

A Design of Actuation Mechanisms  
for Use in 'Huggable' Robotic Teddy Bear

by

Levi Lalla

Submitted to the Department of Mechanical Engineering  
In Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Mechanical Engineering

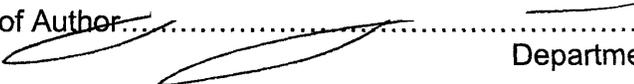
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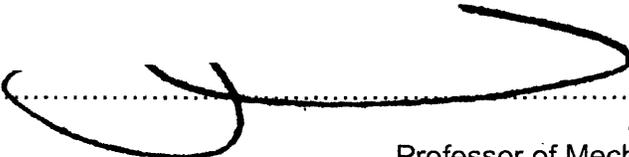
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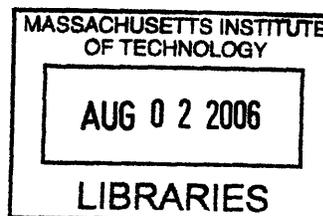
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ABSTRACT

Silent, back drivable actuators were necessary for the Huggable teddy bear, a robotic companion for use in therapeutic applications. The benefits of pet therapy include a reduction in stress and an increase in rate of healing. The Huggable teddy bear will attempt to offer the same benefits through a life-like interaction with the user. Consequently, the actuators were created to be compact due to the small size of the robot. Actuators were also designed to interface with the motor control board used in the Huggable and allow for feedback for use in position control.

Care was taken in the design process to address the issues of manufacturing and assembly. The two mechanisms designed for the Huggable were an eyebrow mechanism and an ear mechanism. The eyebrow mechanism has 2 degrees of freedom (DOF). This was done using a symmetrical design which couples the motion of outer eyebrows together and the motion of the inner eyebrows together. The Ear mechanism has only 1 DOF and is cable driven. These mechanisms will allow the Huggable teddy bear to provide emotional feedback as well as create a realistic response to stimulus.

Up to this point, the designs and mechanisms have been built. Testing of the design will follow to ensure life-like interaction with the user.

Thesis Supervisor: Cynthia Breazeal

Title: Associate Professor of Media Arts and Sciences

# 1. INTRODUCTION

It has been shown that pet therapy can have a positive effect on a patient's health. Some people, however, may be incapable of taking care of a real pet. Others may simply be allergic to pets. For these individuals, pet therapy is not an option and it is in this group where robotic therapy may find its niche. The Huggable teddy bear will attempt to recreate the benefits of pet therapy with a robotic platform. This will be done with realistic feedback to its environment. The Huggable will have a multitude of capacitive, thermal, and tactile sensors, as well as visual inputs from two cameras. These will be used to understand user interaction with the Huggable and allow it to respond appropriately.

The size of an average teddy bear, the Huggable will need small actuators. These actuators will allow for two degrees of freedom (DOF) in the eyebrows as well, as two DOF in the shoulders and one DOF in the ears. In an effort to reduce noise, actuators must be silent and should not contain gears. Actuators should also be back-drivable, so as to reduce damage to actuators, as well as increase realism of robot/human interaction.

The purpose of this report is to describe the specific design issues that accompanied the Huggable project. The following objectives drove this project and the design issues that followed:

- To be viscerally and emotionally pleasing to interact with, both with respect to how it feels to the touch and how it responds to people.
- To provide measurable health benefit to people.
- To be a useful tool for the nursing staff or other care providers that augments existing animal assisted therapy programs (if present).
- To be a computationally flexible platform that allows us to explore other applications for the Huggable technology.<sup>1</sup>

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1 Stiehl, W.D., <http://robotic.media.mit.edu/projects/theHuggable.html>

## 2. BACKGROUND

The Huggable teddy bear is new direction for robotics. A creation of Walter Daniel Stiehl, under the advisory of Cynthia Breazeal, the Huggable is an attempt at creating a convincing robotic companion. This robotic companion is intended to be used as a form of pet therapy. There has been much research done to suggest that pets can have a positive impact on one's health. These benefits include reducing heart and respiratory rate, and showing positive changes in hormonal levels, mood elevation, and social facilitation. These benefits, however, are not accessible to everyone. Concerns about allergies, animal bites, and the inconvenience of scheduling therapy appointments leave many nursing home and hospital patients without pet therapy. It is the goal of the Huggable to make companion therapy more accessible using a robotic companion.

The Huggable is not the first robot proposed to be used in this form of robotic therapy. Previously, off the shelf robots have been used in studies to determine the effectiveness of robots in companion therapy. These robots, however, lack certain functionality that would allow users to more effectively connect with the robots. Unlike the robots used in previous studies, however, the Huggable has full body tactile, capacitive, and thermal sensors. This allows the robot to effectively interact with the human. For example, the Huggable can recognize when it is being held, petted, or even hugged. In response it can then hug, nuzzle, or even shy away. In addition to physical user feedback, the Huggable has several other options for emotional feedback. In order to give the Huggable a sense of emotional feedback, facial expressions must be utilized.

In an effort to increase the feeling of realism, the actuation of the Huggable must be natural in look and feel. Current robots make use of geared motors. These motors are loud and not compliant. If a user attempts to move the robot's arm, the geared motor feels rigid, as opposed to the compliant feel of a living creature's arm. If the motor is forced back hard enough, gears can be stripped resulting in permanent damage as well as an unnatural noise. These features are undesirable because they hinder the Huggable's attempts at realism. It is for these reasons that less common

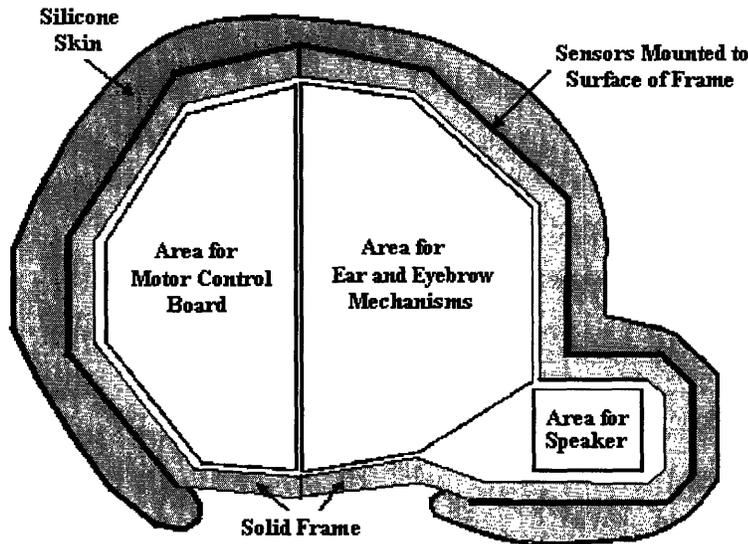
actuators are needed for the Huggable. Actuation must occur quietly and must be back-drivable. The actuators must also contain position feedback as well as integrate into the Huggable's motor control board easily.

### 3. THE DESIGN

This section focuses on the overall design followed by a discussion of the eyebrow and ear mechanisms essential to this design.

#### 3.1. Overall Design

The constraints of the Huggable project lead to a considerable challenge with regards to designing its actuation mechanisms. The size of an average teddy bear, the Huggable provides a small envelope for all components to fit into. The mechanisms for the eyebrow are needed to fit inside of the Huggable's head. Along with these mechanisms the inside of the head must contain a speaker, for audio output, and, in a second revision, the motor control board. The head needs to have a rigid structure on which to mount the various sensors used on the Huggable. This structure will then be covered with a silicone skin and the bear's fur. A cross-section of the Huggable's head can be seen in Figure 1.



This complete assembly should be easy to assemble as well as easily mount to the body of the Huggable.

### 3.1.1 Motors and Potentiometers

The space reserved for the Ear and Eyebrow mechanisms requires a compact design. Roughly the size of a fist, this space must contain three motors, each geared down using a silent back-drivable system, three potentiometers, and several lever arms used to move the eyebrows and ears. The first step was determining what type of motors to use. Ultimately we decided to use inexpensive hobby motors as opposed to expensive high performance motors. Using several bench experiments we determined that the Mabuchi RF 370CA motor was the best motor for this application.

Several motors were tested to determine which would be the best choice for this application. Stall torque, power consumption, size, and noise were all taken into account. As seen in Table 1, one motor was found to be much better for this application than the others.

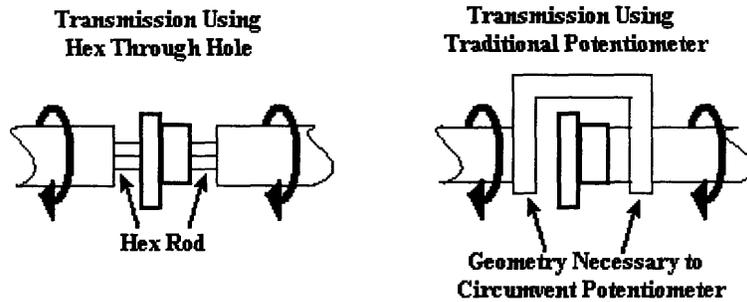
Motor	Stall Torque	Power Consumption	Size	Noise
Mabuchi RPM2	--	-	+	-
Solarbotics RM1a	-	0	0	-
Mabuchi FA-130	0	0	0	-
Solarbotics RM2	+	-	0	-
Mabuchi RF 370CA	+	+	-	+

While most tried motors were found to be noisy, the Mabuchi RF 370CA motor was very silent. From an arm's length away it was barely audible. It provided more than enough torque for this application, and, when compared to some of the other high torque motors, consumed much less power. This motor was, unfortunately, the largest of the motors we tried, but had the added benefit of being face mountable. This mounting option helped to reduce the overall size of the assembly since a more complicated motor mount was not necessary. As long as this motor is used in combination with a position sensor, the motor control board can control it.

The type of position sensor used in the mechanisms makes a large impact on the design. A potentiometer type sensor was decided upon. The potentiometer is a variable resistor and, as per motor control board specs, should have a resistance range

between 0 and 10 k $\Omega$ . As the position of the eyebrow/ear changes, the resistance value of the potentiometer changes as well. This allows the motor control board to know where the mechanism is at all times. Since the mechanism is desired to allow for back driving, a motor position does not directly correspond to a position of the eyebrow or ear. Because of this, attaching the potentiometer to the motor, or any intermediary shafts, would not allow for accurate position sensing if the apparatus were back driven. Upon realization of this it was decided that the potentiometer should be attached directly to the final output shaft.

The eyebrows and ears should remain within a natural looking range. The desired range of any of the mechanism's output shafts is less than 180 degrees. This means that a single turn or less potentiometer is suitable. Many potentiometers were looked at and ultimately Piher PTC10 trimmer potentiometer with hex through hole was chosen. This choice was made base on its compact size as well as its robust design. This potentiometer also has a 2 mm hex through-hole. This is desirable since it allows for rotation of a shaft on both sides of the potentiometer without the need for complicated geometry.



**Figure 2:** Showing the advantage of Potentiometer with Hex Through Hole

Once the motors and potentiometers were chosen the mechanisms themselves could be designed.

## **3.2 The Eyebrow Mechanism**

In this section, the power transmission, bearings, and the mechanism are discussed as they relate to the eyebrow mechanism.

### **3.2.1 Power Transmission**

When designing the eyebrow mechanism a major consideration was obtaining a high functionality in a compact form. Four major design concerns were:

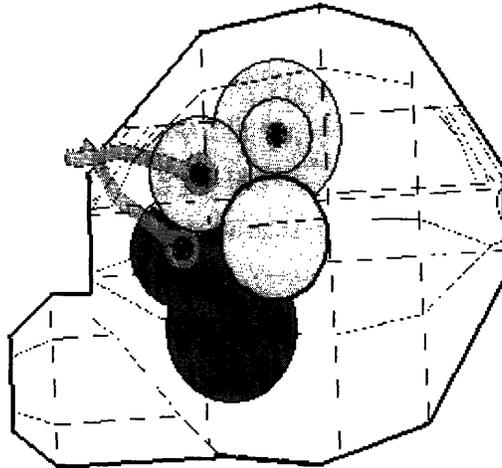
A silent mechanism; No unnatural sounds that would distract user.

A compliant mechanism; Can be moved by a user with minimal resistance and without damage or loss of function.

A compact mechanism; Must fit inside of the head with room for speaker, microphones, and potentially the motor control board.

A geared-down mechanism; Reduce the output shaft speed to make control system's job easier.

The motor needed to be geared down in an effort to make the controlling of the eyebrows easier. This is difficult since gears, due to their rigid feel and unnatural sound, were not an option. Timing belts were considered, but eventually rejected due to their large size. A timing belt driven eyebrow mechanism was modeled and it was found that it would take up about 1/2 of the space in the bear head. This would barely leave room for an ear mechanism, and no room for a motor control board.



**Figure 3:** Model of Eyebrow Mechanism Using Timing Belts

This mechanism only allowed for an 8:1 gear ratio and took up too much space. A gearmotor mechanism which used a compliant transmission was considered but was put on hold due to the loud unnatural sound made by gearmotors. Eventually a rubber belt and pulley mechanism was settled upon.

The advantages of a belt driven pulley system allowed the mechanism to fulfill the design requirements. The belt drive is quiet; there is no noticeable chatter or grinding. The belt drive allowed for a compliant system; the tension in the belt can move the eyebrows, but the belt slips when an external force is applied. The belt drive is compact; pulleys can be made as thin as 0.1". The belt drive obtains a high gear ratio. Because of the compact size of the pulleys, a multiple pulley system can be used and a gear ratio greater than 20:1 can be obtained.

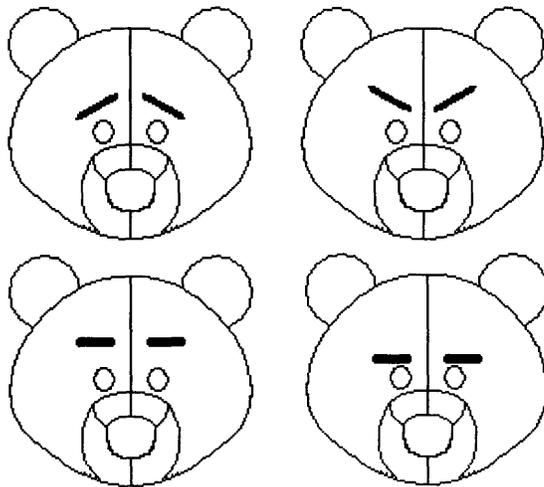
### **3.2.2 Bearings**

In order to overcome frictional forces, the use of ball bearings is recommendable. Several bearing surfaces were tried in a bench top experiment. In the experiment, a steel pin was driven using the Mabuchi RF 370CA motor and some press fit pulleys. Many of the bearings proved to be unreliable. It was found that at low belt tension the motor could not drive the pin. At higher tensions, the motor managed to move the rod,

but the motion was jerky as the belt continuously slipped on and caught onto the pulley surface. This undesirable motion was the result of the high friction of the bearings used. Ball bearings were then tested in the same apparatus and met with great success. The motor easily drove the pin. The resulting motion was smooth and found to be desirable. It was decided that an 1/8" pin was the desired size and ball bearings were selected to match. The ball bearing type chosen was SPD's A 7Y55-FSS2512. This ball bearing has a 1/8" press fit bore, and a 1/4" outer diameter with a 0.3" diameter flange.

### 3.2.3 The Mechanism

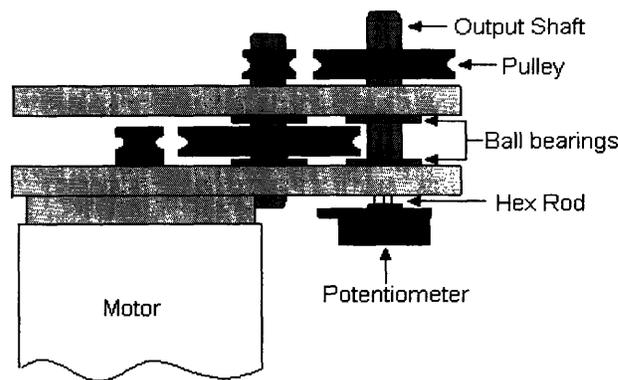
The most elegant solution found for this mechanism was a parallel output shaft mechanism. In this mechanism, two output shafts control the bear's eyebrows. One shaft controls the position of the outer portion of both eyebrows, while another shaft controls the position of the inner portion of both eyebrows. This mechanism couples the motion of the eyebrows resulting in a symmetric eyebrow pattern. In other words, both eyebrows will be mirror images of each other. This was determined to be adequate for the emotional expression range desired.



**Figure 4:** Emotional Range of Bear Using Parallel Output Shaft Mechanism

An attempt was made to keep the design as simple as possible. Several of the chosen components were stock parts that could be purchased online. Some 1/8" x 1" steel pins were used for axles. Round stock delrin was found to be a cheap and easy way to make pulleys in-house. The hex rods can be created from an allen wrench, and the mounting structure can be made easily using either the Media Lab's laser cutter or water jet machines.

In an effort to reduce the complexity of assembly, the apparatus was broken into two sections. The obvious sections of inner and outer eyebrow position control were used. Each of these sections includes one motor, four ball bearings, four pulleys, and an output shaft. A schematic for this concept is shown in Figure 5. Once the two sections are built, they can be combined to form the complete apparatus.

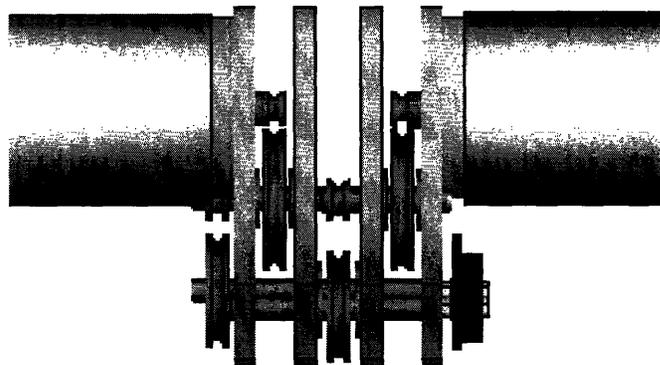


**Figure 5:** A Schematic for the Concept of a Section of the Apparatus

The motor is face-mounted to the structure. A 0.1" pulley is press fit onto the motor shaft. This pulley transfers power to a 0.7" pulley which is riding on two ball bearings. A 0.15" pulley, which attached to the 0.7" pulley, transfers power to a 0.5" pulley. This final pulley drives the output shaft which controls the eyebrow. On the other side of the output shaft a press fit hex rod is securely attached and is used to turn the potentiometer. Each section should have all of these parts and easily connect to each other.

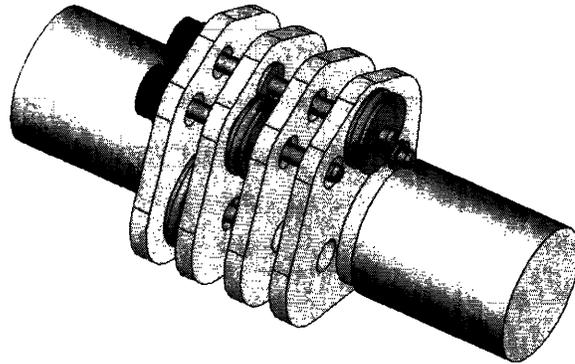
Ideally, the design would be completely symmetrical. This would allow for one section to be made twice and combined, instead of creating two different sections that could be used. Unfortunately, such symmetry was not an option. Several geometry problems did not allow certain parts to be ideally located. For instance, two cameras, which are to be mounted in the eyes of the bear, directly interfere with the apparatus. Because of this one of the pulleys must be moved into the center of the assembly. Since two pulleys will not fit in the center, the assembly become asymmetric.

The final design was modeled using Solid Works 2005. Solid Works is a computer-aided solid modeling tool. Using this tool, a solid model of each component was created. These components were then assembled in a Solid Works assembly file. This allowed for easy debugging of the design, as well as quick and easy alterations to the design. The mechanism was compared to a solid model of the bear head to ensure that it fit.



**Figure 6:** Top View of the Final Model of Eyebrow Mechanism

The two motors are in line with each other. Each motor powers a distinct set of axles and pulleys. The two output shafts can be seen at the bottom of the figure. The ball bearings for both shafts are located between the two center mounting plates. The best placement for the output shaft bearings was up for debate. The further apart the bearings, the better the support. Ultimately, the current placement was chosen because it allows for an easier assembly. Another view of this mechanism is shown in Figure 7.



**Figure 7:** An Isometric View of the Eyebrow Mechanism

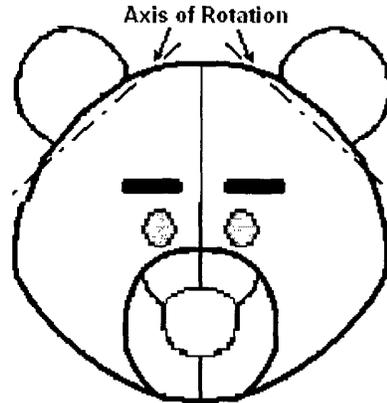
### **3.3 *The Ear Mechanism***

This section discusses the power transmission and the mechanism design for the ear.

#### **3.3.1 Power Transmission**

The design criteria for the ear mechanism are very similar to that of the eyebrow mechanism. Because of this, the two mechanisms look somewhat similar. Like the eyebrow mechanism, a belt drive system is utilized. Once again pulleys are used to gear down the output, and the same motor is used in both systems as well. This does not mean that these systems are exactly alike. There are several differences between the two mechanisms that are a result of the inherent differences in the two.

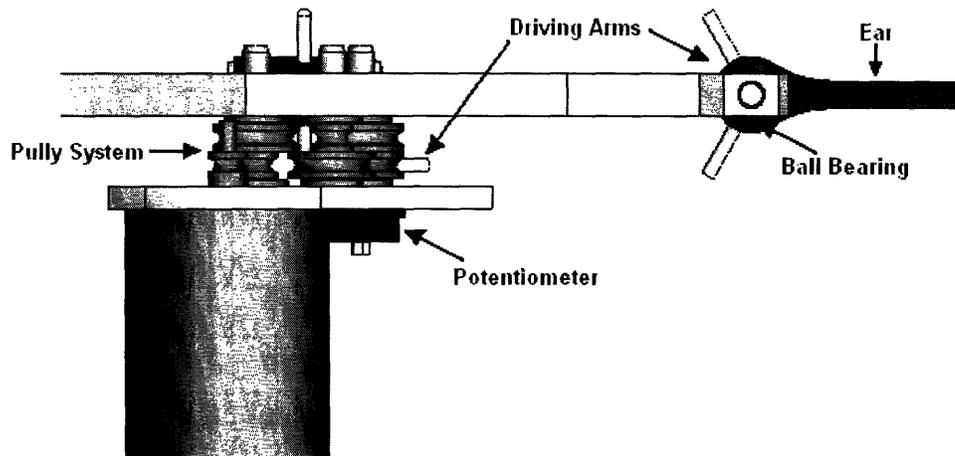
One major challenge in designing the ear mechanism was doing so with only one motor. Due to a lack of motor channels in the motor control board, only one motor can be used to actuate the ears. This is difficult since the two ears are not on the same axis of rotation.



**Figure 8:** Showing the Two Different Axis of Rotation that Need to be Coupled in Ear Mechanism

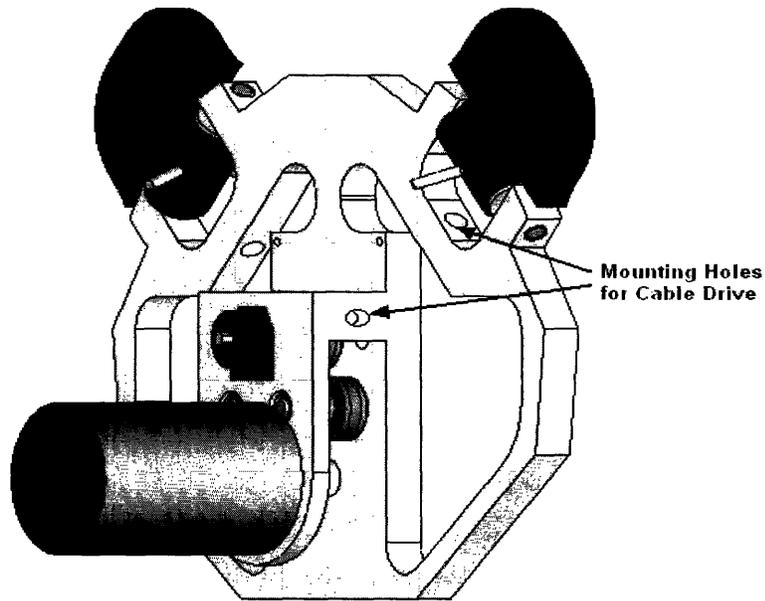
### 3.3.2 The Mechanism

A cable drive system lends itself to coupling different axis of rotation, like those found in this system. The mechanism still had to be geared down, and must be compliant. One way compliance can be obtained is using a cable drive against a spring. If the ear were to be moved in the direction that the cable is pulling, the cable would slacken allowing the ear to move easily in that direction. If, however, the ear were moved against the direction of the cable, the cable goes into tension to counteract this motion. Two-way compliance can be obtained using a capstan mechanism. In this type of system, a capstan would be used to drive both ears. If excess force were applied to the ear, the capstan would slip allowing for compliance. In this system, however, it is difficult to couple both ears together. If one ear were to slip it would be at a different angle than the other ear until it were readjusted. A purely cable driven system would not give the desired response. Because of this, a combination belt and cable drive system was used for this mechanism.



**Figure 9:** Side View of the Mechanism for Ear Actuation

Much like the eyebrow mechanism, the ear mechanism is geared down with a system of pulleys. In an effort to reduce the size of this mechanism, 0.15" and 0.4" pulleys were used. There are two driving arms in the pulley system and two driving arms on each ear. Two cables are attached to each driving arm in the pulley system. Each cable then connects to its respective driving arm on the ears. When either ear or the pulley system is moved, the cable will turn all of the coupled parts. This ensures that the ears remain coupled while the belt drive can slip to allow for compliance.



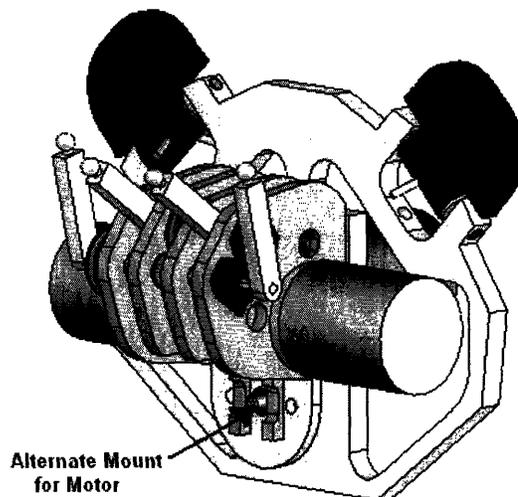
**Figure 10:** View of Ear Mechanism Showing the Mounting Holes for the Cable Drive

The cable for the cable drive will be contained inside of a flexible metallic tube. This tube will run between the two mounting holes shown in figure 10. Similar mounting holes can be found on the other side of the apparatus.

### ***3.4 The Complete Mechanism***

The integration of the two mechanisms was necessary to fit it in the small space desired. As designed, both mechanisms will take up about  $\frac{2}{3}$  of the space in the head. Unused space needed to be reclaimed to make room for these mechanisms. After several slight changes, the whole mechanism was made to fit in the originally allotted front half of the head. This was done by placing the ear mechanism's motor underneath the eyebrow mechanism and embedding the ear mechanism inside some of the unused space of the eyebrow mechanism. The back of the eyebrow mechanism was also tapped so that the two mechanisms can attach to each other. This attachment has the added benefit of making the whole structure more rigid.

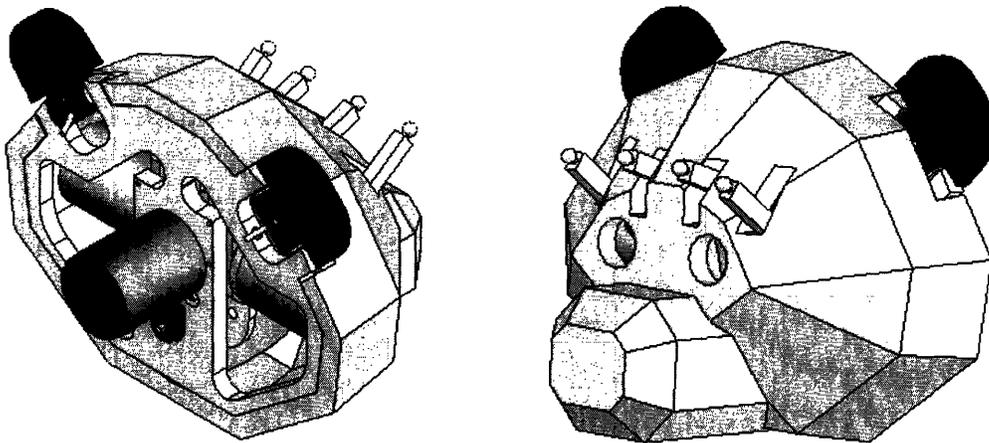
Unfortunately, in its current state, the motor control board cannot fit inside of the head. Even if all mechanisms were removed, the board would be hard pressed to find a place to fit. This is not due to the dimension of the board, as much as to the shape. The back of the head tapers in, but the motor control board is a straight rectangular prism. If either, the size of the head increases, or the shape of the board changes in the future, the design described above is ideal. In the mean time, however, a lack of a motor control board in the back half the the head creates a huge imbalance towards the front of the head. This imbalance can be leveled out by moving the ear mechanism's motor to the back of the head. The final design of the mechanisms can easily switch from one situation to the next.



**Figure 11:** The Complete Mechanism Showing Alternate Motor Mount

As you can see in Figure 11, the motor that controls the ear is currently mounted in the back of the head. There is, however, a second motor mount located beneath the eyebrow mechanism. If the extra space in the head is ever needed, the motor can be moved to this lower position, leaving about half of the bear head empty. In either state, the complete mechanism fits easily within the bear head. Both the eyebrow mechanism and the ear mechanism are located in the proper positions to actuate the bear head. The shape of the ear mechanism allows for easy mounting onto the solid frame of the

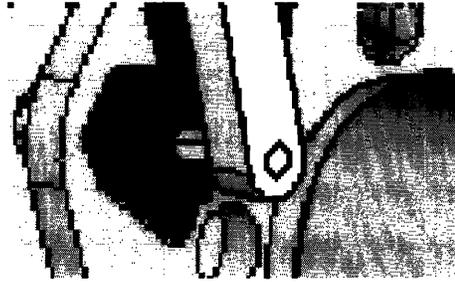
bear head. It matches the inner contour of the frame and can be slid into position. Several screws around the frame will hold the mechanism in place. A space under each ear was left open in hopes of embedding a microphone in each. A future iteration should include a mount for the cameras in the bear's eyes, a speaker in the bear's mouth, and the two microphones in the ears. These should not be a difficult addition, since their position, size, and shape were all considered in the design of this mechanism. A new version of the bear's front head frame is also required. The current frame lacks the slits that allow the ears to poke through the top of the head. In addition, a chamfer should be placed inside this slit to allow the ear to turn without running into the frame.



**Figure 12:** Front and Back Views of Full Assembly, Including Revised Bear Head Frame

The arms of the eyebrow mechanism stick out through slots in the bear head frame. These arms must then go through the silicone skin and fur. The actual eyebrow must be attached after the bear is completely assembled, fur and all. This allows for easy replacement of the eyebrows, in case of wear or damage. The eyebrows snap onto the arms using a standard ball and socket. This will create a strong enough fit so that the eyebrows will not come off during normal use. The ball and socket joints also have the advantage of compensating for the change in distance of the inner and outer eyebrow positions as the mechanism moves. It is worth noting that the output shaft design was altered, such that it now consists of a 0.125" x 0.5" hex broached shaft with the hex rod

making up the remainder of the shaft. This was done to increase the ease of assembly as well as eliminate slipping on the part of the eyebrow arms.



**Figure 13:** Close up of Figure 11, Showing the Alterations to the Output Shaft

The overall desired lengths of the eyebrow arms have not yet been decided. This is because, in order to obtain a lifelike motion, the eyebrows should be as close flush with the bear as possible at all times. This task is best left for later when the full model is built and tried in the bear head. Alterations for this task will be quite easy. The ball joints are designed to be screwed into the arms. By screwing and unscrewing these ball joints, the size can be altered by as much as 1/4". Also, assuming that the arm is tapped deep enough, a section could be cut off the arm without the need of re-drilling and re-tapping.

## **4. MANUFACTURING AND ASSEMBLY**

Once the design was finalized, the parts needed to be manufactured. The ball bearings, rubber belts, and steel pins were ordered as is and did not require alterations. Other parts, including the mounting structure, pulleys, and the hex broached rod required in-house production.

### **4.1.1 The Mounting Structure**

The mounting structure was designed to be simple to manufacture. Redundancy was utilized when possible in an effort to reduce the amount of parts. Ultimately the whole apparatus is made with just four different mounting plates. These plates were designed to be flat, without any protruding objects. Because of this, the plates were easily manufactured using the Media Lab's laser cutter. The laser cutter, acts like a

printer, using a laser to cut instead of ink to print. It can cut a 2-D shape out of varying thicknesses of different materials. This results in an extrusion of the original 2-D shape with the thickness of the material used.

The shape of each plate was taken from the Solid Work models and directly imported into the laser cutter computer. Because the process is computer controlled, a high precision piece can be produced. High precision allows for less worry about tolerances and overall fit. The four pieces were cut out of acrylic. The eyebrow mount plates, and the internal ear mount plate were all cut out of 0.118" stock acrylic. The external ear mount plate was cut out of 0.2" stock. These parts required extra machining to complete, since some of the required holes are sideways and could not be cut on the laser cutter.

The side of the eyebrow plates required a tapped hole in a specific location on its edge. To machine this tapped hole a jig was made. The jig was a simple plate with a hole that fit snugly around the plates. The hole acted as a guide, allowing the tapped hole to be placed correctly on such a thin edge. The hole was then tapped using a 0-80 hand tap. The mounting holes for the cable drive did not require as much precision and were eyeballed, then drilled using a 0.125" drill bit. Some of the laser cut holes need to be machined as well. A snug fit between the plates and the bearings was desired, so the bearing holes were undersized then reamed out to 0.25".

#### **4.1.2 The Pulleys**

The Pulleys were created using a mini lathe. This table top lathe lacked a lot of precision, but proved adequate for this task. 0.75" and 0.5" round delrin stock was turned down into the right size and shape. First, a 0.5" long piece of stock was placed into lathe. One side was faced to provide a clean working surface. Then, the piece was turned around and the other side was faced. A center drill was used to mark the center, then a 0.1" hole was drilled through. A section, roughly the thickness of the desired final pulley was then cut off. A 0.125" x 1" steel pin was press fit into this piece and the rough face of the pulley was faced off to the desired thickness. Finally a small round file was used to create the notch in the center of the pulley. In order to decrease slipping on pulley surface, 6 divots were drilled into the pulleys around the groove. These divots

give the belt more traction while not still allowing for belt slippage at excessive loads.

### **4.1.3 The Mounting Structure**

The hex broached rod was made using a 0.125" aluminum rod. The rod was cut to a length of about 1.25" then placed in the mini-lathe. After facing one side, center drill was used to mark the center and a 0.08" hole was drilled through the length of the rod. A 2mm hardened hex rod was then pressed through the hole. When the hex rod was removed it left a hexagonal hole in the aluminum rod. The aluminum rod was then cut in half and each half was turned down to a length of 0.5".

### **4.2.1 Assembly**

Initially, each section of the eyebrow apparatus was assembled. The motor was fit with its pulley then mounted to the structure. The pulleys were press fit onto their respective axles. Where needed the bearing were then put onto the axles. The fit between the pins and the bearings were quite tight, so the mini-lathe was used to press the bearing onto the pins. Special care was taken to make sure the bearings were not damaged. Once all of the pulley/axle assemblies were made, the bearings were snugly fit into their respective mounts. The belts and the eyebrow arms were then attached. Once both sections were assembled, the two sections were joined. The internal ear mounting plate was screwed into the eyebrow mechanism to add rigidity to the structure.

The ear mechanism was assembled in a manner very much similar to the eyebrow mechanism assembly. The pulleys were press fit onto the steel pins, then the ball bearings were pressed onto the pins using the mini-lathe. The ear driving arms were made using 1/16" steel pins that are pressed into the final pulley in the pulley system as well as the base of the ear itself. When pressing the pin into the ear, special care was taken to make sure that the pin did not contact the axle around which the ear pivots. Once the pulley assemblies were built they are placed in their respective places on the internal ear mounting plate, which was already attached to the eyebrow mechanism. The driving belts were then attached between the pulleys, and finally the external ear mounting plate was pressed onto the pulley assemblies. The mounting

plate was then secured to the eyebrow mechanism using several 0-80 screws.

## **5. CONCLUSION**

The actuators required for the Huggable teddy were designed and built. These mechanisms meet the criteria set for them. They are silent, back drivable, and compact. The full assembly has the potential to fit within the front half of the bear head if necessary but is currently set up with a motor in the back half of the bear head. This was done to help balance the system for the preexisting neck actuator. The eyebrow mechanism has 2 DOF as desired and couples the inner eyebrow positions to each other and outer eye brow positions to each other. The design for the eyebrow mechanism allows for several emotions to be portrayed by the bear. Making the eyebrow mechanism flush with the bear face will be challenging and require trial and error at first. The ear mechanism manages to couple both ears together in spite of their different axis. The mechanism requires a few slight modifications to the existing bear head frame to allow the ears to be in the proper orientation as well as to make mounting the assembly to the frame easier. Up to this point, the designs and mechanisms have been built. Testing of the design will follow to ensure life-like interaction with the user.