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Master's Thesis

Academic Year 2012

PINOKY

A Device to Animate Your Plush Toys

Graduate School of Media Design,
Keio University

Lee Xuanyun Calista

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

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Abstract of Master's Thesis of Academic Year 2012

PINOKY: A Device to Animate Your Plush Toys

Summary

PINOKY is a wireless ring-like device that can be externally attached to any plush toy as an accessory that animates the toy, such as by moving its limbs. A user is thus able to instantly convert any plush toy into an interactive toy. It is hoped that allowing the user to animate their personal plush toys will create a new, surprising, and more personal play experience.

In this paper, the design goals of the PINOKY are discussed, with an overview on the technological implementation, followed by the detailing of the two user studies carried out to evaluate the device. The first user study validates the usability of the PINOKY, while the second user study explores how the device is can enhance the play experience with plush toys in a meaningful way.

Keywords:

Interactive Plush Toy, Tangible User Interface, Robots, Play Experience.

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1. Introduction

1.1. Background

Play is an important part of our lives. For children, play is an essential component of their daily activities [1]. Via play, children explore the world around them and learn more about it. In fact, play has been deemed the right of every child by the United Nations High Commission of Human Rights in order for optimal child development [2]. In general, play is also used to aid and enhance education [3]. For example, instead of simply learning the theory behind mathematical operations from the teacher's explanations, there have been many computer software and websites developed that allow the student to play various mini-games that weave mathematical problem solving into the process (one such website being Math Playground [4]). One teacher has even created an environment named ClassRealm, a classroom system which turned the learning experience into something similar to what can be found in Massively Multiplayer Online Role Playing (MMORPG) games, to stunning results [5]. In a broader perspective, the trend of "gamification" has appeared in the recent years, in a bid to better engage users with otherwise dry content by introducing video game elements to non-video game content in order to improve the user experience [6]. Not only can play be used to enhance otherwise mundane processes, play can also be used, and is important in enhancing human relationships, especially between a parent and child [7].

With the large amount of emphasis being placed on the idea of play and its importance, there have been many research and commercial products with the goal of enhancing the play experience. This research paper hopes to contribute to such a goal.

1.2. Objective

Plush toys have stood out to be one of the most popular [8] and longest-lasting [9] toys in the toy market. In a list compiled by Forbes and the Toy Industry Association of the most popular toys within the last 100 years, plush toys have constantly been featured as notable toys within each decade [10]. Plush toys are also important for young children, as they are soft and do not cause injuries, and provide a sense of security. Although traditional, immobile plush toys have always, and are still popular, there have been many robotic plush toys released which have been extremely commercially successful. Some examples of these toys are the Tickle Me Elmo, the Furby, and Zhu Zhu Pets.

While it is enjoyable to watch a store-bought robotic plush toy responding to the user's interactions, people often have personal memories attached to the plush toys that they have owned for many years. This research aims to come up with a device which allows users to animate their personal plush toys, with the hopes of creating a new, surprising, and more personal play experience.

2. Related Works

In this chapter, I will introduce the various research that are related to my research topic. The first subsection will talk about the importance of plush toys, and the second subsection will discuss the idea of the element of surprise, and its addition to traditional play. The third subsection will introduce research done on robotic plush toys, and give examples of some commercially available animated plush toys. Finally, the fourth subsection will discuss the various techniques that allow for the animation of previously immobile objects.

2.1. Importance of Plush Toys

As mentioned in Chapter 1.2, plush toys are very popular toys. However, besides simply being popular and in existence for an extremely long period of time, plush toys also have many concrete and important uses.

One example of an important usage of plush toys is in the area of education. Plush toys play a vital role during the formative years of young children, by acting as companions and enhancing children's' fantasy play and storytelling sessions [11]. Via them, children also explore various social interactions, one classic example being the act of comforting a "crying" doll [12].

Plush toys have also been found to help smoothen the transition periods in one's life. For example, being attached to a plush toy is been one of the behaviours observed during the transition periods between infancy to childhood, and then again from childhood to adolescence [13]. Thus, we can see that plush toys are important in playing the role of companions who can be around the owner whenever they are required, and provide him or her with mental and emotional support.

2.2. Addition of the Element of Surprise to Traditional Play

Expectation is a vital part of everyday life. It is a product of human adaptation and evolution, wherein the human brain unconsciously attempts to predict the future in a bid to be prepared for it, and thus be able to react to situations more quickly [14]. For example, when a tiger bares its teeth and growls menacingly, we expect to be attacked any moment, and thus mentally make preparations for flight in order to survive. Even in an everyday scenario, when we see the counter at a traffic light junction count down to zero, we know that the colour of the traffic light is about to change, and this will in turn affect our decision as to whether we should cross the road or not.

The feeling of "surprise" occurs when something happens out of the ordinary, when things deviate from what we expect them to be [14]. If the traffic light counter reaches zero, but nothing happens, the pedestrian would be surprised by the unexpected occurrence and confused as to what he should do next. Not all surprises are unpleasant – surprise birthday parties are an example of a happy surprise, as is receiving a result that is better than what has been previously expected.

In the bid to maintain an edge over their competitors, many commercial toy companies have been looking to create products which can pleasantly surprise their owners and make the play experience fresh. One example is Silly Bandz (Figure 1), which is a simple rubber bracelet, but when not stretched, takes the shape of an object.

Figure 1: A child displays her collection of Silly Bandz [40]

This research aims to come up with a means to inject the element of surprise into traditional play with plush toys, in order to create a new play experience.

2.3. Robotic Plush Toys

From Chapter 2.1, we can see that the existence of plush toys is vital. Because of this, there has been increasing research and commercial products made which aim to improve the user experience when interacting with plush toys.

In the area of research, the ActiMates Barney Doll (Figure 2) created by Microsoft is a Barney plush doll embedded with motors for actuation of simple arm and head movements, a loudspeaker for audio feedback, various sensors to detect interaction, microcontrollers and transmitters [15]. The doll is designed to act as a playmate and coach to the child, responding to the child in an appropriate manner.

Figure 2: ActiMates Barney Doll [41]

Another field in which the usage of robotic plush toys is being researched on is in the area of rehabilitation and therapy. When the March 11 disaster happened in Japan in 2011, the robotic seal called Paro (Figure 3) was introduced to the affected community in a bid to help fight off depression and give the survivors mental support [16]. Paro has also been used for various other purposes, such as therapy in hospitals and has been found to aid in relieving stress from both patients and caregivers [17, 18, 19]. The Huggable (Figure 3) is a robotic companion in the form of a plush toy teddy bear [20]. While animal assisted therapy has been proven to be beneficial for therapy purposes, it is difficult to conduct them due to various health and safety reasons. Thus, the Huggable was created to act as a pet surrogate for patients in hospitals and nursing homes.

Figure 3: From left to right: Paro [42], the Huggable [20]

Commercially, while immobile plush toys have been a mainstay in the collection of children's playthings, and even in the lives of many adults, there have been many robotic plush toys which have made an impact in the toy industry.

Perhaps the most internationally-recognised animated plush toy phenomenon is the Furby (Figure 4) [21]. Launched in America during the holiday season in 1998, it was the first commercially successful robot created for domestic purposes. It has shipped millions of units since then, and many new iterations have been developed, such as the emoto-tronic Furbies. Most recently, its makers Tiger Electronics have released an image of a next-generation Furby called Taboo [22]. The main draw of the Furbies was their supposed intelligence and ability to learn, something which no other plush toy could do at the time.

Besides the Furby, there have been many other similar commercially-successful plush toy robot products. Some of the notable ones (Figure 4) are the Tickle Me Elmo (an Elmo plush doll which laughed when squeezed, created by Tyco) [23], ZhuZhu Pets (a set of robotic plush toy hamsters which make noises and scurry around, created by Cepia) [24], and Biscuit (a plush toy dog which behaves and responds like a real dog, created by Hasbro) [25].

Figure 4: Clockwise, from top left: Furby by Tiger Electronics [43], Tickle Me Elmo by Tyco [44], Biscuit by Hasbro [45], ZhuZhu Pets by Cepia [46]

A majority of people would have definitely received or bought plush toys at some point in their life (as can be seen in the survey results detailed in Chapter 5.2), and therefore have certain memories and special feelings attached to them. From the success of the robotic plush toys mentioned above, we can see that there exists a strong demand for interactive play with plush toys. However, the current technology only allows for this interactivity to be extended to a small minority of pre-determined plush toys. It is thus with this in mind that this research attempts to extend this interactivity to the users' personal plush toys as well by animating them, in order to create more meaningful, and new and surprising play experiences.

2.4. Animating Previously Inanimate Objects

There has been much research done in the area of making previously non-interactive objects interactive. This section introduces some of the previous research done with regards to this, and is further subdivided into the different general methods (external and internal sensing and actuation), and a more specific look into the current available products which make plush toys interactive.

2.4.1. External Sensing and Actuation Methods

An exoskeleton is an artificial external structure used to support objects [26]. Exoskeleton suits are wearable external suits which are used to aid or enhance human motion [27, 28, 29, 30, 31].

The theme of exoskeletons is very prevalent in the robotics field of research today, with much emphasis placed by researchers on the development of exoskeleton suits. The Berkeley Robotics and Human Engineering Laboratory headed by Dr. H. Kazerooni has developed several exoskeleton suits to support human lower extremity movement [29]. "Austin" (Figure 5), named after its pilot tester, enabled a paraplegic student to walk again after being instantly and completely paralysed from the waist down in a car accident [30]. The Berkeley Lower Extremity Exoskeleton (BLEEX) (Figure 5) allows regular humans to carry heavy objects over long distances without feeling the strain [31]. Similarly, Robot Suit HAL (Hybrid Assistive Limb) (Figure 5) is an exoskeleton suit developed to aid its users in areas such as rehabilitation, search and rescue, in the workplace, and even in the area of entertainment [32].

Figure 5: Clockwise, from top left: Austin [47], BLEEX [48], Robot Suit HAL [49]

These technologies allow the motions of the limbs to be to be supported and manipulated by a set of motors, with the user giving input on the desired motions indirectly, via the usage of sensors. These sensors sense the user's "intentions" in the form of extremely weak biosignals on the human skin that is sent by the user's brain whenever it needs to control a muscle, and activate the motors in a corresponding manner [32].

Animated Paper [33] (Figure 6) and POPAPY [34] look at ways by which regular paper can be made to move of its own accord. Animated Paper requires the attachment of Bio-Metal (a fibre-type shape memory alloy) to the area which the user wants to make animated. Bio-metal contracts when heat is applied to it. By shooting a laser beam at the Bio-Metal, this causes it to heat up quickly and contract, hence moving the paper that it is attached to (Figure 6). POPAPY utilises a similar concept, except that a piece of heat-shrink tube is used to move the paper. The heat-shrink tube is attached to the area which is to be bent, and when heated (a microwave oven was used for the purposes of the research, although regular heating methods would suffice), the heat-shrink tube curls up, hence pulling the paper that it is attached to, thus causing it to move of its own accord.

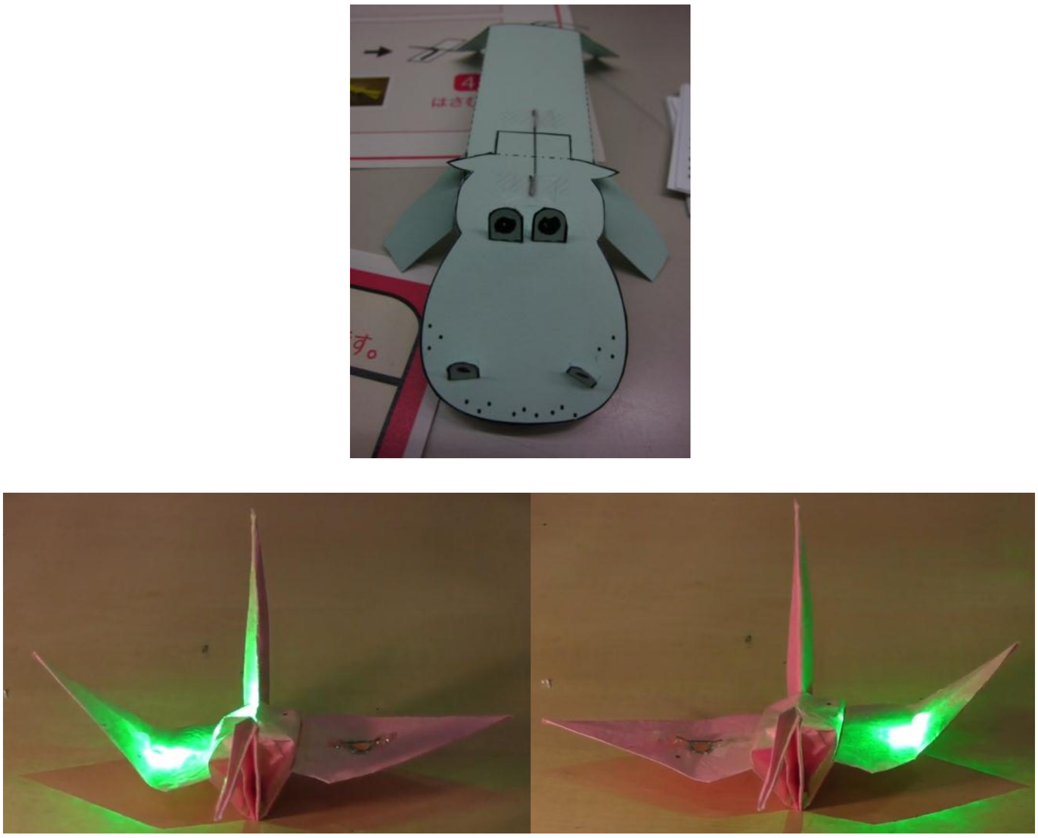

Figure 6: From top to bottom: Movable hippopotamus made using Animated Paper, animating a paper crane using a laser beam [50]

Puppets are inanimate dolls and representative objects that are tools used by puppeteers to tell a story. Some examples of puppets include hand puppets, sock puppets, rod puppets, marionettes, and shadow puppets [35]. Puppeteers manipulate the puppets directly or indirectly, thereby animating them. Rod puppets are manipulated externally using rods, and marionettes are controlled using string directly attached to the puppet (Figure 7).

Figure 7: From left to right: Rod puppets [51], marionette [52]

2.4.2. Internal Sensing and Actuation Methods

All the commercial robotic plush toys mentioned in Chapter 2.3 have their sensors and actuators embedded within the toy to maintain a natural-looking exterior.

Microsoft's ActiMates Barney has motors embedded within it to allow for simple head and arm movements [15]. There are five sensors (four touch sensors and one light sensor) which sense interactions with the user, and there is also a ROM chip and internal radio transceiver to determine the ActiMates Barney's behaviour, and to communicate with other objects in the environment respectively.

The Paro has a total of eight actuators embedded in various parts of its body (neck, front and rear fins, upper and lower eyelids, and eyes) [18]. It also has a variety of sensors to detect user interaction: two microphones for sound detection, ten tactile sensors to sense touch, two light sensors, and a posture sensor. The Paro's behaviour is controlled by a 32-bit PISC processor. All the sensors, actuators and processor are concealed within the body of the Paro, making the Paro look like a regular plush toy seal externally.

Yonezawa et al. created a sensor-doll to be used as a sympathetic communication device [36]. While not being able to move independently, the plush toy receives input from the user and reacts accordingly using musical expressions. There are sixteen sensors of various types (touch-sensitive, infrared proximity, and bend sensors, a microphone, a camera, and an accelerometer), an A/D signal converter, and various other controllers embedded within the body of the plush toy (Figure 8).

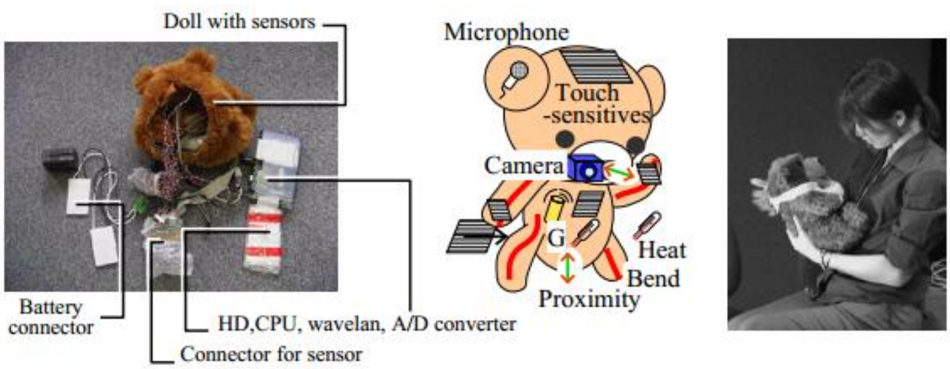

Figure 8: Sensor make-up of the sensor-doll [53]

Instead of using motors like most devices, the Huggable utilises silent back-drivable voice coil actuators because they are able to create smooth motion without backlash, and are thus able to provide a more life-like motion [20]. It consists of a large number of somatic sensors (force, electric field, and temperature sensors) covering the entirety of the area under the plush toy's surface covering (Figure 9). It is estimated that the entire Huggable consists of approximately 1000 Quantum Tunnelling Composite sensors, 400 temperature, and 45 electric field sensing electrodes. There is an embedded PC for wireless communication, and the robotic plush toy is also capable of tasks such as data collection and patient monitoring.

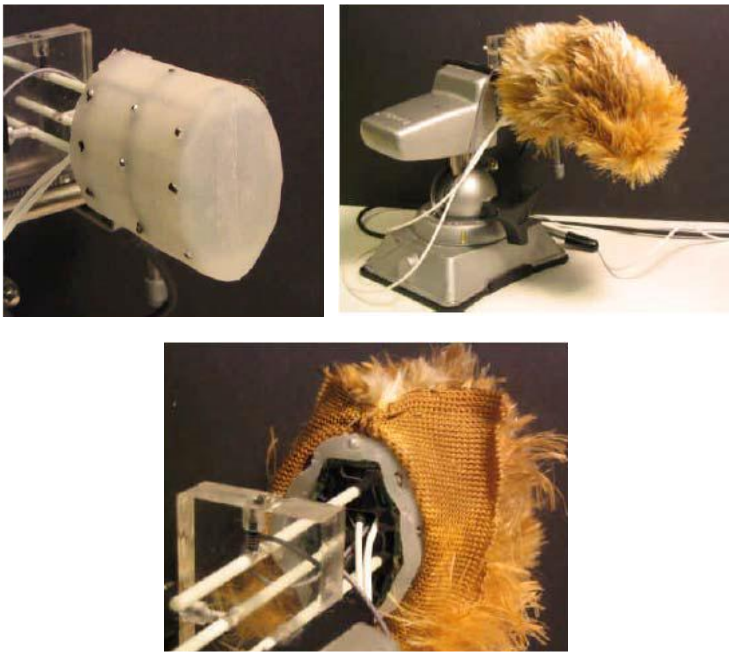

Figure 9: Somatic sensors under the Huggable's fur covering [20]

Although the interface created as part of the Tangible User Interfaces for Real-Time 3D research project is externally actuated manually by the user by pulling on the strings like a puppet in order to control an on-screen character, sensing is done internally [37]. The body of the object is shaped like a cactus, and this interface has 3 2-axis accelerometers and a joystick embedded within the plush toy (Figure 10).

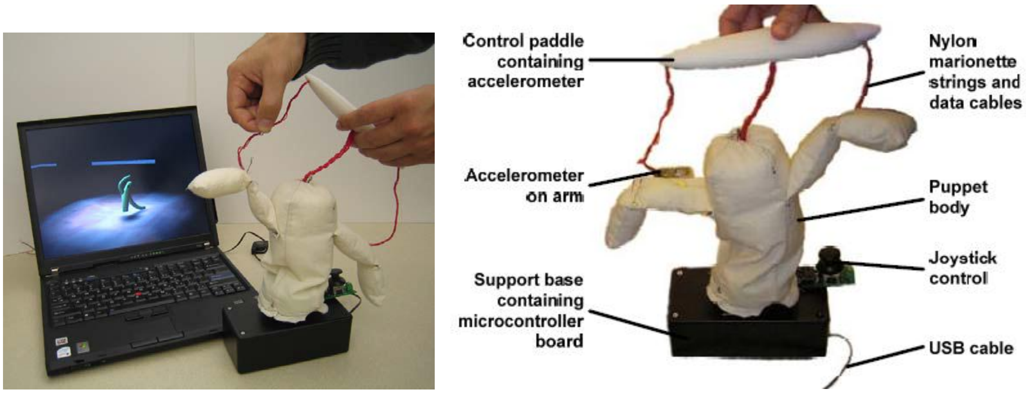

Figure 10: From left to right: Using the puppet input device to control the virtual character, the sensor make-up for the puppet input device [54]

The SenToy is a toy that is meant to be used as a controller to manipulate characters in games, hence only consisting of sensors and no actuators [38]. The sensors are embedded within the toy, and are a combination of two magnetic switches, piezoelectric force sensing resistors mounted on plastic structures, and accelerometers (Figure 11). A microcontroller (microchip 16F877) and radio communication was used to make the controller wireless.

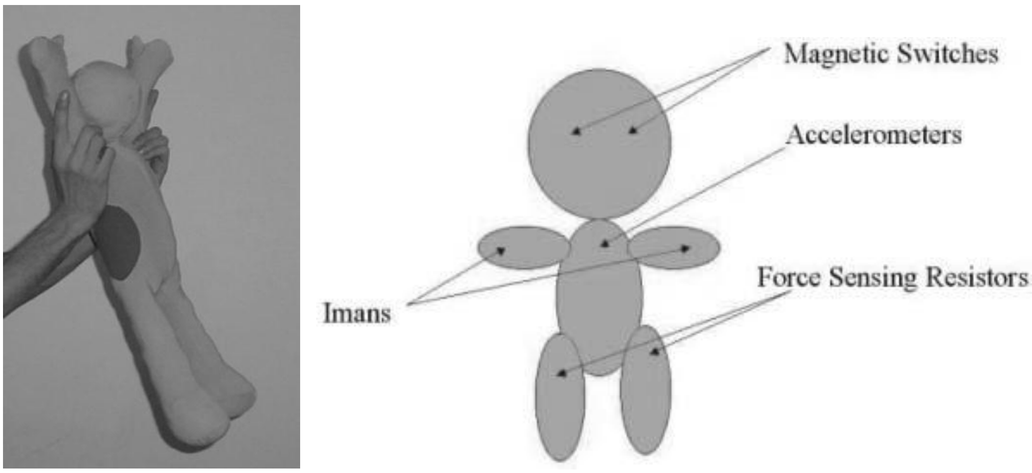

Figure 11: From left to right: SenToy, the sensor make-up for the SenToy [55, 56]

The FuwaFuwa sensor [39] is meant to be placed inside the body of any soft object (not limited to plush toys), and allows interaction with the soft object to be detected by sensing the surface deformation of the object (Figure 12). Instead of using the traditional method of using pressure sensors to detect interaction, the concept proposed uses infrared photoreflectors. By detecting the change in amount of infrared light detected by multiple photoreflectors, the sensor is able to identify the amount of force and the location of the interaction.

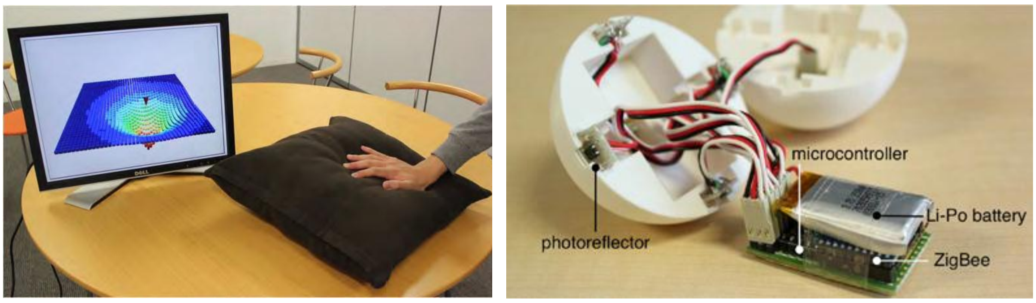

Figure 12: From left to right: Using the FuwaFuwa sensor to detect surface deformations on soft objects, the technical implementation of the FuwaFuwa sensor [57]

3. Designing the Device

In this chapter, I will describe the considerations and explain the rationale behind the design goals set for the device.

3.1. Incorporating the Element of Surprise

As mentioned in Chapter 2.2, the element of surprise occurs when one encounters something unpredictable. Plush toys are generally viewed as immobile toys by their owners, which only respond because the owners control them to act a certain way. While some owners may give their plush toys certain lifelike characteristics, such as a name, and a distinct personality and voice, many, if not all, do not actually expect their plush toys to start moving on their own. Also, as can be seen from Chapter 2.3, animated plush toys which respond to interactions from their owners are popular due to the ability to simulate two-way communication.

Thus, one effective way to incorporate the element of surprise into regular play with plush toys is to introduce a way to animate and simulate two-way communication between the owners and their personal plush toys.

3.2. How People Interact with Plush Toys

Drawing from personal experience, observations, and casual interviews, it can be seen that most people generally viewed plush toys as an embodiment of the character from which it takes its physical appearance.

A plush toy with the physical appearance of Mickey Mouse, for example, will almost always be viewed as and treated by its owner as if it really is the cartoon character itself. Although many will assign it the personality which the actual cartoon character was been given by its creators, there will also be others who use their imagination and flights of fancy to modify the default personality, creating a character which they feel that they can identify more closely with. For plush toys which do not physically resemble any known characters, their owners create unique personalities which they feel are best suited for the particular toy.

Besides giving plush toys unique personalities, there are also some who (sometimes unconsciously) use plush toys as an extension of the self. Some parents use it as a communication tool between them and their young children, as they find that the child is more receptive to what they perceive to be "friendly and helpful suggestions" from a smiling teddy bear to "eat your porridge", as compared to hearing the instructions directly from their parents.

Of course, while many people give their plush toys a sense of life, there will always be some who view plush toys as simply being an inanimate soft object.

Because many people play with plush toys while imagining that they represent a certain character, they will usually animate the toys by moving their limbs to simulate "life". From observations, it was seen that many of the animations made were by moving the plush toy's limbs in a forward and backward manner. Hence, this research strives to create a device that allows for the same kind of motion to be able to be made automatically, without needing the user to be physically in contact with the toy.

3.3. Design Goals and Discussion

While the main goal of this research is to create a device that can animate previously inanimate objects (specifically plush toys in this case), it is also hoped that this will be able to give the user a new kind of play experience. Thus, while it is of the utmost importance to design the hardware well, some thought was also put into the user experience and interaction, as well as aesthetics.

Listed below are several criteria which were important factors when coming up with the design of the device.

1) Easy to use

The usage of the device should be intuitive. This is because it is meant to be able to be used by everyone who owns a plush toy, which includes users spanning a wide age range, and from both genders.

2) No damage to the plush toy

Since the device is meant to be used on personal plush toys, it is very important for the device not to damage the plush toy that it is attached to. Also, it is best to avoid having to require the user to modify their toy in any way (for example, to cut it open in order to insert a device). This is because the toy may have some sentimental value, and users may not be very willing to damage the toy. Also, as the toy is precious to them, they might feel resistant to cutting it in fear that they will not be able to return it to the original state after making the required modifications.

3) Easily attachable and removable without requiring special tools

Even children should be able to easily attach and remove the device easily and quickly without help from the adults. Again, this is because the device is meant to be used by a wide age range of users.

4) Scalability

The device should be attachable to any plush toy on almost any location on the toy. This is because we are unable to predict the size of the plush toy beforehand. Also, it is not possible to expect the user to buy a new device every time they want to attach the device to another part of the plush toy. More than one device should be attachable and controllable, as the user may want to animate different parts of the plush toy at the same time.

5) Safe and robust

As the device is meant to be used by everyone who owns plush toys, regardless of their level of technical proficiency, it should be safe. For example, it should not cause injury to the user's fingers. Moreover, considering that the device is meant to be used during play, and also meant to be used by young children, it should not break if accidentally dropped.

6) Adequate movement actuation

The device should be able to recreate most animations that users use when playing with plush toys (in this case, a forward and backward motion).

7) Hidden technology

Traditionally, people have played with plush toys by animating the limbs of the toys with their hands. Combined with human imagination and the suspension of disbelief, the person animating the plush toy is able to make the toy seem like it has a life of its own. However, whilst human imagination is able to make it feel like the plush toy has "come to life", both the person animating the plush toy and the observer (in the case that they are not playing alone) are able to clearly see how and why the plush toy is moving, and who is the one controlling it. This, unfortunately, does not fully allow the participants in the play session to fully immerse themselves in the experience. Therefore, it is important to have a way to be able to make the standalone plush toy move, without seeming to be controlled externally.

8) Aesthetically pleasing

Aesthetics is an extremely essential aspect of plush toys. Besides being used as toys, many people put their plush toys on their shelves or beds as display objects after play. Therefore, it is very important that the device should look aesthetically pleasing on the toy even when not in use, should the user choose to leave the device on the plush toy after play as an accessory.

9) Allow the user to be able to interact with the plush toy in a natural way

In order to further ease the suspension of disbelief, the manner in which the user interacts with the plush toys should be as natural as possible. Many users treat their plush toys as companions. Thus, it would be good if similar types of interactions which the users already use with their plush toys could be re-created.

With the design goals mentioned above, prototypes of the device were created (the technical implementations are detailed in Chapter 4).

4. Technical Implementation

A total of 3 prototypes were created before the final prototype was decided upon. This section will detail the technical implementations of each of the 3 devices created, and finally discuss the advantages and disadvantages for each iteration of the prototype.

4.1. Prototype 1

This section details the thought process which went into the creation of the first prototype.

4.1.1. Focus

For the first prototype, the focus was placed mainly on coming up with a method to actuate the plush toy, with very little attention placed on the interaction design and user experience. Therefore, for this prototype, the main goal was to simply have the plush toy's limb be able to move in a forward and backward motion.

4.1.2. Design Discussion and Decisions

1) Internal versus External Sensing and Actuation

The first and most basic aspect of the device that had to be decided upon was whether the sensing and actuation would be done internally or externally.

Advantages of External Sensing and Actuation

As discussed in Chapter 2.4.1, external sensing and actuation methods are easy to attach and remove. This makes them both easily and instantaneously usable with any object. Having the sensing and actuation done externally is also advantageous because it allows the user to be able to instantly customise the location and type of motion they want instantly by simply changing the position of the device. In the event of device malfunction, the user is also able to easily fix the problem by either changing to a new device.

Disadvantages of External Sensing and Actuation

However, external sensors and actuators constantly remind the users of their presence, and look unnatural on the object they are attached to (Figures 5, 6, 7). Thus, while the object moves, users can see the exoskeleton moving with the object as well, and this will both take away some of the magic and the element of surprise, and make the suspension of disbelief more difficult.

Advantages of Internal Sensing and Actuation

As compared to external sensing and actuation methods, having the sensors and actuators embedded within the plush toy maintains the coherent feel of the toy, and for the most part, the softness of the toy as well. This is important, because softness is an important property of plush toys. Maintaining the suspension of disbelief and keeping the element of surprise there is much easier in this case, as the plush toy looks exactly like a regular plush toy, and the user will therefore apply the expectations they have towards regular plush toys to it as well.

Disadvantages of Internal Sensing and Actuation

However, having to put the sensors and actuators inside the plush toy requires the user to first cut and open up the plush toy (Figures 8, 9). Since the plush toys may be objects which are fragile, or objects which the users have many personal memories of, and thus cannot bear to cut or modify in any way, having the sensing and actuation done internally will be very difficult. Also, the users themselves will be the ones doing the modifications. As this device is meant to be used by a very wide range of people, this means that there will be some users who are not technically-inclined and/or not well-versed at handicraft (when cutting open and sewing up the plush toy again).enough to make the modifications on their own. Another disadvantage of having internal sensing and actuation is the fact that it takes time to make the modifications to the plush toy before it can be used for the play session. Wanting to play with a plush toy is a spontaneous action, and although once the modification is made, the plush toy can be animated immediately whenever the user desires, it is something which the user has to take into consideration for the initial play session. In the event of a device malfunction, trying to fix the problem might be difficult and inconvenient for the user, as he/she will have to cut open the plush toy again to remove the device.

Decision: External Sensing and Actuation

Ultimately, the convenience and experience of the user should be placed at the highest priority. The device is meant to be used to enhance the play experience, and if the user is put through inconveniences in order to be able to play, it will ruin the play experience rather than enhance it.

2) How the Actuation is Done

In order to decide what the best method to do actuation was, a few similar research were looked at (sensing capability was not looked at for this prototype yet).

There are many different ways by which movement can be actuated. As seen from Chapter 2.4, immobile objects can be animated via the usage of exoskeletons, with the frame of the exoskeleton encasing the immobile object. Animation can also be done via strings pulling on the surface of the object. Bio-Metal is able to move the object that it is attached to when heated to a sufficiently high temperature, voice-coil actuators are able to provide life-like motion, and motors are also a popular choice.

Decision: Motors

Motors were chosen as the actuator because they are easily available, and are able to provide a decent amount of power for a relatively low cost.

3) Body of the Device

Considering safety factors, rounded objects are preferred over objects with straight edges. This is because objects with straight edges have corners, and these corners may be sharp. Since the device is meant to cater to a wide age range of users, safety is of the utmost importance as some users (especially young children) may be careless and injure themselves on the sharp edges during the play sessions. Thus, it was decided that the device would be circular-shaped.

The idea that to animate a certain part of the plush toy, the user would have to place the device at the desired area seems to be an intuitive one. This is similar to how many users currently animate plush toys: if they want the arm of the plush toy to bend, they would place their fingers on where they want the joint to be located, and bend it. Moreover, locating the motors outside of the body of the device makes it more prone to technical problems, as it cannot be protected within the device casing. Thus, locating the motors within the body of the device itself is both technically sound and user-friendly. Similarly, for the sensors, locating the sensor components within the body of the device makes them less susceptible to damage, and it is also more intuitive to have the user input the motion of the limb at the location where the motion is desired.

4.1.3. Construction of the Prototype

Components used:
1 x Microcontroller (Arduino Pro Mini)
2 x DC servo motors (CORONA CS-929MG)

Material used for the body:
Clear acrylic (3mm)

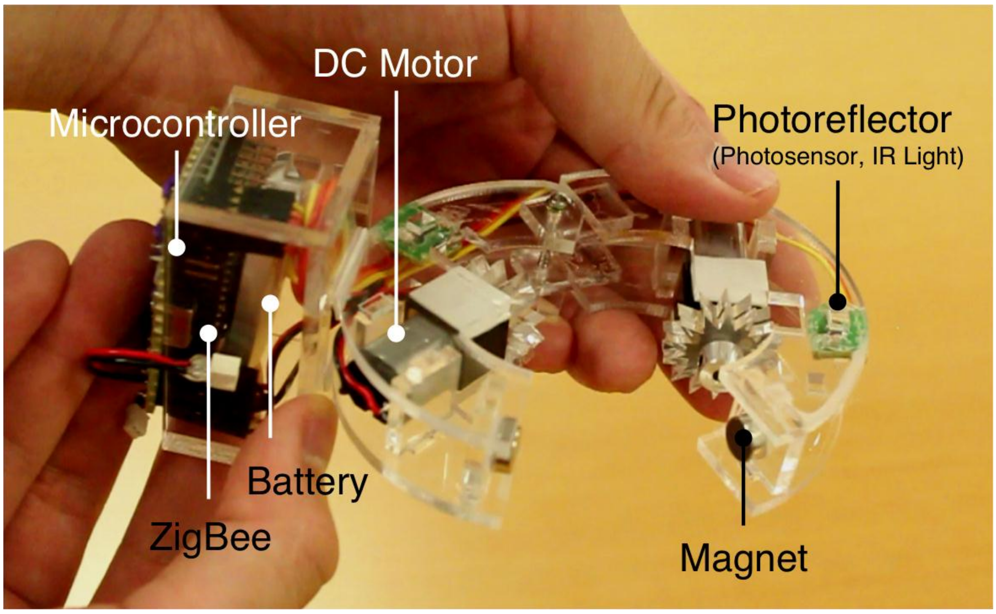

Figure 13: Labelled diagram of the components used in Prototype 1

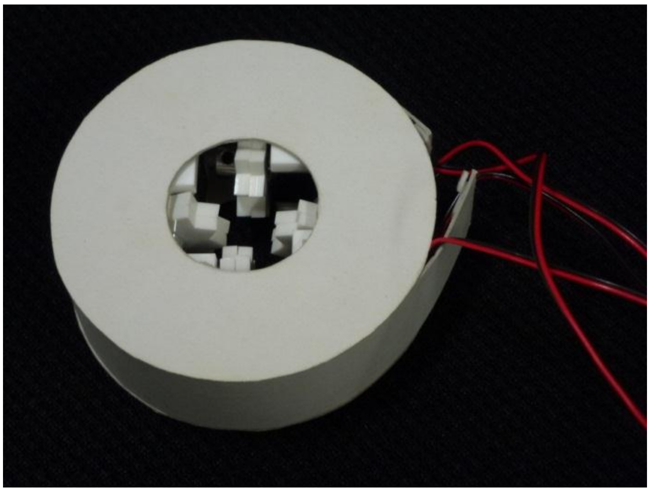

Figure 14: From left to right: Prototype 1 after assembly, the general aesthetics when Prototype 1 is worn on plush toys

Figure 14 shows the finished device. The blueprint of the body was constructed in CorelDraw (refer to Appendix A for the blueprint) and the clear acrylic was cut using a laser cutter to ensure precision, and joined using acrylic glue.

The device was wired and connected to a laptop. A simple set of code was written in Arduino where the limb of the plush toy would move in different directions, depending on what keys of the keyboard were pressed.

4.1.4. Evaluation of the Prototype

Advantages

The device was able to sufficiently actuate movement. How firmly the device was able to grip onto the surface of the plush toy's limb determined how much the limb moved. This means that the larger the cross-sectional diameter of the limb, the better the movement which could be actuated. While this makes the quality of movement actuation dependent on the size of the plush toy's limb, it was noted that on the whole, movement was able to be actuated quite well.

Additionally, it was also observed that the concept of attaching the device to the part which was to be animated was indeed intuitive.

Disadvantages

There were several glaring parts where the device needed to be improved upon.

Firstly, the device was difficult to put on. Due to the fact that it was required that the limb of the plush toy be tightly compressed between the gears in order to create sufficient friction, thus allowing the movement to be properly actuated, the amount of space that the plush toy's limb was to be inserted into because very small. Also, the gears provided a lot of resistance and did not allow the limb to slip through easily. Therefore, it became very difficult to pull the plush toy's limb through the hole, with the amount of difficulty increasing with the size of the limb.

Secondly, with the sharp edges of the gears meant to catch onto the surface of the plush toy to pull and push it in order to create movement, this resulted in some damage being done to the surface of the plush toy, such as pieces of fluff being scratched off the surface. This is an extremely undesirable result, and must be rectified.

Thirdly, the device, although safe because of the circular shape, was dangerous because the gears that caused the plush toy's limb to move had very sharp edges. However, making the edges of the gear rounded will cause a loss in friction, and thus decrease the ability for it to catch onto the surface of the plush toy to properly actuate movement. Also, even though the edges of the gears can be made rounded, it still does not change the fact that they are spikey and can potentially cause injury. Thus, although the usage of gears allows for good movement actuation, a safer method must be found.

Lastly, although it was mentioned in the focus (written in Chapter 4.1.1) that this prototype was focussed mainly on the technical aspect of actuating the plush toy's movement, and not so much on the user experience, the device did look glaringly out of place on the plush toy as a foreign object. This was made even more obvious by the fact that the device was rather large, especially when it was attached to small limbs. Also, because the wires were visible, it further reinforced the fact that the plush toy was not moving of its own accord, as if it was "alive", but rather because the device attached to it was causing it to move. This result further highlighted the need to make the device blend in and appear as natural as possible when attached to the plush toy.

4.2. Prototype 2

Prototype 1 successfully allowed the plush toy to be animated to an acceptable degree. However, as discussed in the evaluation of the device in Chapter 4.1.4, there still remains much to be improved upon. With this in mind, Prototype 2 was developed.

4.2.1. Focus

The focus of this prototype was to try to rectify the pertinent issues brought up in Prototype 1, and create a device which was both aesthetically pleasing and looked natural on the plush toy.

4.2.2. Design Discussion and Decisions

For the second prototype, it was back to the drawing board to see if a new approach could be found for animating the plush toy. The main problems from the first prototype were namely:

1) The device was difficult to put on.
2) The device damaged the plush toy.
3) The device was dangerous.
4) The device was aesthetically unpleasing, and looked glaringly out of place on the plush toy.

In order to try to solve problem 4, items which looked natural on plush toys were noted. These included, but were not exclusive to, items such as accessories (for example, bracelets, and earrings), clothes (for example, shirts, jackets, and pants), and small objects (for example, a pirate plush toy may be holding a cutlass or have a small parrot perched on its shoulder). While having the device embedded in context-specific objects (like the pirate plush doll mentioned earlier) would be nice, this makes it difficult to make the object transferrable between plush toys due to the difference in context (it would be awkward to have a doctor plush doll hold a pirate's cutlass). Clothing are larger, and tend to cover a wider amount of surface area as compared to small accessories. This makes it easier to hide the sensors and actuators within the plush toy's clothing. Also, as many people are already used to the act of putting on clothes for their plush toys, having the device embedded in a familiar wearable will decrease the learning curve of learning how to properly attach the device to the plush toy, hence solving problem 1. Thus this prototype attempts to create a way to animate plush toys by simply wearing a regular piece of clothing that has actuators embedded in it.

In order to try to solve problems 2 and 3, a new method of actuation was considered. Out of all the other methods of actuation, it was decided to try to use Bio-Metal to do the actuation. This is because while Bio-Metal is not as strong as using motors, it might be possible to combine several pieces of Bio-Metal together in order to create the required force. Also, Bio-Metal can be made to contract using the heat generated when electricity is run through it. Therefore, it is possible to insulate the pieces of Bio-Metal between pieces of material. From the discussion in the paragraph above, the device is to be embedded within the plush toy's clothing, and cloth is a plausible material to be used as insulation for the Bio-Metal.

4.2.3. Construction of the Prototype

Components used:
1 x Microcontroller (Arduino Pro Mini)
6 x Pieces of Bio-Metal (3 for each arm)

Material used for the body:
Felt
Velcro

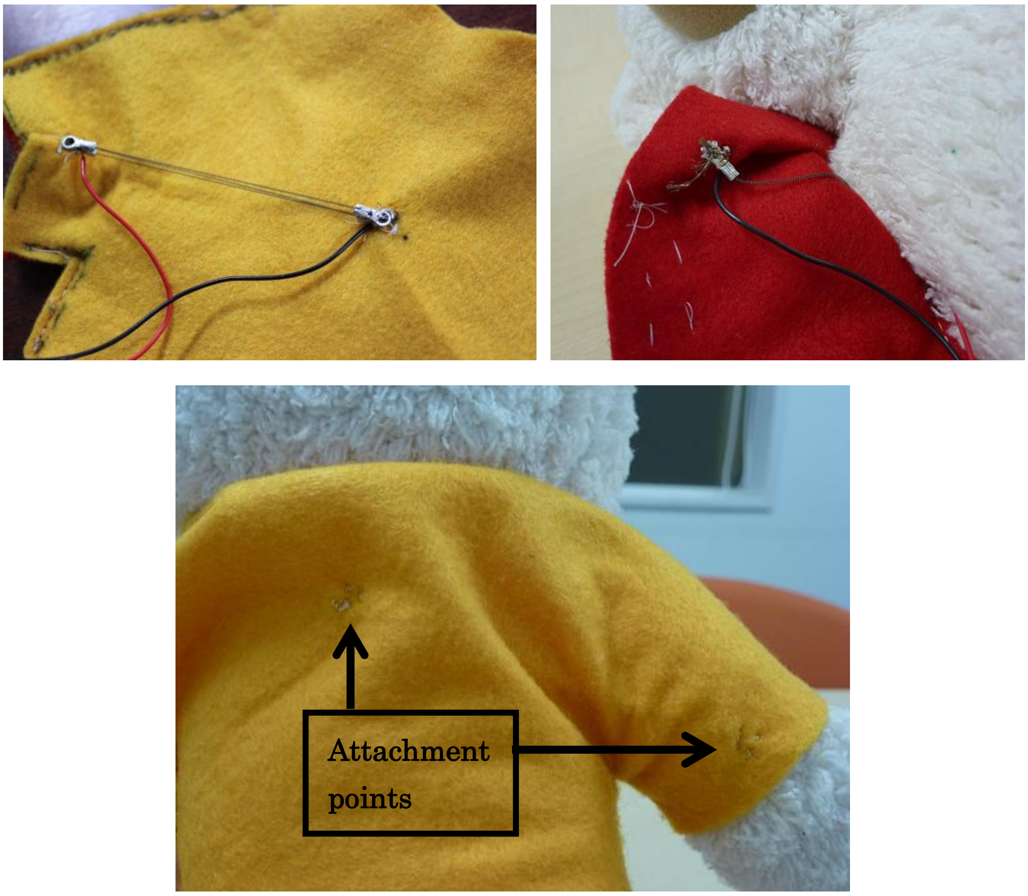

Figure 15: How the Bio-Metal is attached to a regular piece of plush toy clothing

Figure 16: Clockwise, from top left: How the prototype is wired (front view), how the prototype is wired (side view), the general aesthetics when Prototype 2 is worn on plush toys

Figure 15 shows how the Bio-Metal is attached to a regular piece of clothing in order to actuate movement, while Figure 16 shows how the prototype looks like on plush toys.

The device was wired and connected to a laptop. A simple set of code was written in Arduino where the limb of the plush toy would move in different directions, depending on what keys of the keyboard were pressed.

4.2.4. Evaluation of the Prototype

Advantages

As compared to the first prototype, the second prototype was much lighter in comparison, and did not cause the plush toy to become unbalanced and tip over. It was also smaller, and because the actuators were much smaller and able to be embedded within the clothing itself, it blended into the look of the plush toy easily, and maintained the general aesthetic of the plush toy. In fact, since the clothing that the Bio-Metal is attached to is just regular plush toy clothing, it is possible for the user to easily customise the look of their personal devices simply by attaching strips of Bio-Metal to any piece of clothing that they desire. This gives the users the freedom to express themselves creatively, something that was unachievable using the first prototype (since there needed to be a fixed structure to the device).

The second prototype did away with the loud noises made by the motors, which would inevitably remind the user that an external device was causing the plush toy to become animated. Using Bio-Metal as the actuator instead of motors also solved the problem of damage done by the prototype to the surface of the plush toy. This is because the actuator is now pulling on the surface of the clothing that it is attached to, instead of gripping directly onto the surface of the plush toy (as was the case for the first prototype). The movement of the piece of clothing would, in turn, push on the limb of the plush toy and cause it to be moved as well.

Disadvantages

Unfortunately, although the second prototype did solve all the problems that the first prototype had, it had its fair share of problems as well.

While the prototype did manage to move the teddy bear and snake plush toys that it was tested on (Figure 16), the actuation was undeniably much weaker as compared to using motors, and was considerably slower than the first prototype. In fact, the resulting animation was slow enough to be taken as ambient movement. While this may have been desirable for certain purposes, such as having the plush toy move in a continuous ambient manner when placed on a shelf for display purposes, it would most probably be very undesirable for regular play sessions.

The effect of hysteresis was observed in this prototype. This arose because the Bio-Metal, though very quick to shrink when heated up, required time to cool down and return to its original, stretched-out length. Hence, the amount of each movement became smaller and smaller as compared to the previous motion, if heated and cooled in quick succession. As compared to using motors, the amount at which the limb of the plush toy is able to be bent at is also less, and it is also more sensitive to the placement of the Bio-Metal. Also, the speed at which the Bio-Metal contracts is harder to control, which makes for less movement customisation.

Although the device itself is highly customisable, as users can simply sew the Bio-Metal pieces onto the areas where movement is desired, it is difficult to use the same piece of clothing to animate different plush toys. Even though it is possible for similar-sized humanoid plush toys to make use of the same jacket, it will also be strange if the user were to use the jacket to animate the legs of the toy.

4.3. Final Prototype

Prototype 2 solved all the problems faced by Prototype 1, but resulted in a new and different set of problems on its own. The advantages from both the first and second prototypes were taken into consideration, and incorporated into the third prototype.

4.3.1. Focus

The focus of this prototype is to create a device that is able to both actuate motion to an acceptable level, and be aesthetically pleasing when placed on the plush toy. In this prototype, some capability for human interaction is also to be included.

4.3.2. Design Decisions and Discussion

Actuation

After considering both the first and second prototypes, it was clear that motors, while with their own set of disadvantages (notably their comparatively larger size, noise and weight), were able to create better plush toy movements than those created using Bio-Metal. Since being able to animate plush toys is a core function of this research, it was decided that motors would be used, and other methods explored to try to play down the disadvantages if possible.

However, as seen from the first prototype, the usage of gears to grip onto the surface of the plush toy was something which needed changing since they caused damage to the plush toy. Thus, instead of gripping and pulling on the plush toy's limb, some sort of extension to push the limb was looked at.

Difficulty in Attaching the Device

Both the first and second prototypes required the user to pull the limb of the plush toy through the hole in the device. However, in the second prototype, the user also had the option of opening up the device, inserting the plush toy, and then closing the device over it again. This is similar to how some accessories, such as necklaces and bracelets are worn. Several methods, such as using clasps, clips, and adhesives such as Velcro were considered. In the end, it was decided that strong magnets would be used to fasten the ends of the device together. This is because it is easy to hide the magnets within the body of the device, and it is also a very simple and standard method of attaching things in daily life (hence doing away with the need to teach the user how to fasten the device).

Sensing

There are many different sensors which can be used to detect human interaction. Chapter 2.4.2 lists a collection of many different sensors, including temperature sensors, accelerometers, microphones, and so on. For the specific purpose of detecting movement of the plush toy, accelerometers seem to be a popular choice.

Decision: Infrared Photoreflectors

Some sensors like bend sensors are difficult to conceal as they are long, while others are expensive. Although the FuwaFuwa sensor is meant to be used as an internal sensing device, it is possible to use the concept of utilising photoreflectors to detect distance in order to detect interactions. Photoreflectors are also very cheap, and would thus be cost-effective.

Aesthetics

To avoid the need to have wires being visible and having to have the device always connected to a computer, the device would be made wireless by the usage of a battery and some form of wireless communicator. The ZigBee wireless module was chosen as the mode of wireless communication, because it does not require the need to be connected to a server in order for wireless capability to function, and can thus be used without the need for a computer.

Keeping technology hidden from the user is important when trying to add the element of surprise to things. This is because the user is unable to immediately logically determine how the task is done (in this case, moving the limb of the plush toy). While there was some attempt to cover up the technology in the first prototype, it was still lacking. Felt material is soft and slightly furry, and has a similar feel to some plush toys. Thus, it was selected as the material to be used to cover the device, in the attempt to better allow the large device to blend in better on the plush toy.

Interactions

Voice communication is a basic, common, and important mode of human communication. Thus, it was decided that a simple form of voice control would be implemented using a microphone, wherein the user would be able to make any noise, and see the plush toy move in response to it. A movement control was also implemented using an accelerometer, and users would shake the controller to make the plush toy move. Lastly, a basic remote control was created for users who just wanted to see the plush toy move at the press of a button.

4.3.3. Construction of the Prototype

Components used:

For the device:

1 x Microcontroller (Arduino Pro Mini)

1 x Wireless module (XBee Series 1)

1 x Li-Po battery

2 x Infrared photoreflectors (Photosensor, IR light)

2 x DC servo motors (CORONA CS-929MG)

2 x Strong magnets

For the 3 controllers (movement, sound, pushbutton control):

3 x Microcontroller (Arduino Pro Mini)

3 x Wireless module (XBee Series 1)

3 x Li-Po battery

1 x Microphone

1 x Accelerometer

Material used for the body of the device and the controllers:

Clear Acrylic (3mm)

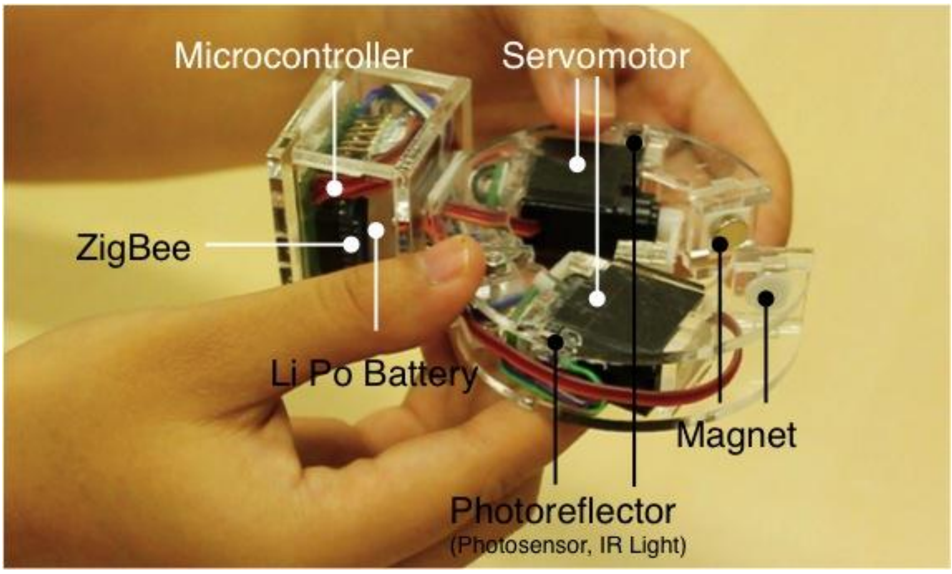

Figure 17: Labelled diagram of the components used in Prototype 3

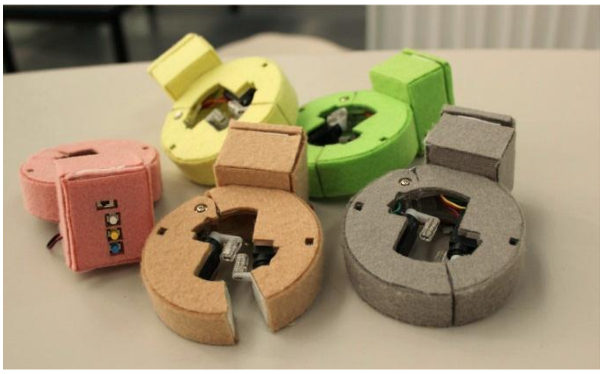

Figure 18: Final look of Prototype 3

The blueprint of the body was constructed in CorelDraw (refer to Appendix B for the blueprint) and the clear acrylic was cut using a laser cutter to ensure precision, and joined using acrylic glue.

4.3.4. System Details and Specifications

Overview

The PINOKY system is a wireless system that users can attach to the part of the plush toy they want to animate. It is designed to be used as an external attachment, crafted to look like an accessory, and is worn in a similar manner as to how one would wear a bracelet. With this device, the user is able to animate his or her plush toys without having to be physically in contact with them. The device consists of 2 servo motors, each of which is in contact with the surface of the plush toy via a plastic arm. These arms are moved by the servo motors, and cause the area in contact to bend by pushing on the covering (see Figure 20). A pair of photoreflectors is used to measure the angle at which the joint is bent. A pair of strong magnets holds PINOKY in position, enabling the user to attach and remove it without using special tools. The user is also able to synchronize the motors of multiple PINOKYs using ZigBee communication. The case is made of laser-cut acrylic and covered with felt to give it a look and feel similar to that of a plush toy (see Figure 18 and 20).

Figure 19: The general aesthetics when Prototype 3 is worn on plush toys

Actuation

While Prototype 1 utilised motors for actuation, it made use of gears to create sufficient friction in order to get a secure grip and pull on the surface of the plush toy. After some testing done using Prototype 1, it was found that the gears caused some damage to the surface of the plush toys. Thus, a different approach was tried for this iteration of the device. The actuator in this version still retains the idea of creating joint movement using two servo motors. However, instead of gears, each servo motor was now fitted with an arm that displaces the surface of the toy. In this way, the joint is bent by pushing on the cover (see Figure 20). By changing the servo motor's speed and rotation angle, it is possible to dynamically control the speed and joint angle of the plush toy. The arms are positioned such that they do not extend beyond the device. For an 8.5 cm plush toy limb, the joint angle range is $-50° < \theta < 50°$.

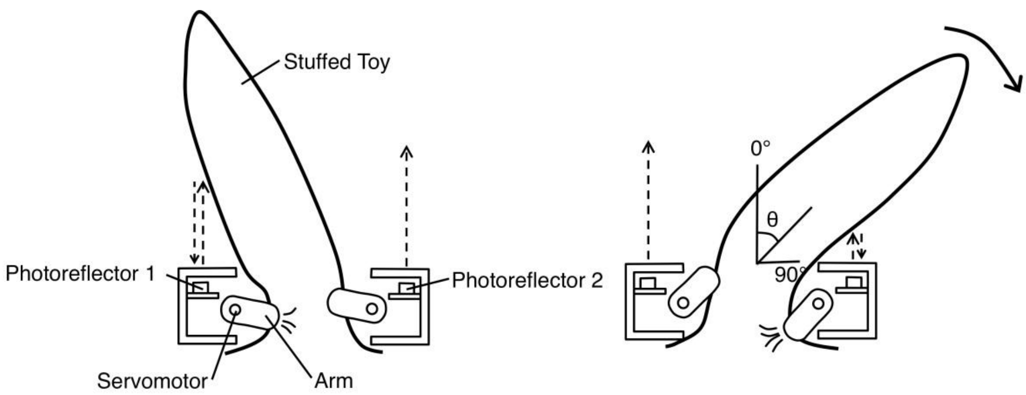

Figure 20: How the movement actuation is done. Extended arms push on the surface of the plush toy instead of pulling on it

Different types of stuffing material and surface covering material give rise to different degrees of movement. It was observed that plush toys which were more filled out with the stuffing material were able to be better actuated. Also, it was easier to actuate plush toys which had stuffing which did not shift about easily. For example, it was easier to actuate a limb filled with regular polyester cotton stuffing, as compared to one filled with beans or sand particles. This is because the polyester cotton filling is able to better retain a limb width as close as possible to the original for the area that is being clamped by the device, as compared to beans which will adjust accordingly to fit the new size. Thus, the limbs which are filled with polyester cotton stuffing will provide something for the arm to push against, thus allowing it to be better actuated.

Sensing

In order to measure the joint angle, a pair of photoreflectors (consisting of a photosensor and infra-red LED) were used. Photoreflectors were chosen as they are cost-effective, and are generally used to measure distances between objects. As can be seen from Figure 20, the photoreflectors are embedded in the device at either end of the ring structure. These photoreflectors are used to measure the distance from the point of embedding to the surface of the plush toy's limb. When the joint bends, one of the sensors becomes closer to the surface, and the photoreflectors are able to detect the change in proximity, hence also detecting how the joint is being bent.

An experiment was conducted to investigate the relationship between the change in the joint angle of the plush toy's limb and the photoreflective properties of the sensors. The length of the plush toy limb chosen was 8.5cm, and the limb was bent from −50 degrees to 50° by hand at intervals of 2°. The results are shown in Figure 21: the red line shows the photovoltaic voltage when a hand covered the sensor. As shown in the figure, the range of joint angles that the system can measure is $\theta < -31.2°$, $34.2° < \theta$.

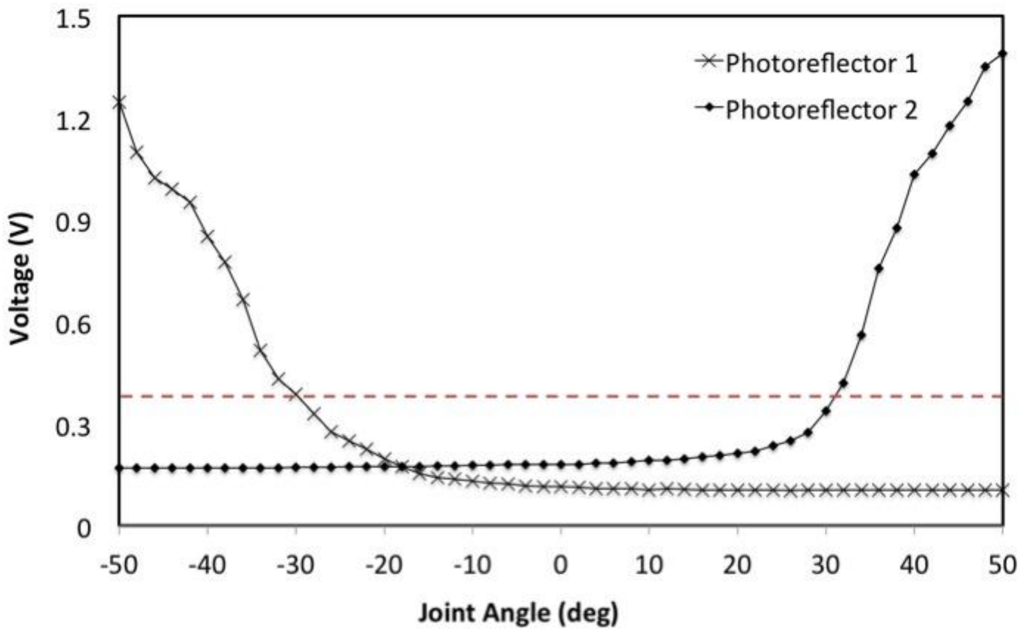

Figure 21: Graph showing the range of the measurable joint angle

Communication

A wireless communication device (ZigBee) is embedded in the PINOKY. It was chosen as it is energy efficient, and has a self-organisation network function. The ZigBee module is able to communicate not only with PCs but also with other ZigBee modules directly without using a server on a PC. For this system, it was used as a standalone module without the usage of any PC support. However, it must be noted that the device is designed to be able to support other configurations. The usage of ZigBee also enables the number of devices to be flexibly increased.

4.3.5. Modes of Operation and Control Methods

A variety of different control methods and modes of operation were prepared for the PINOKY.

Modes of Operation

There are two different modes of operation for the PINOKY. By pressing one of the three buttons (blue, yellow, and white) on the backpack of the device, the user is able to swap between the two modes.

1) Record and Playback Mode

In this mode, the user is able to input motion into the system and have the plush toy play back the desired motion on demand. The blue and yellow buttons are used for this mode. Users must first press the blue button to start recording the motion. After pressing the button, the user can immediately input the motion by moving the limb of the plush toy in the desired manner. This motion is detected by the infra-red photoreflectors on the surface of the device, and stored. Pressing the yellow button will start the playback, and the plastic arms of the device will move in accordance to replicate the recorded motion. The microcontroller memory is sufficient to record behaviour input for up to 1 minute.

2) Synchronisation Mode

In this mode the user is able to synchronise the movements of various PINOKYs. The user must first press the white button on the backpack of all the devices to be synchronised. When the user moves the limb of a plush toy with any of the synchronised devices attached to it, the infra-red photoreflectors on the surface of the device will detect the motion input, and move the plastic arms of all the synchronised devices accordingly to create the same motion in real time.

Control Methods

Three control methods were devised for this iteration of the prototype: movement, sound, and pushbutton control. While the movement and sound controllers (see Figure 22, left and middle) were designed to cause all the PINOKYs to be activated at the same time, the pushbutton remote controller (see Figure 22, right) consists of 4 different coloured square pushbuttons which can activate different sets of devices individually.

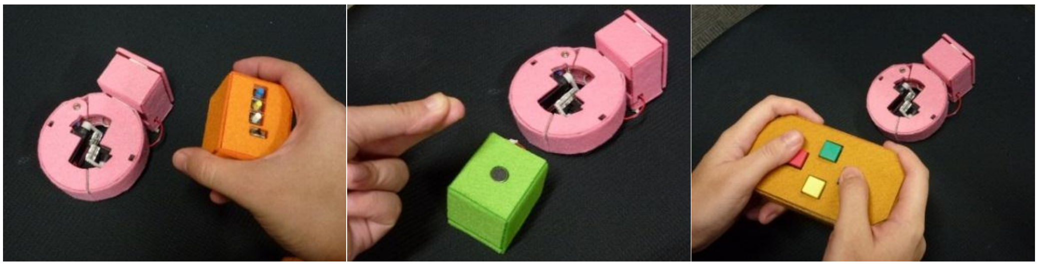

Figure 22: Three different types of control methods. From left to right: movement control, sound control, pushbutton remote control

Before the remote controllers can be used on the devices, a synchronisation of the devices and controllers must be done by pressing the white button located on the backpack of each device and controller. This is also the same button used to trigger regular synchronisation mode.

The movement controller utilises an accelerometer. When the controller is shaken, it will cause the arms of the device to move, hence animating the plush toy. In a similar manner, when the microphone sensor of the sound controller detects a noise, the plush toy will also be animated by the PINOKY. As for the pushbutton controller, the PINOKY devices constructed were split into 4 different sets and colour-coded. Each button of the remote controller is able to operate the set of devices which were of the same colour as the button. As each set of devices exists individually, the user is able to activate as many different sets as desired at the same time.

All code was written in Arduino (refer to Appendix C for the codes).

4.3.6. Evaluation of the Prototype

As this is the final prototype, a set of user tests would first be done, and the prototype would then be evaluated from there (see Chapters 5 and 6).

5. User Study 1: Validity of the Design Guidelines

A total of two user studies were carried out during the course of the research. Each test and its results and evaluation will be detailed in turn in the next two chapters. As this research involves the creation of a new device, one of the most important things to test for is the usability of the device. The user study done on usability will be detailed in this chapter.

5.1. Procedure

The user study was conducted over a span of 4 days (August 31 to September 3 2011) at Miraikan, a science museum in Japan. The booth where the user study was held at was set up at a corner of the museum, and visitors to the museum passing by the area were invited to participate in the user study (Figure 23).

Figure 23: From left to right: Area where the user study was conducted, poster informing museum-goers about the user study

Each user test session comprised of three parts:

1) Participants aged 14 years and older were first required to fill out a pre-test survey (see Appendix D). This was mainly to gain a general feel of how plush toys factor in their daily lives, see how they usually use plush toys, and if they have any particularly memorable plush toys. At this point, the device was still kept away from the participants. Occasionally, some participants (especially children) would pick up one of the plush toys and start playing with it without being instructed to do so. These actions were observed as well, to see how people naturally play with plush toys. These observations were made as discreetly as possible, so as to prevent the participant from feeling self-conscious.

2) Next, participants were given basic instructions as to how to operate the device (push-button remote control, voice control), and the different interaction modes (record and playback, synchronisation). 5 devices and 12 plush toys (6 humanoid, 3 fish, 1 teddy bear, 1 octopus, and 1 snake) were placed on the table. The participants were given about 10 minutes to play freely with them, or whenever they seemed to bore of the play session, whichever came first. The play session was observed, and participants were aware of the fact that they were video-recorded (for privacy purposes).

3) Lastly, participants aged 10 years and older were asked to fill out another survey (see Appendix E) about the experience they had with the device. A casual interview was also conducted to gain a better insight into each of the participant's play session, to see what they felt about the concept, and in the event that they felt the need to elaborate on their experiences.

5.2. Results

A total of 51 participants were involved in this user study. 30 participants filled out the pre-test survey, while 32 participants filled out the post-test survey. This discrepancy in numbers arose from the fact that some participants (especially young children) only tried the device, but did not fill in the surveys.

5.2.1. Pre-Test Survey and Observations

Plush Toy Usage in Daily Life

The 30 participants who answered the pre-test survey about the plush toys that they owned ranged in age from 14 to 70 (average: 34.7 years, standard deviation (SD): 13.7 years), 11 male and 19 female. They were encouraged to describe their plush toys: shape and size, location in the house, memories associated with them, and so on. The results showed that about 70% of the participants owned more than one plush toy. The mean number of plush toys owned was 13.6 (SD: 14.5) and was affected by the family configuration.

Participants remembered the circumstances under which they received the plush toys, and had some memory associated with about 76% of the plush toys on the list: about 58% of the plush toys were received as a gift on special occasions such as a birthday. One participant, a 46-year-old woman, said that she had kept a plush toy for 30 years: "*Even if it was broken or torn, I would fix it myself*". She has since passed the toy on to her son. Another participant said, "*Even if the plush toy is in a bad condition, I won't throw it out because I feel an affinity towards it, as it has a human-like shape.*"

The results also showed that about 73% of the participants' plush toys were placed at easily visible locations, such as around the bed (~34%), on a shelf (~16%), and on the sofa (~9%). However, about 23% had been hidden away in a closet, a toy box, or elsewhere.

How Participants Played with Plush Toys Without the PINOKY

The observations of how participants played freely with the plush toys were useful when designing the interactions using PINOKY to convert an existing plush toy into an interactive toy. Focus was placed on how the participants interacted with the plush toy.

Some movements we observed the participants making with the plush toy were dancing and jumping. Most participants pretended that the plush toy was alive and used it to talk to someone else. One participant said, "*I often use a plush toy as spokesperson to help me convey what I want to tell my child.*" Several other participants used plush toys to play house. Another participant said that her child found it interesting when she synchronised the movements of two plush toys. For these activities, the plush toys' gestures were created by bending the arms, legs, neck, and tail, and voice was added accordingly (Figure 24).

Figure 24: Participants demonstrated how they play with plush toys, bending the limbs (left), and synchronising the movements of similar-shaped plush toys (right)

5.2.2. How Participants Played with Plush Toys Using the PINOKY

Usability

All participants, across a wide age range (2 to 70 years old), were able to easily attach and remove the device from almost any part of a plush toy. While a quick demonstration was given to all participants before the experiment began, it was observed that some children were able to attach and remove the device even before the demonstration was given. This shows that the device design makes it generally intuitive to use.

Number of devices, location of attachment

It was observed that many participants realised that they could attach multiple devices to a plush toy such as an octopus (one to each tentacle) or a snake (multiple devices along the body) and thereby create more complex animations using synchronisation mode. It was also observed that different users attached the devices to different parts of the plush toy (Figure 25).

Figure 25: Attachment locations: ear (left), tail (center), and arms (right)

Difference between user expectations and system performance

As this device is still in the prototype phase, only two sensing points were provided. Initially, some participants were unable to manipulate the plush toy to enable the sensors to detect the user-input movement properly when using the record and playback function. However, once the sensor locations were pointed out to them, they were able to use the function without any problems. Furthermore, there were times when the limb of the plush toy was too short to have its movement detected by the sensors.

Likewise, when told about the record and playback function, many users expected full functionality. Thus, while the device is only able to record a forward/backward motion, there were some users who tried to make the plush toy move in a circular manner.

The device is programmed in such a way that it starts to record the user-input movement the moment the button is pressed. It was observed that there is usually a time lag between the participant pressing the button and the input of the movements. However, the participants seemed to expect immediate playback.

Finally, some of the participants expressed a desire for a smaller device as they felt that it was too chunky. While a smaller device is also something that we hope to create, it is difficult to do so with current technology.

Different styles of play related to demographics

Since all the participants were allowed to freely play with the device, we could observe the relationship between demographics and device use (Figure 26).

Figure 26: Images of participants using the PINOKY

Male participants tended to use the devices on more than one plush toy. They also tended to use more devices than the female participants.

Participants who were 2 years old played with the device under the guidance of an adult (parent or experimenter). A 2 year old girl found the device scary and vehemently refused to allow her mother to attach the device to the plush toy, immediately removing it if attached. A few 2 year old participants showed no interest in the device. This might be because they were unable to fully understand the concept or because the movements of the plush toys were not big enough. In general, it was observed that the 2 year old participants were unable to operate the device on their own. The attachment and removing of the device was mostly left up to the adult, with the child occasionally trying to help.

The 3 year old participants generally needed the guidance of an adult (although one did not need help). One 3 year old boy was observed using the record and playback function successfully. However, during the synchronisation, he focused on moving the plush toy instead of watching the synchronised animation. Another 3 year old participant was observed attaching the device to random locations on the plush toy. Instead of deriving fun from seeing the plush toy become animated, she seemed to have more fun opening and closing the device. In general, the participants of this age group were able to attach and remove the device without help and were able to grasp how to operate the device on their own.

Participants of elementary and junior high school age were allowed to play with the device without adult guidance. Two participants were observed to enjoy playing with the device but eventually removed all the devices and proceeded to have fun simply hitting each other with the plush toys. In general, all participants were observed to be able to fully utilise the device without any problem. They tried both functions of the device on several different plush toys. These participants tended to enjoy the playtime more in the presence of another person (participants showed off the movements they created to their family).

Participants in the age range of 20 to 39 years, although to varying degrees, showed surprise and a sense of wonderment when the plush toy moved.

These reactions were typically more clearly expressed by female participants, with the younger participants showing bigger reactions. Participants also showed an interest (more so for male participants) in the technology behind the device.

There seemed to be a correlation between the age of the participants and how much emotion they displayed. As compared to the previous age category (20 to 39), participants in the age range of 40 to 59 were observed to generally have less reaction and to have more of an air of understanding after they managed to make the device move as demonstrated. There was, however, one exception to this observation. One 59 year old participant showed much joy when the plush toy moved. She also enjoyed attaching many devices to the plush toy and synchronizing all of them. This might be a result of cultural differences, as this participant was an Australian, while the rest of the participants were Japanese.

Lastly, participants 60 years old and above did not show much reaction. Most of these participants were able to understand the operation of the device. However, there was one participant (70 years old) who took some time to fully comprehend the idea and operate the device properly.

Difference in impressions between individual experience and group experience

There was a noticeable difference in the amount of satisfaction the participants derived from using the PINOKY individually and in a group (two people or more). The results were analysed with a between-subjects design analysis of variance (ANOVA). The survey responses from the participants who used the device in a group situation were more positive than those from the participants who used the device individually: Q1 ($F(1,30) = 36.8750$, $p<.01$) and Q3 ($F(1,30) = 66.2188$, $p<.05$). This may be because the participants in a group were able to share their play experience with each other and take turns controlling in the synchronisation mode (one participant commented that it was more enjoyable to him that someone else animated his plush toy rather than him animating the plush toy by himself). Additionally, participants in a group found the device easier to use than participants who used the device individually. This may be because they had someone (who was not a stranger) to turn to for help if they were unable to make the device operate as they intended.

5.2.3. Post-Test Survey

The post-test survey consisted of eight ease-of-use statements. The results are shown in Table 1, which shows the mean, SD, and percentage of positive responses (>4 on a 7-point Likert scale). 25 users reported that the device was enjoyable to use (Q1: 78.1% positive responses). 23 reported that the device was easy to use (Q2: 71.9%). Many participants (68.7%) reported that they did not feel the need to have to learn how to use it (Q7) and that they could easily use it to give movement to a plush toy (Q3). However, 56.2% of the participants reported that they did not feel confident using the device (Q4).

No.	Question	Mean	SD	%
1	It was enjoyable to me that the plush toy moved.	5.19	1.07	78.1
2	I was able to use the device easily.	5.16	1.54	71.9
3	I was able to use the device to give movement to the plush toy easily.	5.16	1.44	71.9
4	I was able to use the device with confidence.	4.34	1.57	43.8
5	I think that most people will be able to use the device to animate their plush toys.	4.81	1.42	59.4
6	I think that the device is an adequate one to animate plush toys.	4.16	1.35	43.8
7	I felt the need to learn many things in order to operate the device.	3.59	1.56	31.3
8	I felt the need to concentrate while using the device	3.19	1.57	18.8

Table 1: Survey Results of the Post-Test Survey

5.3. Evaluation and Discussion

Plush Toys in the Home

From the survey results in the first part of the test, it can be concluded that ownership of plush toys is common, that they are easily visible in the home, and that most owners have memories associated with them. Also, from the observations of how the participants naturally played with plush toys, it can be concluded that most of the participants played with a plush toy by giving it some form of animation.

Validity of Design

The results obtained from the survey and the observations were used to review the appropriateness of the design goals (as described in Chapter 3.3). Also, whether or not the current implementation of PINOKY is able to meet these goals is evaluated.

1) Easy to use

The child participants started playing with the plush toys immediately upon picking them up. Any enhancement to a plush toy should not interrupt such immediate interaction. All participants were observed to be able to use the device without any practice and minimal trial and error, showing that the device is indeed easy to use.

2) No damage to the plush toy

From the survey, it was learnt that many of the participants had strong attachments to their plush toys, so they would likely be unhappy if they were required to have their plush toys cut open so that movement actuators could be embedded. The current implementation does not require any alteration to the plush toy, and no damage to the surface of any of the plush toys used in the experiment was detected after their use.

3) Easily attachable and removable without requiring special tools

One participant commented: "*I wash my plush toy whenever it gets dirty.*" This shows the importance of this particular design goal: to make the device easily attachable and removable. The plush toy should be able to be easily washable. The current implementation of the PINOKY is held in place by a pair of magnets, and it was observed that even some of the 2 year old participants were able to attach and remove the device without help.

4) Scalability

It was observed that participants move various parts of a plush toy when playing with it. This shows the importance of scalability. Participants were seen to be able to attach and use as many devices as they pleased, as the ZigBee module enabled multiple simultaneous connections. Some participants encountered the size limitation of the PINOKY when they tried to attach it to a part of the toy that was too big to fit within the device.

5) Safe and robust

Children often played with the plush toys in a rough manner, so safety and robustness are important. None of the participants were injured during the course of the user study, demonstrating that the device can be safely used, even by very young children. Devices were dropped many times during the experiment, and some participants exerted much force on them. After four days of tests, all the devices were examined and found to be still working properly, showing that the design is both stable and durable.

6) Adequate movement actuation

Observations made of how the participants played with plush toys without the PINOKY revealed that plush toys were usually animated so as to perform various types of movement: jumping, walking, and so on. The swing motion that the PINOKY was designed to create constituted the most often used animation during the observations. Thus, it can be seen that the swing motion is an adequate one for expressing many different types of emotions (for example, many different expressions such as agreement and dislike can be created by manipulating the neck of a plush toy using the swing motion).

Therefore, as an early working prototype, it can be said that the design is sufficient to accommodate most motions that users would expect from a plush toy.

7) Hidden technology

Over the course of the user study, many of the participants commented that they felt as if the plush toys had "come to life". This was interesting to note, because despite feeling like the plush toy was now alive, the participants were still conscious of the fact that they had to attach the device to the particular limb in order to be able to allow it to move in the first place. Thus, it can be seen that the device was largely successful in its attempt to hide the technology, such that it does not get in the way of the user's imagination during play. None of the participants were able to immediately perceive how the actuation was done, and had to ask for an explanation on the technology used, which also shows that the technology was also well-concealed.

8) Aesthetically pleasing

Many participants indicated that they displayed their plush toys in their rooms, which shows the importance of aesthetics. Covering the device with felt so that it matched the texture and look of plush toys seemed to be effective, as there were no complaints from the participants about device appearance.

9) Allow the user to be able to interact with the plush toy in a natural way

Participants were observed during their play sessions, and it was seen that most play sessions were of an experimental nature, with the participant testing the device to see the limits of what it could achieve, trying to find out the different places where they could attach the device to, and testing out the devices to see the response they would get. Although this means that the participants were interacting with the plush toys differently as compared to how they would normally do so during normal play, this is understandable, as there is currently no similar commercially-sold device on the toy market, and what the device is able to do is therefore a very new concept to them.

From the observations and survey results, it can therefore be seen that the design of the device fulfilled almost all the design goals that were set at the beginning, thus making it generally a very effective one. However, there were also certain limitations that the device had.

Limitations of the Device

As the device is still a "proof-of-concept" implementation, there would inevitably be some hardware limitations.

It was observed that for the plush toys with thinner limbs, the participants had to ensure that the limb was properly inserted between the actuators to be able to obtain the correct movement.

Some participants indicated that they would prefer a smaller device, as the current implementation was rather chunky and heavy. PINOKY is currently implemented using a general-purpose microcontroller (Arduino) and a commercial ZigBee module. In a more customized implementation, it would be possible to select components with a smaller footprint and integrate them into a more power-efficient system with a smaller form factor. Moreover, there is a trade-off between servomotor size and torque. While small plush toys can be controlled via other methods, such as using smaller actuators with lower torque, this would not work on bigger plush toys. The implementation of smaller actuators with high torque would greatly reduce device size. However, it is not cost-effective and practical to include these in the current implementation of the device, as it would greatly drive up the production cost. Perhaps this would be viable in the future, when the price of these components drop.

As one participant commented, "*more dynamic movement and variety of movement is needed,*" reflecting the fact that the current range of movement that PINOKY can create is limited. One reason for limiting the range is to prevent the part of the servomotor that actuates motion from slipping on the surface of the toy. It is possible to solve this problem by simply attaching a piece of rubber between the part and the surface.

While it is possible to express many different emotions using the swinging motion that PINOKY can actuate, there are still some emotions that cannot be expressed yet as they require different movements.

Another limitation of the PINOKY is its sensitivity to sunlight. This is because photoreflectors were chosen to be used as the mode of sensing, and these sensors detect both the infrared light from the emitters and infrared radiation from the sun. This may be solvable using an ultrasonic sensor.

Some participants had expressed a wish for alternative input methods, such as using voice instructions. While such interactions are not present in the current implementation, it is possible to create more input methods very easily with the usage of different types of sensors (for example, the accelerometer and motion sensors). In fact, it is also possible to link the device to the Microsoft Kinect and to use that to control it.

6. User Study 2: Animating Personal Plush Toys with the PINOKY

From the first user study done on the usability of the PINOKY, it was seen that the PINOKY was indeed user-friendly, and that the design did manage to fulfil most of the design goals. Several limitations of the device were also discovered. With this in mind, a second preliminary user study was planned and executed, with the focus on finding out if there was a difference between the usage of PINOKY on plush toys which users have built up a relationship with (personal), and plush toys not belonging to the users at all (impersonal). Also, this user study aims to see if the PINOKY is indeed able to enhance the play experience with plush toys to make it a more surprising and personal one.

6.1. Procedure

As compared to the quantitative first user study, the second user study which was conducted was a qualitative one. Each user test session comprised of two parts:

1) The participant was asked to bring along a personal plush toy to the test session. Participants were given basic instructions as to how to operate the device (push-button remote control, voice control), and the different interaction modes (record and playback, synchronisation). They were given about 5 minutes to play freely with them, or whenever they seemed to bore of the play session, whichever came later. The play session was observed, and participants were aware of the fact that they were video-recorded (for privacy purposes).

2) After the play session, the experimenter would conduct a casual interview session with each participant to gain a better insight into each of the participants' play sessions. Some of the main things to be found out from each play session were:

a) How was the experience using the PINOKY – whether there were any areas which could be improved on.
b) How the participant felt when they saw their plush toy moving.
c) Whether they saw a difference between seeing their personal plush toy moving as compared to seeing a store-bought robotic plush toy moving, and which they preferred.
d) Whether seeing their personal plush toy being animated led to the triggering of any memories they had.
e) What they felt about the general idea of play, and if they had encountered any particularly impressionable play experiences before.

While the interview was conducted with some basic questions in mind (see Appendix F), slight deviations and additional questions were inserted depending on the answers the participants provided.

6.2. Results

A total of 3 participants from a university in Japan were involved in this user study. All of the participants were students in their late twenties, and comprised of 1 male and 2 females. Each participant was told to bring their personal plush toys to the user study (Figure 27).

Participant 1 is a 27 year old female from Indonesia. The plush toy she had brought along for the test was a rabbit. She has had it for one year, and it was a gift from her brother.

Participant 2 is a 26 year old male from Mexico. The plush toys he had brought along for the test were a monkey and a bear. Both plush toys were gifts from good friends, and he has had them for about a year each.

Participant 3 is a 27 year old female from Australia. The plush toy she had brought along for the test was a teddy bear. She has had it for 27 years, and it was a gift from her parents, who brought it to the hospital when she was born.

Figure 27: Clockwise, from top: Personal plush toys of Participant 1, Participant 2, and Participant 3

6.2.1. How Participants Played with Plush Toys Using the PINOKY

Participant 1 (P1)

P1 selected the brown PINOKY, connected the power wires, and tried to attach it around the ear of the rabbit. She looked confused at first as to why pressing the button on the remote control caused a different device to move, rather than the one attached to the rabbit's ear. She tried to synchronise the devices, thinking that that might have been the cause of the problem. While not being synchronised was indeed the problem, the participant tried to press the blue button (recording function) to perform the synchronisation instead. At this point, the experimenter stepped in and helped the participant with the synchronisation.

After figuring out the synchronisation procedure, P1 then attached one PINOKY to each of the two ears. She tried to animate both ears, and while the rabbit's left ear was very well animated, the right ear only managed to be animated to a very small degree. Thinking that it might perhaps be a problem with placement, the participant attempted to readjust the PINOKY a few times. Finally, the right ear was able to be animated to a larger degree, though still not as well as the left ear. She proceeded to animate each ear in succession, and smiled when she saw them moving (Figure 28). She also made the comment that it was "So cute!"

Figure 28: P1 animating the ears of her rabbit

Next, P1 took another PINOKY and first tried attaching it to the left front leg of the rabbit, but later changed her mind and attached it to the tail instead. Upon seeing the tail move, she laughed and commented, “That’s cute!” As it was difficult to balance the rabbit properly, she proceeded to prop it up against the box holding all the devices, so she could play with her plush toy without having to hold it up all the time.

P1 then proceeded to try out the voice control. She seemed to enjoy this mode of control more than the pushbutton remote control, saying things like “Bunny!”, “Hey, bunny!”, and “Do you want to play?”. When the rabbit moved its ears in response, she laughed and commented, “It’s cool!” After trying out the voice control, the participant went back to the pushbutton remote control, talked to the rabbit (“Bunny, can you hear me?”) and then pressed the button to animate the ears, as if they were responding to her.

Finally, P1 tried attaching the PINOKY to the right front leg of the rabbit again, and animating it. She commented that “Maybe if I have four, he can walk.”

Participant 2 (P2)

P2 first studied the PINOKY for a few moments before attaching it on the monkey's left arm. The movement was very small, and he looked puzzled and tried to do some readjustments. Although the movement improved, it still looked rather small, as compared to the movement that P1 managed to make with her rabbit's ears. P2 then attached the PINOKY to the monkey's tail, and smiled when the tail twitched.

Although P2 thought of putting the PINOKY around the monkey's neck, he changed his mind, and attached it to the right ear of the bear instead. The device dislodged itself slightly during the animation, and he looked a little taken aback. He then chose a larger-sized PINOKY to use on the same ear, and smiled when the ear moved.

P2 then proceeded to use the larger-sized PINOKY on the monkey again. He tried putting it on the neck of the monkey, leaving the device open, and looked first intrigued, then visibly very surprised and happy when he was able to make the monkey's head move left and right, even holding it up to show the experimenter what he had managed to achieve (Figure 29).

Figure 29: P2 showing the experimenter the monkey nodding its head

After that, P2 chose another PINOKY and tried to animate the monkey's left leg again. Unfortunately, the animation of the monkey's leg was still very small. He then removed the PINOKY and studied its movement.

Lastly, P2 then proceeded to try out the voice control, and looked surprised when making a noise into the voice controller was able to make the PINOKY move (at this point of time, the PINOKY had not yet been attached to any plush toy). He attached the PINOKY to the neck of the monkey again, and made monkey noises into the voice control. While leaving the device on the neck there, he tried to attach another PINOKY to the left leg. However, he removed it again when it still was unable to produce the desired movements. He played with the voice control for a bit more after that.

Participant 3 (P3)

P3 picked up the PINOKY, and said to her teddy bear, "Okay teddy, this probably won't hurt… But I can't guarantee anything," before trying to attach it to the teddy bear's right arm. However, she felt that it looked too small, and changed the device for a larger-sized one.

The participant attached another large-sized PINOKY to the bear's left arm as well. She pressed the button on the remote control, and smiled when the bear's left arm moved. Next, she pressed both buttons to make both arms animated at the same time, and then tried again making them move one after another in quick succession.

After this, P3 tried using the voice control. She was surprised and a little startled when all the devices started moving when she said "Hello?" into the controller. P3 tried talking to the teddy bear ("Hey, teddy!") and waved at it in greeting (Figure 30).

Figure 30: P3 talking and waving to her teddy bear

P3 proceeded to put a small-sized PINOKY around the teddy bear's left ear, and smiled when the ear twitched in response when she pressed the button on the remote control. After that, she tried putting the PINOKY around the bear's left leg. Unfortunately, the leg was a little too large, and the device had difficulty staying closed. However, the participant was still successful in animating the leg.

After experimenting with the leg, P3 tried attaching the PINOKY to the arm of the teddy bear again, but this time to a different location, not at the connecting point of the arm to the body, but instead midway along the length of the arm. She did the same for both arms of the bear, and tried to animate them using the remote control. After seeing the animated response of the teddy bear, P3 voiced out her opinion that she felt that the arms were better animated by attaching the device at the connecting point between the arm and the body. She quipped that she felt like she was performing surgery.

P3 reattached the PINOKYs at the connecting part between the body and the arms of the teddy bear again, making the comment, "Okay, I think that

I've figured out how to fit them better." She then tried hugging the teddy bear and making the arms move via speaking into the voice controller (Figure 31).

Figure 31: P3 hugging her teddy bear and using the voice control to animate it

6.2.2. Post-Test Interview

A casual interview lasting approximately 10 minutes was conducted after the end of each test session, and the results obtained from each session were collated. A full transcript of the interviews is included in Appendix G.

Plush Toy Usage in Daily Life

All three participants had plush toys back in their own countries. With the exception of P2, both P1 and P3 interacted with their plush toys frequently, treating them like close companions and talking to them about happenings in their daily lives. Despite this, all three participants had their plush toys in their homes now placed at prominent places, such as on the bed.

Feelings about the Play Experience

All three participants seemed to visibly enjoy the play experience, and when asked about their thoughts on the play experience, mentioned that it was "cute" (P1) and "cool" (P2).

While the other participants gave affirmative answers upon being asked that seeing the plush toys being able to seemingly move on their own made them remember personal memories which they had associated with the toy (P1 recalled memories about her brother, and P2 said that he recalled how he got to own these plush toys), P3 related her personal memories regarding the plush toy without being prompted to by the interviewer. P3 described how being able to see the plush toy move made her remember how her mother used to animate the toy for her when she was very little, but yet it was now moving in the same way of its own accord, and this was a little "spooky" to her.

All three participants agreed that they felt that it was as if their plush toys had come alive. However, there was a minor disagreement when they were asked if they felt surprised upon seeing their personal, previously inanimate plush toys move after attaching the PINOKY. P2 and P3 both said that they felt surprised when they saw their plush toys moving, with P3 adding that there was a little bit of shock as well. P2 said that although he knew that the device was meant to animate plush toys, he still felt surprised because he did not know what to expect, how to react, and how different parts of the plush toy would react to the device. P3 commented that she was surprised because she was not used to seeing her plush toy move on its own. P1 said that because she was told beforehand that the PINOKY was a device that allowed her to animate her plush toys, she was not surprised when it moved. When asked to elaborate on why this was so, since the type of movement would still be unknown, and that she would have never had encountered her plush toy being able move of its own accord before, P1 said that it was because of the inherent knowledge that a plush toy is in reality an inanimate object. She reasoned that if the toy was to make a really surprising movement, such as hitting her, she would be very upset. Instead, although she knew that she was only able to use the device to animate the ears of her plush toy (a rabbit), seeing the ears move was enough to make her feel happy. However, there is the possibility that there might have been a slight confusion in terms of the feelings of "surprise" and "shock", since P1 added, "*For me, to be able to see my rabbit moving already makes me happy. Like, "Oh! It moves!" It is already surprising.*"

After seeing their plush toys become animated using the PINOKY, both P1 and P3 said that this made them feel like playing with their plush toys more, because it was "cute" (P1), and they were now "far more animated, and far more alive" (P3). P2 said that although he did not personally feel this way due to his age, he thought that his niece would be far more appreciative of this new ability to animate previously inanimate plush toys, and be "very excited to put it in a toy and see the reaction".

Lastly, all the participants expressed their preference of being able to animate their personal plush toys, as compared to buying a robotic plush toy. The fact that the plush toy is a personal item, and that they already had a personal and emotional connection with it was the main explanation given by all three participants:

"*Somehow, it's better to see our toys move… you already have the feelings to (sic) your toys. So when you put something, like energy or soul, it will be like a miracle.*" (P1)

"*What if the kid doesn't like Elmo? That's the problem… this toy was a gift. So maybe I have a very special connection to it. So yes, if I can choose between moving this one or moving Pikachu, I would take this one… because it makes it more personal.*" (P2)

"*I think that a toy that you already have a bond with, and you probably made up stories about it yourself… it's more fun if that become animated* *and moves, compared to something like Tickle Me Elmo, which just feels like he came out of the box that way.*" (P3)

6.3. Evaluation and Discussion

Validity of Design

While the focus of this user study was to see if there was a difference between play sessions using the PINOKY on personal plush toys versus using it on impersonal plush toys, the validity of the device design was also evaluated.

1) Easy to use

P2 had some initial problems with the synchronisation of remote controllers to the desired devices, because he had thought that the synchronisation process was similar to that of Bluetooth. However, that problem was solved after a demonstration by the experimenter. Other than that, all the participants were able to use the system without any problems.

2) No damage to the plush toy

All the plush toys were inspected after the user study, and no damage was found done to any of them.

3) Easily attachable and removable without requiring special tools

Participants were observed to have no problems attaching and removing the device to any part of the plush toy they desired.

4) Scalability

The system was able to accommodate the participants attaching multiple devices and using all of them at the same time. Similar to the participants in the first user study, the participants in this user study also encountered the same problems with varying sizes of the plush toys' limbs. Although most limbs were able to be actuated properly, some limbs were too thick and could not fit properly within the device, while others were too thin and without stuffing, which resulted in minimal movement actuation.

5) Safe and robust

None of the participants, plush toys or devices were harmed during the process of the user study, which shows that the system is indeed safe and robust.

6) Adequate movement actuation

Participants of this user study generally seemed to be satisfied with the type and amount of movement actuation provided. However, P1 did suggest that it would be nice if more variety to control could be implemented, for example having a mode where the plush toy would only respond after the user has finished talking into the microphone, to simulate the user having a conversation with the plush toy, which then responds by waving its arm.

7) Hidden technology

Similar to the participants of the first user study, participants in this user study also reacted in the same manner. Although the device was large and obviously present, they commented that it felt like the plush toys were alive.

8) Aesthetically pleasing

No comments were made about the look of the device.

9) Allow the user to be able to interact with the plush toy in a natural way

The participants of the first user study mainly interacted with the plush toys and system in an experimental way, trying to see the capabilities of the device and testing its limits. While the participants for this user study did do some experimenting with the devices, it was noticed that they also interacted with the toys in a more natural manner than the participants in the first user study. This difference between the usage of the PINOKY on personal and impersonal plush toys is discussed in more detail in a later part of this section.

From the observations of the participants' play sessions and the evaluation above, we are thus able to see that despite the limitations in scalability, participants were generally satisfied with the capability of the system, and that the design of the device was sufficient to fulfil the design goals.

Relevance of Plush Toys in People's Lives

All participants were clearly seen to have placed much importance in plush toys, with P1 and P3 showing much emotional investment in their plush toys. The reasons why P2 might not have seemed to be as emotionally attached to his plush toys in comparison to P1 and P3 might be the difference arising from a comparison of several factors, such as gender (P2 was male, while P1 and P3 were female), the length of time which the participant has owned the plush toy for (P2 has owned her plush toy ever since she was born), who the plush toy was received from (P1 and P3's plush toys were presents from family members, while P2's plush toys were presents from friends and past relations), and so on. However, there was no doubt that P2 did value his plush toys, as can be seen when he was talking about the plush toys he had owned previously, and being able to remember details such as who he got them from. P1 and P3 had brought their plush toys from their home country to Japan. During the interview, P1 described how she had another plush toy which she was unable to bring over to Japan, due to the fact that she was not able to carry it onto the airplane, since putting it in the suitcase was not an option as she did not like the thought of the toy being squashed. P3 had also brought her plush toy with her onto the airplane to Japan. In fact, when she had left the country after the March 11 earthquake, she brought her plush toy back home to Australia with her, because she reasoned that: "*If for some reason I can't come back, well then he needs to come with me now*". While the survey responses from the first user study do show that plush toys are relevant in the daily lives of people, the responses from these three participants show the degree to which people can be emotionally attached to their plush toys, and thus how important the existence of plush toys as an emotional pillar can be in our daily lives.

Difference in Play Using Personal and Foreign Plush Toys

One thing that was interesting to observe was the difference between how participants in the first and second user studies utilised the PINOKY in their play session with the plush toys. Although the goals of each user study were different, it can be seen that while the play sessions of the first user study were more of an experimental nature, while the play sessions of the second user study were not only experimental, but built upon the personal connection which the users already had with their plush toys. It was observed that most of the users in the first user study would try to push the boundaries as to how much they could animate the plush toys (for example, placing multiple rings on different parts of the toys and animating all of them at the same time). Users playing with the toys in a group often showed each other the animations that they had created. While there was still some experimentation observed for the participants of the second user study as this a new piece of technology and users are unsure of what could or could not be done, this was done to a lesser degree. Instead, participants tried to interact with the plush toys more, doing things like talking to the plush toys as if they were talking to a friend, rather than simply just making a random noise into the voice controllers in order to cause the PINOKY to animate the plush toy. This shows how the presence of a personal and emotional connection to the plush toy may affect the play session, and may perhaps be the key to creating more impressionable and meaningful play experiences.

Importance of the Personal Touch to Play

From the play sessions and interviews conducted, it can be seen that participants unanimously preferred being able to animate their personal plush toys over store-bought robotic plush toys. This is despite the fact that the interactions provided by the PINOKY were rather basic as compared to commercial robotic plush toys, and that commercial robotic plush toys were on the whole able to provide better sensing and actuation with a sleeker design. The responses obtained showed the huge importance that the personal emotional bond has, that will in turn affect play preferences. Imagination is a very important component of play. Many people have already "customised" their plush toys to their liking by pro-active imaginative actions such as giving their plush toys names, unique personalities, and even making up stories about them. The amount of personalisation already done by the users will thus allow them to be able to build upon these already-present foundations while using the PINOKY to animate their plush toys, and this will in turn both enhance and add a little surprise to their regular play experience, thereby creating a play experience that is unique to them.

7. Discussion and Future Work

Some of the limitations discussed in the earlier two chapters revolved around the size of the device, the restricted range of sizes for the plush toy limb that could fit into the device, the limited types of movements that could be actuated. As general, commercially-available, cheaper components are being used at the moment, it is possible to decrease the size of the device if more specialised, and perhaps expensive, components were used instead. While Prototype 2 was, in theory, able to allow for any size of plush toy limb to be animated (since all it involved was attaching Bio-Metal to the clothes at the part to be actuated), the actuation was undesirable. Perhaps one method to solve this would be to attach the actuators on a strap that could be adjusted (similar to the strap of a watch or a belt), or attach the motors to a rubberised material instead. Although still size-limiting to a certain extent, these methods definitely allow for a wider range of limb sizes to be accommodated. That being said, motor positioning (especially for the belt) and the quality of actuation would be potential problems in this case. As for the limitation in types of movement that could be actuated, the goal of this research was simply to allow plush toys to become animated without the user having to physically come into contact with and control it. In this aspect, the PINOKY was able to fulfil the goal of this research. Different and more motors could be used to create the different types of movements suggested (for example, moving in different directions and twisting) but at the cost of device size. However, this is not under the scope of the current research, and would be good to look at in the future.

While preliminary, the second user study did seem to suggest that perhaps one of the ways to make a play session more meaningful and engaging to someone is by making the session personal to the player. Making a plush toy "come to life" using the PINOKY may make for a novelty play session, but it is easy for people to tire once the novelty has worn off, as the plush toy now becomes "just another moving plush toy". However, if the PINOKY is instead used on a plush toy that the person has fond memories of and see as a personal companion, then having the companion "come to life" may have a greater meaning to the him or her, and thus the person may continue using the PINOKY, hence creating an enhanced bond between the owners and their plush toys. How the PINOKY's usage can affect the relationships of people with the plush toys they hold dear is an interesting one, and it would be good for a more comprehensive user study to be conducted in the future.

Despite being a working prototype, many participants of the user study asked if it was possible to purchase the PINOKY. This it very encouraging, as it shows that people love the concept of being able to animate their own previously immobile plush toys, and that there may be a potential market for this device. Currently, although there is an abundance of robotic plush toys, there does not seem to be any commercially available alternative at the moment that has similar functionality to the PINOKY. This is in the PINOKY's advantage, if it were to be improved on (the device's limitations were discussed earlier), and eventually commercialised. Also, despite the fact that the PINOKY is used to animate plush toys in this research, it is actually possible for the PINOKY to animate anything, so long as it is a soft object without a rigid internal structure. For example, human hair was able to be animated using the PINOKY. This allows its usage to be expanded, perhaps as a possible novelty hair accessory, for example.

8. Conclusion

PINOKY is a ring-like device that is able to animate plush toys, such as moving their limbs and tails. As opposed to actuators that have to be embedded into the plush toy, the device created for the purposes of this research operates externally. Thus, the user has the ability to transform any plush toy into an interactive toy in a non-intrusive manner, without having to make any alterations to the toy. Because the electronic parts (microcontroller, battery, sensor, and actuator) are in one package and do not require external wiring, the user can easily attach the device to any plush toy as an accessory.

Two user studies were done over the course of this research. The first user study was conducted to determine the validity of the design direction of PINOKY, evaluate the usability of the device, and see how people react to the concept. The survey of how plush toys are used in daily life showed that ownership of plush toys is common (about 70% of the participants owned more than one plush toy) and that most owners have memories associated with them. The observations of how the participants used PINOKY showed that all of them were able to fully utilise the device without any serious problems. The second user study was conducted to explore the possibilities and results of using the PINOKY on personal plush toys, and see how it might be able to enhance the users' play sessions with their plush toys, creating a new and surprising play experience for them. The observations of how the participants played with their personal plush toys using the PINOKY showed that not only did the inclusion of the PINOKY succeed in doing that, it also made the play session a more meaningful one for them.

As this device is still a prototype, it has some limitations, such as its size and the sensing methods. However, the user studies have shown that such a concept of allowing users to be able to animate their plush toys in any way they desire is indeed a welcome one, and is able to contribute to the creation of a new, surprising, and personal type of play experience.

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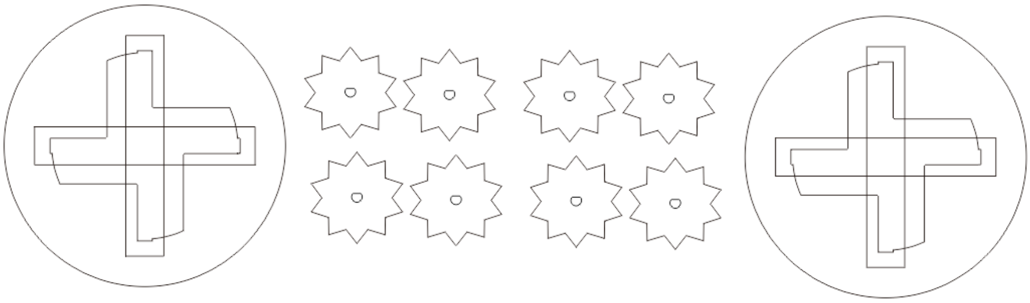
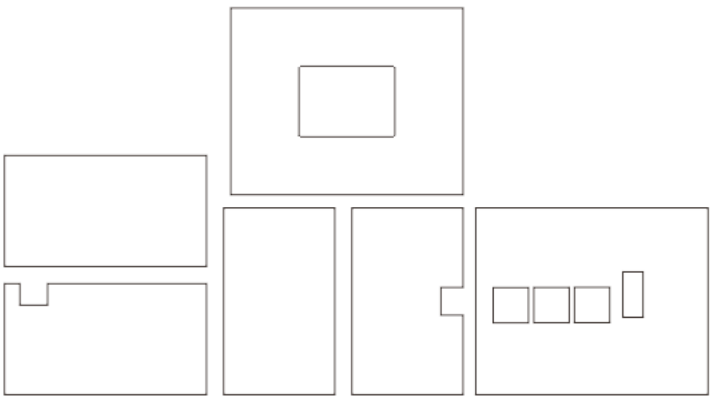
Appendix

A. Blueprint for Prototype 1

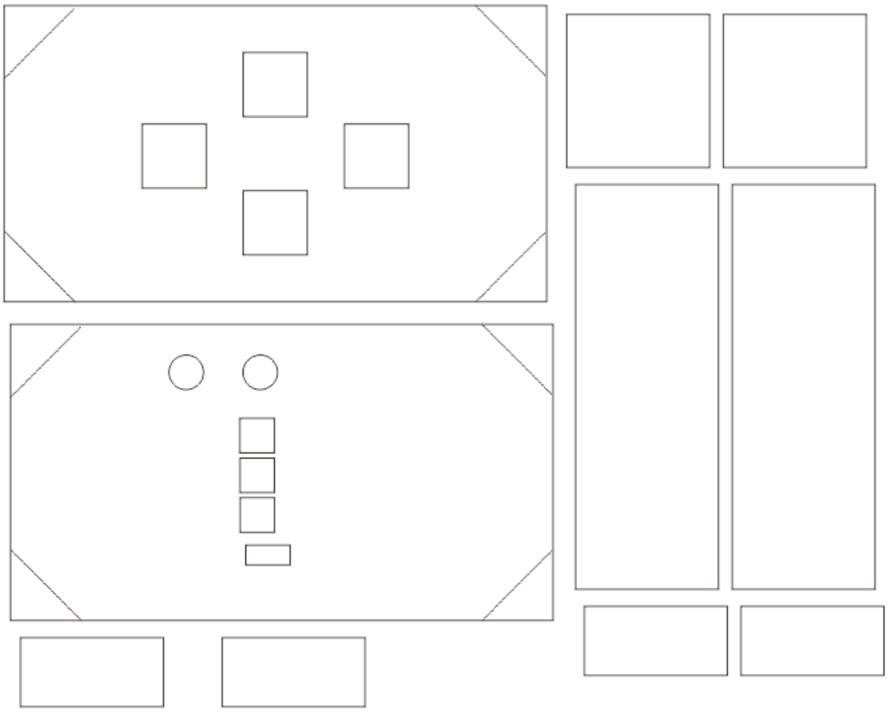


B. Blueprint for Prototype 3

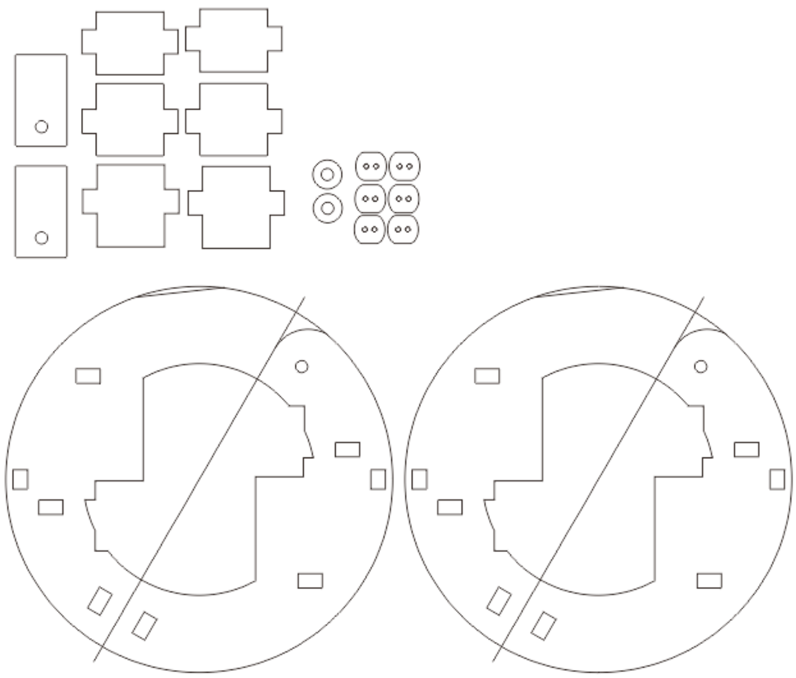
PINOKY's Backpack, and Voice and Movement Controller Casing



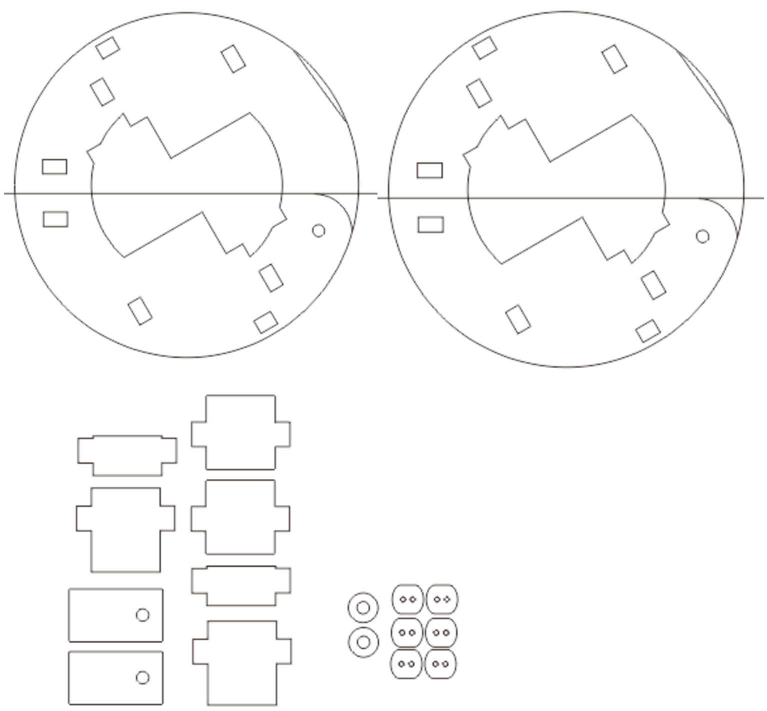
Pushbutton Remote Control Casing



Larger-sized PINOKY



Smaller-sized PINOKY



C. Code for Prototype 3

Pushbutton Remote Control

```
const int bluePin = 10;
const int redPin = 11;
const int yellowPin = 12;
const int greenPin = 13;

int blueState = 0;
int redState = 0;
int yellowState = 0;
int greenState = 0;

char blueDirection = 'B';
char redDirection = 'R';
char yellowDirection = 'Y';
char greenDirection = 'P';

void setup() {
  // initialize serial communications at 9600 bps:
  Serial.begin(57600);
  // initialize the buttons as input:
  pinMode(bluePin, INPUT);
  pinMode(redPin, INPUT);
  pinMode(yellowPin, INPUT);
  pinMode(greenPin, INPUT);
}

void loop()
{
  //read input
  blueState = digitalRead(bluePin);
  redState = digitalRead(redPin);
```

```
yellowState = digitalRead(yellowPin);
greenState = digitalRead(greenPin);

if (blueState == HIGH)
{
  if (blueDirection == 'B')
  {
    Serial.write("C");
    blueDirection = 'C';
  }
  else
  {
    Serial.write("B");
    blueDirection = 'B';
  }
}

if (redState == HIGH)
{
  if (redDirection == 'R')
  {
    Serial.write("L");
    redDirection = 'L';
  }
  else
  {
    Serial.write("R");
    redDirection = 'R';
  }
}

if (yellowState == HIGH)
{
  if (yellowDirection == 'Y')
```

```
    {
      Serial.write("Z");
      yellowDirection = 'Z';
    }
    else
    {
      Serial.write("Y");
      yellowDirection = 'Y';
    }
  }

  if (greenState == HIGH)
  {
    if (greenDirection == 'P')
    {
      Serial.write("Q");
      greenDirection = 'Q';
    }
    else
    {
      Serial.write("P");
      greenDirection = 'P';
    }
  }

  delay(200);
}
```

Voice Remote Control

```
// Analog input pin that the potentiometer is attached to
const int analogInPin = A2;
// Analog output pin that the LED is attached to
const int analogOutPin = 9;
```

```
int sensorValue = 0;            // value read from the pot
int outputValue = 0;            // value output to the PWM (analog out)

void setup() {
  // initialize serial communications at 9600 bps:
  Serial.begin(57600);
}

void loop() {
  sensorValue = analogRead(analogInPin);

if (sensorValue > 800){
  Serial.print("B");
  Serial.print("L");
  Serial.print("Y");
  Serial.print("P");
  delay(200);
  Serial.print("C");
  Serial.print("R");
  Serial.print("Z");
   Serial.print("Q");
  delay(200);

}else if  (sensorValue < 0){
  Serial.print("C");
  Serial.print("R");
  Serial.print("Z");
  Serial.print("Q");
}else {


}
```

```
  // wait 10 milliseconds before the next loop for the analog-to-digital
  // converter to settle after the last reading:
  delay(50);
}
```

Movement Control

```
// Analog input pin that the potentiometer is attached to
const int analogInPin = A3;
const int analogOutPin = 9; // Analog output pin that the LED is attached to

int sensorValue = 0;          // value read from the pot
int outputValue = 0;          // value output to the PWM (analog out)

void setup() {
  // initialize serial communications at 9600 bps:
  Serial.begin(57600);
}

void loop() {
  // read the analog in value:
  sensorValue = analogRead(analogInPin);
  // map it to the range of the analog out:
  outputValue = map(sensorValue, 0, 1023, 0, 255);
  // change the analog out value:
  analogWrite(analogOutPin, outputValue);

if (sensorValue > 770){

  // print the results to the serial monitor:
  Serial.println("B");
   Serial.println("P");
    Serial.println("L");
```

```
        Serial.println("Y");
              delay(150);



}else if   (sensorValue < 200){
       Serial.println("C");
       Serial.println("R");
            Serial.println("Q");
         Serial.println("Z");
         delay(150);



}else {
}
   // wait 10 milliseconds before the next loop for the analog-to-digital
   // converter to settle after the last reading:
   delay(50);
}
```

Device

```
#include <Servo.h>

// *************** //
// USER DEFINITION //
// *************** //

//#define DEBUG

#define SELF_COM1 'A'
#define SELF_COM2 'B'
#define SELF_COM3 'C'
```

```
char com1all[] = {'A', 'O', 'S', 'X'};
char com2all[] = {'B', 'P', 'R', 'Y'};
char com3all[] = {'C', 'Q', 'L', 'Z'};
// PLEASE write length of "com*all" array
#define COM_LENGTH 4

#define R_THRESHOLD 80
#define L_THRESHOLD 80

#define FPS 20
#define MAX_RECORD_FRAME FPS * 30

// ***************** //
// SYSTEM DEFINITION //
// ***************** //

// port definition
#define BTN_BLUE 8
#define BTN_YELLOW 7
#define BTN_WHITE 4
#define SRV_R 3
#define SRV_L 5
#define ANL_SNS_R A2
#define ANL_SNS_L A3

#define SERVO_LOW 45
#define SERVO_CENTER 90
#define SERVO_HIGH 135

#define SENSOR_AVERAGE_COUNT 5

typedef enum MOTOR_DIRECTION {
  MD_CENTER = 0,
```

```
  MD_RIGHT = 1,
  MD_LEFT = 2,
};

// type
enum MODE {
  M_NONE = 0,
  M_RECORD = 1,
  M_PLAY = 2,
  M_SYNC = 3,
};

// global variable
Servo gServoR;
Servo gServoL;
int gRecordBuffer[MAX_RECORD_FRAME];
int gRecordedCount = 0;
MODE gMode = M_NONE;
MOTOR_DIRECTION state_motor_direction = MD_CENTER;

int gInputSensorR;
int gInputSensorL;
int gOutputMotorR;
int gOutputMotorL;
int gSensorThresholdR = R_THRESHOLD;
int gSensorThresholdL = L_THRESHOLD;
char gSyncSentCommand = SELF_COM1;

void setup() {
  Serial.begin(57600);
  gServoR.attach(SRV_R);
  gServoL.attach(SRV_L);
  setMode();
}
```

```
void setMode() {
  pinMode(BTN_WHITE, INPUT);
  pinMode(BTN_YELLOW, INPUT);
  pinMode(BTN_BLUE, INPUT);
  pinMode(SRV_R, OUTPUT);
  pinMode(SRV_L, OUTPUT);
}

void wait() {
  buttonCheck();
  delay(1000/FPS);
}

void loop() {

  while(1) {

    readSensor();
    if (gInputSensorR > gSensorThresholdR) moveMotor(MD_RIGHT);
    else if (gInputSensorL > gSensorThresholdL) moveMotor(MD_LEFT);
    else moveMotor(MD_CENTER);

    wait();

    switch (gMode) {
      case M_RECORD:
        modeRecord();
        break;
      case M_PLAY:
        modePlay();
        break;
      case M_SYNC:
        modeSync();
```

```
        break;
      }
    }
}

void readSensor() {
  static int count = 0;
  static int bufferR[SENSOR_AVERAGE_COUNT];
  static int bufferL[SENSOR_AVERAGE_COUNT];
  int tempR, tempL;

  tempR = analogRead(ANL_SNS_R) * 25 / 256; // convert level 1024 to 100
  tempL = analogRead(ANL_SNS_L) * 25 / 256;

  bufferR[count] = tempR;
  bufferL[count] = tempL;

  gInputSensorR = 0;
  gInputSensorL = 0;

  for (int i = 0; i < SENSOR_AVERAGE_COUNT; i++) {
    gInputSensorR += bufferR[i];
    gInputSensorL += bufferL[i];
  }
  gInputSensorR = gInputSensorR / SENSOR_AVERAGE_COUNT;
  gInputSensorL = gInputSensorL / SENSOR_AVERAGE_COUNT;

  count = count + 1;
  if (count > SENSOR_AVERAGE_COUNT) count = 0;

  #ifdef DEBUG
  Serial.print(gInputSensorR);
  Serial.print(" ");
  Serial.print(gInputSensorL);
```

```
    Serial.println(" ");
    #endif
}

void moveMotor(int flag) {
    #ifdef DEBUG
    Serial.print("---> (motor_direction) ");
    Serial.println(flag);
    #endif

    if ((MOTOR_DIRECTION)flag == MD_CENTER) {
        writeMotor(SERVO_CENTER, SERVO_CENTER);
    } else if ((MOTOR_DIRECTION)flag == MD_RIGHT) {
        writeMotor(SERVO_LOW, SERVO_HIGH);
    } else if ((MOTOR_DIRECTION)flag == MD_LEFT) {
        writeMotor(SERVO_HIGH, SERVO_LOW);
    }
}

void writeMotor(int right, int left) {
    #ifdef DEBUG
    Serial.print("---> (motor) r: ");
    Serial.print(right);
    Serial.print("    l: ");
    Serial.println(left);
    #endif

    gServoR.write(right);
    gServoL.write(left);
}

void buttonCheck() {
    MODE localMode = M_NONE;
    if (digitalRead(BTN_BLUE))      localMode = M_RECORD;
```

```
    if (digitalRead(BTN_YELLOW)) localMode = M_PLAY;
    if (digitalRead(BTN_WHITE))    localMode = M_SYNC;

    if (localMode != 0) {
        gMode = localMode;
    }

    #ifdef DEBUG
    Serial.print("MODE -> ");
    Serial.println(gMode);
    #endif
}

void modeRecord() {

    int recordCount = 0;

    while (1) {

        if (gMode != M_RECORD) break;

        if (recordCount >= MAX_RECORD_FRAME)
            break;

        // if arm is put on right side of ring... record "0"
        // for left... "1"

        readSensor();

        int value = 0;
        if (gInputSensorR > gSensorThresholdR)
            value = gInputSensorR-gSensorThresholdR;
        if (gInputSensorL > gSensorThresholdL)
            value = -(gInputSensorL-gSensorThresholdL);
```

```
      gRecordBuffer[recordCount] = value;
      recordCount++;
      wait();
   }

   gRecordedCount = recordCount;
}

void modePlay() {

   int playCount = 0;

   while (1) {

      if (gMode != M_PLAY) break;

      if (playCount >= gRecordedCount) {
         gMode = M_NONE;
         break;
      }

      int value = gRecordBuffer[playCount];

      #ifdef DEBUG
      Serial.print("count: ");
      Serial.println(playCount);
      Serial.print("value: ");
      Serial.println(value);
      #endif

      if (value > 0) {
         moveMotor(MD_RIGHT);
      } else if (value < 0) {
```

```
      moveMotor(MD_LEFT);
    } else {
      moveMotor(MD_CENTER);
    }

    playCount++;
    wait();
  }
}

void modeSync() {

  while (1) {

    if (gMode != M_SYNC)   break;

    char command;
    if (Serial.available() > 0) {
      command = Serial.read();

      #ifdef DEBUG
      Serial.print("---> command: ");
      Serial.println(command);
      #endif

      if (command == '¥0') {
        // nop
      } else if (command == SELF_COM2) {
        moveMotor(MD_RIGHT);
      } else if (command == SELF_COM3) {
        moveMotor(MD_LEFT);
      } else if (command == SELF_COM1) {
        moveMotor(MD_CENTER);
      }
```

```
}

readSensor();
MOTOR_DIRECTION currentDirection;

if (gInputSensorR > gSensorThresholdR) {
  currentDirection = MD_RIGHT;
  command = 'R';
} else if (gInputSensorL > gSensorThresholdR) {
  currentDirection = MD_LEFT;
  command = 'L';
} else {
  currentDirection = MD_CENTER;
  command = 'S';
}

if (gSyncSentCommand == 'S' && command == 'S') {
   // nop
} else {
  if (state_motor_direction != currentDirection) {
    char* commands;
    char exclude;
    switch (currentDirection) {
      case MD_CENTER:
        commands = com1all;
        exclude = SELF_COM1;
        break;
      case MD_RIGHT:
        commands = com2all;
        exclude = SELF_COM2;
        break;
      case MD_LEFT:
        commands = com3all;
        exclude = SELF_COM3;
```

```
                break;
            }
            for (int i = 0; i < COM_LENGTH; i++) {
                if (commands[i] != exclude)
                    Serial.write(commands[i]);
            }
            state_motor_direction = currentDirection;
        }
    }

    gSyncSentCommand = command;
    wait();
  }
}
```

D. Pre-Test Survey for User Study 1

実験に関する事前アンケート（小学生以下の方は保護者の方と一緒に記入してください）

年齢：

性別：　男　・　女

配偶者の有無：　有　・　無

同居人数：　人

同居人との関係：

- 以下の項目について、当てはまるものにチェック（○）を付けて下さい.

	全くそう思わない						非常にそう思う
例）アンケートは簡単である				○			
	1	2	3	4	5	6	7

	全くそう思わない						非常にそう思う
1. ぬいぐるみが動いてくれたら良いと思ったことはありますか？							
	1	2	3	4	5	6	7
2. ぬいぐるみが動いたら嬉しいですか？							
	1	2	3	4	5	6	7
3. 動くぬいぐるみと遊ぶことは楽しいと思いますか？							
	1	2	3	4	5	6	7

- 以下の質問に答えてください。

1. 家にぬいぐるみは何個ありますか？

__________個

今もぬいぐるみを触っていますか？どんなときに触っていますか？

2. 現在、家にあるぬいぐるみについて詳しく教えてください（記入欄が足りない場合は声をおかけください）

	形状	大きさ	所有者	置いてある場所	そのぬいぐるみに関する思い出
例	くま	約40cm	長男（7歳）	テレビの上	祖父が息子の2歳の誕生日プレゼントとして送ってくれたもの
1					
2					
3					
4					
5					

3. 現在、もしくは以前ぬいぐるみで遊んでいましたか？どのように遊んでいましたか？

4. ぬいぐるみにどのような印象をもっていますか？

5. もしぬいぐるみが動くとしたら、どんな動きをしてほしいですか？

E. Post-Test Survey for User Study 1

実験に関するアンケート

- 以下の項目について、当てはまるものにチェック（○）を付けて下さい.

	全く同意できない						非常に同意できる
例）アンケートは簡単である				○			
	1	2	3	4	5	6	7

	全く同意できない						非常に同意できる
4. ぬいぐるみが動いて嬉しかった・楽しかった.	1	2	3	4	5	6	7
5. 簡単にぬいぐるみを動かすことができた.	1	2	3	4	5	6	7
6. 簡単にぬいぐるみの動作をつくることができた.	1	2	3	4	5	6	7
7. 自信を持ってリングを扱うことができた.	1	2	3	4	5	6	7
8. 多くの人がこの方法でぬいぐるみの動作を作れると思う.	1	2	3	4	5	6	7
9. この方法がぬいぐるみの動作を作る方法として適切だと思った.	1	2	3	4	5	6	7
10. このリングを使うのに沢山学ぶ必要があると感じた.	1	2	3	4	5	6	7
11. このリングを使うのに集中する必要があった.	1	2	3	4	5	6	7

- 以下の質問に答えてください.

リングはどのような点が使い易いと感じましたか？

リングはどのような点が使い難いと感じましたか？

- これが製品化された場合，いくらぐらいまでなら購入を検討しますか？

＿＿＿＿＿＿＿＿＿＿ 円以下

- 以下の項目について、当てはまるものにチェック（○）を付けて下さい.

	全くそう思わない						非常にそう思う
例）アンケートは簡単である				○			
	1	2	3	4	5	6	7

	全くそう思わない						非常にそう思う
12. ぬいぐるみが動いてくれたら良いと思ったことはありますか？							
	1	2	3	4	5	6	7
13. ぬいぐるみが動いたら嬉しいですか？							
	1	2	3	4	5	6	7
14. 動くぬいぐるみと遊ぶことは楽しいと思いますか？							
	1	2	3	4	5	6	7

アンケートは以上です．有り難うございました.

F. Post-Test Interview Questions for User Study 2

About the Relevance of Plush Toys in the User's Daily Life

Do you have many plush toys?

Do you play with them or do anything with them?

How do you play with them?

About the Play Experience Using PINOKY

How was the play experience? Describe your feelings.

Were you surprised when the plush toy moved?

Do you feel that you want to play with your plush toy more now?

There are already robotic plush toys like Tickle Me Elmo and the Furby. Do you see any difference between this and those? Which do you prefer?

Do you have any comments and feedback on the device? Was it difficult to use, or were there any behaviour or functionality which you would want to include?

Were there any past memories which you have recalled while experiencing this new style of play?

This is currently an individual play session. How do you think it will affect group play?

About "Play" in General

Have there been any previous toys or play experiences that you have found impressionable?

What is play to you? Do you think play is useful?

G. Interview Transcripts for User Study 2

<u>Participant 1</u>

Do you have any plush toys at home?

Yes. I have the small ones. Really small ones, which don't have ears or anything. And because I know that they will be too small for the device, so I didn't bring them.

But you brought them over to Japan with you?

Yes. I brought them here because I like them.

Do you usually play with them at home?

I don't really play with them, but I like to see them on my bed. So every time I make I bed, I will put them at the top.

So it just makes you feel good to see them.

Yes, and every time I hug them.

Oh, but they're quite small, right?

Just this one (gestures to the rabbit). I have one big one, the Weepy Sea Officer, which is like a puppet. I play with it.

How was the play experience just now?

First, I think it's cute to see my rabbit able to move like that. But somehow, maybe because the ring is too heavy and the rabbit's ear is too soft, it keeps falling over. And maybe also because it's heavy, sometimes it doesn't move, but it's pulled back.

What do you feel when it moved?

It looks cute, and I'm happy. People like to interact. Maybe if they can interact more, for example for the voice mode control, when you talk, it moves. But when you talk and you finish talking, and then it moves, maybe it is more real? Because it gives you the impression that it's giving you an answer.

So not really at the same time?

Yes.

Were you surprised when it moved?

If you give them labels that it can react to your voice, you won't be surprised. But you will expect that your toys will give you a response.

On the toy market today, there are toys that can respond to interactions, for example Tickle Me Elmo. You already know that the toy will move in a certain way. But with this device, while you know that the toy will move, you don't really know how the movement will be. Do you think that that makes a difference, or the fact that you know that it can move already makes it not surprising?

Because we know that it's not alive. If it gives you a really surprising movement, I think I'm going to cry.

Why?

What if it suddenly hit me? So I know that it can only move the ears… For me, to be able to see my rabbit moving already makes me happy. Like, "Oh! It moves!" It is already surprising. But to give it more interactive gestures may be good.

So, you feel that you need more and different types of interaction.

Yes.

Do you feel that you want to play with your toy more now?

I think so, because it's cute.

As compared to last time, when you just put it on display and talked to it? Do you feel like you want to do more things with it?

Yes, for example I have a video chat with my brother or sister and I can just play with it (acts out having a conversation with the caller, and then having a mock conversation with the plush toy and having it respond accordingly). But right now, I have to move it myself, right? So I can play with it, but it's obviously me controlling the toy. If my toys can look like they are moving of their own accord, and agree with what I'm saying, it would be cool.

As I mentioned earlier, there are already toys out there that can respond to human interaction. Do you feel that there is any difference between those toys and having your own toy be interactive? Which one do you prefer? Having your own toys move, or having one that you buy from the store move?

Somehow, it's better to see our toys move. Rather than we know that we can just buy Elmo off the shelf. Like, I have had this rabbit for one year, and I only talk to it alone, like "Oh bunny, I am so sad today". But somehow, if it can reply me back, it is surprising. And you already have the feelings to your toys. So when you put something, like energy or soul, it will be like a miracle.

Something like your toy is coming alive?

Yes, like Pinocchio.

That's actually why the device is called PINOKY.

Do you recall any past memories when you saw it move?

This rabbit, I got it from my brother. I miss him, and want to talk to him. So talking to the rabbit feels like I am talking to my brother.

So I suppose when you're playing with the rabbit, do you remember memories with your brother?

Yes, I will remember my brother. I feel like playing with him, even though it's impossible now since he is so far away in another country. That's why I love this rabbit.

Do you have any other toys or play experiences that you've found very impressionable?

It's not a toy, but I have this long pillow. I have one of it, which I think I got when I was five. Until today, and it's shrinking and really small now because it's losing the fluff inside. I used to talk to the bolster. I call him Santet, which in Indonesian means voodoo. Because I feel like talking to it when I'm sad. Sometimes I hit, sometimes I hug. But that thing is so understanding, because he never gets mad. I always thought that that thing is a character, not only a long pillow.

What is the whole idea of play to you? Do you think play is useful?

I think play is useful. I worked in the creative industry, now studying creative things. If you don't have this playful mindset, you will be always thinking inside the box. And if you don't play, you will be too serious. And somehow, adults have killed their imagination because they thought that they need to always think of reality. But actually, imagination is the thing to keep you alive. And maybe you will see me become cheered up and happy, because I keep my imagination. I think that, for example, real life gets you really tired and exhausted. Somehow, you just have to enter your imaginary world from the toys. That's why people have hobbies, right? They imagine themselves as professional in something, in their own box. But that's important.

Okay, that sounds a little bit bordering on delusion, but I guess that works for them.

Well, when people only live in their imaginary world without thinking about the real life, that guy is called "crazy". But we have to keep our imagination and playfulness to keep us okay.

I feel sorry for people who think too seriously, because they will be too tired sometimes.

Participant 2

Do you own any plush toys at home?

3.

How about back in your country?

There are a few, maybe 3 to 4. There might be more, but in my bed there are 3.

Do you play with them, or just leave them on display?

They just lie there. There's a Nemo, there's a Hulk…

Are they gifts?

This one (that I brought to the user study today) was a gift, the Stitch was part of a Halloween costume, the Hulk was a gift, and Nemo I think I got it myself.

How do you find the play experience?

It's cool. In my opinion, maybe part of it is because there's a lot of trial and error? Like in many parts I was trying, like "oh, here!" and then it doesn't move at all, and then "here!... No". And then when I put it here…

Oh it didn't move at all?

No, maybe it was because it's too short. I guess depending on the animal, for example if I put it here, maybe it will just flop around. But for example when I put it at the head, it was a lot better because it was like saying yes.
Maybe because of the emotional connection. Like if it just moves the legs… When I was trying the leg, it was just making small motions. So, I don't really relate. But when I saw him say "yes" (the toy moved its head), it was more like "oh, he agrees!". Maybe it's because we think, like, "yes" means he understands and he agrees.

So it's more of the location?

In my opinion, you relate to something. Because again, when it moves the arm, I could still imagine that it was just a machine moving the arm. But when I saw him move the head, it was a lot more like "oh! I can talk to him and he would reply". It's like, he's alive, but it's more emotional. I liked it when he reacted with the head.

How you do feel when it moved? Was it surprising? Were you happy?

Yea, it was surprising. Because you don't really know what to expect or how to react. Like how the toy would react to the device.

Even though you knew that this thing would make it move?

I knew it would make it move, but well I think each part got a different reaction. Like for example, the tail didn't move even though I spent some time with it.

Does it make you feel like you want to play more with it?

Well, I'm 27 so it'd be pretty strange if it does. But I do imagine, for example, my niece – she's 3 – I do imagine that she would be very excited to put it in a toy and see the reaction.

Do you feel that there is a difference between using your own toy and a store-bought robotic plush toy? For example there is Tickle Me Elmo, and others where you can poke the toy and have it move.

Yea, but what if the kid doesn't like Elmo? That's the problem. Like for example, if I have this one, this toy was a gift. So maybe I have a very special connection to it. So yea, if I can choose between moving this one or moving Pikachu, I would take this one.

So you feel that the special connection with this one makes it better?
Yea, because it makes it more personal.

Any feedback on the hardware? Was it hard to use?
No. Well obviously this is a very rough hardware. I imagine that a consumer model wouldn't have, like, "okay you have to plug this cable in here…". Obviously for a prototype, it's easy and straightforward. The only thing for me that I struggled with was the synchronising. When I went from this device to another one, I thought I had to synchronise the remotes somehow, but it turned out to be just a different coloured button on the remote control that I had to press. I thought it was like pressing white and white, similar to how Bluetooth synchronisation is done.

Do you remember anything, though? Like any past memories you've hard with the toy?
Yea, definitely. Like, this was a gift from an ex, and this was a gift from Veronica, so I do know where they all come from.

Do you have any previous toys and experiences which you found impressionable?
I was obsessed with dinosaurs when I was a kid. So most of my toys were dinosaurs. And I was lucky that I had a house with a big garden. So I was all about the setting. I don't ever recall playing with my dinosaurs inside the house. It was always like "oh I have to go to the jungle". For me, probably a memory would be the setting. Maybe as a kid, it enhances the experience. I used to take my dinosaurs to the garden and pretend that it was like a jungle.

Would you think that it would be different for group play, though?
I'm not sure if it would be enhanced, or if it would probably be better as a single-player experience. Like many kids usually, especially now, many of them are single kids so they're alone. Maybe they're in the car, and they're just like "oh, I have my toy". Maybe the parents are driving. Maybe in that situation, the interaction with the toy can be more personal?

Like in a "you're my buddy" way?

Yea, because for me, if I'm with other kids, probably I want to interact with them more than with the toy. But when I'm alone, maybe I would like some interaction with my toys, Mexico and Irish Monkey.

What is the idea of play to you? Do you think it's essential?

Of course. Do you mean like playing with a toy, or playing in life?

Playing in life.

Yea, I'm of the idea that we're here to play and to have fun. Like even if you're going to the convenience store, you can have fun along the way. To enhance life.

<u>Participant 3</u>

Do you have many plush toys at home?

Not many, maybe around 4 or 5.

Do you play with them, or just put them there on the shelf?

Most of them just sit on the shelf. I played with them when I was younger.

How do you usually play with them?

Well, he's the exception to the rule (the plush bear she brought to the user test) because I still play with him.

So you *do* still play with your plush toys.

Yes, he sits on my bed. We probably don't play, we probably talk more.

Like "I'm feeling terrible today"?

That, and when you're feeling good as well.

How's the experience when you saw him move?

It reminded me of when I was really little, my mum would kinda animate the bear, and she would bend his head or make his arms wave. It would be like "Goodnight, Veronica!" (demonstrates the bear waving its arm). So it was kind of spooky, because it was reminding me of what my mum did, but also it's like he's saying by himself "Hey, Veronica!"

So it's like he's coming alive?

Yea.

Were you surprised when he moved?

Yes. It's kind of surprising, because you're not used to seeing him move on his own.

Even though I've told you that this device makes things move?

Yes, but it still gives you a feeling of like, you know, surprise. Or like, shock.

Do you feel like you want to interact with him more?

Yea, well he's far more animated and far more alive.

You know of toys like Tickle Me Elmo where you poke them…

I had a Tickle Me Elmo.

Do you think that this is different as compared to those, because these are all robotic plush toys that can move.

I think the big difference is that you already have a bond with your toy before you put these on. And you're putting them on yourself. So you're kind of expecting that you're going to have some form of interaction. But like I remember with my Tickle Me Elmo, it scared my little cousin so much, because he didn't know what to expect, and he couldn't see what was making it work. So then it was scary, like "it's not a teddy bear, it's a robot".

Scary?

Yea, he was terrified.

The impression that I have was that people were shocked when they heard it laugh, and they find it fun.

Well he was about 2 or maybe 3 at the time, and he was absolutely terrified. I think the big difference is that you can see what makes this work as well. So I would imagine that this would be a lot less scary.

Which one do you personally prefer, though? A toy that you don't really have a bond with that moves, versus one which you have a bond with, or do you think that there is no difference?

I think there's a difference. I think that a toy that you already have a bond with, and you probably made up stories about it yourself… it's more fun if that become animated and moves, compared to something like Tickle Me Elmo, which just feels like he came out of the box that way.

Do you have any comments on the device? Too big, too chunky…?
I think my teddy bear might be too fat or something, because I was trying to put these ones on, but it took a little while to find the right position to be able to clamp him in there. But maybe I just needed a slightly bigger sized-ring. For the legs it was too big, but for the arms it works fine once you find the right angle.

Do you have any previous toys or play experiences that you found impressionable?
Like I said with my mum, that was one of my earliest memories. It would be my mum animating soft toys.
Not so much of the toy itself, but the interaction that left the impression, you'd say?
Yea, definitely. Otherwise, I'm just trying to think of other toys that I had when I was little… When I was a baby I had a squeaky carrot, and apparently I loved my squeaky carrot.

Do you think that using the device would change in a group situation, or do you think that it would be the same as solo play?
I think it would probably change in a group situation, because I guess there would probably be a lot more interaction between different people and their toys? And maybe more interaction between the toys as well. And I guess you could synchronise them, right? Because you can use the same colours on the other toy, and that way you could kinda be playing with your friend's toy. So yea, it would be different in a group.

Generally, what is play to you? Do you think it's useful? Or it doesn't really serve a function?
I think it serves a really important function in that it's very healthy. I think that play is something that it's very sad when you see adults who've lost that ability to play with things. And sometimes it's just transferred into a sport or something, like golf or another very adult hobby. But I think that kind of wanting to be able to do something just because it's fun, rather than to

perform any kind of other function, I think that a pretty healthy thing for you well-being and state of mind.