Robotic companion creatures

Maya Gounard

Abstract

Studies have shown that robots can be used in a therapy setting to help humans relax. Several complex robots have been built and tested in various settings, however all are expensive to produce. This paper presents the development and construction of simple, inexpensive robots that could be used in therapy sessions. Four robots were built and two programmed over the course of three months. Two of these robots were shown to a small group of teenagers and the results showed overall positive reactions to the robots. An AIBO was programmed as a side project and this experience is also discussed.

1. Introduction

It has been shown that interactions with animals can be emotionally beneficial to people, and animal therapy in hospitals and nursing homes is becoming more and more common (Baum et. al, 1984)(Gammonley and Yates, 1991). Animal therapy is expected to affect the individuals psychologically (e.g relaxation), physiologically (e.g. physical improvement of health), and socially (e.g. stimulates communication between patients and caregivers). However, many hospitals and nursing homes do not allow animals due to the increased chance of infections, bites, scratches, and allergies. There are also individuals that live in apartments or dormitories that do not allow animals due to the damage they can cause. These people may experience feelings of loneliness that could be avoided with the presence of an animal.

One possible solution to these animal-free situations are robotic companions. A number of such robots have been developed and tested with inhabitants of animal-free environments, namely nursing homes. Work has been done with Sony's robotic dog AIBO (Tamura, et al., 2004), Omron's robotic cat NeCoRo (Ohkubo et al., 2003), and the robotic baby seal Paro (Wada, 2007). These are all highly complex robots made to mimic their biological counterparts. They contain numerous motors and sensors and have various features like learning behavior. However, they are expensive to produce; the AIBO—marketed as a robotic pet—cost about $2,500 and was discontinued in 2006. NeCoRo was also marketed as a robotic pet and sold for $1,500. Paro is being used exclusively in nursing homes, and costs $6,000.

To explore this new area of robotics I set out to design, build, and program several simple robots to act as companions for people living in animal-free environments. While these robots cannot compare to the complexity of a real animal, my hope is that through simple interactions a human user can gain some emotional benefit. For a robot to replace a pet it would need to be very complex, as it would be a part of a home for an extended period of time. Yet for short therapy sessions the robots behavior may not need to be very complex to provide comfort for the user. If people are able to connect with such a simple robot there may be a case to begin producing simpler, less expensive robots for therapy purposes.

2. Related Works

Robots are becoming more and more common place in therapy. Ben Robins and the other researchers involved with the Aurora project have been exploring the use of humanoid and non-humanoid robots in "education and therapy of children with autism (Robins et al., 2004)." In one study they tested the use of Robota, a robotic doll, with autistic children to see if the children could learn to mimic Robota (Robins et al., 2005). Robota is a simple robotic doll capable of raising and lowing its arms and legs. It also has a limited visual system and the ability to move its limbs on its own, which were not used in this study. The goal of the study was to see whether autistic children could learn to mimic the robot in hopes of developing a better tool for the learning of social skills. For this study they had four children between the ages of 5 and 10 interact with the robot several times over a 101-day period. During the trials, the robot was set up in a room familiar to the children and controlled by an investigator to mimic the child's movements. The results were different for each child and they're level of engagement varied greatly, however in most cases they're amount of imitation increased over time.

While Robin's study was in the UK, most work with therapy companion robots is being done in Japan. AIBO, NeCoRo, BN-1, and Paro were all developed in Japan and used in studies in care facilities. BN-1 was robotic cat built by Bandai as a robotic pet and was a simpler robot than the others listed. One group of researchers in Japan tested AIBO, NeCoRo and BN-1 in a nursing home and pediatrics ward (Ohkybo et al, 2003). They found that while AIBO and NeCoRo could be presented on a table, BN-1 was too mobile and had to be used on the floor. They noted that NeCoRo's behaviors were slower and that it worked better with their older subjects, while AIBO was faster and kept children's attention longer. They observed that while subjects recognized that AIBO was not an animal that the robot was treated as if it was. NeCoRo was found to be the best of the three for being held by the user, although some of its behaviors were vague and hard to interpret.

Another study was done with both an AIBO and a toy dog being used us patients with severe dementia (Tamura et al., 2004). In this study there were two experiments. One group of patients were presented with a mechanical toy dog for two days in short therapy sessions than an AIBO for two days in the same setting. A second group was presented with an unclothed AIBO (normal AIBO) on the first and last days and a clothed AIBO on the second day. The covering made for the clothed AIBO was made of soft material and covered all by the face of the AIBO. All therapy session were conduction with a occupational therapist present. They found that patients communicated with each other more and that overall socialization increased in the presence of either AIBO or the toy dog. Patients interacted with the toy dog more quickly than with the AIBO, presumably because they could identify the toy dog easier. During sessions with the AIBO the occupational therapist had to encourage the patients to interact with the robot. They did not find a difference between the clothed and unclothed AIBO.

The newest therapy robot that has been developed is Paro, a robotic baby harp seal. Unlike the robots previously mentioned, Paro has be developed solely as a therapeutic tool, rather than as a robotic pet. Paro has mainly been tested in elderly care facilities in Japan and has been shown at exhibitions around the world (Shibata et al., 2004). In the most recent study done in an elderly home, Paro was placed in common spaces on residential floors from 8:30am to 6pm, during which the space was video taped. 12 patients were interviewed about their experiences with Paro and urine samples were taken from 9 patients to measure the levels of the hormones 17-OHCS (which has been shown to increase during stress) and 17-KS-S (which is high in healthy people). Overall time spent in the common space was seen to increase with the presence of Paro, with many patients interacting with the robot while there. Communication between patients increased, which Paro sometimes acting as a conversation starter. Also 17-OHCS levels decreased over time, while 17-KS-S increased—showing physiological improvement in these patients.

These studies show that robots can be used to benefit human users. Paro especially shows what can be achieved with a robot specifically designed for therapy purposes—being designed to be held and pet very easily. To further explore the use of therapy robots I designed and built my own. The rest of this paper explains my project, each of the robots I built, the results from a small group of teenagers, a discussion about the project and the results, an overview of work done with an AIBO and a discussion about that work.

3. Comfort Creatures

The robots I have been developing—called Comfort Creatures—are all simple in design and functionality. They each contain only one to two servo motors to give them motion and a sensor or two to provide them with information about their surroundings. The sensors used are just lengths of stranded wire; these pick up the small electrical fields produced by the human body to detect human presence. They are not very accurate, however they do not need to be. They must be able to tell the difference between a human presence, the lack thereof, and the sensor being touched by a human (e.g. being petted). As the wire sensors are capable of this they are sufficient for my robots.

Comfort Creatures are autonomous robots; they are not controlled by a user but instead respond to human interaction. Their programming is also simple; they do not "learn" or have "daily cycles" as AIBO and Paro do. They simply react to human interaction and occasionally do a few other random behaviors.

Each robot is unique in design and does not resemble any particular animal. Designing after specific animals was avoided deliberately as it has been found when people have knowledge about a particular animal, such as a dog, they expect the robot version to act as if it were a real dog (i.e. the "uncanny valley" effect) (Shibata, 2004). By creating robots that do not have animal counterparts, a new user does not know what to expect and thus can interact with it with a more open mind. Robots of different designs were built because different people find different things attractive. In May of 2008, I showed two Comfort Creatures I had developed that year at a student showcase. One robot was a large dome shape, built to sit on a person's lap, while the other was a small oval shape just larger than the average person's hand. Many people enjoyed my robots, but some disliked the small one, preferring to pet the larger robot. Other's preferred the small robot, and a number of people kept coming back to pick it up again. This experience convinced me that if I wanted to reach the broadest audience possible that multiple different robots would be a good course of action.

The following robots were built in 2009 and are in various stages of completion. They all still require rechargeable battery packs, which will be installed in the fall of 2009. My intention is to get approval to begin testing them with residence of Hampshire College and an elderly care facility in the fall. The majority of this work was done at the University of Minnesota during the CRA-W's Distributed Research of Undergraduates program.

3.1. Lap Monster


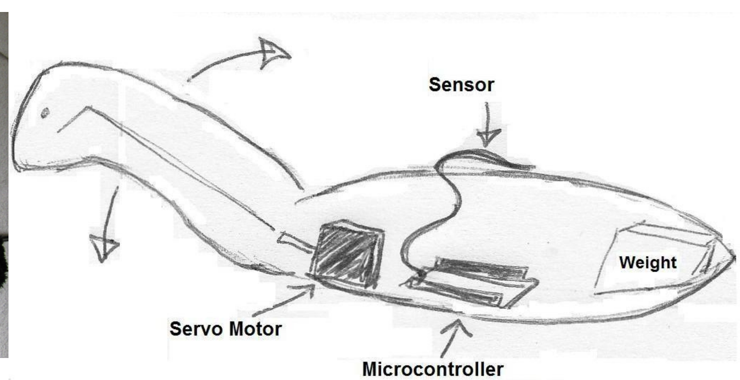

Fig. 1. Left: The Lap Monster with its neck raised. Right: Inside the Lap Monster; arrows around the neck indicate movement.

The Lap Monster was completed in May of 2009 (Fig. 1, left). It consists of a body and a long neck and is meant to be held in one's arms or on a lap. The shell of the body is made of plastic and held together with Velcro. Housed inside this shell are a servo motor, Arduino Diecimila microcontroller, and a weight to provide the robot with a weight similar to an animal of its size (Fig. 1, right). A sensor wire on its back detects human presence and being pet. The microcontroller reads the sensory information and moves the motor according to the code on it. The shell of the body is encased in foam to make the robot soft to the touch. The neck is also made of plastic and attached to a steel shaft that is connected to the servo motor, which moves the neck up and down. Bubble wrap covers the neck for a soft feel. The outside of the robot is covered with soft fabrics and a pair of eyes at the top of the neck.

The code for the Lap Monster was completed in July of 2009. When the robot does not detect a human it squirms fiercely by wiggling its neck up and down quickly, causing its body to rock slightly if it is on a flat surface. If it detects human presence its actions become slower, more calm. When pet along its back it raises its neck in correlation to the hand movement. After being pet several times it goes into a “sleep” state, where it lowers its neck and stops moving. It will stay in this state for a period of time or until it is pet again. These behaviors repeat for as long as the robot is on.

3.2. Shoulder Bot

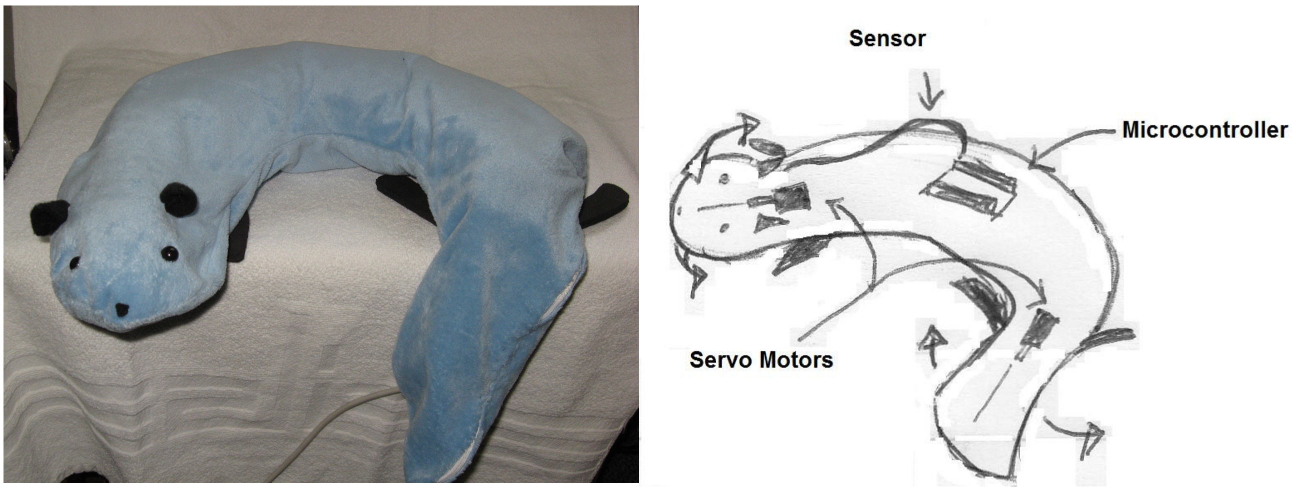

Fig. 2. Left: The Shoulder Bot. Right: Inside the Shoulder Bot; arrows around the head and tail indicate movement.

The Shoulder Bot was built in June of 2009 (Fig. 2, left). It is shaped like a long, thin mammal with a tail and small head. It is designed to be worn around the user's shoulders or held on their lap. It can also be used when placed on a flat surface. The body, head, and tail of the robot are made completely of foam, making it soft and light. The fact that it is light is very important so that it does not cause strain if worn on the shoulders. Two servo motors are set into the foam, one for moving the head up and down and the other for moving the tail back and forth (Fig. 2, right). A sensor wire is located in the head and sends information to the Arduino Deumeilanove microcontroller located in the middle of the body. The microcontroller is covered with a dome of plastic and foam to protect it. The outside of the robot is covered with a soft blue fabric which was hand sewed to fit the foam body. A zipper is located along the left side of the tail (visible in Fig. 2, left) so that the fabric can be removed to be cleaned. The ears and nose are made out of black fleece, while front and back paws are made of black, foam-like plastic.

The code for the Shoulder Bot was completed in July of 2009. When not in the presence of humans or if not given attention for some time, the Shoulder Bot will occasionally move its head in a random head-bobbing motion. When pet on its head it responds by raising its head in correlation to the movement of the hand. Its tail sweeps randomly both with and without human interaction

3.3. Little Green Monster

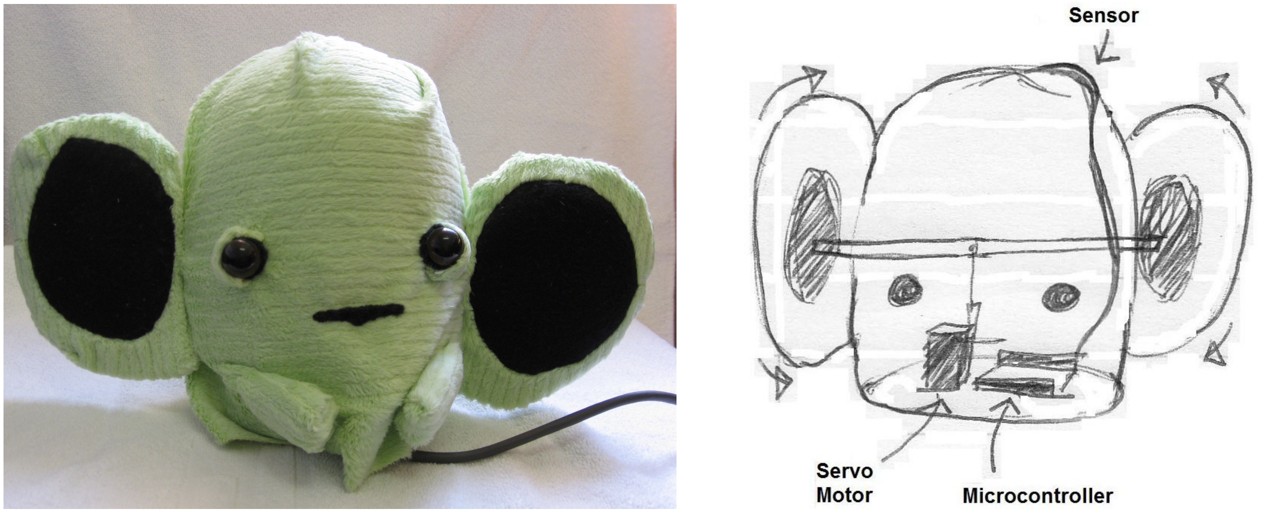

Fig. 3. Left: The Little Green Monster. Right: Inside the Little Green Monster; arrows around the ears indicate movement.

The Little Green Monster was built in July of 2009 (Fig. 3, left). It has large eyes and ears and is built to sit on a flat surface or a user's lap. A dome of plastic provides the shape of the robot, while housing one servo motor and an Arduino Deumeilanove microcontroller. These are attached to a base which is connected to the dome via wires. The sweeping motion of the servo motor pulls and pushes a small wire connected to shafts which run into the ears (Fig. 3, right), causing the large ears to move up and down. The dome is covered in a layer of foam and then a soft, green fabric covering that was hand sewed. The base of the dome sits on a slanted piece of foam, so that the robot looks up slightly. A sensor wire on the top of the head detects the presence of a human, sending signals to the microcontroller within the dome. The ears are made of foam with a small piece of cardboard to help them keep their shape and to connect to the shafts coming from the dome. The outer covering of the ears was hand sewed out of the same green fabric on the body and black fleece. The paws are made of foam and covered with the green fabric, while the nose is made of black fleece. Eyelids were made out of the green fabric for the big eyes to make the eyes bulge less. The bottom of the robot has not yet been completed as it still needs its rechargeable battery pack.

The code for this robot is still under production. The goal is for the ears to wiggle in different ways depending on if and how it is being interacted with.

3.4. Wriggle Bot

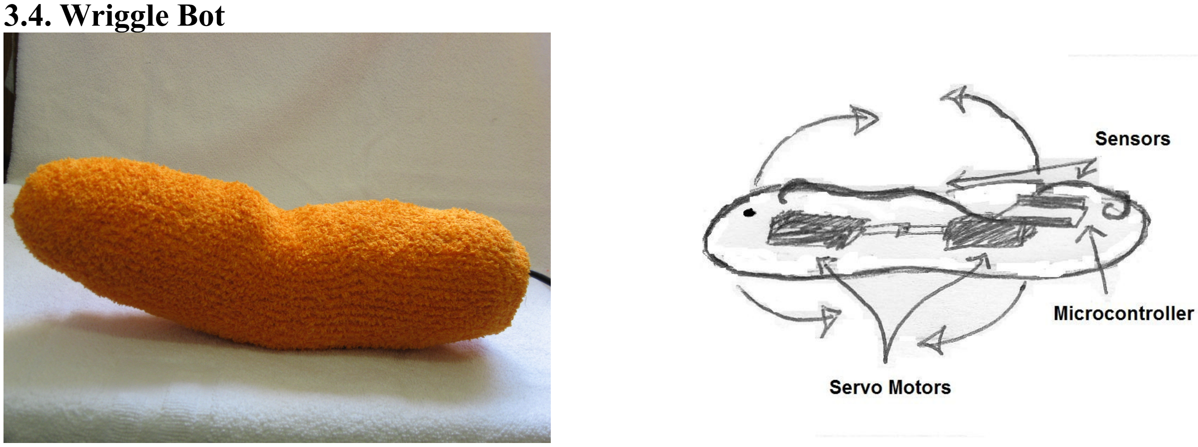

Fig. 4. Left: The Wriggle Bot. Right: Inside the Wriggle Bot; arrow coming out from the body indicate movement.

The body of the Wriggle Bot was completed in June of 2009—although it is still in need of outer features such as eyes (Fig. 4, left). The design of this robot comes from another robot that I built in the spring of 2008. My older robot was smaller so the microcontroller could not fit on the body and I was forced to run wires from the motors and sensors on the robot to a box containing the microcontroller and battery. Even though it was attached to a box, many people enjoyed interacting with it and picking it up. Thus I decided to revise this design to be large enough to house the microcontroller and battery pack.

The Wriggle Bot is designed to be held in the user's arms. The body is made of two halves; on each half is a servo motor protected by a shell of plastic (Fig. 4, right). An Arduino Deumeilanove microcontroller is housed under the plastic on one half of the body (the battery pack will take up this space on the other half). On each half there is a sensor wire for detecting human presence. The servo motors are attached together, giving the robot a large range of motion. A foam strip lies between the two halves to provide shape and a soft feel to this area. The body is covered in a covering made of fleece, then a soft, stretchy fabric, and finally a soft, orange, fabric capable of stretching. Outer features such as eyes have not been added yet.

The code for this robot has not been completed yet. The intention is for the robot to wiggle its body differently depending on if and how it is being interacted with.

3.5. Results

In June of 2009 two groups of high school students were introduced to two of my Comfort Creatures, Lap Monster and Shoulder Bot. While I talked about my project, the robots were passed around the table so that the students could touch and hold them if they liked. After the presentation short questionnaires were passed out to those interested in giving feedback. The questionnaire contained the following questions:

- Which Creature did you like best?
  - Both
  - Lap Monster
  - Shoulder Bot
  - Neither
- How did holding/petting them make you feel? (check all the apply)
  - Happy
  - Sad
  - Bored
  - Excited
  - Relaxed
  - Other
- What did you like best about them? (check all that apply)
  - They way they look
  - They way they feel
  - How they respond to touch
  - Other
- Did you find the creatures: (check all that apply)
  - Cute
  - Creepy
  - Easy to hold
  - Difficult to hold
  - Soft
  - Hard
  - Fun
  - Boring
  - Other
- How old are you?
- What is your gender?
- Do you have a pet?
  - Yes
  - No
- If you do, what type of pet do you have?

A total of 24 high schoolers filled out the questionnaires; 15 boys and 9 girls ranging in age from 15 to

17, the majority being 17. 18 of them had pets. The results were as follows:

Which did you like best?			
Both	Lap	Shoulder	Neither
6	1	16	1

How did holding/petting make you feel?				
Happy	Sad	Bored	Excited	Relaxed
14	0	1	6	16

Did you find the creatures:							
Cute	Creepy	Easy to hold	Difficult to hold	Soft	Hard	Fun	Boring
17	3	16	3	17	1	10	0

What did you like best about them?		
The way they look	The way they feel	How they respond to touch
6	9	22

3.6. Discussion

The results show an overall positive reaction to my robots. Only one person had solely negative responses. The majority preferred ShoulderBot (16 of 24 teens), felt relaxed (16 of 37 responses) and happy (14 of 37 responses) when holding and petting the robot, found the robots cute (17 of 67 responses), soft (17 of 67 responses), and easy to hold (16 of 67 responses), and like how they responded to touch (22 of 37 responses). These results show that overall they enjoyed the experience and the robots, though several of them did comment that after a while they would get bored.

While these are good results, this group does represent the target age demographic for Comfort Creatures. These robots are really for adult therapy and not for juvenile entertainment. In the fall I hope to test my robots with individuals living in animal-free environments, such as college students and residents at an elderly home. These sessions would be designed as therapy sessions with the robots present for interaction with interested residents. A questionnaire about how the resident feels would be presented before and after the session.

Such simplistic robots have never been tried in therapy. Most researchers make an argument for complexity because the user is expected to interact with robot for an extend period of time, more like someone would with a pet. This was the case with AIBO, where it was expected to replace a pet dog. In cases such as this the complexity is vital to retain the user's attention and interest. However therapy tools may only be administered during therapy session, which would involve short periods of exposure. In such settings where the user is only interacting with the robot for a few hours once or twice a week the complexity of the robot might not be necessary. In such a short time window the user may not even be able to really see how complex the robot truly is. For example Paro is a very complex robot. It has a daily cycle and exhibits different behaviors depending on what time of day it is, it understands some voice commands (currently only in Japanese), and has several sensors and motors with which to interact with the world. Paro has mainly been used in elderly care homes, set up in a common space for the residents to interact with as they wish (Wada, 2007). This is again more of a robotic pet setting than a robotic therapy setting, as the residents can interact with Paro for an extended period of time over several days. If a user were to only interact with Paro during therapy session they would only know its daily cycles if they interact with it during different times of day, and even then they may not make the connection unless they witness Paro switching cycles. The purpose of my robots is to test whether simple robots can benefit the wellbeing of the user in a therapy setting. If this is the case than such robots could become more mainstream, being more a more affordable option for facilities such as hospitals.

I fully designed each robot before I began building, which helped the construction process go quite smoothly and relatively quickly. Because each robot is different in design, each on had to be constructed in a completely different way. For example ShoulderBot's body is made completely out of foam, a medium I had never really worked with. I greatly enjoyed overcoming the odd obstacles that I encountered while building. Programming the robots was the biggest challenge for me. Figuring out what types of behaviors for the robots to exhibit, how they should be exhibited, how the robot should respond to touch, and then writing the code to make it all happen was quite challenging. Unique code had to be written for each robot as their abilities are all very different. Making each of them cute and attractive in their own way was an interesting task that is still not complete.

4. Programming AIBO

Fig. 5. Astro the AIBO, model ERS7.

While at the University of Minnesota, I was given the opportunity to program a Sony AIBO. These robot contain numerous motors and sensors can be programmed to do many different behaviors. As my robots are very simple, working with the AIBO was a chance for me to explore the possibilities of such a complex robot. I chose to focus on trying to make the AIBO appear cute and likable, as this is what my robots do for the most part. I programmed the AIBO using URBI, a programming language that allowed me to send code to the AIBO via Bluetooth. This meant that I could write code, send it to the robot, and see the results of the code in seconds.

The AIBO is a robotic dog manufactured by Sony from 1999 to 2006. I worked with one of the newer models, an ERS7, named Astro. The robot has motors in its head, tail, neck, mouth, and four legs, allowing it to do a number of motions including walk. It has touch sensors on its head, back, under its chin, and on the bottom of its feet (so it can tell if they are on the ground), obstacle detectors in its chest and face, and a camera in its nose. It also has a panel of LEDs across its face, most of which are white with some blue, green, and red lights in various locations.

Over several weeks I became comfortable with URBI and wrote a simple program for Astro. To begin with I found functions to change Astro's stance from laying, to sitting, to standing within URBI. I programmed Astro to change from one position to the next if touched for a length of time on the head or chin depending on its current stance. Thus, if Astro is laying and the chin sensor is triggered for two seconds, it will raise itself into a sitting position. If the chin sensor is again triggered while Astro is sitting, it will raise into a stand. When the head sensor is triggered for three seconds while Astro is standing, it will lower into a sit, and again triggering the head sensor will lower it further into a laying position. Astro also responds to being pet on the head or upper back by wagging its tail, either quickly or slowly (with a greater chance of the quick wag) depending on a random selection. Astro also responds to being pet on the head with head and mouth movements. The movement that Astro does depends on a random selection from the four response functions available, with some being more likely than others. When left alone, Astro will look around randomly and occasionally bark to get the attention of the user. Finally, running parallel to all the other code, rectangular eyes are shaped out of the LEDs on the face (fig. 5) and made to blink semi-randomly.

4.2. Discussion

Working with the AIBO was different from working with my own robots. One big difference was that as the creator I know exactly what my robots are and are not capable of, whereas with the AIBO I had to spend time exploring the system. As the AIBO is a very complex robot I did not have the time to explore all of its abilities, such as the camera and obstacle detection. I've wanted to build a mobile robot for some time now, but working with the AIBO really showed me how complex it would need to be. Obstacle detection would be a must for navigation and if the robot was going to be placed on a table than an edge sensor would be needed. Even a wheeled robot would need strong motors so that it could move on various surfaces. While making a mobile robot would be an interesting challenge, am not sure that it would be a necessary feature for my therapy robots.

The appearance of the AIBO is very different than that of my robots. While AIBO can be considered cute, it was really built to be able to move around, and clothing AIBO would hamper its movement. It is also awkward hold when on as it squirms in your hands. My robots are built around being nice to hold and touch, and thus are very different in appearance and function. While AIBO does succeed as a robotic pet I think it is not a suitable robot for individuals with limited mobility.

5. Conclusion

Therapy robots are useful tools for providing comfort and companionship to those in animal-free environments. While most which are currently in production are very complex, little research has been done to determine how complex they really need to be to benefit the user. The therapy robots that I built and programmed are part of an ongoing study on how people respond to simple therapy robots. If these simpler, cheaper robots are successful it could make therapy robots an affordable for animal-free environments like hospitals and elderly homes to provide.

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