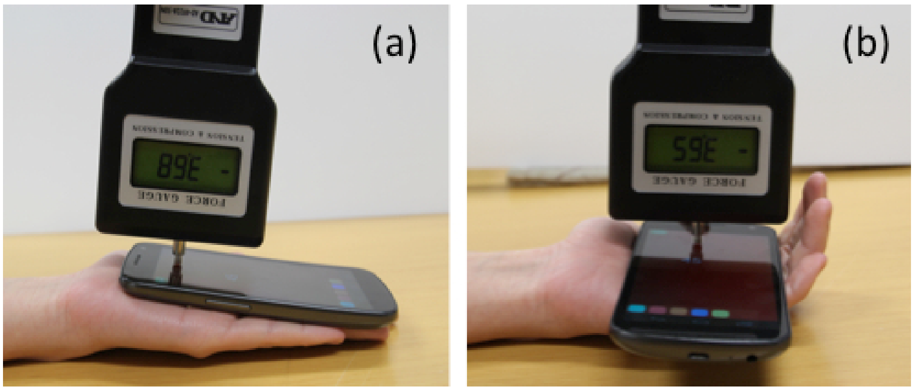
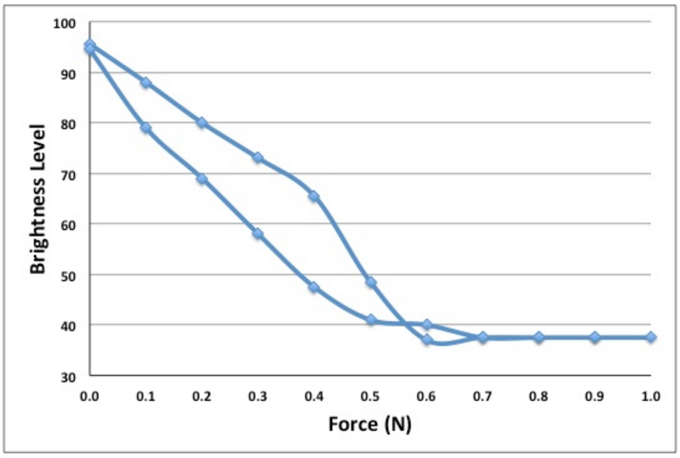


Figure 8.4: Experiment taken when phone is placed (a) parallel and (b) perpendicular to palm

Figure 8.5 illustrates the results of the experimentation. From the results, we can observe that the brightness level reduces as the force applied on the screen increases when the phone was placed at both positions. Both graphs show a drop in brightness values of approximately 60. When the phone was placed (a) parallel to the palm, the minimum force to apply on the screen before it reached the minimum brightness value was 0.7N, while when the phone was placed (b) perpendicular to the palm, the minimum force was 3N. The forces values above these values did not show any changes to the brightness values. The reduction in brightness illustrated in both graphs shows that our method is capable of detecting the pressure asserted on the device.

Normally, when one place the phone on a hard surface, regardless of the color, the minimum brightness level will be black. However, as observed in the graphs, the minimum brightness level when placed on the palm did not surpass 30. Sim-



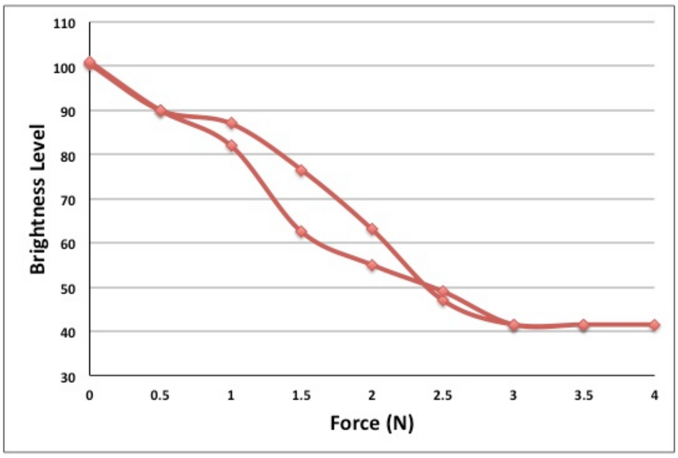


Figure 8.5: Results of Change in Brightness Level when Forces are asserted when the phone is placed (a) parallel and (b) perpendicular to the palm

ilarly, when we observed the screen color at minimum brightness level, which is illustrated in Figure 8.3 (right), we can observe that it is red in color. The reason for this is because red light can penetrate through our hands [14].

A.3 Application

This section will introduce few proposed applications, which can utilize this pressure sensing function. Figure 8.6 shows a painting application where the thickness of the line changes according to the pressure asserted. The brightness change is more obvious on the left side where the camera is placed. Using this function, we can create applications where user can take a picture and decorate the picture with lines or decoration that changes thickness according to pressure.

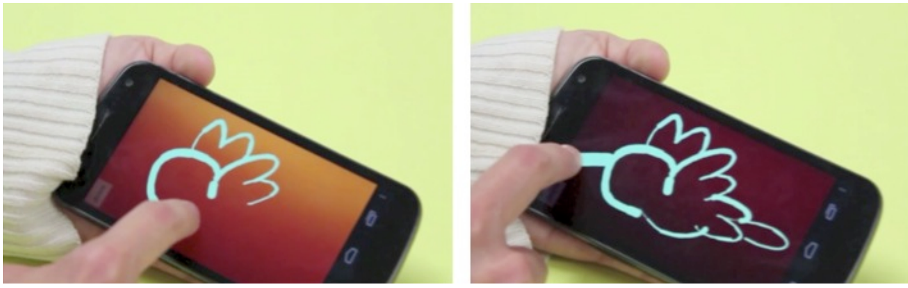


Figure 8.6: Painting

Besides that, font size is a good way to convey emotions. We propose an emotional text application by squeezing the phone to change the size of the font and send it to other users (Figure 8.7). Figure 8.8 shows a gaming application that also utilizes the squeezing detection. The game is to catch the falling character. When user squeezes the phone, the hands in the screen will move in to capture the character. Lastly, Figure 8.9 shows an application where user can choose a musical instrument and squeeze the phone to change the pitch of the sound.

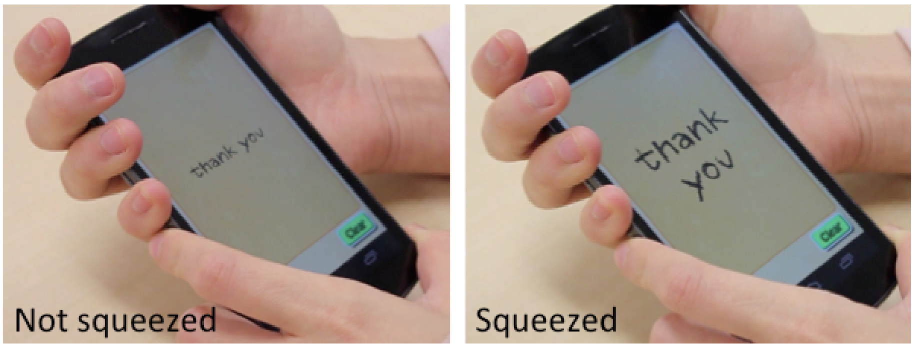


Figure 8.7: Sending different text sizes

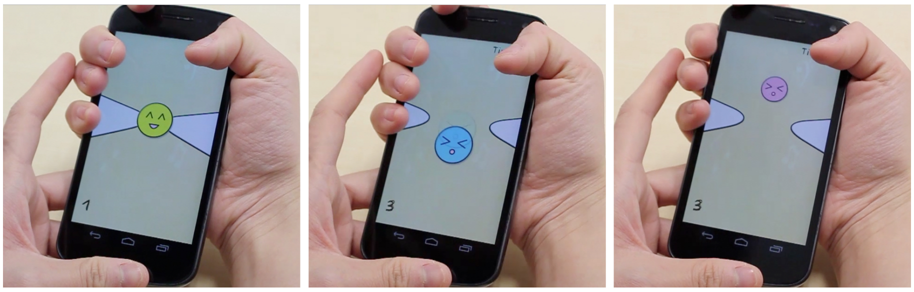


Figure 8.8: Game to catch falling character

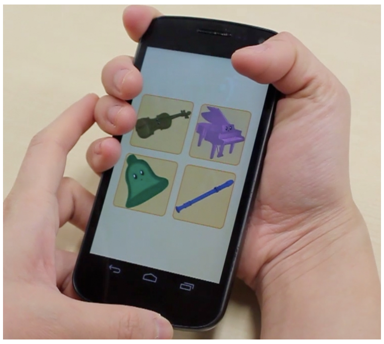


Figure 8.9: Sound by changing pitches

A.4 Conclusion

This is a proposed method to detect two types of pressure interactions on a mobile phone by utilizing the camera and flashlight of the phone. In other words, the concept of using camera and flashlight to detect the brightness change is not just limited to soft objects but can also be widely use for other applications as well.