Project PEAC: A Personal, Expressive Avatar Controller for the Operation of Virtual Characters

by

Kristopher B. Dos Santos

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Signature of Author: ______________________
Department of Mechanical Engineering
May 10, 2010

Certified by: ______________________
Cynthia Breazeal
Associate Professor of Media Arts and Sciences
Thesis Supervisor

Accepted by: ______________________
John H. Lienhard V
Collins Professor of Mechanical Engineering
Chairman, Undergraduate Thesis Committee

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Abstract

The purpose of this thesis was to design and construct a prototype for the control of virtual avatars in a virtual space. It was designed with the intent to feature multiple interfaces such that the user would have many options to control a virtual character. The design was to have kinematic interactions (changing the physical pose of the interface), proximal touch (enabled by capacitive sensing), whole-body movement (enabled by an internal measurement unit), touch pressure (enabled by QTC film), and finger-tip gesture (enabled by a touch screen). After many iterations of a mock prototype, a test was created to determine whether certain affordances of the controller would be used in controlling a virtual character. The mock prototype featured objects that represented the proposed technology for the controller. Participants in the test viewed example animations from two different virtual worlds, and were asked to emulate the actions and emotions shown on the screen. They also rated the controller on the different actions and emotions on a seven point Likert scale for comfort and intuitiveness. It seemed that having a figurine that could pose into the positions for actions and emotions was very helpful and was received well from the ten participants. The other technologies were not used as much, and so the results of this study will assist in redesigning the controller to affectively utilize the given technologies.

Thesis Supervisor: Cynthia Breazeal
Title: Associate Professor of Media Arts and Sciences

Acknowledgements

Without the assistance and guidance of many, this thesis would have not been possible.

First and foremost, thanks go to Prof. Cynthia Breazeal for the supervision of this project and all of her words of wisdom and guidance. She was the one who presented this problem, and with her assistance, a physical solution (even if not fully functional) came to light.

Thanks must also go to Sigurður Örn of the Personal Robots Group for assistance and guidance on how to go about testing this device. He was there to calmly suggest how to go about testing what was created, and allow the project to not get so complicated at the last minute. He was also able to provide a lot of advice on how to run a human test study, and how to actually process this data in a statistically significant manner. Siggi, ég skulda þú a einhver fjöldi maður, takk fyrir allt!

As well, Dan Stiehl of the Personal Robots Group deserves thanks for being a great mentor from the very beginning. Working for him and the Huggable Project provided a lot of experience that assisted in the completion of this thesis.

Thanks also go to Tom Lutz of the MIT Media Lab for assistance in rapid prototyping, even though it did not quite fabricate as planned.

The Personal Robots Group deserves thanks for the use of their facilities and their graduate students for brainstorming, advice, and guidance. They are an amazing group of individuals, and without their help, surely this project would have not progressed as it has.

Thanks must also go to Anthony Merriman, Class of 2012, for providing World of Warcraft character animations for the use of demonstration in the human test study.

Lastly, the author would like to thank his parents for the immense support that they have given him for the past 22 years. They have always been there to provide, guide, and just simply listen. Without them, the author would have not have made it through these past four years at MIT. Gracias para todo, e eu te amo ambos.

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1 Introduction

The use of virtual interaction has soared in the past decade, with the Internet and various applications facilitating this growth. Massively multiplayer role-playing games such as World of Warcraft and the Sims Online has led to hundreds of similar virtual environments for users to explore, play, and most importantly, socialize. From SecondLife to Animal Crossing, more and more games provide the opportunity for people to step inside a virtual avatar and experience a whole new world besides their own. However, it seems that the way to control these avatars is still through old methods, i.e., a mouse and keyboard, or a gaming controller; something with buttons and analog sticks. People have already witnessed the future of gaming control with the Nintendo Wii's "Wiimote" and Microsoft's Project Natal, but the user is still faced with a relatively high level of abstraction. Is it possible to offer more "feeling" to a controller? Can a controller offer more interaction within a virtual environment, while still being confined to a size that fits in the palm of a hand? And do people actually want this?

1.1 Project Objective

The objective of this thesis project is to develop and prototype such a controller than would allow users to affectively interact in a virtual world. The controller would be able to utilize different technological components in order to give users complete freedom in expressing themselves in the virtual world. The scenario is set as follows: imagine that a person approaches a large screen that shows an environment and a virtual avatar. The person would be able to pull out of their pocket a controller that would give them complete control of the avatar, and allow him/her to interact with objects in the environment and other avatars. The controller should support kinematic interactions (changing the physical pose of the interface), proximal touch (enabled by capacitive sensing), whole-body movement (enabled by an internal measurement unit), touch pressure (enabled by QTC film), and finger-tip gesture (enabled by a touch screen). Through combinations of these various interactions, the user would have a wide variety of expressions to use, from showing happiness to a friend to adding physical emphasis in virtual storytelling.

The proposed uses of these interactions enable the virtual avatar in different ways. The potentiometers would enable physical joints to translate to moving body parts of the character.

Touch screens and capacitive sensing would allow for activation of certain options, such as accessing menu items or activating a location on the avatar's body to which it reacts. Pressure sensing would create a push button effect to certain areas of the controller, such as activating certain modes of the avatar (grabbing, first-person view, etc.) [1].

For the purpose of this thesis, the main objective is to construct a proof of concept of this controller. This prototype should be able to illustrate (if not completely enable) the types of interaction capabilities of the controller. It should also allow people to think about the idea of remote puppeteering and multiple interfaces for the control of virtual characters, and whether or not these various interfaces are necessary or desirable.

2 Background

2.1 History of "Sympathetic" Interfaces

To better understand the task presented, the scope of pre-existing technology must be described. For instance, the word "sympathetic interface" was first used to describe a plush toy that used various sensing technology to alter the actions of a virtual avatar [2]. Johnson *et al.* developed this toy as a semi-autonomous controller, a "voodoo doll" similar to the Active Blobs developed by Isidoro and Sclaroff [3]. In the Active Blob case, the actions of the "voodoo doll" were seen and interpreted with motion detection software, and thus, the manipulation of the blob translated into actions for the avatar to perform. However, these projects do not seem to fully control virtual avatars. So far, they only can control limited movements or actions. Lee and Ryu [4] developed a hydraulic system for controlling construction robots in the virtual and physical space. The idea was to create a system compact enough for the user to have better mobility than existing haptic systems that limit users with excessive wires. The mechanism itself fits within the span of the user's full arm, and provides a skillful manipulation of a virtual hand, but is still huge and bulky for the purposes mentioned above. To reference something very small and compact, Kumazawa [5] developed a compact haptic device that used finger reactions to control objects and provide feedback to the user. Seesaw-like projections interact with the fingertips as the user presses one side of the arm, creating tactile feedback. This provides a low-cost, mechanical method of feeling "virtual keys" within a "narrow area" (4).

2.2 The Huggable's Sympathetic Interface

The use of a sympathetic interface has proven to be very effective in controlling 3D characters and their physical robotic counterparts. In the Personal Robots Group of the MIT Media Lab, there exist two robots that utilize such a control scheme: the Huggable Project and MeBot. Although the robots were designed for different purposes, both have an ability to be used in telepresence. The operator of the robot can communicate through it via an internet connection, and through visual/audio input, the operator can see and hear the surrounding in which the robot is located. What is unique is that these robots have controllers that mimic the shape of their robotic counterparts to allow for a more intuitive control of the robot. For instance, the Huggable Project, designed by Dan Stiehl, uses a passive controller that resembles a smaller version of the robot itself.

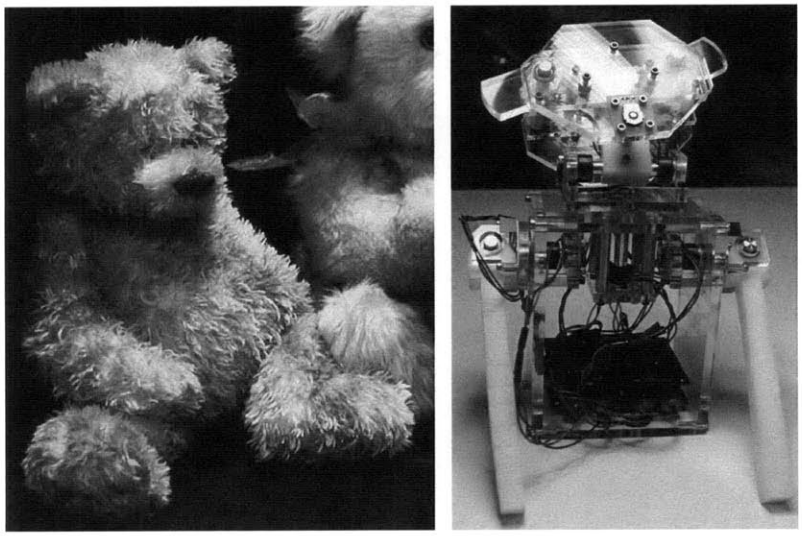

Figure 2-1: The sympathetic interface used to control the Huggable Project. It has an equal amount of degrees of freedom to the actual robot, and can control each one.

The Huggable Project is a robotic teddy bear created for usage in health care, education, and long distance interaction. The sympathetic interface for this robot allows for more control of the degrees of freedom (currently, there are eight), and can be used to exhibit gestures that are not already choreographed for the Huggable to do. Rigged with a potentiometer for each degree of freedom, the sympathetic sends voltage differences that are translated into angle data to the robot via the C6 behavior system. As a result, moving the arm of the sympathetic controls the arm of the Huggable in real time. However, the sympathetic in its current state is not a full haptic device because of its inability to reset itself to a "home" position, and cannot give force feedback to the operator. The joints are all unrestricted, freely moveable with ball bearings. Fortunately, the robot itself goes to an idle state when not being "puppeteered" [6].

2.3 MeBot's Sympathetic Interface

One solution to the free joint problem, which was used in the sympathetic controller of MeBot, was to allow the controller to be manipulated like an action figure. The MeBot, created by Sigudur Orn, is a robot created for socially embodied telepresence.

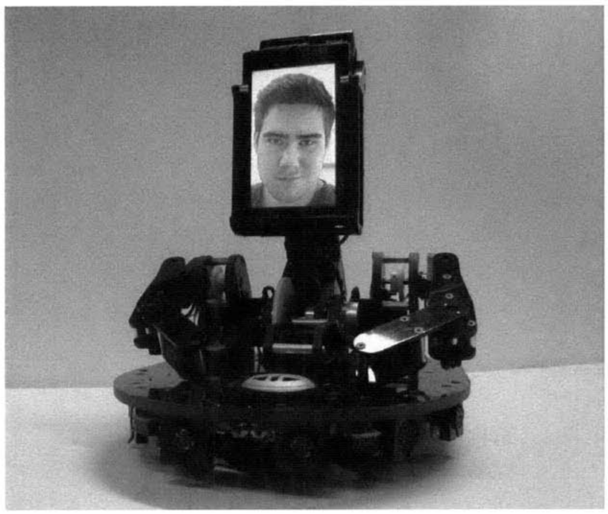

Figure 2-2: The MeBot, a social telepresence robot designed by Sigudur Orn.

To control the head of the robot, a program translates the movement of the operator's head via facial tracking to coordinate the neck and head movements of the robot. To control the arms of the robot (which contained three degrees of freedom each), a controller was made with passive elements and potentiometers to translate movement of these arms to the robot in real time. Instead of ball bearings, the arms were connected using 1/4" Delrin rod stock that was milled to fit the potentiometer's specs (4mm diameter hole with a __ deep flat). The arms were fabricated out of Delrin plates that, at the joints, were drilled to a loose fit (+0.005") for the Delrin rod to fit. However, the plate at which the potentiometer was mounted was designed like a clamp-on shaft collar that could be tightened to control how stiffly the joint could move.

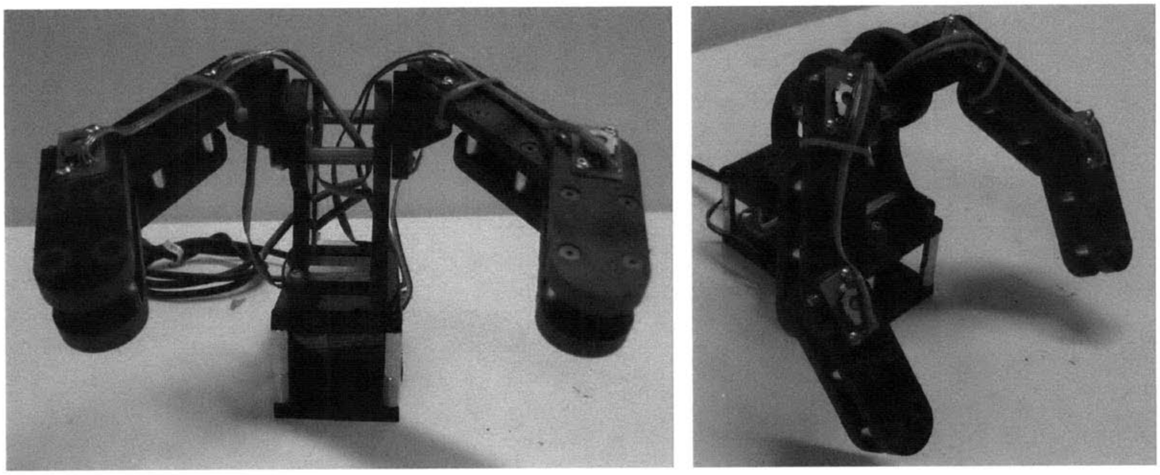

Figure 2-3: The sympathetic interface for controlling the arms of the MeBot. All potentiometer information is sent via USB to be processed into arm movement.

With the adjustable friction, the controller could be "posed" into position; much like a toy figurine would be posed. As the controller was released, the arms would stay in the posed position, and the robot would default to an idle position. Unfortunately, this controller also does not contain force feedback, but it can allow for visual feedback on its limbs, since communication between the operator and the robot's environment (and anyone in it for that matter) can allow the operator to use the head and neck motion to become aware of obstacles in the path of the robot's arms. In its current form, the controller is simple to manipulate, easy to grasp, and translates movements relatively well (with minimal motion delay) [7].

3 Proposed Technology

3.1 QTC Film

As stated in the objective, certain technologies are proposed for this controller in order to engage multiple levels of interaction with the virtual character. One such technology is quantum tunneling composite, or QTC film for short. QTC film is developed by Peratech Limited, and is a material that combines metal filler particles with an elastomeric binder. The result is a lightweight, strong, and malleable material that can transform from insulator to conductor with variable pressure. As a comparison to carbon composites, QTC film is much more sensitive to pressure change and the bounds of minimum and maximum resistance are much greater. The spiky nature of metal-elastomer particles allow for a buildup of electrons and a reduction of the effective potential barrier through which the electrons tunnel. This also reduces the amount of energy needed for the electrons to travel. QTC Film, due to its versatile nature in pressure sensing, would be ideal in showcasing levels of certain actions in the virtual world, such as exhibiting grip to pick up something or pushing around the character. It would also serve as a durable touch screen for finger tip gestures and contact [8].

3.2 Capacitive Sensing

As a complement to the QTC film, capacitive plates are also proposed for use in touch capabilities. For the Huggable Project, a "sensitive skin" was built by using electrodes implanted into circuit boards to create electric field sensors. The sensors are designed to monitor the flow of electrons between objects and themselves. An alternating current runs between the object and the sensor due to the reversal of charges of the alternating voltage. This current is affected by the capacitance between the two, and based on the distance between the object and the sensor, the dielectric property of the material, and the area, the capacitance will change [9].

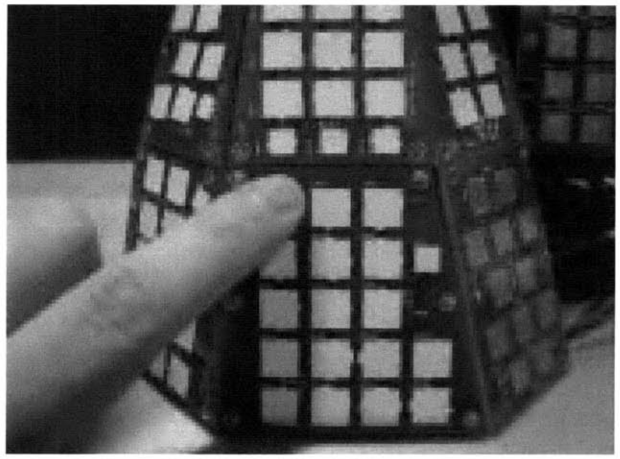

Figure 3-1: An example of the electric field sensors used in the Huggable Project's "sensitive skin".

The Huggable's "sensitive skin" was fine-tuned to react highly to human contact, and was coupled with temperature sensors to distinguish between conductive materials like aluminum. The possible use for capacitive sensing in this controller would give a similar effect, in that the virtual character could react to human touch. Specifically, if the operator wanted to tickle the character or provide a warm gesture, the capacitive sensors can allow the controller to sense human contact and have the virtual character react accordingly [10].

3.3 Inertial Measurement Unit

For the ability of sensing controller tilt and movement in space, it is proposed to use an inertial measurement unit (IMU). A standard IMU uses a combination of gyroscopes and accelerometers to measure translation and rotation in space. The accelerometers convert changes in internal capacitance to a signal that is translated into acceleration. The gyroscopes use their resistance to rotation to determine the angle at which the device is rotated. For example, Sparkfun Electronics offers 5 degrees of freedom in an IMU that combines a dual-axis gyroscope (IDG500), and a triple-axis accelerometer from Analog Devices (ADXL335). The whole combination has a 0.1" circuit board footprint and weighs less than 2 grams; hence, these devices can become very small [11]. Just an accelerometer containing three axes, such as the LIS302DL from STMicroelectronics, covers very little volume (3.0x5.0x0.9mm). A small device such as this could be placed in the device for object orientation in the virtual space [12]. Also, the virtual character could react in certain ways due to the motion of the controller in the physical space.

3.4 Potentiometers and Encoders

Lastly, it is proposed that some sort of manipulation of the controller is required to allow for a more engaging experience in controlling the virtual character. The idea is that certain parts of the controller can be jointed and positioned, and this data would be sent to the character to move into certain positions. This is done using potentiometers, variable voltage dividers that can change their resistances based on the position of their divider. For this case, rotational potentiometers would be used. The turn of the divider creates a difference in resistance proportional to the angle of turn. This way, the output voltage of the potentiometer can be converted into a position for a joint to move. Currently, the potentiometer in use for many of the projects in the Personal Robots Group is the Panasonic EVW-AE4001B14 variable resistor.

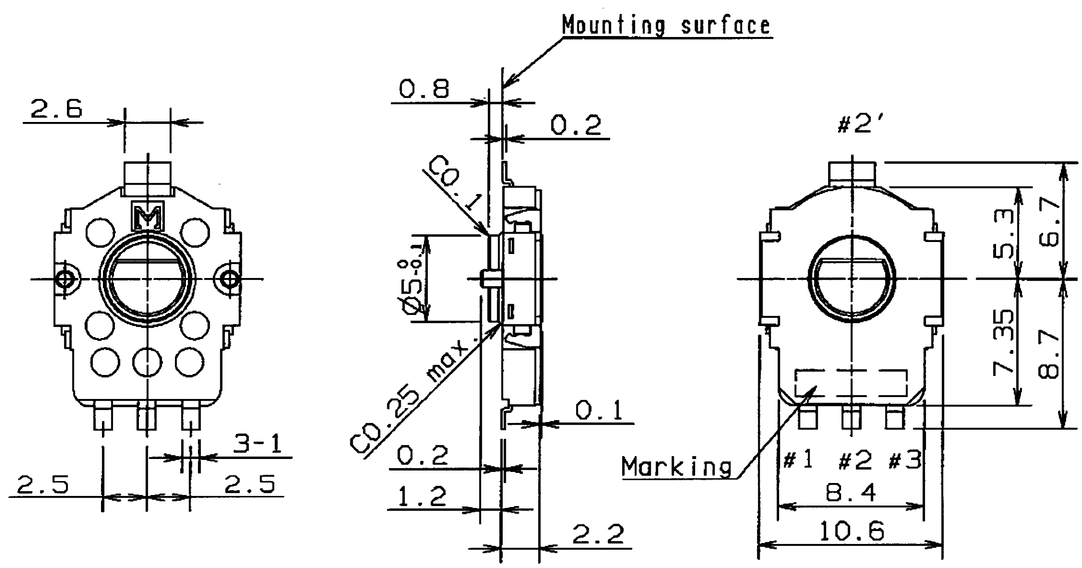

Figure 3-2: Part drawing for the Panasonic EVW-AE4001B14 variable resistor.

Its flat, slim profile (2.2 mm thick) and its small size (10.6x15.4 mm) make it an ideal potentiometer for tracking small joint movement [13]. Another option is to use a no-contact magnetic encoder, such as the AS5030 from Austria Microsystems. The encoder is able to track the angular movement of a round magnet for 360 degrees of rotation, and is very small (recommends a magnet diameter of 6 mm). There are also multi-axis encoders that work like joysticks; this could be used for traversing the virtual environment or looking around the space [14].

4 Design Process

4.1 Initial Concepts

The initial stages of developing this controller involved three different concepts. The first concept was labeled “compact”. This design would feature the most common of controller features, such as buttons and analog sticks, but would also contain one or more touch surfaces in which different interactions can take place.

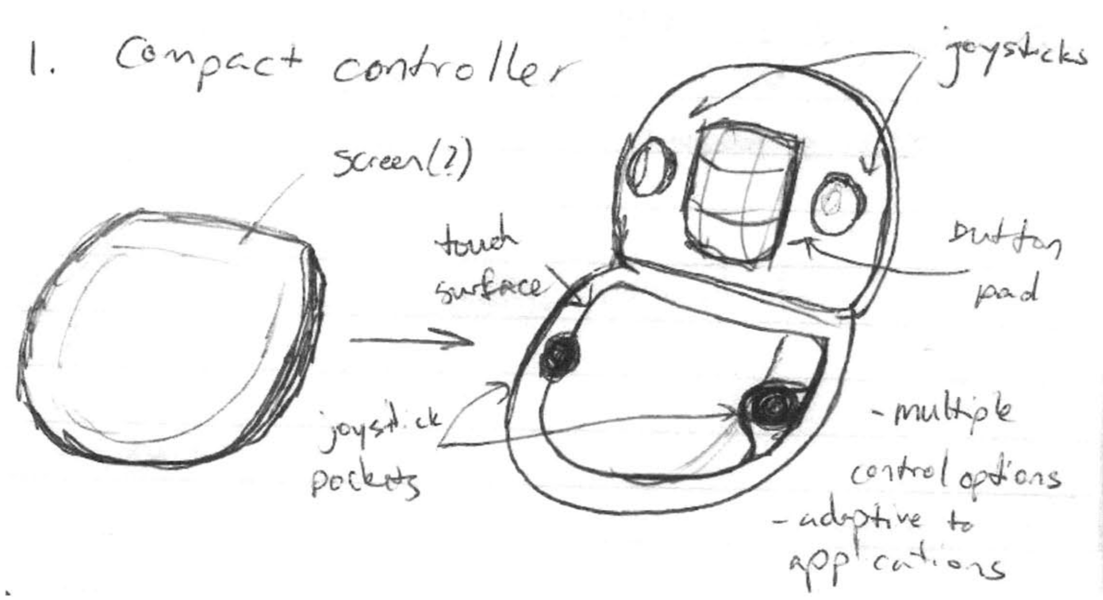

Figure 4-1: Compact controller sketch.

The idea behind this design is to fit as many control options into a very small space: a compact, foldable concept. The user would be able to walk up to a large screen displaying the virtual environment, flip open the device, and begin controlling the virtual avatar and interacting within the space.

Another concept (inspired by the Active Blobs) was centered on interpretive control of the device; thus, it is labeled “interpretive”.

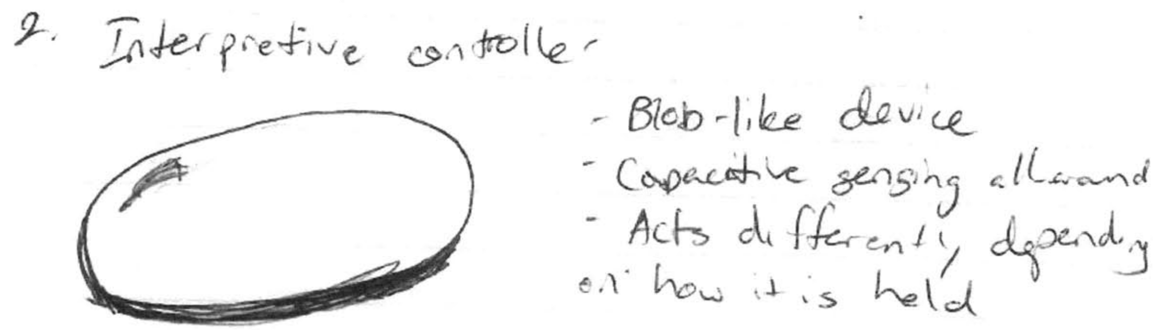

Figure 4-2: Interpretive controller sketch.

The controller would be very simple: no buttons, no joysticks, but pure touch sensing. The surface of the device would be able to sense the position and orientation of the fingertips and palm, and act as different control schemes based on this information. Paired with accelerometer or IMU data, this form on interpretive control would encompass a variety of control schemes by using the visual information the user takes in from the screen as feedback for how to hold and operate the controller.

One last idea to pursue was a more collapsible design that can be physically manipulated by the user to suit the needs of the task in the virtual environment. This concept, labeled "transforming", would be able to fold out and moved around much like an action figure toy.

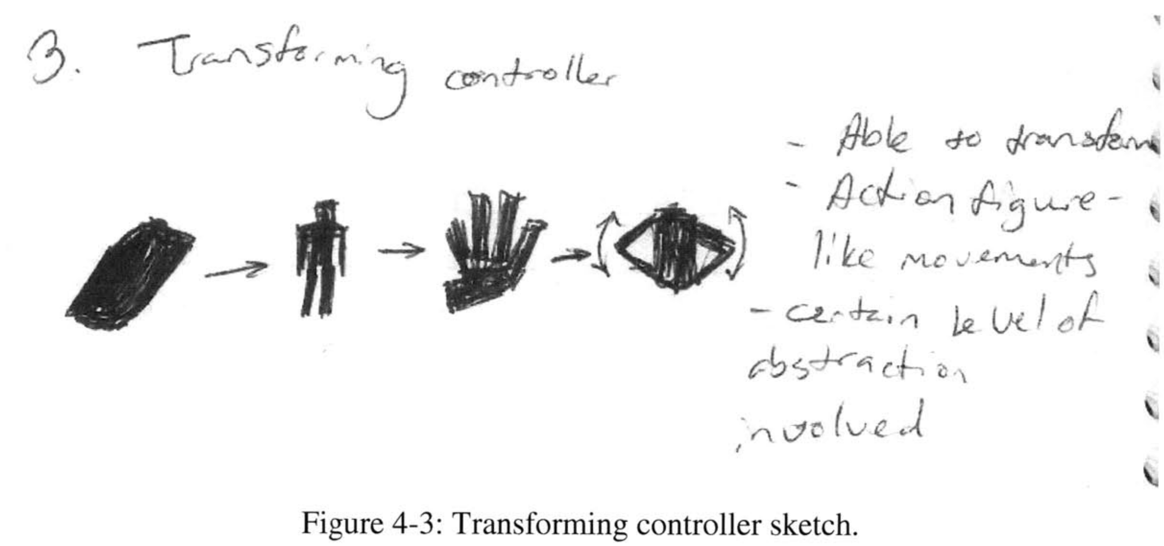

Figure 4-3: Transforming controller sketch.

The initial design would contain a main "body" with four long digits and a short digit; this was to provide the user to create a human figure for full-body avatar control. The idea was then to be able to transform this controller into more defined shapes for simplicity of controlling virtual objects/parts of the body. For instance, the digits would have mini-straps that attach to the thumb and fingers, thereby providing virtual hand control. Various configurations would also allow for more control options, such as vehicle steering or pen control.

4.2 Discoveries and a Narrowed Down Concept

Upon research of existing designs, the "interpretive" controller seemed to already exist – as the "Bar of Soap" developed by the Object Based Media Group of the MIT Media Lab. The idea behind this device was similar to the concept for the "interpretive" controller. Based on the contact between the human hand and the device, and how the device is oriented in 3D space, the device will act as the device the user wants to use. For instance, holding the device like a camera will allow it to act as camera; holding it like a remote will give the device remote properties. The device in its current version contained one accelerometer, 72 capacitive sensors, and two low-power ChLCD screens. It was able to recognize interactions with 95% accuracy [15]. Although the "Bar of Soap" did not control virtual characters, the planned concept would have been very similar, and was scrapped.

As for the remaining two concepts, both had their merits and limitations for controlling virtual characters. The "compact" concept seemed to contain all the necessary technology, but was not unique at all. The "transformative" concept had the ability to change shapes for different needs, but had no plan for visual feedback without containing screens. After consulting with Dan Stiehl and Cynthia Breazeal of the Personal Robots Group, the only reasonable option was to combine the two.

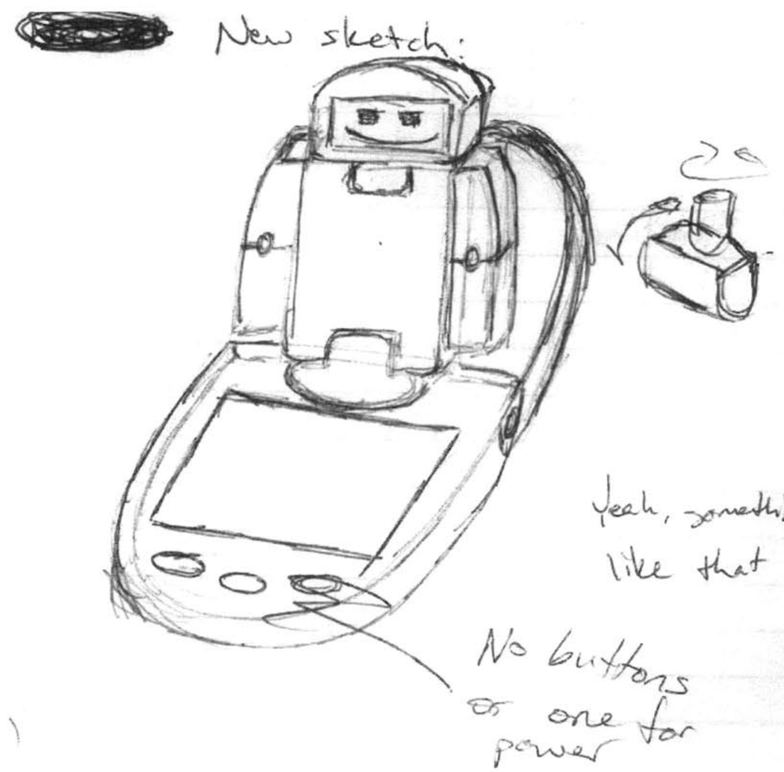

Figure 4-4: Combination concept sketch.

This new concept involved the foldable form of the "compact" concept, while containing the "transformative" concept as an interactive component. Two touch screens would be placed on the device: one on the cover (for remote control purposes) and one on the inside base (for menu options or finger gestures). The device would contain a figurine with joints that could be posed for avatar movement. It was also suggested to place a tiny screen in the head of the figurine to represent facial expressions created by the user. It even could be fitted with QTC film or capacitive sensor plates to add more interaction with the figurine.

Once this form became conceptualized, the concept needed to be solid modeled. For pocket-sized operation, the device needed to fit in the palm of the hand. In this case, the model started from the foundation of the approximate area of the human hand (7.4" long by 3.1~3.3" wide). However, the device could be a bit longer once unfolded, as long as it is no longer than 125% of the length of the human hand.

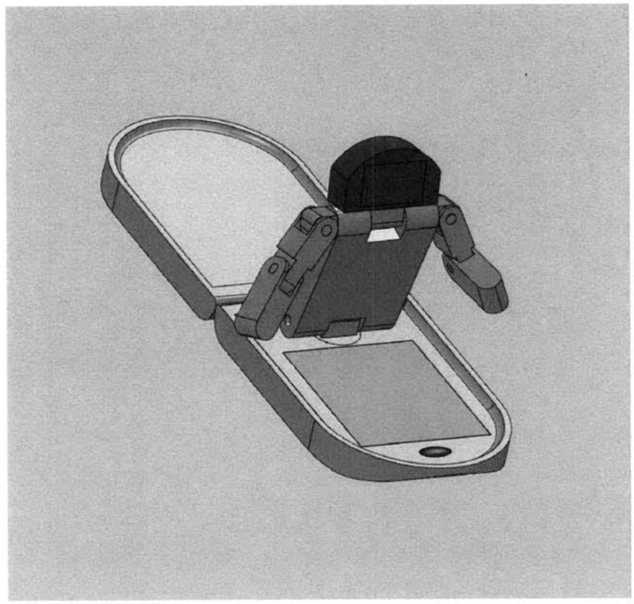

Figure 4-5: SolidWorks model of the combined concept.

According to St. Venant's Principle, this factor would prevent the device from falling over the hand and give stability while balanced in the palm [16]. Therefore, the two halves of this concept had a base area that measured 4.625" long by 3" wide, and compacted to be 1" thick.

This initial solid model had a shelled-out top cover that would house the touch screen on the top of the device. This top cover also served to protect the figurine that would provide joint motion control. The base was intentioned to house all of the electronics: the IMU, the battery, the processors for all of the potentiometers, and so on. On the top surface of the base, a push button and a touch screen provided an on/off switch and a touch screen that could be capacitive, pressure sensitive, or resistive. The user would toggle menus on this screen for certain actions, and even have the ability to write or draw things on this surface. The figurine would also be shelled to contain potentiometers for the joint movements. The sensing plates would be placed on the outside, while all the necessary wiring wound be encased and run down the figurine, possibly through a small pipe-like "spine". The head would contain some sort of video screen that would display the simplistic interpretation of the avatar's facial expression, either in "emoticon" format, or other. All parts for the figurine were to be molded or 3D printed, then fitted with the necessary components. For the initial concept model, the joints were merely press-fits for placement purposes. The concept was to have in total 10 degrees of freedom: two at the base of the model for rotation and leaning, two in the head for similar motions, and three in each arm for shoulder and elbow movements.

4.3 The Foam Model

To gain a physical grasp on this concept, a prototype was constructed of high-density foam. The parts were converted into three-view drawings, then printed out to be cut out and taped to cut pieces of the foam.

Figure 4-6: The foam mockup of the concept.

One view was cut first, then the other, using a band saw. Any holes going through pockets were drilled first, and then pockets were cut using the band saw. 1/8" fiberglass rod stock was used for shaft material. The unique pockets in the base were milled using a 3/8" end mill on a Sherline Mini Mill. The resulting model gave a good idea of the size of the controller, but was very flimsy, and hard to maneuver. This model could not accurately give a feel for the manipulation; the shoulders were not robust enough and the model was not properly secured at its base. The weight of the figurine made it fall out of its rotary slot, and therefore could not give an accurate representation for rotating the figure.

4.4 The Attempted 3D Printed Model

After consulting Cynthia Breazeal, the waist degree of freedom was added to the figurine to give it more possibilities for expression.

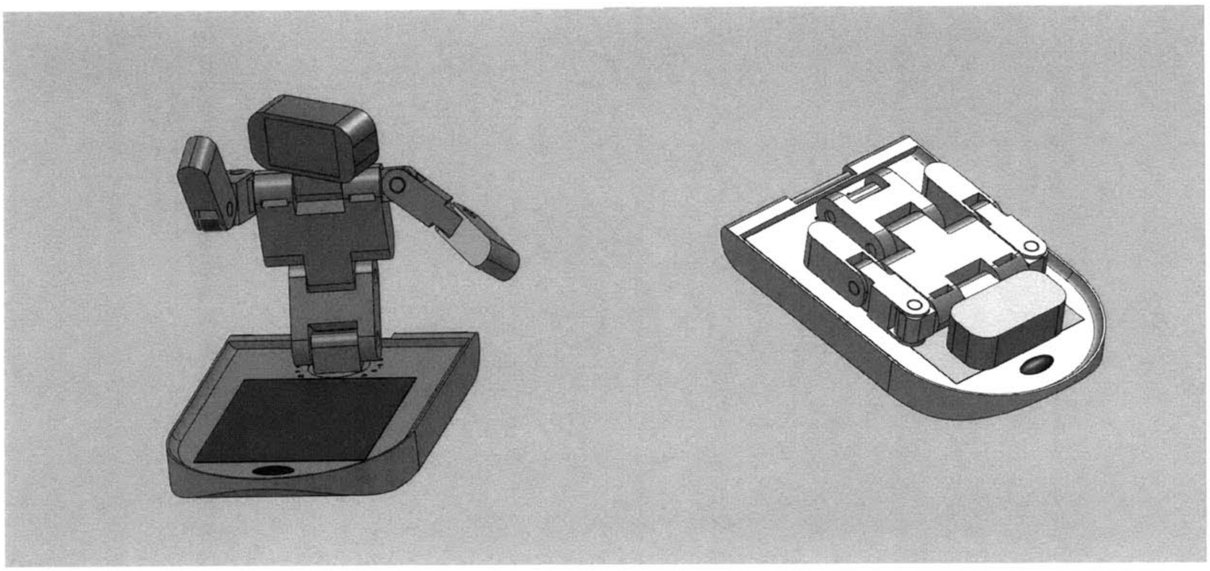

Figure 4-7: The new SolidWorks model of the concept (left) and the model prepped for 3D printing (right).

With a waist, it was possible to create more actions, such as bending down or sitting. In order to have a better physical feel for the controller, it was remodeled for 3D rapid prototyping.

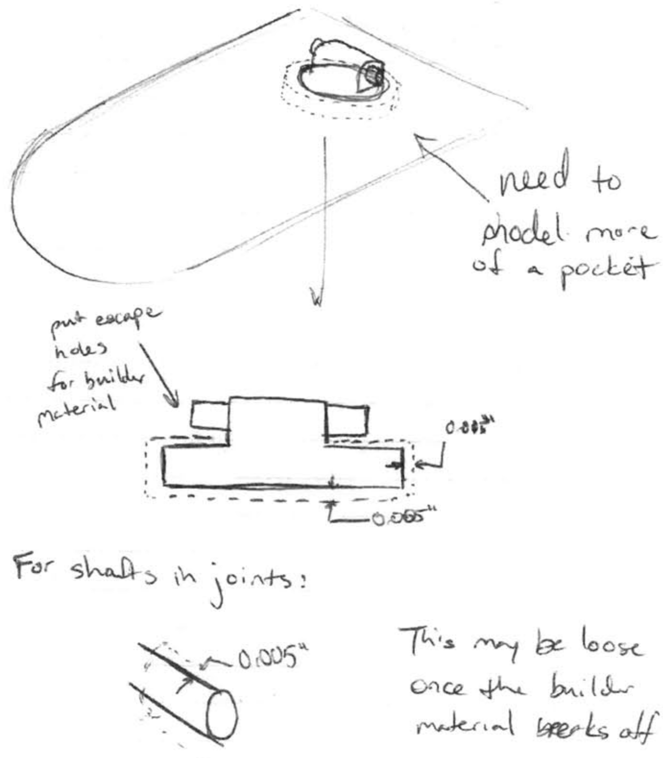

Figure 4-8: Sketches of how to account for builder material in rapid prototyping the concept and allowing the free joints to move.

The joints were spaced such that builder material could define the separation between shaft and hole, and extra holes and slots were put into certain areas so that builder material could be cleared. An offset of 0.008" was used to space all of the moving parts in the figurine. With this configuration, the joints were going to be very loose, but the intention was to gain a physical sense of the figurine's freedom at its joints.

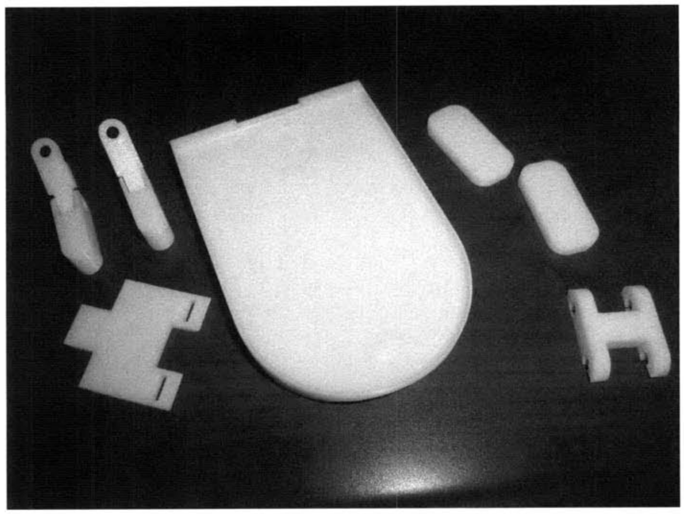

Figure 4-9: Resulting pieces of 3D printing the concept.

Unfortunately, the 3D printing process failed to create a fully operational model, since the conversion from Solidworks to the software of the rapid prototyping machine did not solidify many of the geometries of the model. As a result, many of the pieces of the figurine were only half printed, or not printed at all. Also, the rotary slot did not space itself from the base, and therefore, locked the rotary base of the figurine.

4.5 The Plated Prototype

A third prototype was made of the controller, completely remodeled with Delrin plates of 1/4" thickness and 1/8" thickness.

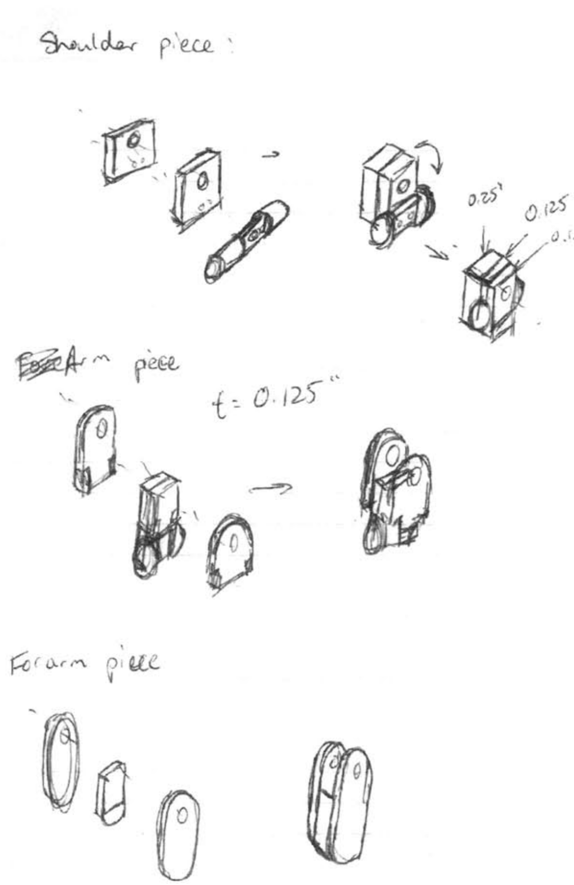

Figure 4-10: Sketches of some of the pieces and how they would fit together to create the 3D parts.

The layering of the cut plates created complex geometries, and allowed pockets and joints to be secured. All of the plates were secured using 2-56 thread size screws, which provided a good compromise of size and clamping pressure at this scale. Each part had through holes for all of the plates except for the last, which contained the tapped area for securing, so as to not excessively constrain the screws. The same principle was applied to the shaft holes, in that some plates were drilled such that they had a looser fit to the shaft. However, the plate closest to where a potentiometer would be located was drilled to a tighter tolerance so as to provide a bit more friction for posing. Placing the potentiometer at the other side where the looser plates were would cause potential error in the values. To center some of the joint shafts and fasten them in the right locations, flats were milled on either side of the shoulder and elbow shafts so that they could be stacked with the plates.

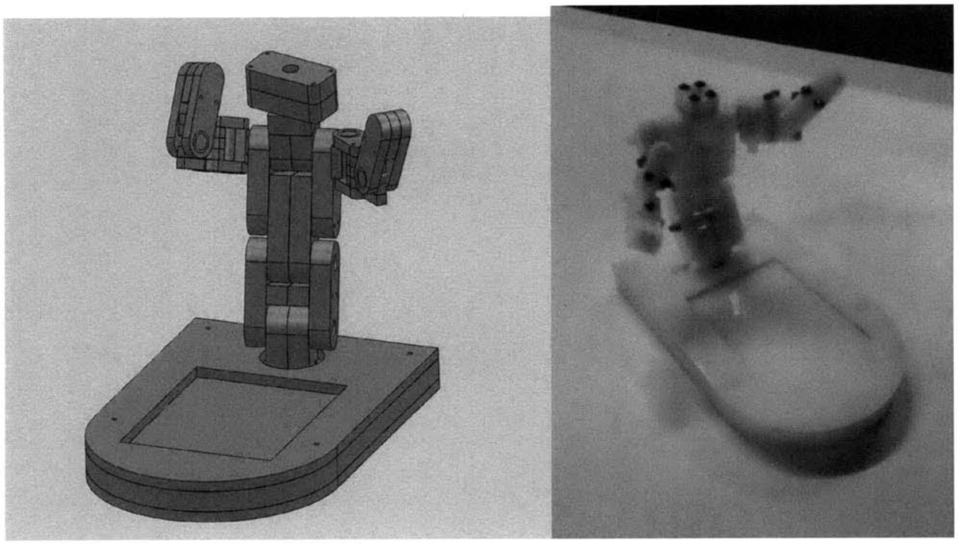

Figure 4-11: The plated prototype in SolidWorks and the built version sans head.

Due to the oversized nature of the plates (+0.015”), certain measurements did not align perfectly when constructing the plated model. For instance, clearance holes for the rotary disk and the neck plates needed to be drilled to loose fit (#41 drill bit, 0.096”) in order to match the tap holes for attachment. Also, the Delrin rod stock was slightly oversized as well (+0.004”), so this made reaming holes a bit difficult. Furthermore, the combined error of the plates’ misalignment created constraint on the shafts that went through them, creating unnecessary friction. The joints, therefore, did not move as smoothly as intended.

5 The Final Prototype

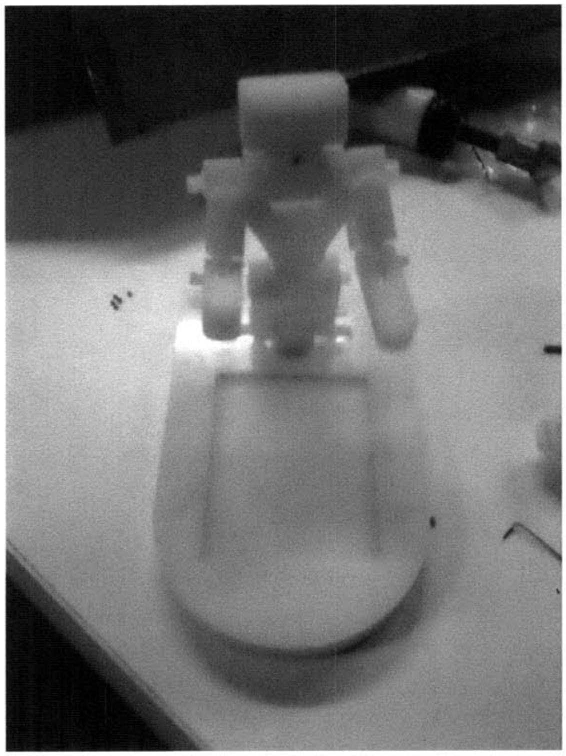

Figure 5-1: Final prototype, sans faux technology.

A final prototype was built to alleviate some of the issues with the plated prototype. The base was kept the same, but the use of thicker plates and process plans for drilling and milling were implemented for the more complex geometries. For some of the pocketed pieces, a process plan was made to fabricate the piece to specification.

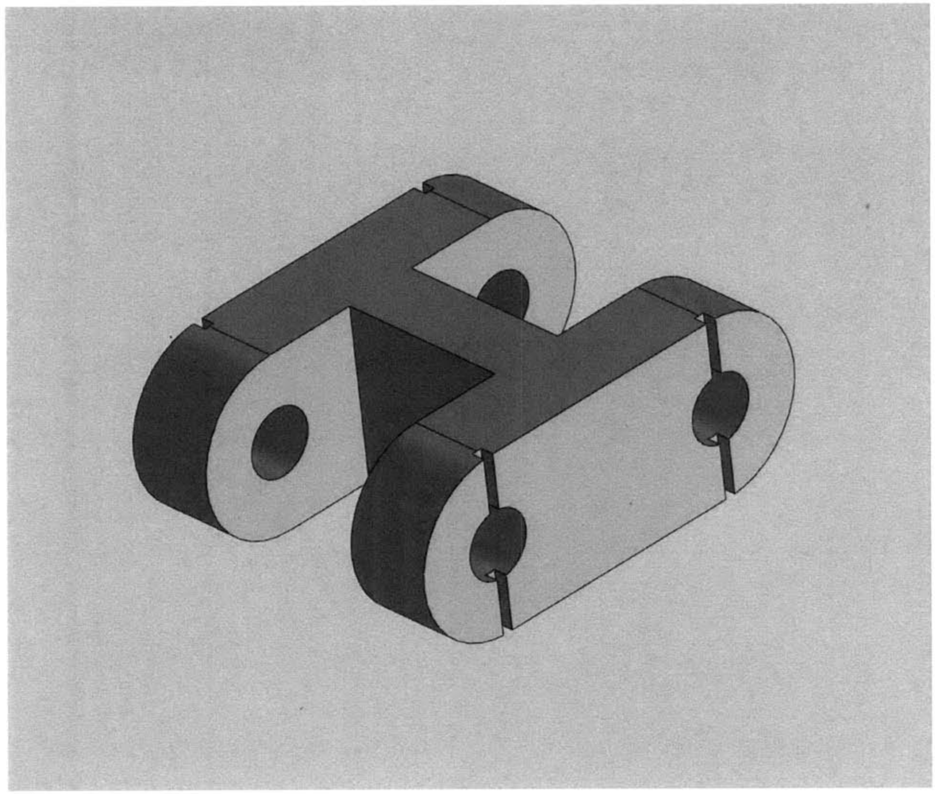

Figure 5-2: Example part for the thicker-plate prototype. Surface seen on top is taken as on top. Curved surfaces on the left are taken as front.

Table 5-1: Process plan for the waist part

#	**Process**	**Sides to Clamp**
1	Waterjet piece from 1/2" Delrin stock	
2	Square right side using 3/8" end mill	Top, Bottom
3	Square left side using 3/8" end mill	Top, Bottom
4	Drill two through holes on right side using Letter "F" 0.057" drill bit	Top, Bottom
5	Mill pocket on front side up to relief holes with 1/8" end mill	Right, Left
6	Mill pocket on back side up to relief holes with 1/8" end mill	Right, Left
7	Countersink all holes	

These thicker plates were also cut using an OMAX waterjet machine instead of a lasercutter, due to the thicknesses (1/2" and 3/8"). The use of thicker parts eliminated the need for several of the fasteners in the figurine, and ultimately reduced the number of parts of the controller.

Upon assembly, certain holes became either too loose or too tight for their necessary specification. The holes in certain parts of the body in the figurine needed to be a press fit, while certain joint holes in the arms needed to be loose enough for operation. For loosening some of the joints, lubrication was applied to the shaft holes, and slots were given a spacious tolerance so as to not provide extra friction. For the shafts that were to remain stationary, set screws were inserted into the necessary locations shown below.

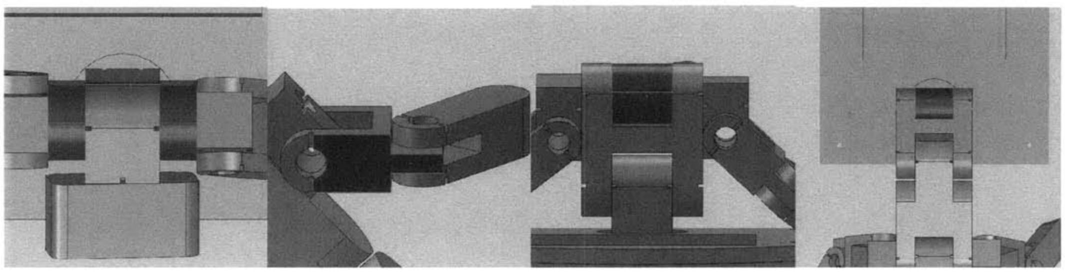

Figure 5-3: Locations of where set screws were placed (highlighted).

The waist piece became very loose in the process of the fabrication, since the weight of the figurine would knock it off balance, and would not stay posed. Therefore, the same technique used in the MeBot's sympathetic arm controller was used to adjust the friction of the waist degrees of freedom.

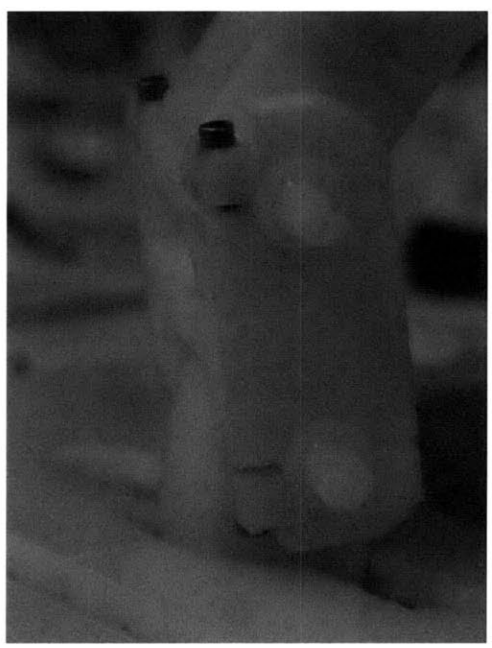

Figure 5-4: Clamp-on shaft collar modification made to the waist part.

Table 5-2: Process plan for the waist modification.

#	Process	Sides to Clamp
1	Cut a notch into front side of the edge for drilling	Top, Bottom
2	Cut a notch into back side of the edge for drilling	Top, Bottom
3	Drill a hole into each notch on the front using 3/64" drill bit	Top, Bottom
4	Drill a hole into each notch on the back using 3/64" drill bit	Top, Bottom
5	Tap holes on the front using 0-80 bottoming tap	Top, Bottom
6	Tap holes on the back using 0-80 bottoming tap	Top, Bottom
7	Cut halfway across shaft hole in the bottom side into the shaft hole in the front with a bandsaw	Top, Bottom
8	Cut halfway across shaft hole in the bottom side into the shaft hole in the front with a bandsaw	Top, Bottom
9	Drill close fit hole into top tapped section on front using #52 0.0635" drill bit	Top, Bottom
10	Drill close fit hole into top tapped section on back using #52 0.0635" drill bit	Top, Bottom

By using this technique, the friction was adjustable for the joints in the base of the figurine and for the waist degree of freedom. This greatly improved the mobility of the figurine while preventing it from falling out of place.

To simulate some of the technology proposed for the controller, different objects were placed on the prototype. These objects were merely for simulation, so as to not damage actual technology and prevent excess wiring from getting in the way for experimentation. Touch sensors for proximal and pressure sensing were simulated with thin pieces of high density foam, glued on all sides of the head, two sides of the forearm, and two sides of the body. The soft feel of the foam would hopefully encourage users to press it or squeeze it. The touch pad was simulated using a "magic slide" toy. The toy is comprised of three layers: a clear thin plastic film, a grey plastic film, and a black wax surface. With a stylus, one would mark on the top plastic surface, and the marks would show black through the film. But lifting both plastic films would "erase" the marks, and allow for new marks to be created. This would represent finger gestures that would be drawn or marked on the touch screen.

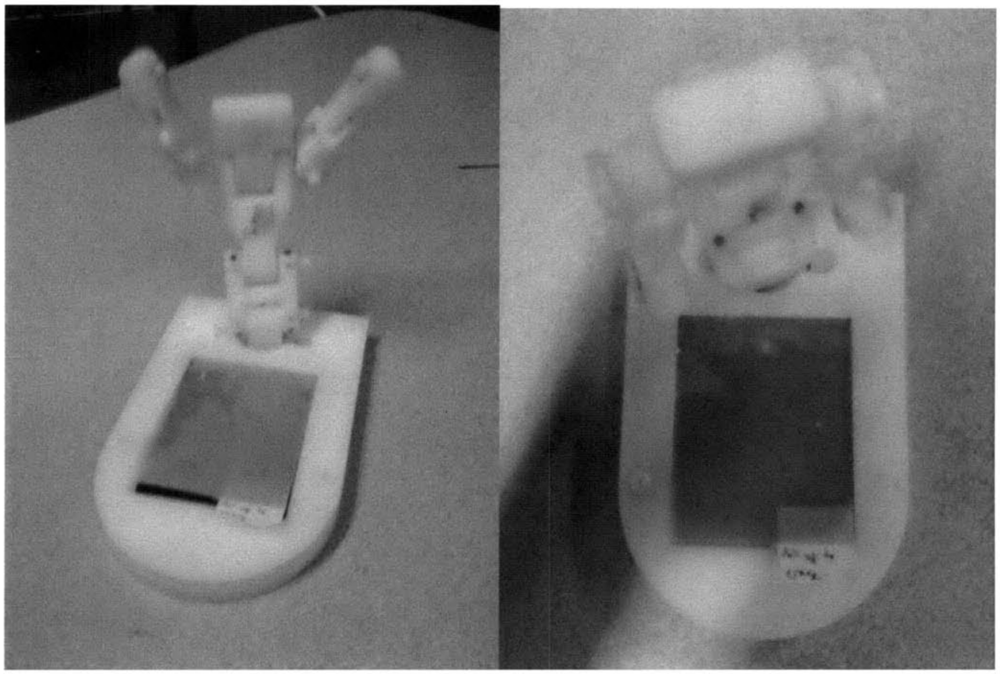

Figure 5-5: The completed mock prototype for testing in the study, complete with faux affordances (pink foam areas for touch sensing, "magic slate" for a touch screen).

Although the shafts were machined with a flatted 4 mm end to fit the Panasonic EVW-AE4001B14 potentiometers, they were not used for the human test study described in the next section. The external wires would possible affect interaction with the prototype and would not take valuable data for rating the follow aspects of the controller. With the simulated objects, and without using the potentiometers, the prototype was ready for human testing.

6 Human Test Study

A human test study was designed in order to test the usage, comfort, and intuitiveness of the prototype. The proper Couhes courses were taken to certify the proctor of the study, with the reports of completion located in the appendix of this thesis. All test subjects were informed of the nature of the study, and were given proper consent forms that described what their rights were as participants. A total of 10 participants were asked to perform the study, seven males and three females. The ages of the participants ranged from 20 to 35, and all have had experience manipulating virtual characters. The study was performed at the MIT Media Lab, in an office of the Personal Robots Group. It was performed in one sitting, and participants only received the gratitude of the researcher as compensation.

6.1 Study Design

The study was designed in the following scenario. The participant sat in front of a computer screen, with the prototype placed in front of them. The prototype is positioned with the figurine standing up straight, arms at the side, and head looking forward. The base was faced towards the participant, with the "touch screen" clear of any marks, and the stylus placed next to the device. The participant was shown a series of video clips from two different video games, World of Warcraft and Animal Crossing. The clips taken of World of Warcraft performed actions that would be performed in a virtual world. The actions are:

- Walking
- Running
- Walking and Turning
- Running and Turning
- Sitting
- Lying Down
- Pointing in Front
- Waving
- Clapping
- Bowing
- Pickup off the Ground

After each action was performed by the virtual character (played multiple times for clarity), the participant was asked to recreate the action he or she saw, with the intent of emulating the action. It was not required to perfectly imitate the action (in some cases, it was impossible due to the absence of those degrees of freedom), so the participant was expected to use the given affordances (figurine, tilt sensing, touch screen, touch sensitive areas) to imagine how their actions would translate to the on screen character. After each performed action, the participant was asked to rate it on a 7-point Likert scale for comfort and intuitiveness. A rating of 1 meant that they strongly disagreed with it being comfortable/intuitive, and a rating of 7 meant that they strongly agreed with it being comfortable/intuitive.

After performing and rating the actions, the participant watched a series of clips from Animal Crossing. In this case, the virtual character displayed an emotion, and the participant used the same affordances to emulate the action. The emotions were:

- Delight
- Sadness
- Outrage
- Sleepiness
- Laughter
- Fear

After seeing each emotion (again repeated as much as the participant needs to be clear), the participant was asked to again recreate what they saw. Since these emotions were not as defined as actions were, it was more interesting to observe the participant use the affordances to recreate the emotion they see. And again, they rated the performed emotion on the same Likert scale for comfort and intuitiveness. After both series of video clips are done, they rated some overall statements that discussed comfort, intuitiveness, and ease of use, along with rating each of the affordances and some other comments on the same Likert scale. A copy of the survey used in this study is available in the appendix.

The study was designed to produce mostly qualitative data. The numbers gathered from the study were used to average the ratings for the interactions, and these averages were plotted against each other in certain plots. There was also video data that captured only the interaction with the prototype. This video data served to observe common interactions and note on more unique ones.

It was hypothesized that most of the action animations would be replicated using the figurine. The actions would be performed by using the most basic of movements from the figurine. The emotions were hypothesized to come almost completely from drawings on the touch screen, in the form of "emoticons". The tilt sensor was hypothesized to not be used at all.

7 Results

7.1 Video Observations

The study was very interesting to observe, in that things that might have seemed obvious to the creator was not so much to the participants. All of the interactions logged from the video were placed into a spreadsheet located in the appendix of this thesis. The interactions were separated into the four affordances, and details were noticed on each of their interactions. Walking and running may have been the most peculiar of the interactions. The intent to perform this action was to pivot the figurine at its base and lean it forward, similar to a joystick. However, none of the participants did this action. Commonly, participants swung the arms back and forth (8 out of 10), and even slid the device forward. A couple of the participants only used the touch pad to represent this, either with a line or an arrow. The comment that came from these participants was that since the figurine had no legs, it was not clear how to simulate walking or running. Given a humanoid figurine, they expected full control, and they had missing degrees of freedom.

Adding the turn seemed to be clearer, as all the participants (10 out of 10) incorporated rotating the figurine at its base. This was the intended action for the controller, and everyone seemed to have no trouble with rotating the figurine. As well, sitting and lying down were very common. Sitting and lying down had very similar motions, with 9 out of 10 participants performing the same action. For sitting, this was pivoting the figurine back at its base and forward at its waist. For lying down, this was simply pivoting the figurine at its base all the way back. These were the intended actions of the controller, and the comments that were made on these interactions were that since they were full body motions, it felt easier to do than some of the other actions. However, the one unique action for sitting involved pressing down on the figurine's head, which was not expected at all. Neither was the unique action for lying down, in which the participant took the whole controller and placed it down on the figurine's back. Pointing in front was also a very clear motion, with 10 out of 10 participants using the figurine arm to point in front. Of course, this was the intended motion, but it was intended to point at the screen. What was interesting to note is the amount of participants that made the arm point at the user (5 out of 10 participants). Since it was not made explicit that the participants were controlling the avatar from third-person behind, this action (and others) were directed at the user for some of the cases. A similar effect was seen in the waving and clapping animations, with 4 out of 10 participants directing the wave or clap at themselves. However, the basic actions were very similar to what was intended, lifting one arm and moving it side to side and up and down, and wiggling the arms inward to make the arms "clap", respectively.

Bowing was also a clear action, with 10 out of 10 participants incorporating a pivot of the waist forward, which was intended. The animation itself incorporated the use of an arm, and 6 out of 10 participants replicated that motion, which was not required. Again, it seemed that the same participants who directed their waves and claps at the user did so with the bow as well; this may have had something to do with the initial orientation of the prototype in that the participants did not want to reorient it to face the screen.

Picking up off the ground had a peculiar common interaction that was not as intended for this action. The intended action was to "bow" the figurine and direct an arm to the ground, with a squeeze of the forearm to "activate" a grab. 6 out of 10 participants did this motion without indicating the use of squeezing the arm; the other 4 pivoted the figurine at the base and leaned it forward, pivoted it at the waist and leaned it back, and directed an arm towards the ground without indicating a squeeze. This motion tried to imitate the kneeling motion of the virtual character when it picked up something off the ground.

The emotion section produced even more interesting results, seeing as how it was more abstract. This section did not have an intended action, because the idea was to see how the participant represented the emotion as they saw it. For delight, most participants attempted to copy the avatar by clapping the figurine's hands and drawing some sort of smile or happy face (9/10 for clapping, 6/10 for drawing happy face). One unique interaction here was rocking the base back and forth to simulate a bouncy motion.

Participants also tried to copy the avatar for sadness as well, by bowing the figurine a bit, with the head looking down (6 out of 10). 5 out of 10 participants drew a sad face, 2 of which drew either tears or a cloud in addition. The head being down was common for all except one, who did not interact with the figurine at all.

Outrage was very different for everyone. Only two participants tried to recreate the avatar's motion (leaning head down and hitting the arms to the torso), one of which also stomped one side of the controller to represent a leg stomping. Everyone else had different ways of expressing this emotion, whether it was drawing an angry face, shaking the figurine, or sketching a thunderstorm. This was definitely one of the more difficult emotions to represent, and it showed in the interactions of the participants.

Sleepiness was a bit clearer to represent, as most participants tried to copy the avatar by lifting an arm to the head as if to cover a yawn (6 out of 10). Out of the participants using this motion, only four leaned the figurine back at its waist. Only one person drew a yawning face, and three people actually wrote "zzz". One person just leaned the whole controller to one side. Laughter had many different interactions with the figurine and the touch pad. Only four participants drew a laughing face, while one drew action lines similar to the avatar's, and one wrote "LOL". Only one participant squeezed the head while rotating it side to side at the user. Five participants rocked the head back and forth, with two of those participants using the arms to cover their "laugh". This emotion definitely involved a lot more physical body movements than intended, so it was interesting to see how the participants user the figurine's body to accentuate laughter.

Fear was by far the most difficult emotion to represent. Only one participant actually tried to copy the avatar by moving the arms inward a bit, leaning the head down, and drawing the action lines shown on screen. A more common interaction was shielding the face of the figurine with the arms (5 out of 10), with two of those involving a lean back, as if to curl up into a ball. Two participants actually shook the controller a bit to simulate shuddering, with one of those involving rotating the figurine back and forth quickly. Two participants only used the touch sensitive areas to squeeze the arms and body, with one of those bowing the figurine a bit.

7.2 Likert Data

Table 7-1: Average ratings for the questions in the study survey

Walking	Average rating	Standard dev
I feel comfortable using this controller for this action	3.9	1.969207398
It was intuitive to use this controller to perform this action.	4.1	1.728840331
Running		
I feel comfortable using this controller for this action	3.6	2.118699811
It was intuitive to use this controller to perform this action.	3.7	1.82878223
Walking/Running with Turn		
I feel comfortable using this controller for this action	3.8	1.751190072

Table 7-1 (Cont.): Average ratings for the questions in the study survey

It was intuitive to use this controller to perform this action.	4.2	1.475729575
Sitting		
I feel comfortable using this controller for this action	5.6	1.349897115
It was intuitive to use this controller to perform this action.	6	1.054092553
Lying down		
I feel comfortable using this controller for this action	6.2	1.032795559
It was intuitive to use this controller to perform this action.	6.4	0.699205899
Pointing in Front		
I feel comfortable using this controller for this action	6.4	0.699205899
It was intuitive to use this controller to perform this action.	6.7	0.483045892
Waving		
I feel comfortable using this controller for this action	5.9	1.100504935
It was intuitive to use this controller to perform this action.	6.1	0.737864787
Clapping		
I feel comfortable using this controller for this action	5	1.054092553
It was intuitive to use this controller to perform this action.	5.4	1.173787791
Bowing		
I feel comfortable using this controller for this action	5.5	1.509230856
It was intuitive to use this controller to perform this action.	5.7	1.494434118
Pick up off the Ground		
I feel comfortable using this controller for this action	4.6	2.118699811
It was intuitive to use this controller to perform this action.	4.8	2.1499354
Delight		
I feel comfortable using this controller for this action	5.5	0.849836586
It was intuitive to use this controller to perform this action.	5.5	1.08012345
Sadness		
I feel comfortable using this controller for this action	6.1	0.875595036
It was intuitive to use this controller to perform this action.	6	0.471404521
Outrage		
I feel comfortable using this controller for this action	4.4	1.0749677

Table 7-1 (Cont.): Average ratings for the questions in the study survey

It was intuitive to use this controller to perform this action.	4.2	1.398411798
Sleepiness		
I feel comfortable using this controller for this action	4.8	1.619327707
It was intuitive to use this controller to perform this action.	4.7	1.418136492
Laughter		
I feel comfortable using this controller for this action	4.8	1.316561177
It was intuitive to use this controller to perform this action.	5.2	1.398411798
Fear		
I feel comfortable using this controller for this action	4.5	1.900292375
It was intuitive to use this controller to perform this action.	4.8	1.619327707
I feel comfortable using this controller to control a virtual character.	5.1	1.370320319
This controller is intuitive for controlling virtual characters.	5.1	0.875595036
This controller is easy to use for controlling virtual characters.	4.6	1.0749677
Having multiple ways to use the controller allows for more character expression.	6.2	0.788810638
Touch sensitive surfaces on the figurine helped me control the avatar.	3.1	2.131770261
Having a separate touch screen helped me control the avatar.	5.3	2.311805451
Having a movable figurine helped me control the avatar.	6.4	0.699205899
Having a tilt sensor helped me control the avatar.	4.4	2.170509413
I would prefer to use more traditional control methods (joystick, mouse) to control a virtual character.	4.1	1.728840331
I would consider purchasing a device like this for avatar control.	4.2	1.316561177

The Likert data were analyzed by averaging across the participants and plotting the relevant averages against each other, with standard deviations shown as calculated in Excel. The differences were analyzed using a t-test, and alpha was set to 0.05 as the significance tolerance. The t-test uses the value determined by ratio of the difference of averages to the standard error of deviation (1), as shown below [17].

$$t := \frac{X_1 - X_2}{\sqrt{\frac{\sigma_1^{\,2}}{n_1} + \frac{\sigma_2^{\,2}}{n_2}}} \tag{1}$$

Here, X represents the mean of the group, σ represents the standard deviation of the group, and n represents the number of participants for the group of data. This value is compared to an alpha value based on the degrees of freedom (here, calculated as n-1) found in a student t-chart, and was labeled as a significant difference if the corresponding alpha value was less than 0.05 [18].

The first comparison chart, show in Figure 7-1, pitted comfort against intuitiveness for the action. On average, the four full body actions (sitting, lying down, pointing, and waving) were more comfortable and intuitive than the other actions ($p<0.05$). The full body animations also had a lower standard deviation than the others as well. Although it seemed that the actions were more intuitive than comfortable to perform, the differences were not significant ($p>0.05$).

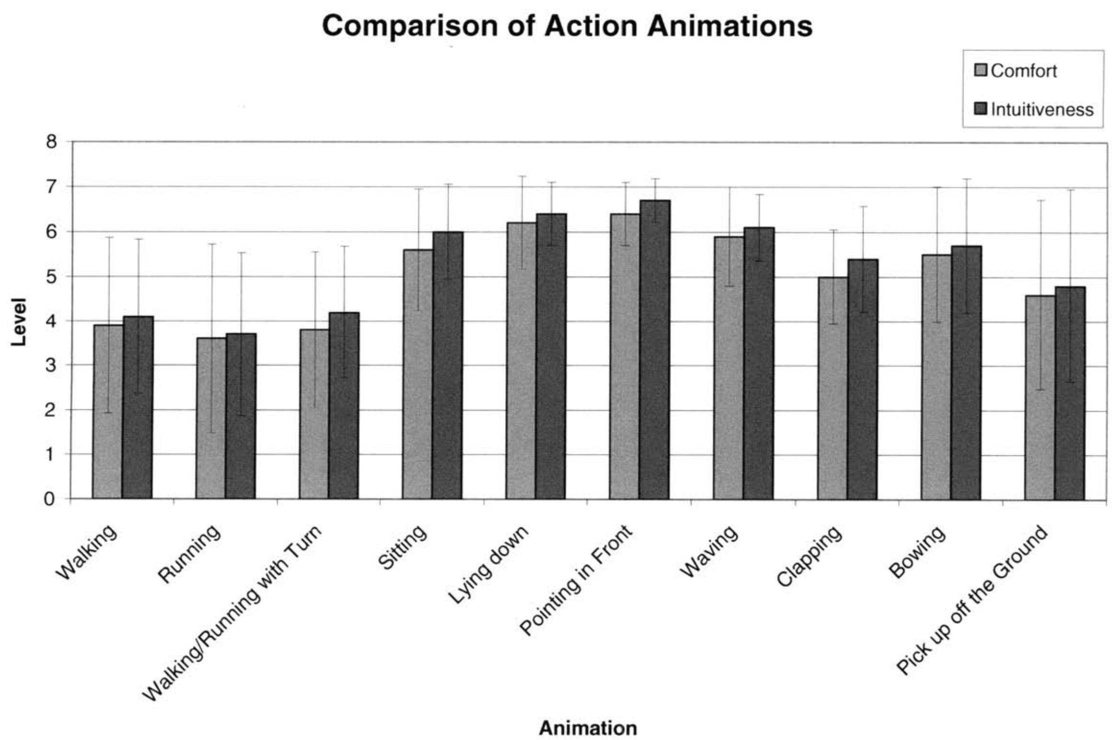

Figure 7-1: Comparison of action animations by rating.

The second comparison chart, shown below in Figure 7-2, pitted comfort against intuitiveness for the emotions. This chart proved to be more interesting to compare, since it was not clear at first to see what the most comfortable/intuitive emotion to perform was. Sadness seemed to the most comfortable with all of the emotions ($p<0.05$), except for delight, in which the difference was not significant ($p>0.05$). As well, sadness seemed to be the most intuitive, except the differences between sadness and delight and sadness and laughter were not significant ($p>0.05$). Again, the differences between intuitiveness and comfort in performing the emotions were not significant ($p>0.05$).

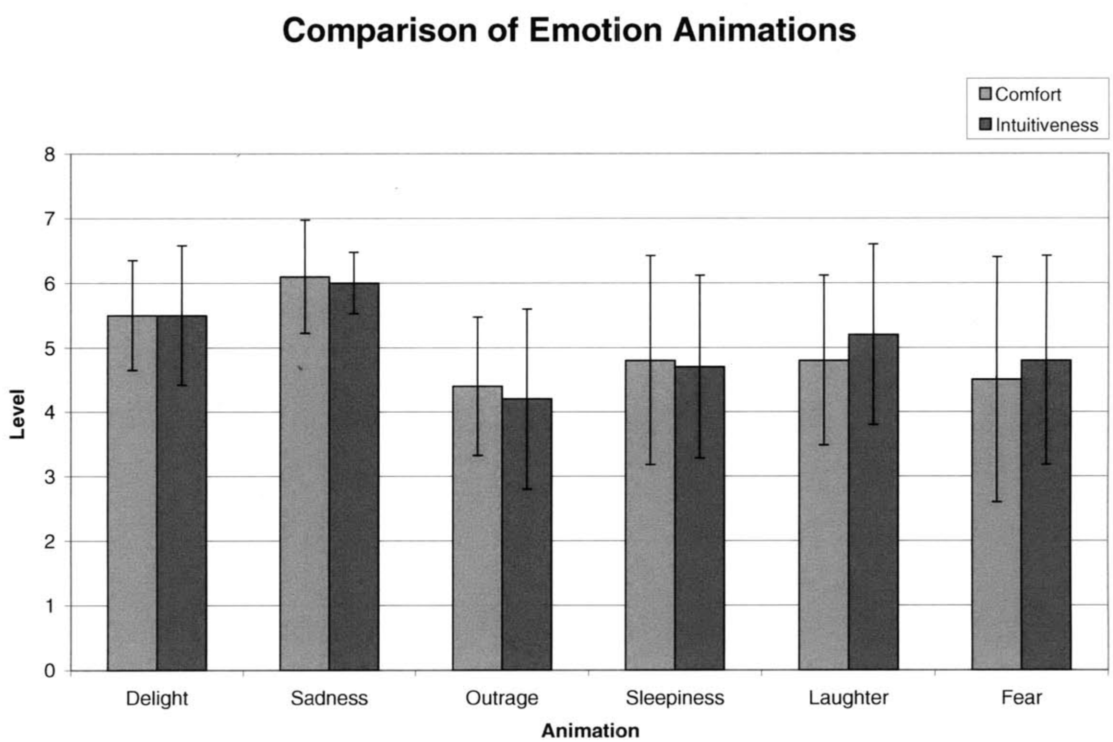

Figure 7-2: Comparison of emotion animations by rating.

The third comparison chart (Figure 7-3) evaluated the overall interactions based on comfort, intuitiveness and ease of use. They were based off of the ratings for the three questions in Section 4 of the survey that asked about the general agreement of using the controller. Comfort was more of a personal question, while ease of use was more general. These results were not significantly different ($p>0.05$), so the lines may have been blurred between these rating categories.

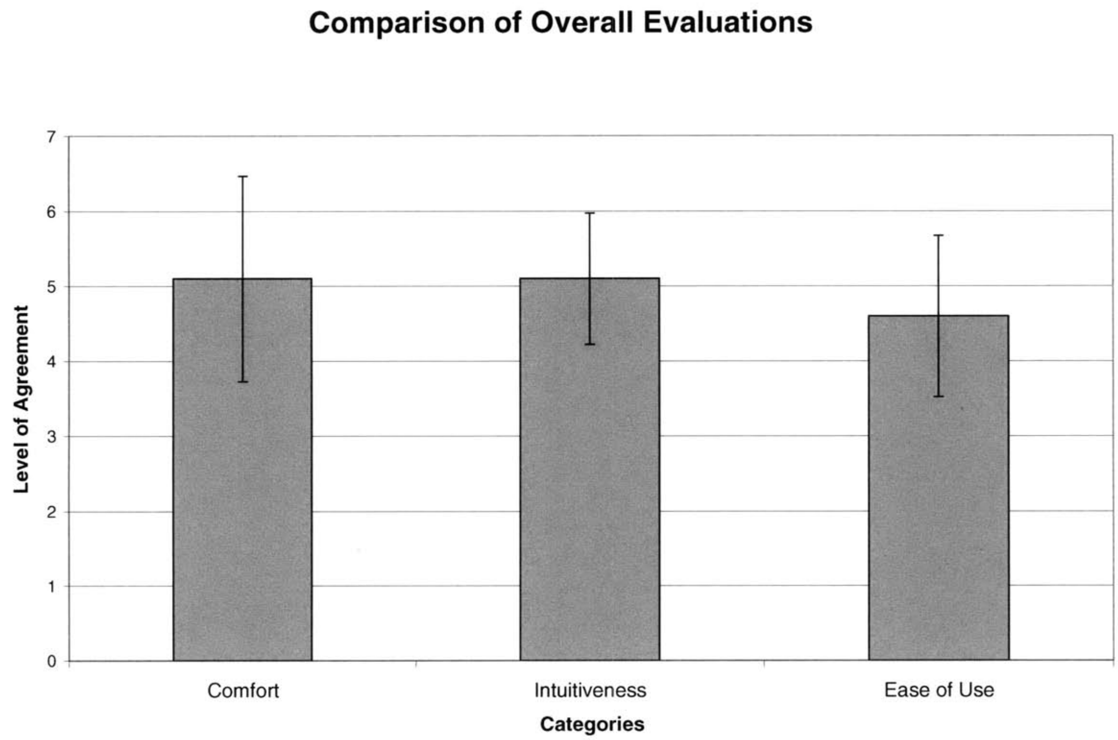

Figure 7-3: Comparison of overall interaction by level of agreement.

The final chart, shown on the next page as Figure 7-4, compared the usefulness of the given affordances along with the preference of traditional methods (keyboard, mouse). The rating for the latter option was valid, since in section 1 of the survey, all participants answered that they were comfortable using traditional methods to control virtual characters, even though traditional methods were not explicitly simulated. The figurine had a clearly high usefulness, and was significant different from all affordances ($p<0.05$), except for the touch screen. Other differences were not statistically significant ($p>0.05$).

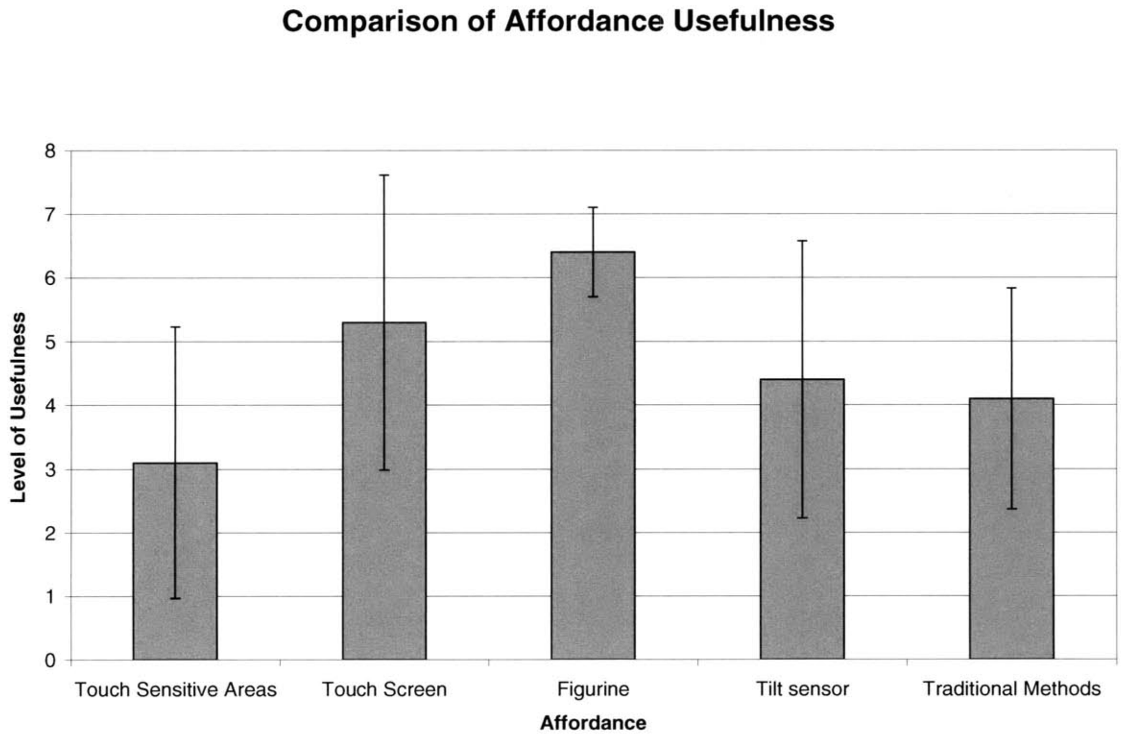

Figure 7-4: Comparison of affordances based on usefulness.

8 Conclusions and Future Work

The purpose of this thesis was to construct and evaluate a prototype controller for the control of virtual characters. The mockup prototype and the simulated technologies served well as a first study of effectiveness. The sample size was quite small, but a bigger sample size with a much more defined controller would alleviate some of the insignificant differences, and hopefully increase the overall ratings. The data taken from this study will be used to refine certain aspects and improve the design of the controller. To improve comfort, the mechanisms of manipulation will be tweaked, so that the figurine is easier to move around, and may possibly enable more degrees of freedom. Intuitiveness will be improved by redesigning the more abstract areas of the controller such that certain actions are more understood by the user to perform. Rating the affordances allow for improvements on where and how involved each affordance is in performing actions and emotions. There needs to be a balance of technologies, and haplessly shoving several options into one device is a reckless design decision.

It seemed that the figurine (a fairly new option in the world of mobile control) was received well by the participants, and so vast improvements will be made so that it is even simpler to use. The other technologies will have to be rearranged and redesigned such that they make more sense to use, especially tilt sensing and capacitive/pressure sensors. When this is redesigned, the actual technologies will be implemented into the controller, and another study will take place with a bigger sample size. Hopefully the controller will be mapped to an actual virtual avatar, so that participants can interact and have visual feedback with their actions.

References

1. The Sympathetic Interface Project and Statement of Work, in *MIT Media Laboratory Special Interest Group Membership Amendment to Media Laboratory Consortium Agreement.* The Sympathetic Interface Project Special Interest Group (SIG) Agreement, MIT Media Laboratory (2009).
2. M. P. Johnson, A. Wilson, B. Blumberg, C. Kline and A. Bobick, Sympathetic interfaces: using a plush toy to direct synthetic characters, in: *Proc. SIGCHI Conf. on Human Factors in Computing Systems: The CHI is the Limit*, Pittsburgh, PA, pp. 152–158 (1999).
3. J. Isidoro and S. Sclaroff, Active Voodoo Dolls: A Vision Based Input Device for Nonrigid Control, in: *Proc. Computer Animation* (1998).
4. Y. Lee and D. Ryu, Wearable Haptic Glove Using Micro Hydraulic System for Control of Construction Robot System with VR Environment, in: *IEEE Internation Conference on Multisensor Fusion and Integration* (2008).
5. I. Kumazawa, Input Devices with Simple and Compact Haptic Feedback Mechanisms Driven by Finger Movement, in: *Proceedings of the First Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*, pp. 497-498 (2005).
6. J. K. Lee, R. L. Toscano, W. D. Stiehl, and C. Breazeal, "Semi-Autonomous Robot Avatar as a Medium for Family Communication and Education" in *Advanced Robotics 23* (2009).
7. S. Örn, "MeBot: A robotic platform for socially embodied telepresence," in *MIT MAS Masters Thesis* (2009).
8. Peratech, Limited. "QTC Technology," Available at http://peratech.com/qtcmaterial.php
9. Lion Precision. "Capacitive Sensor Operation and Optimization," in *Capacitive Sensor TechNote LT03-0020* (2009). Available at http://www.lionprecision.com
10. W. D. Stiehl and C. Breazeal, "A "Sensitive Skin" for Robotic Companions Featuring Temperature, Force, and Electric Field Sensors," in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2006)*, Beijing, China (2006).
11. IMU 5 Degrees of Freedom IDG500/ADXL335. Sparkfun Electronics. Available at http://www.sparkfun.com/commerce/product_info.php?products_id=9268
12. STMicroelectronics 3-axis Accelerometer Spec Sheet. Available at http://www.st.com/stonline/products/literature/ds/12726/lis302dl.htm
13. Panasonic 10k Ohm 10mm 347 Degree SMD. Available at http://parts.digikey.com/1/parts/945479-pot-10k-ohm-10mm-347-degree-smd-evw-ae4001b14.htm
14. Austria Microsystems AS5030 Rotary Encoder. Available at http://www.austriamicrosystems.com/eng/Products/Magnetic-Encoders/Rotary-Encoders/AS5030
15. B. Taylor. "Bar of Soap," Object Based Media Group. Available at http://web.media.mit.edu/~bttaylor/BoSweb/BoS_index.html
16. A. Slocum. "Saint Venant's Principle," in *FUNdaMENTALS of Design, Topic 3:FUNdaMENTAL Principles* (2008).
17. The T-Test. Research Methods Knowledge Base. Available at http://www.socialresearchmethods.net/kb/stat_t.php

18. T-Statistics Reference Table. Available at http://www.pindling.org/Math/Statistics/Textbook/Tables_references/student_t_upper_tail_alpha.htm

Appendix A – Study Survey

Project PEAC Study Survey

Section 1: A Little About You

What is your gender? _____

What is you age? _____

Have you ever controlled a virtual character before? (e.g. video games, SecondLife?) ______

If so, do you feel comfortable operating a virtual character with current methods? (e.g. mouse, keyboard, joystick) _____

Today, you will be viewing a series of videos that demonstrate virtual characters displaying actions and emotions.

After viewing a video clip, you will be asked to recreate the action or emotion using the provided prototype controller. This controller has several features:

- A plastic and wax surface that you can mark with the provided stylus, which simulates a touch screen
- You may pick up the device to orient it in space to simulate tilt sensing (like the iPod Touch / iPod Nano)
- A figurine with 11 joints to use in remotely puppeteering the virtual character
- Pink foam pads that simulate touch-sensitive areas on the figurine.

Please feel free to use any of these features to recreate the given action or emotion. After each action or emotion, fill out the corresponding section of the following survey, then fill out the last section at the end of the study.

Section 2: WoW Character Action Demo

Please rate the follow interactions:

	Strongly disagree						Strongly agree
Walking							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Running							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Walking/Running with Turn							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Sitting							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7

Lying down							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Pointing in Front							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7

Section 2: WoW Character Action Demo (Continued)

Please rate the follow interactions:

	Strongly disagree						Strongly agree
Waving							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Clapping							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7

Bowing							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Pick up off the Ground							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7

Section 3: Animal Crossing Emotion Demo

Please rate the follow interactions:

	Strongly disagree						Strongly agree
Delight							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Sadness							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7

Outrage							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Sleepiness							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Laughter							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7
Fear							
I feel comfortable using this controller for this action	1	2	3	4	5	6	7
It was intuitive to use this controller to perform this action.	1	2	3	4	5	6	7

Section 4: Final Thoughts

Lastly, please rate the following statements.

	Strongly disagree						Strongly agree
	1	2	3	4	5	6	7
I feel comfortable using this controller to control a virtual character.	1	2	3	4	5	6	7
This controller is intuitive for controlling virtual characters.	1	2	3	4	5	6	7
This controller is easy to use for controlling virtual characters.	1	2	3	4	5	6	7
Having multiple ways to use the controller allows for more character expression.	1	2	3	4	5	6	7
Touch sensitive surfaces on the figurine helped me control the avatar.	1	2	3	4	5	6	7
Having a separate touch screen helped me control the avatar.	1	2	3	4	5	6	7
Having a movable figurine helped me control the avatar.	1	2	3	4	5	6	7
Having a tilt sensor helped me control the avatar.	1	2	3	4	5	6	7
I would prefer to use more traditional control methods (joystick, mouse) to control a virtual character.	1	2	3	4	5	6	7
I would consider purchasing a device like this for avatar control.	1	2	3	4	5	6	7

Thanks for participating!

Appendix B –
Couhes Course Completion Reports

CITI Collaborative Institutional Training Initiative
Human Research Curriculum Completion Report
Printed on 5/2/2010
Learner: Kristopher Dos Santos (username: krisds)
Institution: Massachusetts Institute of Technology
Contact Information Department: Mechanical Engineering
Email: krisds@mit.edu
Social & Behavioral Research Investigators:
Stage 1. Basic Course Passed on 05/02/10 (Ref # 4376198)
Required Modules
Date
Completed Score
Introduction 05/02/10 no quiz
History and Ethical Principles - SBR 05/02/10 4/4 (100%)
Defining Research with Human Subjects - SBR 05/02/10 5/5 (100%)
The Regulations and The Social and Behavioral
Sciences - SBR
05/02/10 5/5 (100%)
Assessing Risk in Social and Behavioral Sciences - SBR 05/02/10 5/5 (100%)
Informed Consent - SBR 05/02/10 5/5 (100%)
Privacy and Confidentiality - SBR 05/02/10 3/3 (100%)
Research with Prisoners - SBR 05/02/10 4/4 (100%)
Research with Children - SBR 05/02/10 4/4 (100%)
Research in Public Elementary and Secondary Schools -
SBR
05/02/10 4/4 (100%)
International Research - SBR 05/02/10 3/3 (100%)
Internet Research - SBR 05/02/10 4/4 (100%)
HIPAA and Human Subjects Research 05/02/10 2/2 (100%)
Workers as Research Subjects-A Vulnerable Population 05/02/10 4/4 (100%)
Conflicts of Interest in Research Involving Human
Subjects
05/02/10 2/2 (100%)
Massachusetts Institute of Technology 05/02/10 no quiz
For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.
Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator

CITI Collaborative Institutional Training Initiative (CITI)
Social and Behavioral Responsible Conduct of Research Curriculum Completion Report
Printed on 5/3/2010
Learner: Kristopher Dos Santos (username: krisds)
Institution: Massachusetts Institute of Technology
Contact Information Department: Mechanical Engineering
Email: krisds@mit.edu
Social and Behavioral Responsible Conduct of Research: This course is for investigators, staff and students with an interest or focus in **Social and Behavioral** research. This course contains text, embedded case studies AND quizzes.
Stage 1. Basic Course Passed on 05/03/10 (Ref # 4376199)
Elective Modules
Date
Completed Score
Introduction to the Responsible Conduct of Research 05/02/10 no quiz
Research Misconduct 2-1495 05/02/10 5/5 (100%)
Data Acquisition, Management, Sharing and Ownership
2-1523
05/02/10 5/5 (100%)
Publication Practices and Responsible Authorship 2-1518 05/02/10 5/5 (100%)
Peer Review 2-1521 05/02/10 5/5 (100%)
Mentor and Trainee Responsibilities 01234 1250 05/02/10 5/6 (83%)
Conflicts of Interest and Commitment 2-1462 05/02/10 5/6 (83%)
Collaborative Research 2-1484 05/03/10 6/6 (100%)
The CITI RCR Course Completion Page. 05/03/10 no quiz
For this Completion Report to be valid, the learner listed above must be affiliated with a CITI participating institution. Falsified information and unauthorized use of the CITI course site is unethical, and may be considered scientific misconduct by your institution.
Paul Braunschweiger Ph.D.
Professor, University of Miami
Director Office of Research Education
CITI Course Coordinator
Return
Completion Report https://www.citiprogram.org/members/learnersII/crbystage.asp?strKeyI...
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Appendix C – Participant Behaviors

List of Participant Behaviors

Participant Behaviors	1	2	3	4	5
Walking					
Figurine:	Swung arms side to side at screen	Swung arms side to side at user	No action	No action	Swung arms side to side
Tilt sensing:	Slid device at screen	Lifted up device a bit and slid device at user	No action	Picked up device, leaned it at user	Slid device forward at screen
Touch screen:	No action	No action	Drew a line at screen	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Running					
Figurine:	Swung arms side to side faster, leaned forward a bit at screen	Swung arms side to side faster at user	No action	No action	Swung arms side to side faster, leaned forward a bit at screen
Tilt sensing:	No action	Lifted up device a bit and slid device at user	No action	Picked up device, leaned it more at user	Slid device forward
Touch screen:	No action	No action	Drew two lines at screen	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Walking and Turning					
Figurine:	Swung arms side to side, rotated figure at its base at screen	Swung arms side to side, rotated figure at its base at user	Rotated figurine at base at user	Rotated figurine at base at user	Rotated figurine at base back and forth at screen
Tilt sensing:	No action	Slid device at user	No action	Picked up device, leaned it at user	Slid device forward
Touch screen:	No action	No action	Drew a line at screen	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Running and Turning					
Figurine:	Swung arms side to side faster, rotated figure at its base at screen	Swung arms side to side faster, rotated figure at its base at user	Rotated figurine at base at user	Rotated figurine at base at user	Swung arms side to side faster, rotated figure at its base at screen
Tilt sensing:	No action	Slid device at user	No action	Picked up device, leaned it more at user	Slid device forward
Touch screen:	No action	No action	Drew two lines at screen	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Sitting

Figurine:	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms at side at screen	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms in lap at user	Pivoted figurine at its waist and leaned it back at user	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms at side at user	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms in lap at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	Pressed on top of head	No action	No action

Lying Down

Figurine:	Pivoted figurine at its base and leaned it forward, arms at side at screen	Pivoted figurine at its base and leaned if back, arms at side at user	Pivoted figurine at its base and leaned if back, arms at side at user	Pivoted figurine at its base and leaned if back, arms at side at user	Pivoted figurine at its base and leaned if back, arms at side at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Pointing in Front

Figurine:	Lifted right arm and pointed it forward at screen	Lifted right arm and pointed it forward at screen	Lifted left arm and pointed it forward at user	Lifted left arm and pointed it forward at user	Lifted right arm and pointed it forward at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Waving

Figurine:	Lifted right arm and wiggled it up and down and side to side at screen	Lifted right arm and wiggled it side to side at screen	Lifted left arm and wiggled it side to side at user	Lifted left arm and wiggled it side to side at user	Lifted right arm and wiggled it up and down and side to side at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Clapping

Figurine:	Lifted both arms and wiggled them inward at screen	Lifted both arms and wiggled them inward at screen	Lifted both arms and wiggled them inward at user	Lifted both arms and wiggled them inward at user	Lifted both arms and wiggled them inward at user and at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Bowing					
Figurine:	Pivoted figurine at waist and leaned it forward at screen	Picked up left arm and lifted up towards figurine, pivoted figurine at waist and leaned it forward at screen	Pivoted figurine at waist and leaned it forward at user	Picked up right arm and lifted up towards figurine, pivoted figurine at waist and leaned it forward at user	Picked up right arm and lifted up towards figurine, pivoted figurine at waist and leaned it forward at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Picking up off the Ground					
Figurine:	Pivoted figurine at base and leaned it forward, pivoted at waist and leaned it back, and directed right arm towards the ground at screen	Bowed figurine, directed right arm towards the ground at screen	Bowed figurine, directed left arm towards the ground at user	Bowed figurine, directed left arm towards the ground at user	Pivoted figurine at base and leaned it forward, pivoted at waist and leaned it back, and directed both arms towards the ground at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Delight					
Figurine:	Clapped a few times with the arms and lifted them up at screen	Leaned figurine back a bit, clapped a few times with the arms at user	Lifted arms up at user	Clapped a few times with the arms at user	Clapped a few times with the arms and lifted them up at screen
Tilt sensing:	As arms lifted, the base rocked back and forth	No action	No action	No action	No action
Touch screen:	No action	No action	Drew a smile, no eyes	Drew a happy face	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Sadness					
Figurine:	Bowed the figurine, head down at screen	Head down, arms bent at user	Head down at user	No action	Bowed the figurine, head down at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	Drew a sad face with tears	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Outrage					
Figurine:	Leaned head down, hit arms towards torso of figurine at screen	Moved back and forth at user	No action	No action	Slammed arms down, leaned a bit forward at screen
Tilt sensing:	No action	No action	No action	No action	Hit base on the table
Touch screen:	No action	No action	Drew slanted inward eyebrows, frown	Drew a thunderstorm	No action
Touch sensitive areas:	No action	Squeezed head	No action	No action	No action

Sleepiness					
Figurine:	Leaned figurine back and motioned right arm towards head, bending elbow back at screen	Leaned figurine back a bit at user	Raised left arm up to head at user	Leaned figurine forward at user	Leaned figurine back and motioned right arm towards head, bending elbow back at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	Drew "zzz" and bubbles vertically	No action	Drew "zzz" in a thought bubble	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Laughter					
Figurine:	Picked up left arm a bit, rocked head back and forth at screen	Leaned figurine back a bit at user	Rotated head a bit at user	No action	Rocked head back and forth at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	Drew action lines similar to on screen character	No action	Drew a happy face with wide open mouth	No action
Touch sensitive areas:	No action	No action	Pressed sides of head a few times	No action	No action
Fear					
Figurine:	Bowed figurine forward a bit at screen	Head down a bit, arms in a bit at user	No action	Put arms in front of head, leaned back a bit at user	Wiggles figurine bit, bent up right arm towards head at screen
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	Drew vertical zig zag lines similar to on screen character	No action	No action	No action
Touch sensitive areas:	Squeezed body and arm areas	No action	Squeezed body and arm areas	No action	No action

List of Participant Behaviors

Participant Behaviors	6	7	8	9	10
Walking					
Figurine:	Swung arms side to side	Swung arms side to side at user	Swung arms side to side at user	Swung arms side to side at user	Swung arms side to side at user
Tilt sensing:	No action	Slid device forward	No action	No action	"Waddled" the controller
Touch screen:	No action	No action	No action	Drew arrow at user	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Running					
Figurine:	Swung arms side to side faster, leaned forward a bit at screen	Swung arms side to side faster at user	Swung arms side to side faster, leaned forward a bit at user	Swung arms side to side at user	Swung arms side to side faster at user
Tilt sensing:	No action	No action	No action	No action	"Waddled" the controller faster
Touch screen:	No action	No action	No action	Drew fast forward arrow at user	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Walking and Turning					
Figurine:	Swung arms side to side, rotated figure at its base at screen	Swung arms side to side, rotated figure at its base at user	Swung arms side to side, rotated figure at its base at user	Swung arms side to side, rotated figure at its base at screen	Swung arms side to side, rotated figure at its base at user
Tilt sensing:	No action	No action	No action	No action	Slid device forward
Touch screen:	No action	No action	No action	Drew arrow at screen	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Running and Turning					
Figurine:	Swung arms side to side faster, rotated figure at its base at screen	Swung arms side to side faster, rotated figure at its base at user	Swung arms side to side faster, rotated figure at its base at user	Swung arms side to side faster, rotated figure at its base at screen	Swung arms side to side faster, rotated figure at its base at user
Tilt sensing:	No action	No action	No action	No action	Slid device forward
Touch screen:	No action	No action	No action	Drew fast forward arrow at screen	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Sitting					
Figurine:	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms in lap at screen	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms at side at user	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms at side at at user	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms in lap at user	Pivoted figurine at base and leaned it back, pivoted at waist and leaned it forward, arms at side at at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Lying Down					
Figurine:	Pivoted figurine at its base and leaned if back, arms at side at screen	Pivoted figurine at its base and leaned if back, arms at side at user	Pivoted figurine at its base and leaned if back, arms at side at user	No action	Pivoted figurine at its base and leaned if back, arms at side at user
Tilt sensing:	No action	No action	No action	Tilted whole controller back to lean on figurine's back at user	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Pointing in Front					
Figurine:	Lifted right arm and pointed it forward at screen	Lifted left arm and pointed it forward at user	Lifted right arm and pointed it forward at user	Lifted right arm and pointed it forward at screen	Lifted left arm and pointed it forward at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Waving

Figurine:	Lifted right arm and wiggled it up and down and side to side at screen	Lifted right arm and wiggled it up and down and side to side at screen	Lifted right arm then left arm and wiggled both up and down and side to side at user	Lifted right arm and wiggled it up and down and side to side at screen	Lifted left arm and wiggled it side to side at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Clapping

Figurine:	Lifted both arms and wiggled them inward at screen	Lifted both arms and wiggled them inward at screen	Lifted both arms and wiggled them inward at user	Lifted both arms and wiggled them inward at screen	Lifted both arms and wiggled them inward at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Bowing

Figurine:	Picked up left arm and lifted up towards figurine, pivoted figurine at waist and leaned it forward at screen	Pivoted figurine at waist and leaned it forward at screen	Picked up left arm and lifted up towards figurine, pivoted figurine at waist and leaned it forward at user	Pivoted figurine at waist and leaned it forward at screen	Picked up left arm and lifted up towards figurine, bent head down at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Picking up off the Ground

Figurine:	Bowed figurine, directed right arm towards the ground at screen	Pivoted figurine at base and leaned it forward, pivoted at waist and leaned it back, and directed right arm towards the ground at screen	Pivoted figurine at base and leaned it forward, pivoted at waist and leaned it back, and directed right arm towards the ground at user	Bowed figurine, directed right arm towards the ground at screen	Bowed figurine, directed both arms towards the ground at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	No action	No action	No action	No action	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Delight

Figurine:	Clapped a few times with the arms at screen	Clapped a few times with the arms at user	Clapped a few times with the arms at user	Clapped a few times with the arms at user	Clapped a few times with the arms at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	Drew a happy face	Drew a happy face	Drew a happy face	Drew a happy face	No action
Touch sensitive areas:	No action	No action	No action	No action	No action

Sadness

Figurine:	Bowed the figurine, head down at screen	Bowed the figurine, head down at user	Bowed the figurine, head down at user	Bowed the figurine, head down at user	Bowed the figurine, head down at user

Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	Drew a sad face with a cloud	Drew a sad face	Drew a sad face	Drew a sad face	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Outrage					
Figurine:	Leaned head down at screen	No action	Lifted arms up a bit at user	No action	Leaned head down, hit arms towards torso of figurine at user
Tilt sensing:	Stomped base lightly on table	No action	No action	Stomped one side of base lightly at user	Stomped one side of base lightly at user
Touch screen:	Drew angry face	Drew face bearing teeth	Drew angry face	Drew angry face	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Sleepiness					
Figurine:	Leaned head down and waved left arm around at screen	No action	Leaned figurine back and motioned both arms towards head, bending elbow back at user	Leaned figurine back and motioned left arm towards head, bending elbow back at user	Picked up left arm and moved it in circle at user
Tilt sensing:	No action	Leaned whole controller onto side	No action	No action	No action
Touch screen:	Drew face with squiggly mouth	No action	Drew yawning face	Drew "zzz"	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Laughter					
Figurine:	Wiggled arms out at screen	Arms out, rocked figurine at waist back and forth at user	Picked up both arms a bit, rocked head back and forth at user	Rocked head back and forth at user	Rocked head and torso back and forth, wiggled arms back and forth at user
Tilt sensing:	No action	No action	No action	No action	No action
Touch screen:	Drew a happy face with wide open mouth	Wrote "LOL"	Drew a happy face with wide open mouth	Drew a happy face with wide open mouth	No action
Touch sensitive areas:	No action	No action	No action	No action	No action
Fear					
Figurine:	Put arms in front of head, leaned back a bit at user	Put arms in front of head at user	Put arms in front of head at user	Rotated figurine back and forth at user	Put arms in front of head at user
Tilt sensing:	No action	No action	No action	Shook controller a bit	Shook controller a bit
Touch screen:	Drew sad face with x's for eyes	No action	No action	Drew sad face	No action
Touch sensitive areas:	No action	No action	No action	No action	No action