THE NEXT FURBY

Bachelor Assignment Gerrit Eisma s0126039

Title page

This report is written for the bachelor assignment for the study Industrial Design at the University of Twente.

General information

Assignment	The Next Furby
Tutor	H. Tragter
Date of publication	February 2nd 2011
Number of copies	2
Number of pages	44
Number of appendices	9

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Introduction

The goal of this project is to develop a new Furby, with the knowhow and technology of 2010. A Furby is an electronic plush toy designed in 1998. It has a wide variety of electronic input, varying from touch sensors to a light sensor mounted between its eyes. It will respond to the input by moving its eyes, ears, mouth and/or by moving up and down, while telling one of over 150 programmed sentences. It can even reach stages like hunger and tiredness, so it will ask for being fed if it gains the status hungry.

The whole project consists of multiple stages, of which this assignment is the first one. In this report there will be a focus on analysis, to have a solid base for next stages of the project. The analysis covers multiple types of research. It contains research about all of the different kind of Furbies ever produced, the history of robotic pets and other robots available on the market. Further an analysis of the ideology behind the Furby has been carried out, by extracting the idea behind the Furby and its target group.

Another big part of the research was a deep analysis of the internal working of the Furby. Therefore multiple Furbies have been sacrificed in the name of science by skinning those to the last part of it. This way a lot of information could be derived about the mechanical aspect, the electronic aspect and the behavior patterns of Furby. Not only has this been done to the 1998 Furby, but also to its successor, the Emoto-tronic Furby from 2005.

By evaluating the gained results and by creating personas scenarios could be created. From these scenarios all kind of possible problems have been derived, which can be used as input for further stages in the project. These problems have been sorted out. At last plans have been made to hack the Furby, which can also be used later by other students to test behavior on it. So at the end of this assignment there is a hacked Furby and report with valuable analysis for next stages of the project.

1. Overview of the Furby

1.1 The Furby

One of the latest fads of the past millennium can be allocated to the Furby. This electronic plush toy became a worldwide success when it was first launched on the market at the end of the year 1998. The Furby is a relatively small toy with a height of approximate 15 centimeter, a furry skin, giant ears and a face with human like eyes and a beak. It carries visual characteristics from both a hamster and an owl. The Furby was reintroduced in 2005 with a complete new model, but the original Furby remains the most successful version, with a selling number of over 40 million.

Furbies were one of the first successful attempts to produce and sell domestically-aimed toy robots in stores. The original Furby is equipped with different type of sensors, like electronic switches, an infrared sensor and audio sensor. It also has a speaker and is driven by a single reversible motor. A newly purchased Furby starts out speaking entirely its unique language called Furbish, but is programmed to speak less Furbish as it gradually start using English language fragments or any other real language.

The creators are Dave Hampton and Caleb Chung, who spent 18 months to develop this toy. They got inspiration for inventing the Furby when they found the key chain virtual pets like the Tamagotchi very limiting with the small screens, crude graphics and beeping sound. They wanted to improve the virtual pet idea by creating a real-world cuddly pet with a more advanced vocabulary. Eventually it was brought on the market by Tiger Electronics. The name Furby is derived from 'Fur ball', the working title of the Furby.

1.2 Different generations

1.2.1 Introduction

Two generations of Furbies have been released throughout the years (Figure 1.1). Each generation contains different types of Furbies. For example, the first generation exists of three different types, the original adult Furby', the Baby Furby and the Shelby Furby. The first generation will be discussed first.

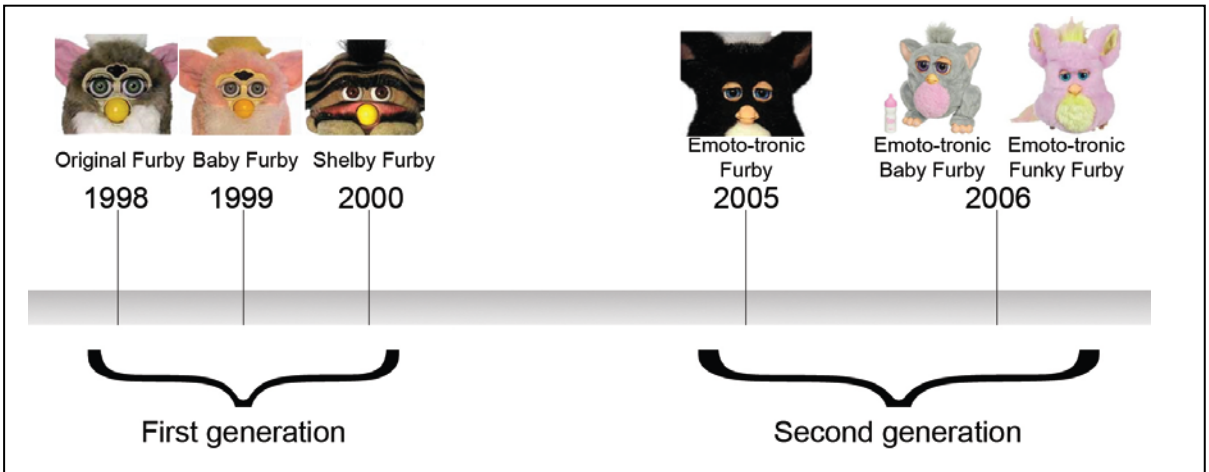

Figure 1.1: The introduction of Furby generations timeline

1.2.2 First generation

The original adult Furby

The first adult versions of the original line of Furbies (Figure 1.2), consisting of six different appearances, were launched at the worldwide market in October 1998. Hardly one month after the release were the Furbies almost completely sold out all over the world. The next versions were released at the beginning of 1999. The advantage over his predecessor is implementation of a deep sleep mode, to prevent Furby from waking up in the middle of the night.

In total there have been designed eight different groups of six Furbies each for the original line, but the last two groups have never been released at the market (Figure 1.3). Later versions are characterized by more distinct colours, although these were still based on animals. Their functionality remained the same. Production of the original Furby continued until halfway 2000. Furbies originally retailed for about 30 dollar, but the excess demand and limited availability drove the price over 100 dollar.

Figure 1.2: The 'Original Furby'

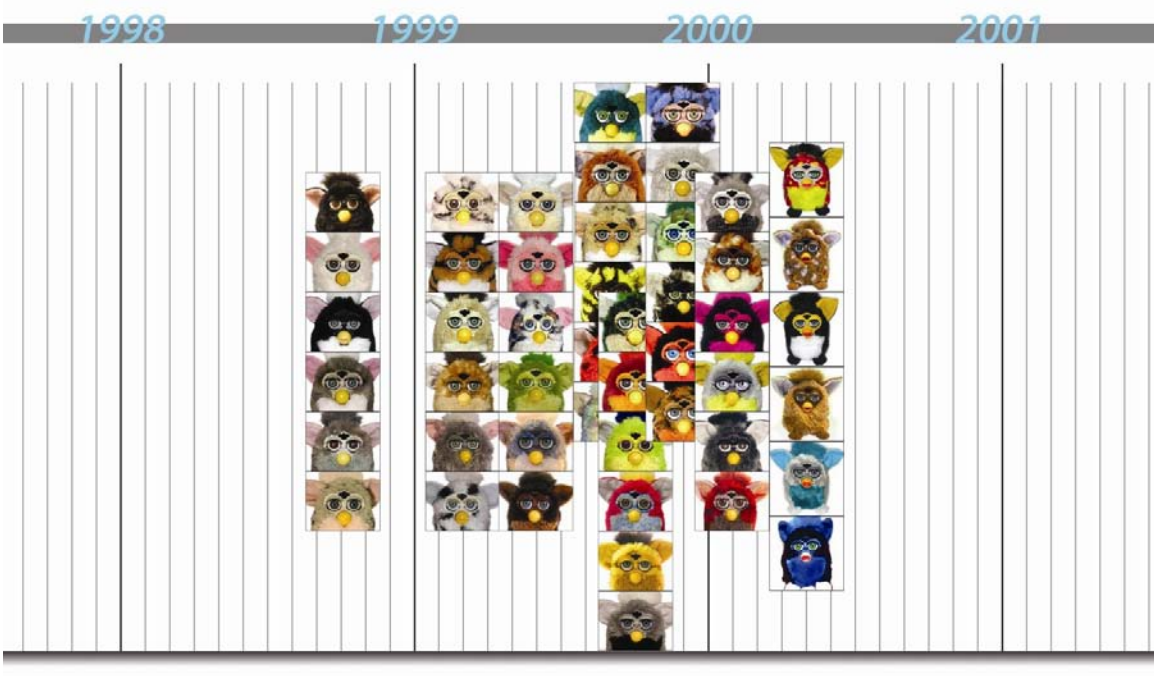

Figure 1.3: Timeline of the different versions of the original Furby line. See Appendix A for a bigger version of this image.

The Baby Furby

In July 1999, following the success of the original Furbies, the Furby Babies line was introduced (Figure 1.4). These are smaller versions of the original adult ones, with more baby-like colours, higher voices and more childish personalities. They can't dance, as they cannot move their bottom, but they do have a larger vocabulary. They can communicate with all of the other Furbies from the first generation via the infrared port.

Figure 1.4: Baby Furby (right) next to an original adult Furby

The Shelby Furby

In 2000, when the fad was coming to an end, Hasbro introduced a new kind of Furby. This Furby is called Shelby (Figure 1.5), which resembles the original Furby regarding its functions, but has a different visual appearance, it looks like a clamp. Like all Furbies, this offspring of the Furby Family is also able to communicate with all of the other Furbies of the first generation.

Figure 1.5: Shelby Furby

Other first generation Furbies

Other late descendants of the original Furby family are the Yoda-Furby and the ET-Furby (Figure 1.6), based on the similar characters in respectively the movies Star Wars and ET. They were mainly used for promotional intentions. These Furbies, which are only sold in small numbers, are not able to communicate with other versions of Furbies. There have also been released a lot of special original adult Furbies, but only in small numbers. Those were Furbies to be sold for Wall-Mart only for example.

Figure 1.6: ET-Furby

1.2.3 Second generation

Emoto-Tronic adult Furby

The Furby was reintroduced in August 2005 with the release of the new Emoto-Tronic Furby (Figure 1.7). It currently is the latest species of Furby released. It is larger than the previous version, and has been upgraded with a more emotional face, making it possible to show some sort of facial expressions, and a voice recognition system, enabling them to be able to communicate better with humans. Unlike the Furbies originally released, just one order is necessary to make them 'sleep', and they have an on/off switch. They can only communicate with other Emoto-Tronic Furbies, though to a lesser extent than the communication between original Furbies, and they cannot communicate with the original Furbies or with the Funky Furbies. They also lack light sensors and basic motion sensors and do not respond to loud sounds as the originals do. It never came close to the success of the first Furby regarding sales numbers.

Figure 1.7: Emoto-tronic Furby (left) compared to the original Furby

Emoto-Tronic Baby Furby

A new version of the Emoto-Tronic Furby was released in 2006 (Figure 1.8). It is smaller than its predecessor with a more baby-ish appearance. Compared to the adult version is has fewer features. Its vocabulary is less extended. The legs are movable now; they unfold when the Baby Furby is awake.

Figure 1.8: Emoto-Tronic Baby Furby

Emoto-Tronic Funky Furby

Following the release of the Baby Furby, the Funky Furby was released 2006 outside United States. These are available in 2 different sets of bright colors and they do have a long furry tail at the back. It does sing new songs and can dance to the music if it is played loud enough (Figure 1.9).

Figure 1.9: Emoto-Tronic Funky Furby with its distinct tail

2. Smart Toys

2.1 Definition of smart toys and robotic pets

The Furby is an example of a smart toy. But what defines a smart toy in this context?

> Smart toys are interactive standalone objects for children to play with, which use technology to create simulated animal intelligence and enhance play by interacting with the child.

The toy is either interactive by initiation of open-ended play suggestions, when the toy initiates a play scenario by calling for attention, or by responding to the actions of the child, via input and output devices, mostly microphones, cameras, touch sensors and keyboards for input and speakers, actuators and screens for output. The Furby can also be classified as a robotic pet. A robotic pet is an artificially intelligent machine made in the image of an animal commonly kept as a pet.

Regarding the word smart in smart toys, it means the object exhibits intelligent behavior. It uses technology to improve play by interacting with the user. It is not intended to be an educational toy which claims that by playing with it the child becomes smarter.

2.2 History of smart toys and robotic pets

The Furby was not the first smart toy on the market, nor will it be the last. Here is an overview of smart toys through the years.

The first smart toys in this definition were available in the late 70's with the introduction of the microprocessor. One of the first smart toys on the market was the Texas Instrument's Speak & Spell, which was available around 1978. It is used for spelling games and guessing a mystery code. Its input device is a keyboard, its output devices are a LED read-out and speakers which give sound effects. One of the first robotic pets from the same period is Teddy Ruxpin (Figure 3.1), a robotic teddy bear from 1985. It reads children's stories via a recording device built into its back and swivels its eyes and mouth. It was largely successful all over the world.

Figure 3.1: Teddy Ruxpin

Another very popular smart toy, the Tamagotchi, was released in 1996, a couple of years before the introduction of the Furby. It is a relational artifact, a small virtual creature with a screen housed in its egg-shaped plastic shell. The user has to take care of it by feeding it, cleaning it or amuse it by performing actions using three buttons. If this is done properly, the toy will be "happy" and it will flourish and survive. (Figure 3.2)

Figure 3.2: Tamagotchi

The Furby was not the only great innovation of smart toys in the 90's. The AIBO was introduced in 1999, a small robotic dog from Sony, with an initial price of 2500 dollar in a limited

edition. It is able to walk, see its environment via a camera and recognize speech. It was an unexpected success, because the AIBO wasn't designed for any practical purpose. Sales continued until 2006, with limited produced units, making it still a very valuable artifact at EBay.

The continuing development of Furby-type technology has led to the release of the FurReal line of toys in 2002 (figure 3.3), and was launched again in 2006. These pets are based on real life pets, and move and make sound like them. They have limited programmed movement and have touch and sound sensors as input devices.

Figure 3.3: FurReal puppy

A lot of robotic pets have been introduced since then, but most of them are just simple toys with less advanced electronics compared to the Furby and less possible interaction between humans and the toy. Most of the toys are just a display of possible technology instead of being a real playable toy.

3. Robotic human behavior

3.1 Introduction

The Furby shows some extent of human behavior. It is programmed to eat, sleep and play with children and talks in English, the movements of its beak synchronized with the speech. The 2005 edition of the Furby is even able to understand talk by voice recognition. It tells jokes and is able to play a game with the child. It also has an extended facial expression. There are more robots on the market with human behavior. Here are some examples, rather non commercial version of robotics. These robots contain a lot of complex mechanical movement, electronics and behavior, which can be applied to the new Furby as well.

3.2 Kismet

One of the most famous examples of a robot with human behavior is Kismet, shown in figure 3.3. Kismet is a robot made in the late 1990s at Massachusetts Institute of Technology, and it engages people in natural and expressive face-to-face interaction. The idea behind it is to connect different viewpoints regarding social development, psychology and ethology in order to achieve a more natural and intuitive social interaction with a human user. It gets visual and auditory input from the environment and reacts by giving signals to the user caregiver through gaze direction, facial expression, body posture, and vocal output. The research forms a base to support several social cues and skills that could ultimately play an important role in socially situated learning with a human instructor.

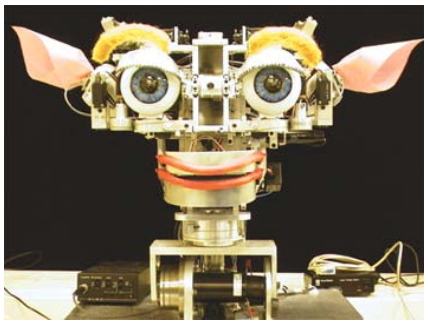

Figure 3.3: Kismet

3.3 ASIMO

Another humanoid robot is the Honda ASIMO (Figure 3.4). It is a complete standalone object, which is able to maneuver by itself, carrying a backpack with batteries. It is able to detect obstacles and climb stairs, although there were a lot of troubles with it. Videos of ASIMO tumbling down the stairs are widely spread around the internet. The ASIMO focuses less on expressive facial interaction; in fact it doesn't even have a human like face, so it can't show expressions. However, it has the ability to recognize objects or the capability to learn new objects. It also can read facial expressions of other people. ASIMO isn't built in intention to simulate a real person, but rather the social interactive part of it.

Figure 3.4: ASIMO

3.4 Actroid

A robot with a more anthropomorphist look is the Actroid, developed by Osaka University, which is shown in figure 3.5. At first glance it has the lifelike visual appearance of a young Japanese female. The Actroid is able to mimic lifelike functions as blinking, speaking, and breathing. These robots are interactive, they have the ability to recognize speech and process it, making it able to respond in kind. The hardware and power needed to drive this robot cannot be stored in the robot, as it is way too large. It is hidden under or behind the robot, covered from seeing it. The first models of this robot dates back to 2003, but newer models are still being developed.

Figure 3.5: Actroid

4. Idea behind the Furby

4.1 History

To understand the meaning behind the idea of the Furby we have to go back to ancient times. It started with the domestication of animals. Animals were no longer considered as enemies or food by human, but were domesticated to be kept for exploiting their own activities. People started to get a friendship with them and the animals slightly lost their utility function. They eventually lost their utility function during the industrialization, when machines took their jobs over. People started to keep animals mainly as pets and started to get a close relationship with them, having them as a companion object, as someone who understands them and protects them from loneliness. An example of this path of evolution is a dog, a domesticated wolf, which were bred for multiple tasks like herding sheep and for assisting in hunting, but are now mainly considered as a pet.

Pets are also important for the development of children, as pets play an important role in the development of the identity of the children. Children even get a more intimate relationship with pets than adults do. The children learn about responsibility towards their pet, but also learn how to associate with living beings through respectful behavior toward the pet. If they don't treat the pet well, the pet will reply the same to them, it will literally show fight. And at last, when their pet dies, they will be prepared for the most tragic moments in their further life.

4.2 Cuddly toy

The next step in the evolution towards the smart pet was the cuddly toy. These toys had a few advantages over real pets. Children were able to take them with them all the time, and a cuddle toy is more manipulable as a pet, as it does not struggle with the child. It is a lot cheaper and can be discharged easily, without the possibility to harm an animal. For example, the introduction of the teddy-bear was a huge success. Because they are so impersonal, they are very useful to project all fantasies on them.

As technology developed, toy designers introduced more electronic toys on the market, of which Furby was one of the most successful attempts launched on the toy market. Essentially it has the function of a teddy-bear, with the additional option to attain sensory input and give limited feedback on social interactions to the children. It fulfills the same function as a living pet, but with the ability for children to carry them all the time and with safe and user friendly emotions of the pet, a combination of a teddy-bear and the good and safe aspects of a real pet. But still it is rather a toy, because it cannot die and it will not behave different when it gets ignored.

4.3 Comparison and evaluation

The Furby is more advanced as a simple teddy bear, but less advanced as a computer program. Whilst the teddy bear gives the child utter freedom in their imagination to play fantasy games with them, as it doesn't struggle back at all, the Furby limits these play by having a very limited own personality with its own will. They don't stimulate the imagination at all. For older children who don't play those role playing games anymore, but make use of the functions of the Furby, it is also limited. It has only a few open-ended play suggestions and its replies on sensory input are very predictable, therefore it offers only limited play value. One of the most heard remarks about the Furby and smart toys in general is that being a technical marvel often, they only have very limited play value. And because they cannot learn they are limited to predefined programmed speech and actions. As a result, it is most likely they repeat sentences often, making them very boring. There are many stories on internet about children get tired quickly of them after only having played with it for a couple of times.

5. Target audience

The Furby was original designed for small children for ages around 4 to 6. Around that age, children tend to play fantasy games with their toys, completely losing themselves in their role. These fantasy games include games like playing a mother and raise children, or playing a policeman and catch thieves. The toy helps children to start a relationship with things and objects in de world outside, preparing it for the adult world by growing towards an own identity. When kids get older this role-playing games decreases and their play activities get more mature, like board games and video games.

At these ages children develop very quickly. A child develops by playing, but no child plays with the intention to develop, he just plays because it is fun. Playing is about the experience, discovering and repetition so experience and insight will develop. To accomplish this toys have to be challenging. If toys are not enough challenging, children will get bored quickly. This happens when toys have very limited functions. Using toys must be fun; they may but not need to have an educational role, although some parents prefer those kinds of toys. But as young children get many stimulants and impressions daily, toys help children to process these activities. If they learn something from it, it is much to the good.

It has to be considered that parents are the ones who buy the toys for their children, so there should be paid attention to their wishes. These wishes can involve for example a maximum desirable price or safety regulations. If parents don’t think the quality and the rate of playfulness is worth the price they pay for it, they will not buy it.

6. Analysis of the Furby

6.1 The original 1998 adult Furby

Analysis of the 1998 adult Furby mainly occurred by deriving information from the internet and by reverse engineering of a Furby, by dismantling it completely. This Furby is very popular among hackers, as it is easy to manipulate, so there is a lot of detailed information available on the internet. Only the original adult has been examined, as all of the Furbies of the first generation are much like the same. They have the same basic functions and electronics.

6.1.1 Mechanical aspects

The 1998 Furby is able to perform some mechanical movements. It is able to lift his ears, turn its eyes and eyelids up and down, open its mouth and bend a little bit forward. All these actions are made possible by just a single reversible motor, which drives a series of gears and cams (Figure 6.1). These cams got an opening on the side in a certain closed pattern. These openings guide a pin, which is connected to the body part, so repositioning of the pin will move that body part.

Movements made possible by rotating the cams:

Movement	Type
Eyes	Open and close
Mouth	Open and close
Ears	Up and down
Bottom	Lift up and back down

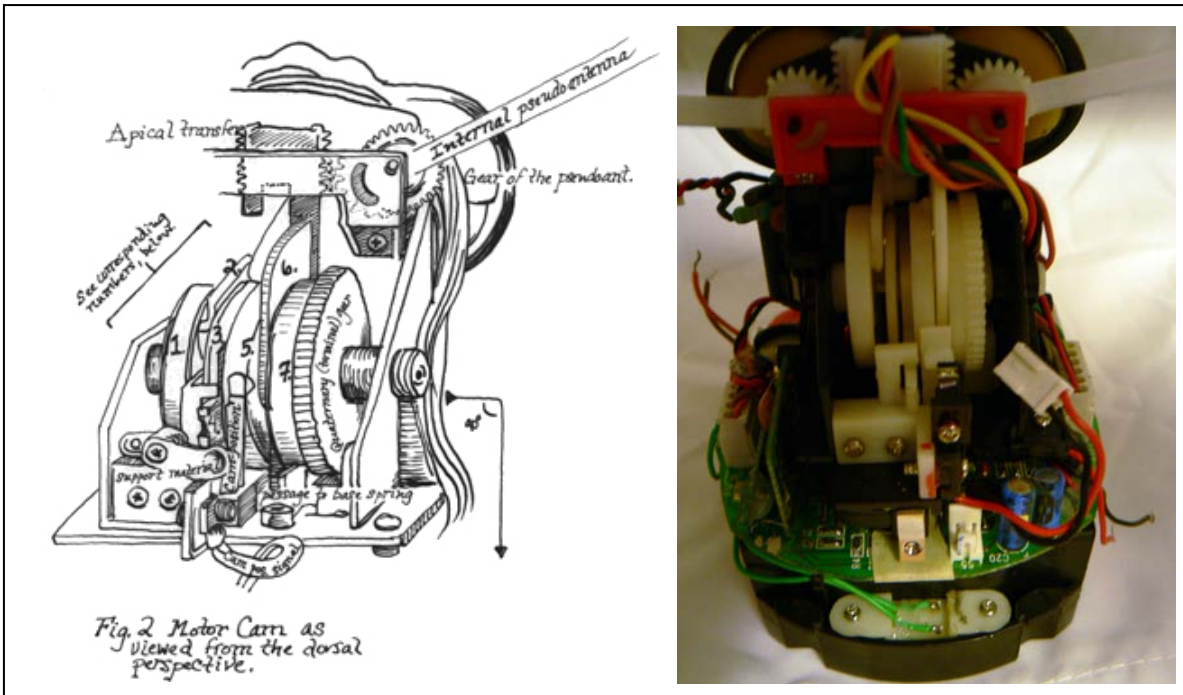

Figure 6.1: The cam with corresponding items, the separated items can be found in figure 6.2

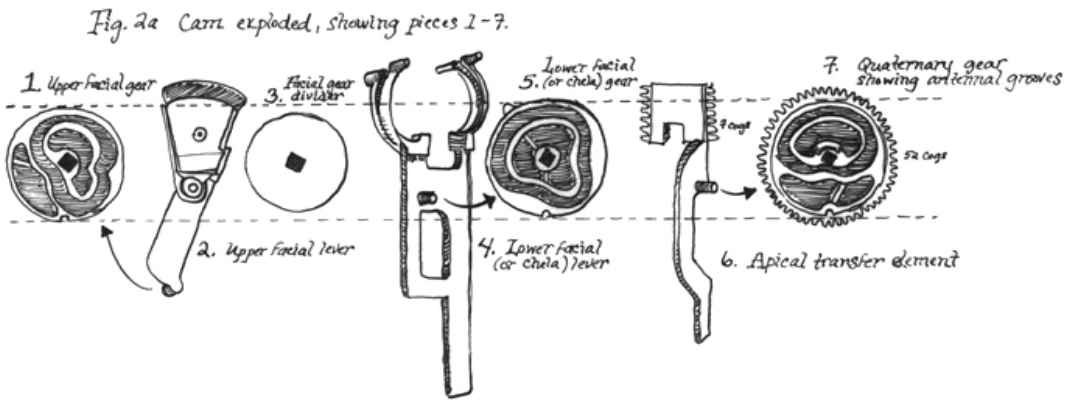

Figure 6.2: detailed view of the components of the cam

These cams are all on the same drive shaft, so one full rotation of the shaft will put the Furby through all combinations of eye, mouth, ears and lift motions. Each angular region of the shaft's rotation can be described as combinations of each motion controlled part's state. By arranging these states on the cams, sequences of animated motion can be achieved by rotating the main shaft forwards and backwards. For an example of the mouth movement, see figure 6.3.

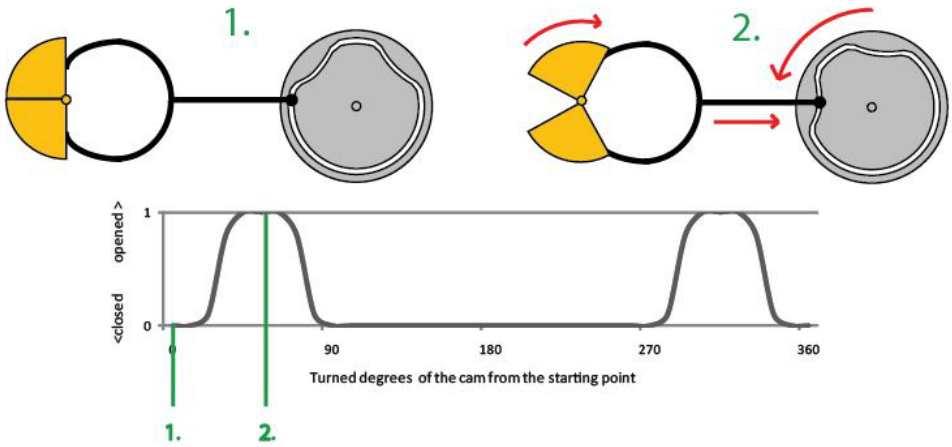

Figure 6.3: The gray round object is the cam for controlling the beak. By rotating it, the black pin will be moved in the slot of the cam, therefore pulling the mouth open along its axis.

The series of gears and cams makes it possible to drive all motions with just one motor; however, the downside of this solution is that all of its motion patterns are predetermined by the patterns on the cams, so the actions on the cam can only be accessed sequentially (figure 6.4). This means that in order to perform a specific action, Furby has to spin through other actions in order to get to the desired action. For example, in order to get to sleep, it has to spin through other programs like eat to get to the sleep motion. It does have a separate part on the cam for each major function though, so it is able to move a body part separately by moving the main shaft a little bit backwards and forwards in a narrow rotation of the cams.

The reference point of the cam in figure 6.4 is on 0 degrees. There is a little bump on one of the cams, which can be detected by a pressure sensor. When the batteries are plugged in it searches for this bump first. At the end of an action it always returns to this point, the neutral stance. As can be seen in the graphic, the Furby in its neutral stance has it ears in a neutral position, its eyes are just a little bit closed, its beak is closed and it has not lifted itself of the ground

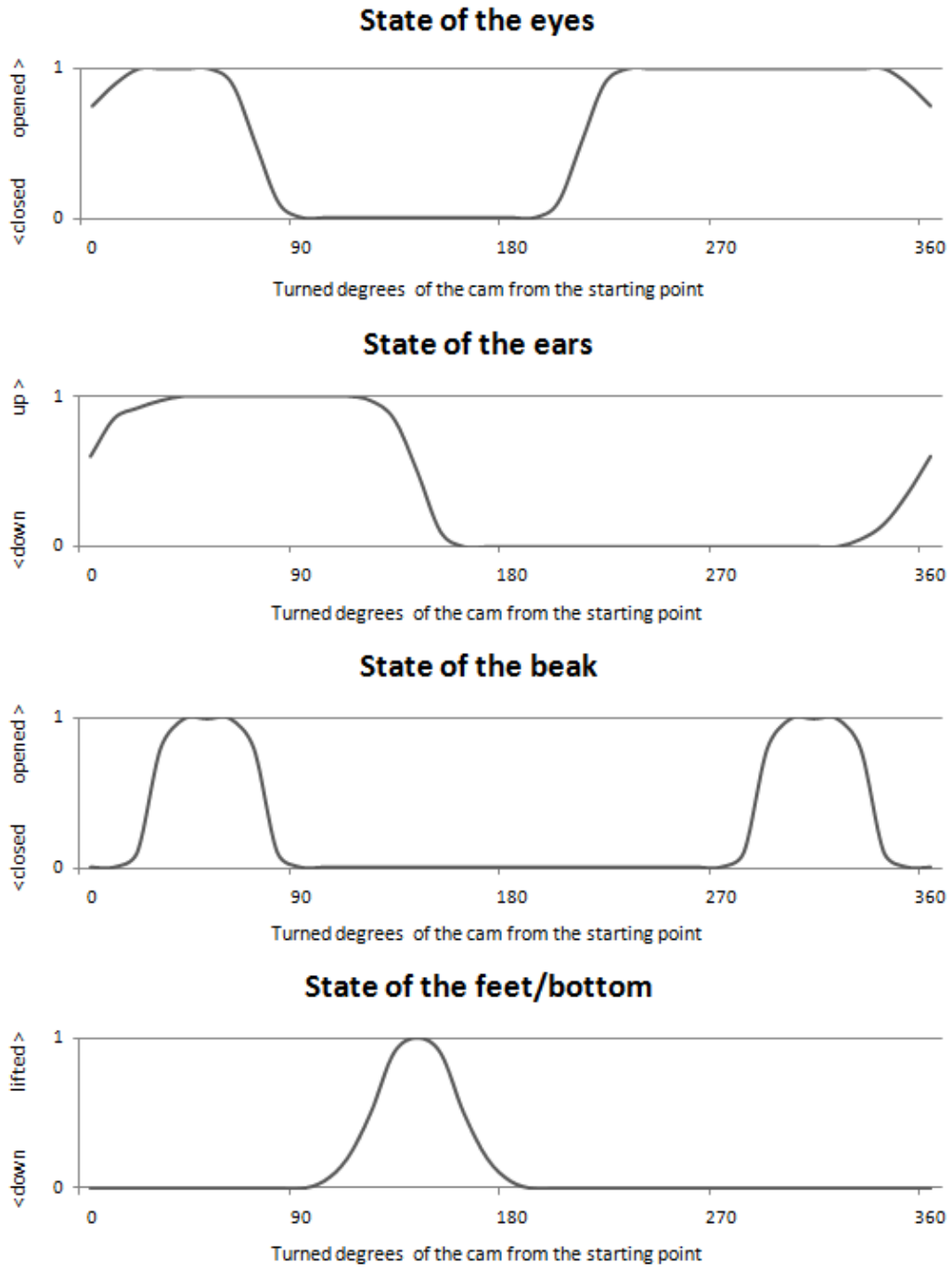

Figure 6.4: The state of the Furby on different angles of the cams. See Appendix B for a bigger version of this image.

All of the mechanical body parts are mainly made from low-cost plastic and are protected against obstruction caused by reckless or unaware children. The gears slip when the environmental stress is too heavy, preventing the series of gears and cams of being damaged. All of the parts are protected by a stronger black plastic hull of 2 millimeters thick, giving the Furby its shape, which in its case again is covered by the furry fabric. (Figure 6.5)

Figure 6.5: A Furby showing its plastic hull

6.1.2 Electronic parts

The sensory input of the old Furby consists of very simple and cheap sensors. It has 3 mechanical touch sensors, one attached to its tummy for tickling, one on its back for petting and another one as a tongue in its beak for feeding. It is also equipped with an audio sensor and a photo sensor, which are 1-bit sensors and are only able to detect respectively sound or no sound and light or darkness. Furthermore it is equipped with a 3-positional tilt ball-sensor for detecting if it is upright, lying down or upside down. For communication with other Furbies it is equipped with an IR-transmitter and an IR-receiver, which makes it possible to communicate at small distances. It has a small speaker on its tummy, a low budget speaker of not a very high quality. A total list of these parts can be found below:

Input sensors	**Type**	**Position**
Tickling tummy	Custom switch (two pieces of metal that touch)	Mounted on top of speaker
Petting back	Micro switch	On Furby's back, behind the large button
Feeding	Custom switch (two pieces of metal that touch)	In its beak, disguised as a tongue
Determining starting point of cam	Custom switch (two pieces of metal that touch)	Right on the cam with a little knot on it
Light Sensor	Light dependent resistor (LDR)	Between the eyes, the middle dot
IR Receiver (for talking to other Furbies)	Infared receiver	Between the eyes close to the left eye
Inversion	Tilt switch	On printed circuit board
Sound	Microphone (1 centimeter)	On the right of Furby's chest
Reset Button	Micro switch	On Furby's bottom
IR Encoder for motor position	Infrared LED - disc with slots - infrared receiver	Behind the face, close to the motor
Electronic output	**Type**	**Position**
Talking	Speaker (3 centimeter)	On its belly
Moving parts	DC motor and cam and gear assembly	Behind the face
IR Sender (for talking to other Furbies)	Infared LED	Between the eyes close to the right eye

Pictures of most of these parts can be found on the next page, figure 6.6. A detailed picture of the position of the electronic components of the Furby, made by a MIT student, can be found in Appendix C. A schematic of the electronics can be found in Appendix D, made by an anonymous person.

The Furby is driven by integrated chips on the main printed circuit board located at the bottom of Furby. These are located at two small circuit boards, containing the CPU, which is a 3.58MHz 8-bit CPU, and it also contains ROM memory, voice samples and maybe more. However, these integrated chips are masked with a plastic blob, preventing reverse engineering, making it impossible to get the exact specifications of the Furby and to change the existing code. To make adjustments to the code

to make it work differently you have to use another integrated chip and connect it to the sensors in place.

The Furby is driven by four AA batteries, providing 6 Volts as power output. The batteries can be replaced without running the risk of losing memory data, because of the use of EEPROM (Flash), so Furby will never forget its current state of mind unless the reset button is triggered. It also stores its name and if it has to call the user mommy or daddy.

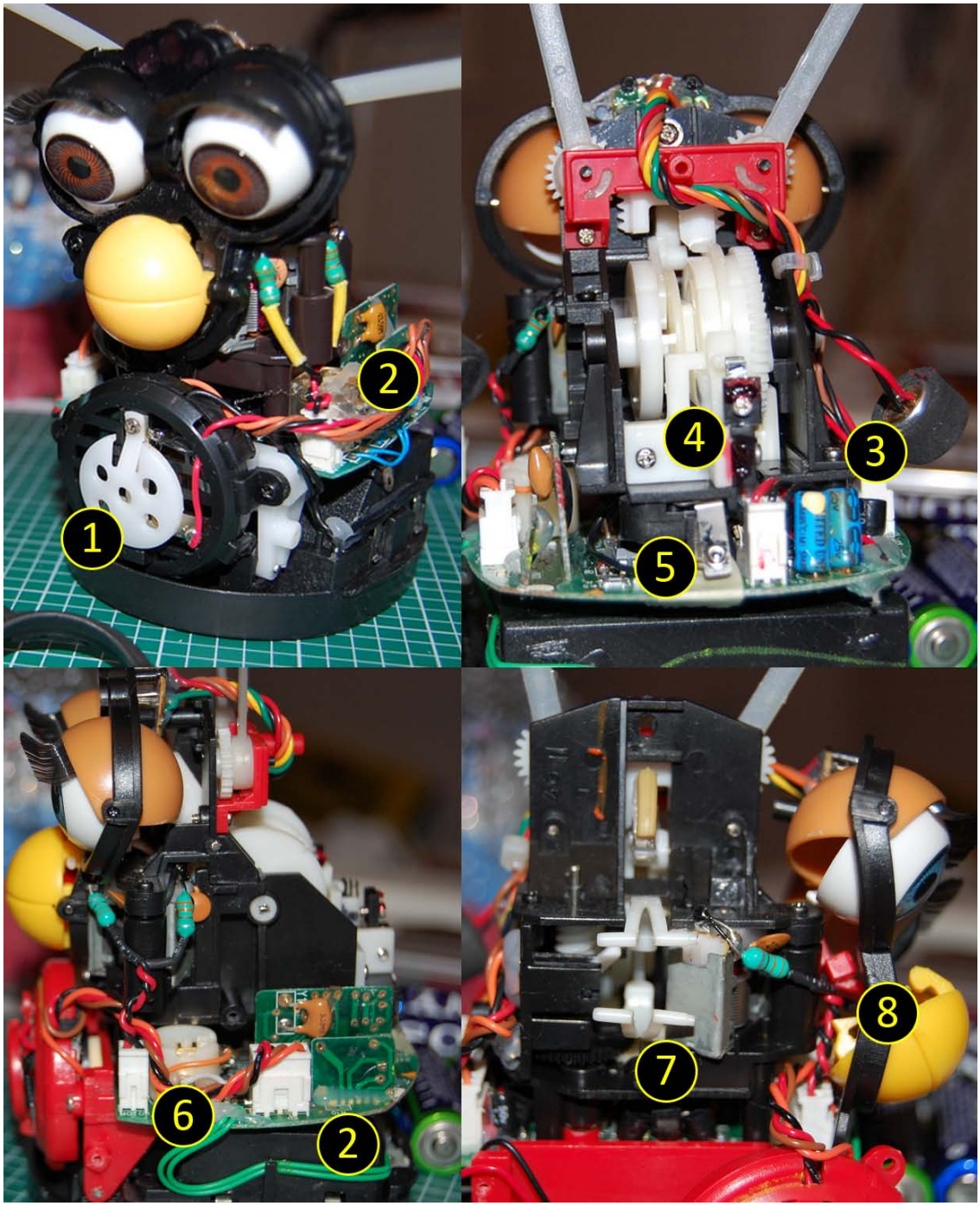

Figure 6.6: Speaker and tummy sensor is at (1), (2) are the integrated chips, (3) is the microphone, the switch for the cams is at (4), at (5) is the back micro switch for petting, (6) is the tilt switch, (7) is the motor and the beak sensor is at (8).

6.1.3 Behavior

The Furby is programmed to show lifelike behavior, by showing needs like sleeping and feeding. Although the Furby has mostly 1-bit sensory input only, the programmed behavior is rather complicated. Triggering a sensor (or if the timer runs out) will always cause a reaction. There are up to 25 different reactions for a single sensory input, as can be seen in the table.

Type	**Action**	**Total different reactions**
Touch sensor back	- Pressing sensor	- 13
Touch sensor tummy	- Pressing sensor	- 25
Touch sensor beak	- Pressing sensor	- 14
Photodiode between eyes	- Covering all light sources	- 12
Microphone right of beak	- Producing a loud sound	- 18
3-positional tilt ball-sensor	- Put the Furby on its back - Put the Furby upside down	- 25 - 18
IR-receiver and detector between eyes	- Put another Furby face-to-face in front of it	- 5
Timer running out	- Doing nothing for 34 seconds	- 10
Going to sleep	- Follows after actions above	- 5
Waking up	- Put Furby upside down, only when asleep	- 5
Total		- 150

State diagram

AI actions and reactions follow a fixed order. This is visualized in an adoption of a state diagram, figure 6.7, and explained next. The diagram starts at the blue spot. When batteries are plugged in it will start from there and it can get to two states: Idle state and therefore ready to receive further action (with five different kind of sentences possible) or going back to sleep again, via one of four different sentences. This kind of reaction exists of a spoken sentence as output from the speaker and mechanical movement as output from the motor by rotating the cams. The beak movement is synchronized with the speech of the Furby. When in idle state, interaction with the Furby, changes in the environment or just simply time going by will trigger a reaction. After the action Furby will return to the idle state or go to sleep.

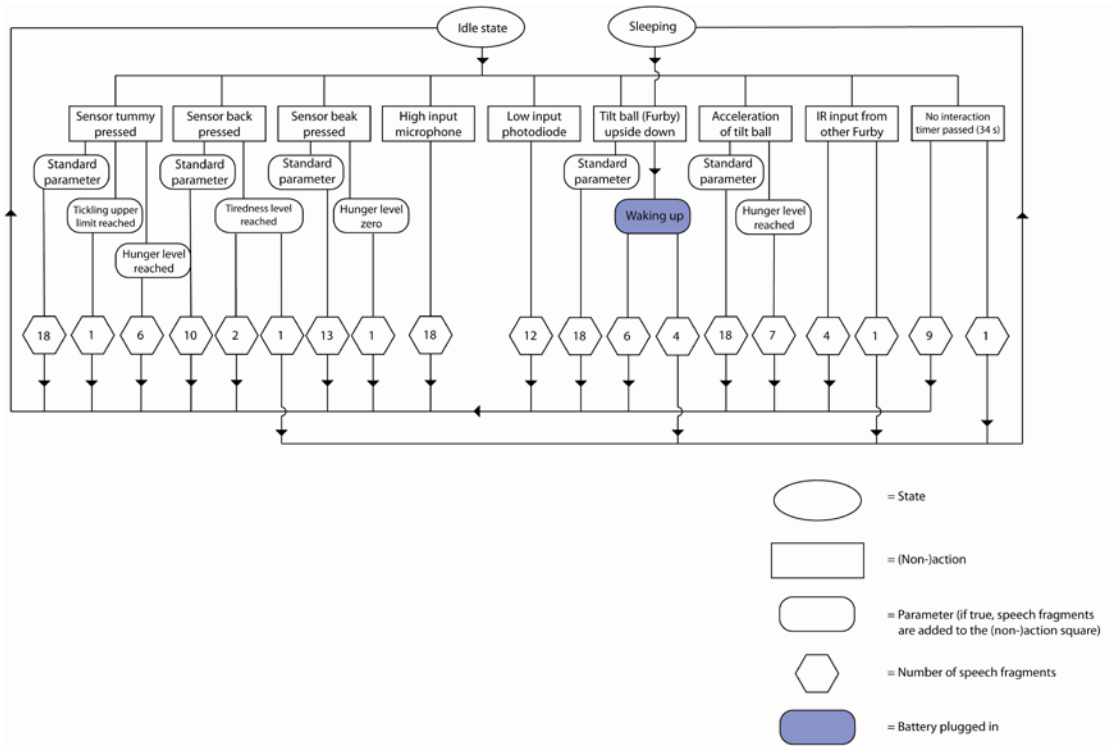

Figure 6.7: Interaction state diagram of Furby, a larger version can be found in Appendix E.

Each kind of action (for example pressing its belly sensor or covering the photodiode) has its own corresponding set of possible speech sentences. These sentences are grouped under different parameters, which have values. There is always a standard parameter active for every different type of interaction, containing a few to a dozen different sentences. When other special parameters (if it has other parameters, see figure 6.7) are true, for example the parameters hunger or tiredness, these sentences will be added to the possible reaction Furby will give by speech, thus increasing the total amount of possible reactions when triggered.

Sentences

All these sentences are build up from little speech fragments, containing Furby words but mostly English words. There are a total of around 100 different speech fragments (Appendix G). These fragments make up for at least a total of 150 unique sentences. A sentence is never used again under a different kind of interaction, so when Furby's belly is tickled, the sentence from the parameter hungry is always different from a sentence of the parameter hungry by triggering the accelerometer. Not all sentences have been derived, because reverse engineering has been applied, so the chance that some sentences slipped through is possible.

Example of possible unique sentences, formed with fragments, for the action touching beak sensor. The complete list for all actions can be found in Appendix F.

Standard parameter				
Yum	*Burping sound*	Ha	No	Again
Yum	*Burping sound*	Hahaha-hahaha		
Yum	Again	Ra-ra		
Yum	Again	Please	Ra-ra	
Yum	Hungry	Ra-ra		
Yum	Maybe	Again	Ra-ra	
Yum	Maybe	Again	Please	Ra-ra
Yum	Okay	Done		
Yum	Okay	Ha	No	Like
Yum	Ra-ra			
Yum	Very	Good	Ra-ra	
Yum	Yum	Maybe	Again	Ra-ra
Yum	Yum	Ra-ra		
Hunger level zero (special parameter)				
Farting sound	No	Hungry	Wah	

Parameters

An action applied to the Furby always leads to a standard set of reactions, now named as the standard parameter. This parameter is always active. Furthermore, Furby has some parameters with changing values. These are level of hunger, tickling belly limit, level of tiredness and waking up. When these parameters are active, these sentences will be added to the possible outcomes of the standard parameter. Furby will randomly pick a sentence from all of these parameters, except when the parameter value is at limit, it will return only one kind of message. Also some sentences are heard more frequently than other, these sentences are given a higher chance of being picked.

Hunger parameter

As can be seen from the state diagram, Furby can reach the level of hunger by tickling its tummy for a long time or by pushing it around, thus activating the accelerometer of the tilt ball. Each of both interactions will cause the value of hunger of the Furby to rise. When this level exceeds a limit, these parameters will be true and by interacting with the Furby these sentences can be activated also.
Note that Furby will only ask to be fed when being pushed around or being tickled on its tummy. Feeding the Furby, by triggering the sensor in the beak, will lower the hunger value. Therefore Furby will stop saying it is in need of being fed, when the value is beneath the limit again. The hunger value can even be brought down to zero by feeding it, Furby will notify the user by saying it is not hungry anymore after being fed.

Sleeping parameter

The status sleeping is comparable. Furby gets sleepy by petting its back, thus adding to the value of the sleeping parameter. However, when the sequence of petting is interrupted by performing another action, this parameter is set to zero again. Furby can also get to sleep randomly by doing three things: doing nothing, or by interacting with another Furby which can trigger the going-to-sleep action, or by a sleeping Furby upside down, so it is forced to wake up and it will randomly go to sleep again or stay awake. Note that these actions are random, whereas the petting back action is not. As the Furby goes to sleep, the action can be cancelled by pressing the belly sensor, thus letting him stay awake. When Furby awakes, the value of the parameter is always set to zero, disregarding the duration he has been asleep.

Other parameters

Tickling the Furby on its belly will cause the parameter tickling to rise to a limit. If this limit is reached, Furby will only say that he is tired of being tickled on its belly. This parameter can be lowered by doing all kind of interactions, except for tickling of course.

The parameters level of hunger and belly tickling cannot be influenced by taking the batteries out of the Furby, so the value of the parameter is stored in its EEPROM.

An overview of the special parameters is shown below:

Special parameters	Value	Influenced by	Action
Need to be fed	- Below limit - Above limit - Zero	- Pressing tummy sensor and tilting Furby will cause this value to rise - Pressing beak sensor will lower the value - Eventually, this value will reach zero if fed multiple times	- No reaction if below limit - Gives hunger sentence for interaction 'tummy sensor pressed' and 'acceleration of tilt ball' if above limit - When value is zero, it will ask to stop being fed
Amount of belly tickling	- Below limit - Above limit	- Belly tickling will add to this value - All other interactions will cause this value to drop	- No reaction if below limit - If above limit it will return a 'stop petting' sentence only if being petted on the back
Need to sleep	- Below limit - Above limit - Random	- Limit is only of use when petting its back, only long consecutive streaks will cause it to go to sleep - Interaction with other Furby, waking up from sleep and timer running out can trigger a random action for going to sleep	- No reaction if below limit, but other actions can get it to sleep randomly (see left) - If petting back streak is not interrupted, it will eventually fall asleep and set the value to zero again - If a random sleeping action is triggered, it will fall asleep immediately - The going to sleep action can be cancelled by pressing the tummy sensor
Waking up	False or true	- True when in sleep mode, waking it up by tilting it upside down	- Furby will get to sleep again - Furby will wake up

Easter eggs

Furby was also equipped with some Easter eggs, intentional hidden features, which could not be retrieved from the manual. When actions are performed in are in a certain sequence, these Easter eggs were triggered. For example, if Furby gets fed for three times in a row and then gets petted on his back, he will burp ten times in a row. Later models got an instruction manual with a description of all of these Easter eggs.

Overview

This is how the Furby's behavior works, bottom up concluded:

- Speech fragments (100), containing one or sometimes multiple words, are the building blocks of sentences. The movement of the beak is synchronized with the speech.
- These speech fragments are used for a total of 150 programmed different sentences. A single speech fragments can be used in multiple sentences.
- Parameters contain multiple sentences with different chances of being picked. A parameter consists of unique sentences only, in other words they cannot be found in other parameters.
- A parameter is coupled to a certain action of the Furby. There is always a standard parameter per action active. Sometimes actions have multiple parameters with changing values, thus being active or not. If active, these sentences are added to the possible outcome of reactions.
- Once a reaction is performed, it will return to the idle state or go to sleep. When in idle state, it will wait for input from its sensors or wait for the counter to finish to get to the next reaction. When Furby is asleep, it can only be awakened by tilting it upside down, but there is still a chance Furby will continue to sleep.

6.2 The 2005 Emoto-Tronic adult Furby

6.2.1 Introduction

There is less information available on the internet about the 2005 Furby in comparison with the 1998 Furby. The reason for this is the lower level of popularity of the 2005 Furby and because it is harder to hack, thus being less favorite amongst hackers. Therefore more information had to be derived by reverse engineering a secondhand Furby. While doing so it was clear the Emoto-tronic is not as innovative as the 1998 version, because it has almost the same guts and the same behavior as the old version, only a few things are noticeable upgraded. These things will be explained below. The skinning process is described in Appendix H. Note that this research is not as extended as the previous one, as the old Furby will be hacked afterwards.

6.2.1 Mechanical aspects

Technically seen the Emoto-Tronic Furby has improved a little bit compared to the previous version of the Furby. A lot of it original features have remained, as it is able to move its ears, open its beak synchronically with speech, swing a little bit (but now sideways instead of forward) and move its eyelashes. But it has also been extended with new kind of movements. Furby is now able to move its eyes sideways, move the Mohawk on his head, move its forehead, the corners of his mouth and his belly. These last three actions are very hard to notice, because of the rigid fur that is covering these parts.

This Furby is equipped with two reversible motors instead of one. Therefore it has a bigger variety in its moves and doesn't have to spin through all of it moves in order to get to the right one. One of the engines is positioned in it belly, which actuates the movement of its feet and the opening of its beak. The motor drives the middle gear with bulging squares on it (figure 6.8). This gear is surrounded by two other gears with some sort of flippers on it, each positioned in another direction. Driving the middle gear in a certain direction will cause one gear on the side to slip, but will drive the other one. So one direction of the motor will only result in the movement of one body part. The other motor is positioned in the head of the Furby and controls all of the remaining features at the beginning. This motor drives a system of wheels and cams similar to the original Furby, although a little bit smaller, and is positioned behind the eyes.

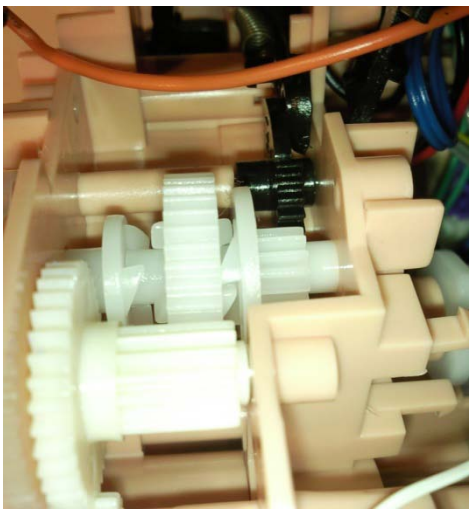

Figure 6.8: Mechanics in Furby's belly

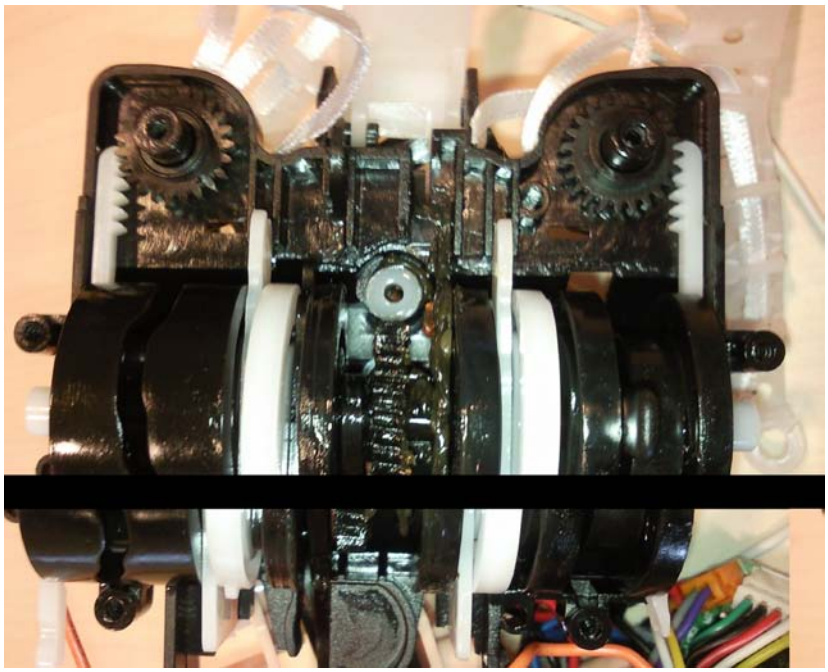

Figure 6.9: Mechanics in Furby's head. The left cam is new and is used for the movement sideways of the eyes.

Again all the weaker inner parts are protected by a thick hull. To make its mouth softer silicones have been used. Again all of the inner parts are protected from obstruction by slipping the gears when the environmental stress is too heavy. The motor drives a system of wheels, which are connected by elastics, to prevent the motor from getting damaged when the gears get jammed.

6.2.2 Electronic parts

Furby has a lot more and more powerful electronics, making the new Furby bigger as the previous one. However, it is equipped with the same type of sensors as the 1998 Furby, except for the light sensor, which is not included. Therefore the new Furby is not able to distinguish a light or dark environment. Another change is the removal of the infrared emitter and receiver, this is replaced by RF. The wires functioning as antennas are wrapped around the hard plastic shell of the Furby (figure 6.10). Also, the Furby is no longer able to determine its orientation in 3D as accurate as previously anymore, as the 3-positional tilt ball has gone. However, it is able to notice if it is upside down or not using an overturning sensor.

It is equipped by a powerful RSC-4128 processor, an embedded speech microprocessor that does everything from voice recognition to text-to-speech, input/output and dual tone multi-frequency output. As can be derived from the processor and by playing with it, Furby's focus has been put on the speech recognition function. The other electronics don't show any real improvements compared to the 1998 Furby.

Figure 6.10: Its antenna wires

6.2.3 Behavior

Most parts of the old 1998 Furby can be applied to the new Furby as well. It learns speaking English instead of Furbish as time goes by or when the user pays more attention to it and it has got the same needs for feeding, attention and sleeping. The only thing that has improved is the speech recognition function, making Furby now also able to communicate with the user by speech, although in a very simple way. It has to be activated by a command (Hey Furby) to start the speech recognition function, otherwise it does not react, and it can only be used in silent environments, otherwise it will most likely misinterpreted the command given to the Furby. There are a few commands available, it can play a game with the user and tell a few jokes, songs and stories. Other commands are for asking if Furby is hungry, if it is happy and telling Furby to get some sleep. In total there are 9 different commands which open a new scenario.

6.3 Evaluation

6.3.1 Introduction

The results gained from the research will be evaluated below. Although Furby is already quite a clever and complex product, there is still a lot of room for improvements, as it has a lot of downsides. These downsides regard technology, behavior and design and are described below.

6.3.2 Technology

The technology put in both editions of the Furby is very limited. It is only fit with relative small and cheap electronics, therefore making it unable to perform complex operations. The processor of the old Furby has not enough power to execute complex calculations. The processor of the New Furby is more powerful, but as it is in fact an embedded speech microprocessor, it focuses mainly on the speech recognition function. Apart from the speech recognition function the new Furby does not show much of a difference regarding the old Furby.

The sensory input of both Furby is also limited. In both type of Furbies the same basic sensors are used, mostly 1-bit sensors which are only able to distinguish the difference between switched on or off, for instance dark or light and if its touch sensors are pressed or not. The 1-bit sensors also do not make it very possible to derive enough information from the environment to improve the interaction. Also it is not able to communicate or react in a natural way. Specific commands can only be given by a combination of different interactions in a specific order, which have to be looked up in the manual in order to use them. It is a clever solution with only limited sensory input available, but it is not very user friendly and not natural. Only the speech input from the new Furby has complex sensory input, as it can determine if the words spoken by the user match the command.

Both Furbies are equipped with a microphone. The 2005 Furby uses the microphone for speech recognition and it will only react on the command “Hey Furby”, to other sounds in the environment it will not react. Even after being activated it can only react to very strict commands. His older brother is also equipped with a microphone, but it is only able to distinguish if there are sounds surrounding them or not, like an on/off switch. However, this rather simple function contributes more to the lifelikeness of the Furby, because it reacts on sound activities in the environment.

Another problem caused by the limited technology put in it is the lack of consciousness of its environment and people around it. Because of the basic sensors used in the Furby it cannot get very specific information from the room it is in. Therefore it looks like a very static object. For example, the 2005 edition of Furby is not even able to get any form of visual input from the environment. Although it has eyes, it cannot see anything, what can be considered as a strange thing. The reason there are humanlike eyes can be attributed to the intention to make the Furby anthropomorphic. The original Furby is able to differentiate dark and light environments by using an IR sensor; the newer edition is essentially a step backward by missing this function.

The visual feedback to the user is limited. Most of the feedback is mainly and only given by speech, in synchronization with the movement of its mouth. It can only support this feedback by moving its ears, open and close its eyes and wiggle a little bit. It is unable to move any of it limbs. Furby also has only very limited responses. Because of the limited technology put in it, it looks like a computer providing limited output on strict commands.

6.3.3 Behavior

The behavior of the different kind of Furbies is quite similar. When just out of the box it should be programmed to speak Furbish only, but as time passes it is programmed to speak English more and more or any other of one of the 24 languages it is programmed to speak, just like it is actually learning that language. This path is divided into 4 stages; Furbish only, speaking mostly Furbish with some English, speaking more English with plenty of Furbish still and speaking mostly English with some odd Furbish phrases. However, even intensively use of a Furby did not reveal any differences, or too small to recognize. When resetting the Furby it still starts speaking with a lot of English words with almost no Furby words. At last it should also be able to manipulate the chance of getting a specific reaction a little bit. If Furby performs an action and gets petted a lot as a reward, it should show this behavior more frequently. However, this was not noticeable after testing, so this is probably of no or very little influence.

Both Furbies show the same lifelike functions as sleeping, eating and winking with their eyes. But it does not go any further than this, as Furby lacks emotions and mood as it has no facial expression. However, the expressions of Furby have improved over time. The new Furby is able to frown its forehead and lift the corners of its mouth, but this is hard to see because of the rigid fur and the movement of it is not integrated with the state of emotion of the Furby, as far as it has any.

If Furby reacts on an interaction, it is only done by speech and the limited available supported movement. There is no physical resistance for example. When it gets fed when it does not want to, it reacts only after it is fed that it does not want anything, along with some movements of its eyes and ears. It cannot hold it jaws together or turn its head away.

They show the same humanlike or childish performance, by dancing, telling jokes (only the 2005 edition) and playing games. However, these jokes and games are limited to only a few ones. It happens quite often that the Furby tells three of the same jokes in a row, making it not very challengeable to play with them.

In general, its behavior is not very extended and quite linear, thus not very unpredictable. The higher the contingency, the more lifelike and, more importantly, more interesting it is considered by humans. Lifelikeness is important to make it possible to interact more naturally with the child, thus more challenging. There has been a lot of research to human-like natural communication of robots. They often showed the effective usage of body properties in communication, for example head movements, facial expressions and arm gestures.

When time goes by technological inventions will provide better and cheaper technology to implement in the Furby, which will enhance its functionality and make the play experience richer. At this moment however, this is not the case regarding the speech recognition and it will take more years to realize this. At the moment there isn’t even a flawless working speech recognition system for more advanced personal computers, and those are also not very cheap. But there are still a lot of things left to improve regarding user interaction, behavior and design.

6.3.4 Design

One of the biggest plus points already available is the furry skin, making it very attractive to take the Furby in your arms and cuddle it. But when doing this, you realize it is not as soft and flexible as a normal teddy bear for example. Also it is quite heavy in comparison to other cuddle toys available. Not only the Furby with its electronics weigh very much, but also the four batteries placed in it takes up a lot of weight. Therefore it cannot substitute a teddy bear, and is not very suitable for children of a very young age.

The current Furby of the first generation looks a lot more like a bunch of packed electronics, with a hard casing and a thin furry top skin layer on it. The newer Furby looks a bit less like a packed bag of electronics, as it looks like it has a head separated from his belly, but is still very heavy (heavier than its brother) and very hard skin, apart from the same furry top layer. Apart from the very strong looking appearance, it has some vulnerable spots like its ears. If something breaks down during normal use it is most likely to be its ears. The furry ears are only attached to its hull by a very thin thread.

Another positive aspect about the Furby is the wide range of available skins, therefore making every Furby quite unique, with a lot of exotic colors and prints to choose between. A problem with the skin is that it is not easy to remove for cleaning it. Attached to its hull it can never be cleaned properly, as there is always a risk of doing damage to the electronics or its hull.

7. Scenarios

7.1 Introduction

To derive possibilities to improve the Furby, scenarios are used. These scenarios are actual practice scenarios, which focuses on the flaws and failures of the product during the use of it by the target group. This way new visions and requirements (needs and wishes) are derived for adaptation to the new design of the Furby, by extracting problems from the scenarios.

First of all the main characters for the scenarios, the so called personas, have been created. In order to create valid personas, information about the target group has been used. The following personas represent a significant part of the target group with regards to goals and personal characteristics. By creating lifelike validates personas, more accurate scenarios can be written.

Input from the critical actions in the actual practice scenarios has been get from the previous research, especially from the previous chapter analysis of the Furby, by adapting these characteristics of the Furby into possible following problems. Another way of getting input for the scenarios was just simply by testing all of its functions and translating it to possible bottlenecks for children which are included in the scenarios. The (possible) problems are isolated from the scenarios and translated into a list of requirements. It also counts as direct input for improvements to the new Furby.

7.2 Character generation

7.2.1 Persona scenario 1

Profile	
	
Principal character	
Name	Loes de Bruyn
Gender	Female
Age	9
Place of residence	Amersfoort, Netherlands
Personality	Talkative, arrogant and little bit spoiled
Hobbies	Riding horse and playing hockey
Family	
Father	Tom de Bruyn
Occupation	Project engineer
Mother	Marieke de Bruyn - Schilperoord
Occupation	Secretary
Marital Status	Married
Brothers and sisters	None
Home situation	
Living situation	Family house
Living environment	Lush neighborhood
Financial situation	Wealthy income
Family situation	As the only child of the family Loes get all the attention and her parents take her out often to go somewhere
Pastime	Her parents are gone most of the time for working, but if they got time they spend it with her. She usually gets what she wants

7.2.2 Persona scenario 2

Profile	
	
Principal character	
Name	Nick Thompson
Gender	Male
Age	11
Place of residence	Washington, United States of America
Personality	Busy, often derived and always curious.
Hobbies	Playing videogames and technical toys like Lego Technic
Family	
Father	Ben Thompson
Occupation	Office job at a bank
Mother	Angelina Lopez
Occupation	Housewife
Marital Status	Married
Brothers and sisters	One older brother and a younger sister
Home situation	
Living situation	Free-standing house
Living environment	Proper child friendly neighborhood
Financial situation	Secure
Family situation	Nick is the middle child of 3; he needs a lot of attention but cannot always get that in such a big family.
Pastime	The children mostly have to entertain themselves, as the parents are always busy.

7.2.3 Persona scenario 3

Profile	
	
Principal character	
Name	Megan Jones
Gender	Female
Age	6
Place of residence	London, United Kingdom
Personality	Shy, easy-going and full of joy
Hobbies	Swimming and drawing
Family	
Father	Richard Jones
Occupation	Teacher
Mother	Cheryl Bates
Occupation	Waitress
Marital Status	Living together
Brothers and sisters	Two older sisters
Home situation	
Living situation	Family house
Living environment	Busy street
Financial situation	Normal
Family situation	Megan is the youngest of three sisters. She usually has to play with the old toys of her sisters and does not get new toys often.
Pastime	She usually plays inside, since her parents cannot always supervise her when they are at work

7.3 Actual practice scenarios

7.3.1 Scenario 1

March 3rd, 1999

Loes cannot wait to get her presents. She has been awake all night to wait for this day to begin. Today they are going to celebrate her ninth birthday. Her parents enter her bedroom and kiss her to congratulate her. “Go get your presents, they’re downstairs!” Her mother Marieke says, but before she can finish her sentence Loes is already raging down the stairs to get to the living room. Father and mother, still half asleep, smile at each other and stumble down the stairs as well. They find Loes with the present already embraced in her arms. She quickly tears the paper apart. When she sees the present she releases a scream of pleasure. “A Furby!” she shouts out loud. She has begged for it for weeks. Several classmates did already get a Furby, which they proudly showed off on school. All children were jealous at them, but now she too can show her Furby off to all her friends.

But before she has to go to school there is some time left to play with the Furby. After she has put some batteries in the Furby she turns it on. The loud sounds of mechanical movement can be heard clearly as it makes some movements with it ears, eyes and mouth. Almost instantly the Furby turns back to sleep, saying it is sleepy. Loes tries to tickle its belly and pet his back, but the Furby refuses to stay awake. Mom comes to the rescue, grabbing the manual out of the pile of the ruptured paper. After reading it for a minute she discovers it is put in deep sleep mode. When Loes switched the Furby on she had to turn it upside down, that is why it went into deep sleep mode. She turns it upside down again and, as a miracle, the Furby wakes up. She leaves her daughter alone with it again and prepares herself for work.

They are a bit late, but just before the bell rings they enter Loes’s classroom. Her mother drops the little surprises she can give to the other classmates to celebrate her birthday. As Loes enters the classroom, all of the children come to watch the new Furby. All of them would like to have one of those Furbies, but there is a big waiting list to get one from the shop. The high demand for the Furby has driven the price up to 100 dollar. Her best friend agrees with her to bring the Furby to school tomorrow, so the Furbies can talk to each other and learn to do new stuff. She also teaches Loes some special tricks to do with the Furby, like playing games with it and let it do a dance. To activate these features she has to interact with the Furby in a specific order, for example covering the eyes for 3 times in a row. These things are all stated in the manual, but because of the excitement she has not read it yet, therefore she is not able to do all the tricks with the Furby. But after she is done reading she knows all the things Furby can do and is she able to enjoy Furby to its fullest potential.

7.3.2 Scenario 2

March 24th, 2000

Nick opens the box of the Furby hastily. He usually plays games on the computer, for the time he is not distracted. He has always been impatient and often never finishes playing with something. But since the popularity of the Furby has grown extremely he ‘demanded’ a Furby as well. Finally his parents gave in and bought a Furby for him. He has never seen such a technological novelty and is very curious about it. He puts batteries in it and turns it on.

Now the Furby is ready to play, and he presses the Furby on all different spots on the toy, to find out where the Furby does react to and where the sensors are placed. The sensors have to be pressed very hard to get a reaction of it. Luckily the Furby does not have real feelings, because the petting on the back and the tickling of the tummy can rather be described as just hitting the touch sensors very hard in order to get a reaction. He tries some combinations of interactions in order to get to the extra features, but he fails a lot of times. Some of these features require a lot of interactions, which have to be executed again and again after the Furby has stopped speaking, so it is ready for another interaction. Or sometimes he accidentally hits a wrong sensor, for example one of the sensors on the body which he has to hold, as some of the interactions require a firm grip.

Eventually he gets it right, but he is quite frustrated now. Even after a few days he still has troubles with it. He is trying to find new patterns of behavior, to see what the Furby is also capable of apart from the standard couple of reactions on interactions he has seen again and again last days. In order to do so he just keeps on feeding the Furby. The feeding of Furby happens by just simply sticking a finger in its mouth. Although Furby states it is not hungry anymore, Nick keeps on feeding him in order to see what will happen. But every time he feeds it, it just says 'yam, yam' again and repeats it is not hungry anymore. It just cannot get nauseous or angry, or just simply keep its mouth closed. To the disappointment of Nick, who hoped for a more extended behavior of the toy.

A few weeks later he is already back to playing games on the computer and rarely touches his Furby. The novelty is gone, and all what is remaining is toy with very limited possibilities compared to his computer games.

7.3.3 Scenario 3

December 25th, 2005

It is the first day of Christmas, and like usual there are presents underneath the Christmas tree for the kids. Megan looks to find her present, and quickly she finds a great box covered with shiny red paper and silver ribbons knotted to it. She quickly unfolds her present. The first thing she does is embracing her new Furby. It looks very soft on the outside with its furry skin all over the place, but Megan notes it is not as soft as her other stuffed animals. Those limbs of her stuffed toys can be manipulated, but as far the Furby has limps it is not possible to move them. It has to be treated with a lot more respect than normal stuffed animals, as it can break down easily, but her parents think she is old enough to take good care of her present.

She tries to make contact with the Furby, as it eyes are looking from side to side, but as the Furby does not have any visual sensory input it does not react to her. She tries to say Hello to Furby, but it does not react to any sounds she makes. She finds out she has to shout "Hey Furby" first in order to enable the speech recognition function. Megan tries it, but still Furby does not react to her. She calls her mom, who tries to reduce the environmental noises by turning off the radio and tries it again. This time it works, the Furby reacts to it and is ready for another command. She takes the manual and asks Furby to perform a dance. It looks like Furby has to think about it, but after a few seconds it says ok and starts doing a dance. Then Megan tries to do the same, but the Furby does not get what she is saying. Instead of performing a dance for her the Furby tells a joke with a crackly voice, definitely not what she asked for. She now tries again by speaking louder to it, in fact she is almost shouting. This does not change anything, it is just the articulation which is not that good, the reason the Furby does not get the command. But again it tells a joke, the same joke as it just told her before.

It is the same for the other functions. It can only tell a few stories, jokes and songs; there is not really a lot of variation in it. But that does not matter for Megan, for now she just got a great present. Usually she has to play with the old toys of her older sisters, but now she got something brand new to play with during the Christmas holidays.

7.4 Evaluation

All problems have been derived from the text of each scenario (Appendix I). All problems from the scenarios and problems encountered earlier during the research are listed in the table on the next page. The problems are sorted on input, output, behavior and general problems.

The problems are rated with one to five diamonds to derive the relevance, difficulty and price. High relevance means the relevance of the problem to research or solve it. Higher rated problems on relevance contribute more to the improvement of the Furby, the so called 'Next Furby'. The tag low difficulty means how difficult it is to solve this problem. Some problems cost a lot of time and a lot of programming, so these are rated with a low number of diamonds. At last the price is taken into consideration. If a problem takes a lot of time to solve and the costs of the components are high, the problem gets a lot of diamonds.

The table shows that there are some problems with high relevance, but these are hard to solve and will probably have an impressive price tag, for example giving Furby facial expressions. The component costs are very high and do also cost a lot of time, thus human resources. It is most likely that these problems exist, because it has never been considered by the designers to implement these features, simply to save costs and preventing the Furby from getting too expensive for the customer. Other problems with lower relevance but also with low price and difficulty can be interpreted as mistakes in the design process, such as a bad manual.

The table gives an overview of the total list of problems discovered during the assignment. By rating these problems on relevance, difficulty and price there it is easy to make a comparison with the other problems. So it can be used to find a focus for next assignments for designing 'The Next Furby'.

	Importance		
Problem solving	High relevance	Low difficulty	Low price
General			
High price	◊◊◊	◊◊	◊◊
A manual is needed for understanding	◊◊	◊◊◊◊◊	◊◊◊◊
Manual is incomplete	◊	◊◊◊◊◊	◊◊◊◊◊
Stiff compared to stuffed toy animals	◊◊	◊	◊◊
Low durability	◊◊◊	◊◊	◊◊◊
No manipulable limbs	◊◊◊	◊◊◊	◊◊◊
Noisy mechanical parts	◊◊	◊◊◊◊	◊◊◊◊
Sensory input			
Bad sensor sensitivity	◊◊◊	◊◊◊◊	◊◊◊◊
Adjust placement of sensors	◊◊	◊◊◊	◊◊◊
Differentiating applied pressure on sensor	◊◊◊	◊◊◊	◊◊◊
Bad visual input	◊◊◊◊◊	◊	◊
Feeding is just touching	◊◊◊	◊◊◊	◊◊◊
Bad sound input	◊◊◊◊◊	◊	◊◊
Activating special features requires strict sequence of interactions	◊◊	◊◊◊	◊◊◊◊
Technological output			
Low mobility	◊◊◊◊	◊◊	◊
Limited audio output	◊◊◊◊	◊◊◊◊	◊◊◊
Feedback is mainly given by speech with low mechanical support	◊◊◊◊	◊	◊
Audio feedback is hard to understand	◊◊	◊◊	◊◊◊◊
No facial expressions	◊◊◊◊◊	◊	◊
Behavior			
(De)activating sleep mode	◊◊◊◊	◊◊◊◊	◊◊◊◊
Actions cannot be interrupted	◊◊	◊◊◊◊◊	◊◊◊◊◊
No mood	◊◊◊◊◊	◊◊	◊
Limited play value	◊◊◊◊◊	◊	◊◊

8. Furby hacking

8.1 Introduction

The last part of the assignment consists of modifying a Furby. In its original state it is not possible to make any adjustments to the behavior of the Furby or control its actions, while this might be necessary for further research about building the next Furby. This way it is possible to test new behavior, for example different moods. In order to control the actions of the Furby it has to be hacked.

8.2 Hacking

To gain control of the Furby the program code has to be changed. But as all of Furby's important components, components containing information about the behavior and the microcontroller, are covered in a plastic blob, it is not possible to hack (this is the main reason for covering this components in a plastic blob). These controlling units are placed on special so called daughtercards, which are plugged in on the main board. By doing so they can be placed and replaced easily. As one of the daughtercards probably contains information about the language files, Furbies with different languages can be assembled very easily this way.

In order to hack the Furby a certain printed circuit board has to be used to replace the current microcontroller and storage unit. The 12 and 25 pinouts of the daughtercard have to be commuted to the printed circuit board in order make use of every electronic component Furby has to offer.

This method has the consequence that everything has to be build up from scratch, because all programmed date is lost by installing an own printed circuit board. Therefore all the sound files are lost, so when these have to be implemented again they have to be recorded first. All these sound bites have been examined already, but all programmed code containing commands to drive the motor in a certain pattern have to be researched first in order to replicate them. The original Furby also contains some parameters in its code with values, for example hunger, which has to be implemented as well to match the behavior of the original Furby. Another option is to make an own adaptation of the Furby instead of replicating it, by programming new kind of sounds with other corresponding movements.

The Furby is very tight engineered. The microcontroller is as small as possible and probably pushed to its limit. There is also no free space available inside, so when hacking the Furby by replacing the microcontroller it has to be realized it cannot be put inside. Therefore the new equipment has to be put outside the Furby via a data cable running from the place of the daughtercards to the microcontroller.

8.3 Arduino

An Arduino controller (figure 8.1) is perfectly suited for this task. An Arduino is a microcontroller with complementary components to facilitate programming and incorporation into other circuits. It measurements are approximately 4 by 6 centimeter. The Arduino series are created in order to make using electronics in projects more accessible. So called shields can be mounted on top of an Arduino unit, which are add-on modules with a specific function. For an example an Ethernet module can be

mounted on top of it, in order to create a ready to use Ethernet port to connect it to the Internet. All of the models contain digital I/O pins for use by other circuits, so the sensors of the Furby can be attached to it and the motor can be driven in a controlled way. It comes standard with PWM (Pulse with modulation) pins, which can be used to control the speed of the motor, so the Furby can eventually simulate different speed in its motions, which are caused by for example tiredness.

Figure 8.1: Arduino microcontroller

Another big advantage of the Arduino series is that it the hardware is programmed by a simple wiring based language, which makes it more accessible for non-programmers. The language is pretty similar to C++. The software is open source, so it permits users to change or improve the software. Also a lot of written software can be found on forums. Because all of the Arduino units use the same code, it is easily interchangeable. This way electronics found on internet which are built with an Arduino can be replicated very easily.

8.4 The execution

Edwin Dertien, research engineer and teacher for Creative Technology at the University of Twente, has already hacked a Furby in a simple way. By using an Arduino microcontroller with an ethernetshield, a Furby is now able to be controlled via internet by pushing command buttons on an internet page. Sensory output can be read out on the site as well. It has no audio files and corresponding code, so it is not able to speak. However, the motion can be controlled by directing the motor, so it drives Furby to a certain point on the cam, so a motion pattern can be created.

The programmed code is already available at internet, so it is not very hard to replicate this model. Just by fixing the wiring as described previously and adding the code the Furby can put to work easily. This will be done by me as much as possible, with the possibility to get support from Edwin Dertien. The goal is to replicate the behavior of the original Furby, by implementing direct sensory feedback with motion output. If this succeeds easily and there is time left. There will be a try to get sound output as well. As the report has to be handled in before the Furby will be hacked no progress can be shown yet, but that will come during the presentation. The final result will be an easy to manipulate Furby, which can be used by other persons working on this assignment.

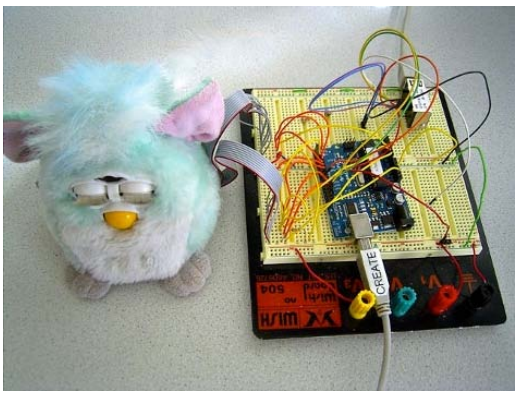

Figure 8.2: Edwin Dertien's hacked Furby

9. Conclusion

For the higher goal, developing the next Furby, thorough analysis has been carried out to found a solid base for further assignments. The focus on this research has been on the technical aspect, but other relevant aspects like the market and target group have also been examined. The main part of the analysis was the research of the mechanical and electronic aspects and the behavior of the Furby. By testing it intensively and examining all of the parts of the Furby closely a clear view is created about the specific working of the Furby.

By using the information from the research and the scenario's a large list of problems has been created. This also contains valuable information for next assignments in this project, as it gives a good insight what has to be improved to create the next Furby.

This research provides enough information to hack the Furby. The to-be-hacked Furby makes it easy for other students to test behavior, for instance testing new behavior. But it also gives the possibility to test the old behavior in a controlled environment. As the behavior pattern has been brought to the light, it can be recreated a lot easier, or even being improved more easily. The easy to understand software from the Arduino should make it very approachable for other students.

All in all there can be concluded that the goal of this assignment, to found a solid base for further research, has been accomplished. Considered the given time all the most worthy research has been done.

10. Sources

Overview of the Furby:

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http://www.yodajeff.com/interactiveyoda/history.shtml
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http://www.ai.mit.edu/projects/sociable/overview.html
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Analysis of the Furby:

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Furby hacking

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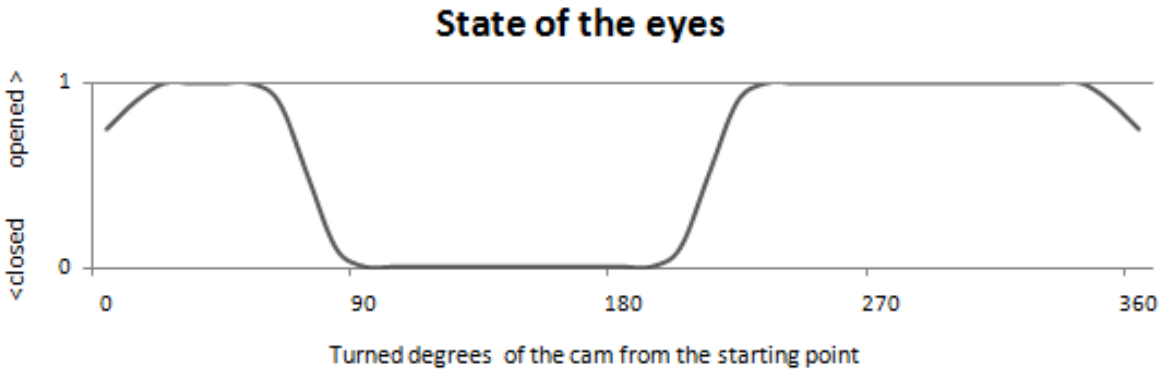
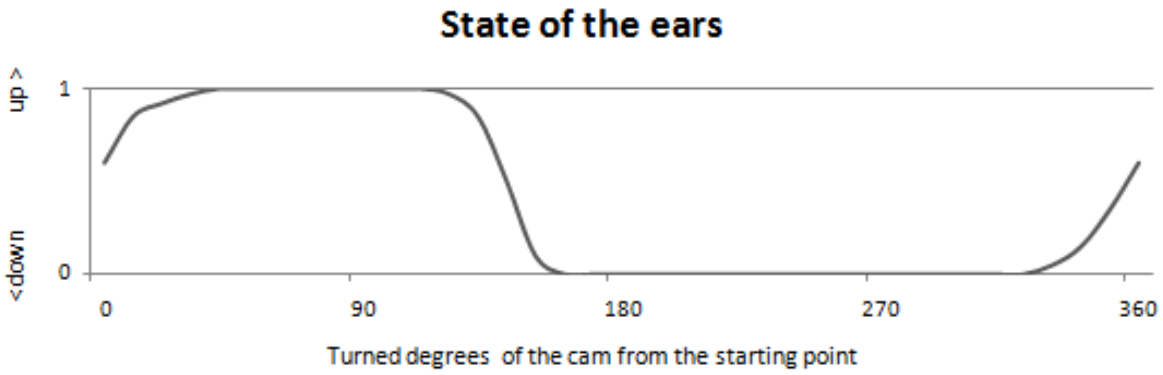
http://hackaday.com/2009/08/31/internet-enabled-furby/
http://hackfurby.com/rebuild.html?page=5

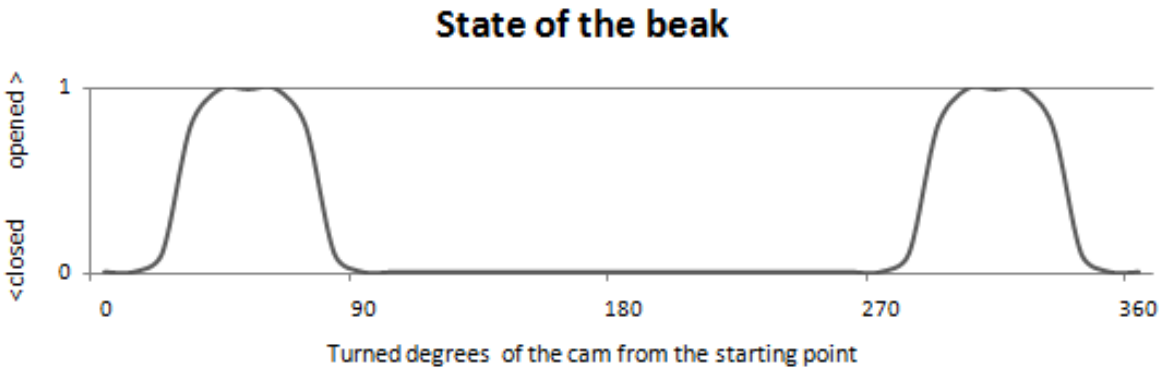
Appendix

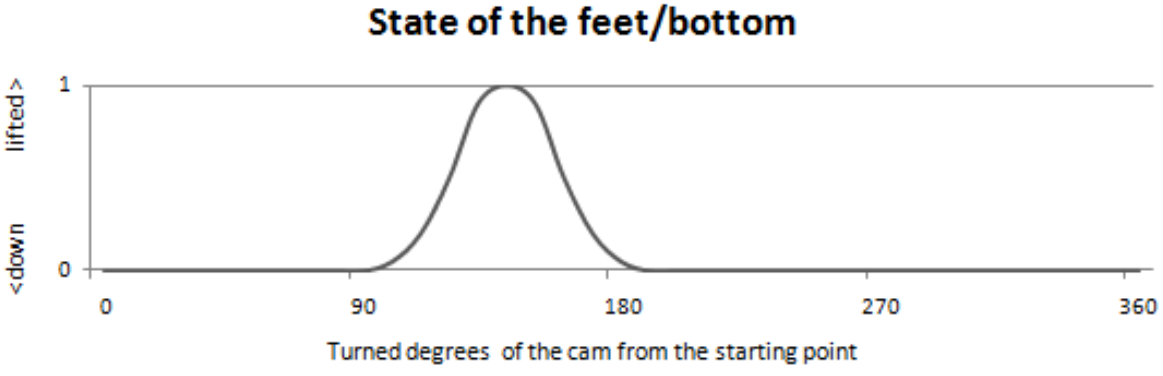
Appendix A: Furby Timeline

Appendix B: Cam rotation

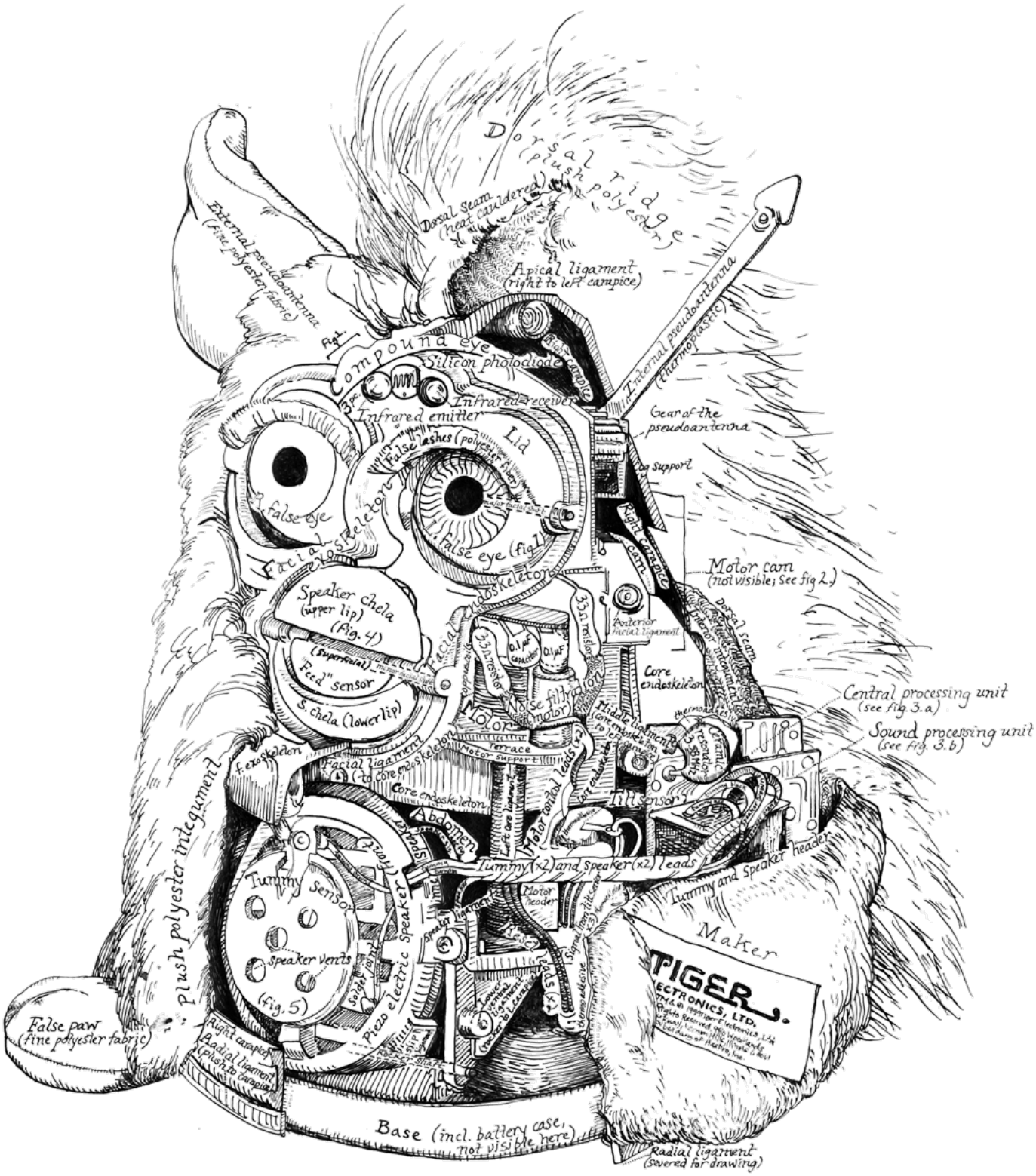




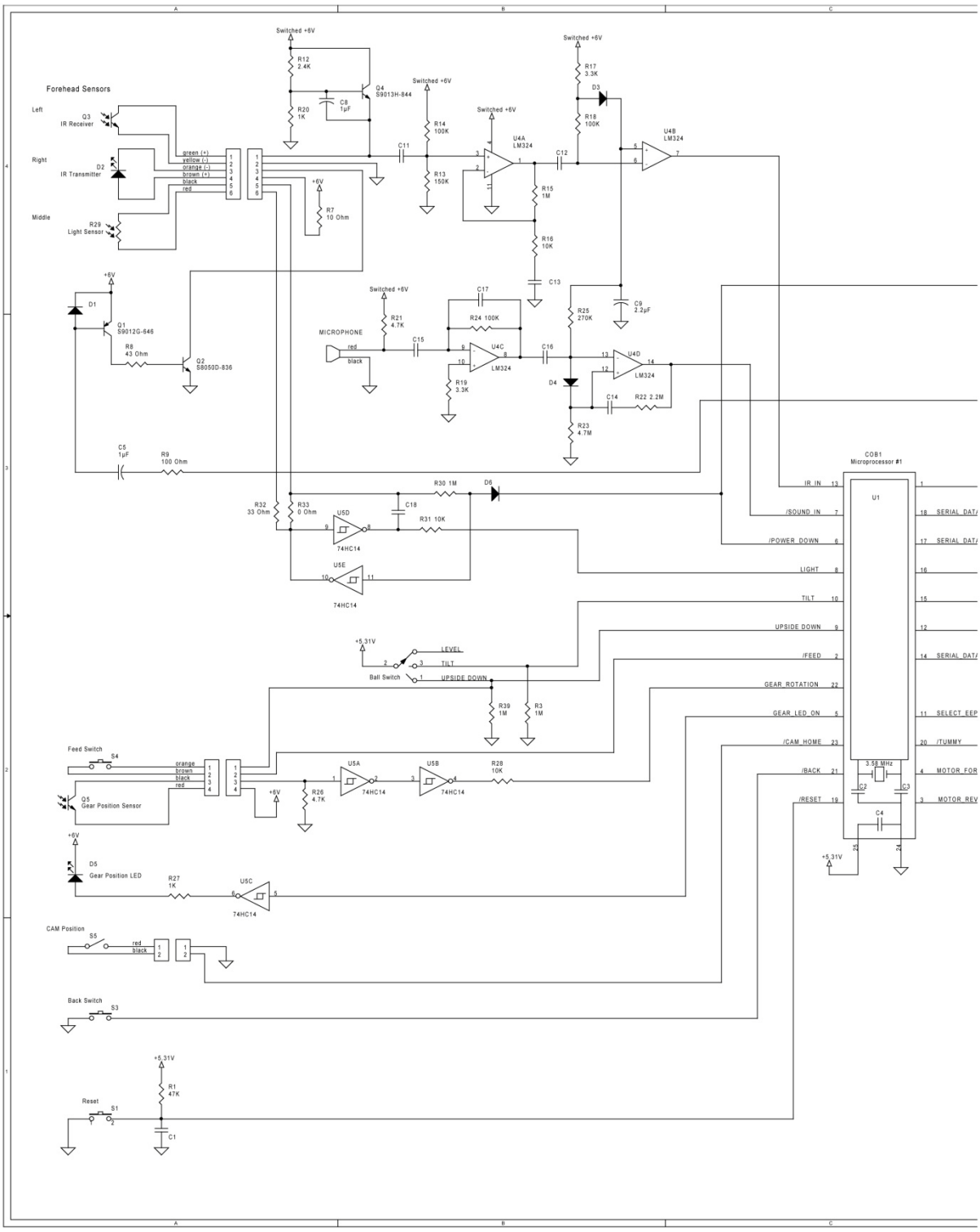




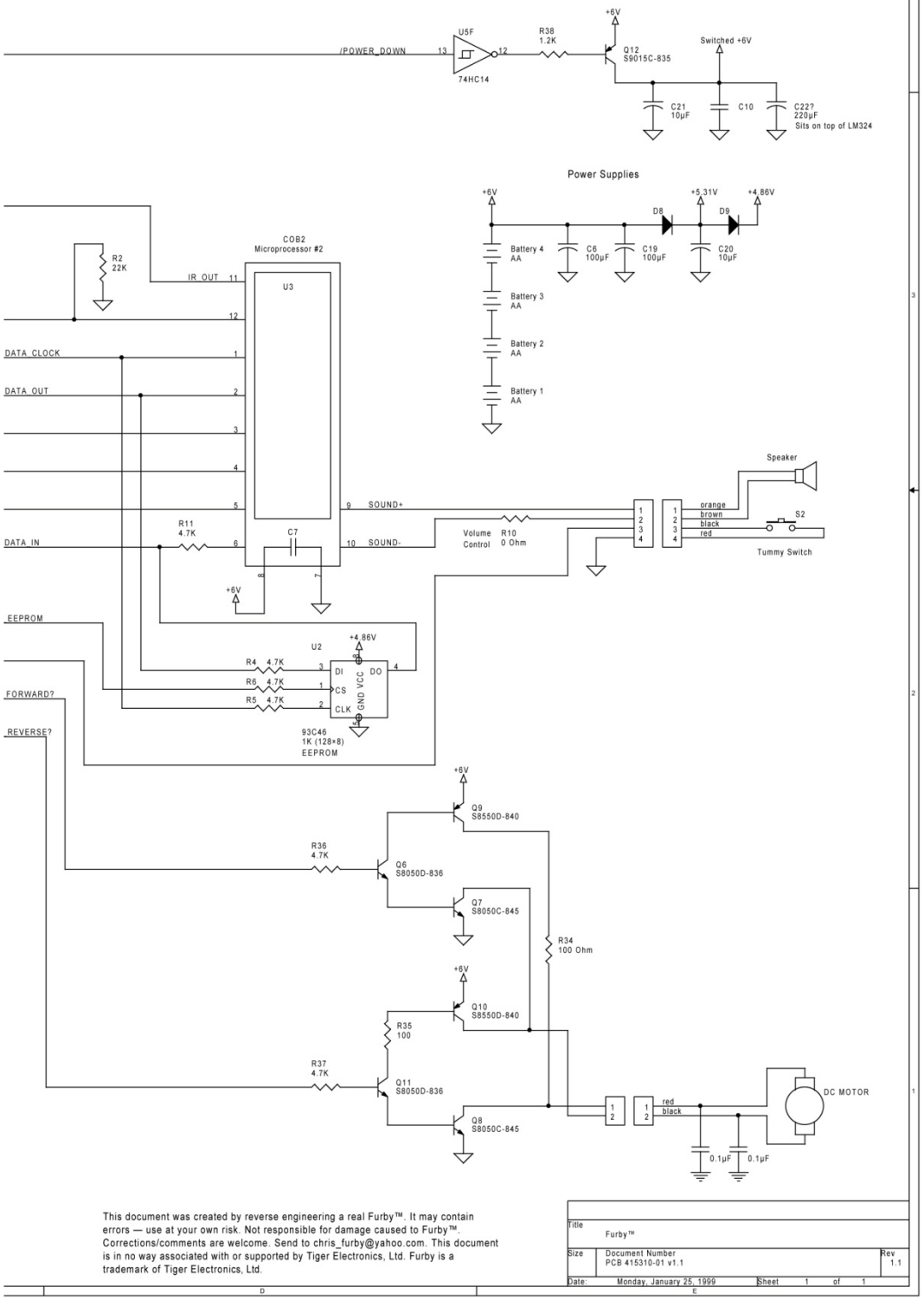
Appendix C: Furby's components



Appendix D: Furby electronic schematic



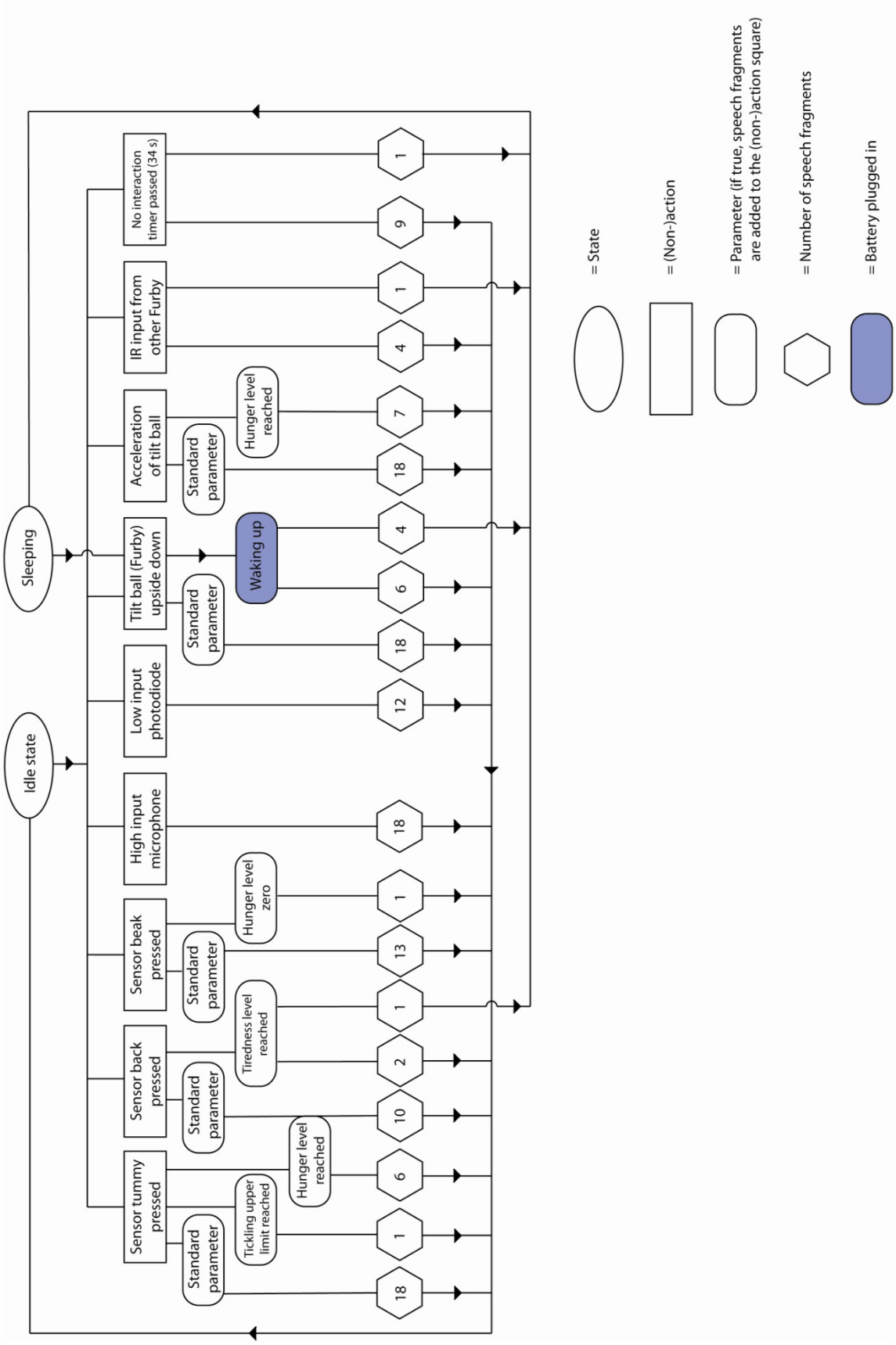
Furby™ Electronics



This document was created by reverse engineering a real Furby™. It may contain errors — use at your own risk. Not responsible for damage caused to Furby™. Corrections/comments are welcome. Send to chris_furby@yahoo.com. This document is in no way associated with or supported by Tiger Electronics, Ltd. Furby is a trademark of Tiger Electronics, Ltd.

Title	Furby™	
Size	Document Number PCB 415310-01 v1.1	Rev 1.1
Date: Monday, January 25, 1999	Sheet 1 of 1	

Appendix E: State diagram Furby



Appendix F: All sentences spoken by Furby

Tummy sensor					
Standard parameter					
Aha boo-djak	Hihihiii	Big	Fun		
Ah-hahaha					
Ah-hahaha	Hardy				
Ah-hahaha	Hihihiii				
Ah-hahaha	Hihihiii	Tododo-totodoo			
Ah-hahaha	Me	Love	Tickle	Hahaha-hahaha	
Ah-hahaha	Me	Love	You	*Kissing sound*	
Ah-hahaha	Oh-oh	Hug	Me		
Ah-hahaha	Peek-a-boo	*Kissing sound*			
Hahaha-hahaha					
Hahaha-hahaha	Ne-ne-ne-ne-ne-ne	*Farting sound*	Hihihi		
Hahaha-hahaha	Ne-ne-ne-ne-ne-ne	Hihihiii			
Hahaha-hahaha	Tickle	Again			
Hey	Tickle				
Hihihiii	You	Tickle	Me		
Hmmmm	Hmmmm	Whoa	Ra-ra		
Wa-wa-wa-wa-wam	Hihihiii				
Wa-wa-wa-wa-wam	Hihihiii	Hey	Hardy		
Tickling upper limit reached (special parameter)					
Ah-hahaha	No	Tickle	Again	Please	Hihihiii
Hunger level reached (special parameter)					
Ha	Big	Hungry			
Ha	Hungry	Bidou-bidou-bidou-bidou			
Ha	Hungry	Ra-ra			
Ha	Hungry	Whoa	Ra-ra		
Hmmmm	Please	Hungry			
Hungry	Whoa	Ra-ra			

Back sensor				
Standard parameter				
Burping sound	Oh-oh	Heheh e		
Purring sound	*Purring sound*	Me	Obay	
Purring sound	Ha	Very	Happ y	
Purring sound	Hug	Me		
Purring sound	Me	Love	You	*Kissing sound*
Purring sound	Pet	Me		
Purring sound	You	See	Me	
Roaring sound	*Roaring sound*			
Roaring sound	Pet	Again		
Sighing sound	*Yawning sound*	Me	Hardy	
Tiredness level reached, staying awake (special parameter)				
Purring sound	*Yawning sound*	Maybe	Sleep	
Purring sound	*Yawning sound*	Sun	Down	
Tiredness level reached, going to sleep (special parameter)				
Goodnight song singing	*Yawning sound*	Me	Sleep	Meh

Beak sensor				
Standard parameter				
Yum	*Burping sound*	Ha	No	Again
Yum	*Burping sound*	Hahaha-hahaha		
Yum	Again	Ra-ra		
Yum	Again	Please	Ra-ra	
Yum	Hungry	Ra-ra		
Yum	Maybe	Again	Ra-ra	
Yum	Maybe	Again	Please	Ra-ra
Yum	Okay	Done		
Yum	Okay	Ha	No	Like
Yum	Ra-ra			
Yum	Very	Good	Ra-ra	
Yum	Yum	Maybe	Again	Ra-ra
Yum	Yum	Ra-ra		
Hunger level zero (special parameter)				
Farting sound	No	Hungry	Wah	

Microphone								
Standard parameter								
Ahh	Me	Scared						
Ahh	Me	Scared	Whoa	Dododo	Dododo			
Dance	Wah	Dododo	Da-tekda					
Dance	Wah	Dododo	Dododo	Love	Dance			
Dance	Boogie	Dododo	Dododo					
Dododo	DJ	Dance	Big	Fun				
Dododo	Dododo	DJ	Dance	Dance	Big	Fun		
Huh	Big	Sound	Doo					
Huh	Big	Sound	Dododo	Dododo	DJ	Dance	Big	Fun
Huh	Where	Doo						
Oh	Loud	Sound						
Oh-oh	Hard	Listen						
Oh-oh	Hug	Me						
Oh-oh	Hug	Me	Dance	Dododo	Da-tekda			
Sound	Down	Please						
Wah	Huh							
Whoa	Huh	Hide						
Whoa	Big	Sound	Wha					

Light sensor				
Standard parameter				
Ah	No	Light	Ah	
Hahaha	Doo doo			
Hey	Light	On	Please	
Hey	No	Jo-wah		
Hey	Wa	Light	Please	
Hey	Me	No	See	You
Maybe	Me	Scared	*Sighing sound*	
No	Light	No	Fun	
Okay	Okay	Sun	Down	
Okay	Hahaha	Kiss	Me	*Kissing sound*
Woah	*Sighing sound*	Tamtitatidumtidoo		
You	Hide	Light	Hihihiii	

Inversion sensor (Upside down)				
Standard parameter				
Sighing sound	*Sighing sound*	Down	Down	
Ah	Worry			
Down	Down	*Sighing sound*	*Sighing sound*	
Ha	No	Like		
Hey				
Hey	Ha	Worry		
Hey	Hey			
Hey	Me	Scared		
Hey	No	*Sighing sound*		
Hey	No	Again		
Hey	No	Joke	Whoa	
Hey	Oh	Worry	No	Again
Hey	Worry			
Oh-oh	Down			
Oh-oh	Down			
Oh-oh	Hey			
Oh-oh	Hey	Worry	Whoa	
Whoa	*Sighing sound*			

Inversion sensor (Tilting Furby)					
Standard parameter					
Sighing sound	*Sighing sound*	Whoa	Ra-ra		
Sighing sound	*Sighing sound*				
Sighing sound	Please	Again			
Me	Love	You	*Kissing sound*		
Wèèh					
Wèèh	Again	Kho-koh	Hihihi	Hey	Hardy
Wèèh	Do	It	Hehehe	Ah-hahaha	
Wèèh	Hihihiii	Ah-hahaha	Hihihiii		
Wèèh	Kho-koh	Again			
Wèèh	Whoa				
Whoa					
Whoa	Me	Happy	Whoa		
Whoa	Ok	Kiss	Me	Obay	*Kissing sound*
Whoa	Peek-a-boo	hahaha	Me	Obay	
Whoa	Whoa	*Sighing sound*	Titumtidum	Titumtidum	Hehehe
Whoopy	Fun	Hehehe			
Whoopy	Fun	Hihihiii			
Whoopy	Har	Again			
Hunger level reached (special parameter)					
Sighing sound	Ha	Big	Hungry		
Sighing sound	Ha	Hungry	*Sighing sound*		
Sighing sound	Ha	Very	Hungry		
Sighing sound	Please	Hungry			
Ha	Hungry	Ra-ra-ra			
Ha	Hungry	Whoa	Ra-ra-ra		
Hungry	Whoa	Ra-ra-ra			

Interaction with another Furby via IR
Standard parameter (staying awake)
Dance together
Goodnight song singing
Telling jokes
Hide and seek game
Standard parameter (going to sleep)
Yawning at each other

Timer running out			
Standard parameter (staying awake)			
Goodnight song singing	*Sighing sound*		
Sighing sound			
Sighing sound	Boring		
Telephone ringing sound	Hahaha hahaha		
Bidou bidou bidou bidou			
Dididididi	Tumtididum	Dididididi	Tumtididum
Doodoodododoodo	Hihihiii		
Jadadada	Tumtididum		
Wèèh	Wèèh		
Standard parameter (going to sleep)			
Snoaring sound			

All Hunger level reached sentences			
Hunger level reached for tickling tummy			
Ha	Big	Hungry	
Ha	Hungry	Bidou-bidou-bidou-bidou	
Ha	Hungry	Ra-ra	
Ha	Hungry	Whoa	Ra-ra
Hmmmm	Please	Hungry	
Hungry	Whoa	Ra-ra	
Hunger level reached for tilting Furby			
Sighing sound	Ha	Big	Hungry
Sighing sound	Ha	Hungry	*Sighing sound*
Sighing sound	Ha	Very	Hungry
Sighing sound	Please	Hungry	
Ha	Hungry	Ra-ra-ra	
Ha	Hungry	Whoa	Ra-ra-ra
Hungry	Whoa	Ra-ra-ra	

All going to sleep sentences					
By petting back					
Goodnight song singing	*Yawning sound*	Me	Sleep	Meh	
Purring sound	*Yawning sound*	Maybe	Sleep		
Purring sound	*Yawning sound*	Sun	Down		
Snoaring sound	Ok	Me	Done		
By doing nothing					
Weeeh	Me	Sleep	Again	*Snoaring sound*	*Snoaring sound*

Waking up				
Hmmm	Papadapadou	hihihi	Me	Obay
Hmmm	Tumtididum	Tumtididum	Ah-hahaha	
Weeeh	Ok	Sleep	Done	
Weeeh	Sun	Up	Wèèh	
Hmmm	Ok	Me	Hug	
Weeeh	Whoa	Me	Big	Sleep

Appendix G: All speech fragments

All speech fragments		
Burping sound	Hahaha-hahaha	Oh
Farting sound	Happy	Oh-oh
Goodnight song singing	Har	Okay
Kissing sound	Hard	On
Purring sound	Hardy	Papadapadou
Roaring sound	Hehehe	Peek-a-boo
Sighing sound	Hey	Pet
Snoaring sound	Hide	Please
Telephone ringing sound	Hihihi	Ra-ra
Yawning sound	Hihihiii	Ra-ra-ra
Again	Hmmmm	Scared
Ah	Hug	See
Aha boo-djak	Huh	Sleep
Ahh	Hungry	Sound
Ah-hahaha	It	Sun
Bidou-bidou-bidou-bidou	Jadadada	Tamtitatidumtidoo
Big	Joke	Tickle
Boogie	Jo-wah	Tododo-totodoo
Boring	Kho-koh	Tumtididum
Dance	Kho-koh	Up
Da-tekda	Kiss	Very
Dididididi	Light	Wah
DJ	Like	Wa-wa-wa-wa-wam
Do	Listen	Weeeh
Dododo	Loud	Wèèh
Done	Love	Wha
Doo	Maybe	Where
Doo doo	Me	Whoa
Doodoodododoodo	Meh	Whoopy
Down	Ne-ne-ne-ne-ne-ne	Woah
Fun	No	Worry
Good	Now	You
Ha	Obay	Yum
Hahaha		

Appendix H: Stripping of an Emoto-tronic Furby

The subject

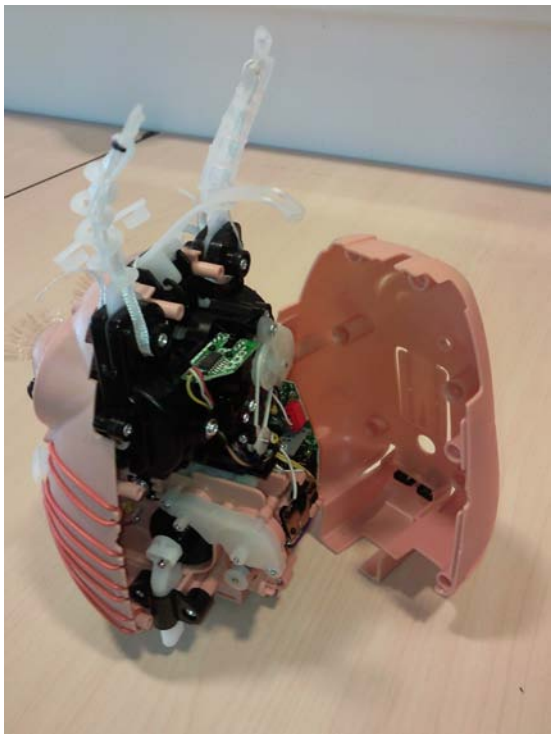
Removing the feet

Zipping the Furby open

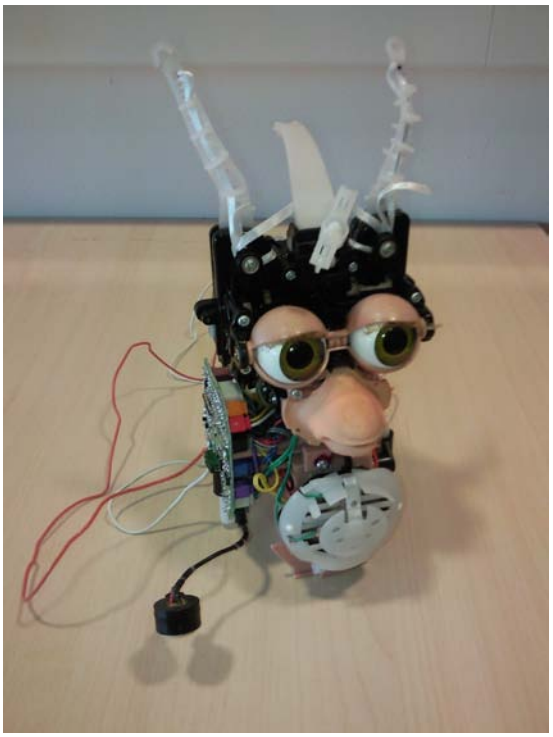
The Fur is protected from being removed by some kind of claws, hooking into the shell

Now the skin is only attached to its mask

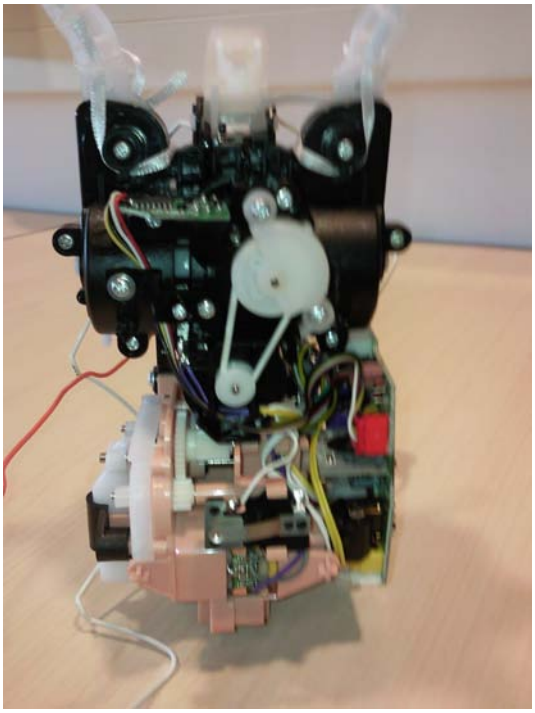
The Furby without the fur. The wires are antennas



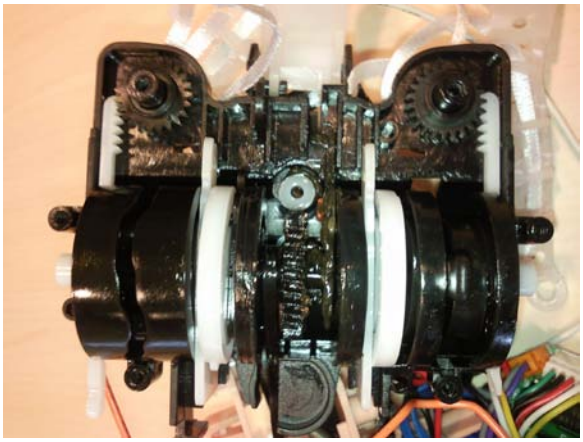
Cracking Furby's shell



The shell is removed only now



The interior from behind

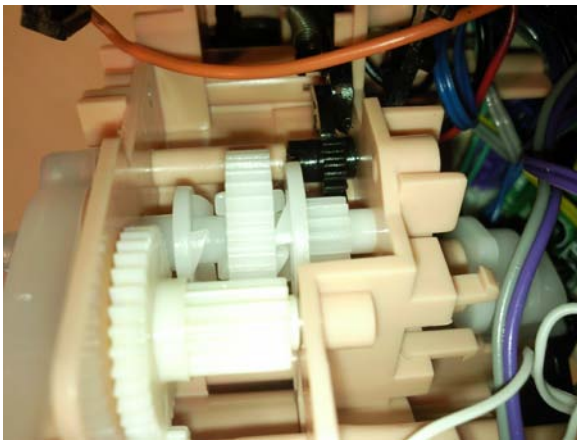


The gears and cams in the head isolated.

These are for movements of the eyes,

corners of the mouth, ears, frowning its

forehead and its belly



The gears in its belly for moving the legs and

the mouth

Appendix I: Problems derived from actual practice scenarios

Scenario 1:

- Mechanical parts are noisy
- The Furby turns to sleep when it is switched on
- Furby needs a manual to be understood
- Furby is expensive
- Special features can only be activated by a strict sequence of interactions
- The special features cannot be found without the manual

Scenario 2:

- The sensors are not very sensitive
- The sensors cannot differentiate the power of the applied pressure
- The special features are hard to activate
- An action can only be started when another has ended
- Sensors gets touched or activated accidentally
- Feeding is nothing but touching a sensor
- Feedback only given by speech
- Furby has no mood
- Furby has no facial expressions
- Limited play value

Scenario 3:

- Furby is not as soft as usual stuffed toy animals
- It has no limbs which can be manipulated
- Surviving a drop from quite a height is not quite likely
- No visual input at all
- Moving eyes suggest it is able to get visual input
- No reaction to sound input, it can only be activated by commands
- Sound input can be distorted by environmental sounds
- Sound input does not work properly
- Limited options available for audio output