The Huggable: A Platform for Research in Robotic Companions for Eldercare

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Abstract

Robotic companions are one new type of technology being created to assist and care for elders. One important research question is how should such systems be designed? In this paper we present the Huggable, a new type of robotic companion which is being designed to function as both a fully autonomous robot and semi autonomous robot avatar. In this paper we describe how the semi autonomous robot avatar version of the Huggable can be used as a research tool to help determine exactly how robotic companions for eldercare applications should be designed. In addition to describing the system, we present four research scenarios in which the Huggable can be used to help motivate this discussion.

Introduction

Robotic systems allow for the embodiment of computer systems in the real world of humans. Robots can not only hear through an auditory system and see through a vision system, but unlike computers they can have a somatic system to detect touch and a motor system to actually move around in the real world. Thus the form of the robot has an influence on the types of intended applications. Larger human-sized systems such as Pearl (Pollack, Brown et al. 2002) invoke a different interaction scenarios from smaller pet-type robots such as the Paro (Wada, Shibata et al. 2005), the NeCoRo (Omron Corporation Product Literature), or the AIBO (Tamura, Yonemitsu et al. 2004).

Today, the field of robotics holds many parallels to the development of the personal computer – there exists numerous hardware systems without much standardization. Each university has their own robot, often developed for a very specific research application. Additionally the expense in both money and time of developing a robot system often makes entry into the field of robotics difficult. Thus while software systems can be shared and lead to collaboration, it is often the hardware which becomes the true bottleneck. While there is currently some movement on developing a standard robot system for mobile manipulation (Willow Garage Website), this system is very different from the robots designed for robot assisted therapy.

Additionally, as robotic systems are developed it becomes very important to first fully understand the potential applications for such systems. As such, the designers of that system must discuss the potential applications with experts in the field. Those with first hand knowledge of the problem of eldercare – specifically the doctors, nurses, and staff of nursing homes and geriatric wards of hospitals can be incredibly valuable in the early stages of design. However ultimately, the robotic platform itself must be designed in such as way as to allow for multiple modes of interaction through various sensing modalities.

We believe that the traditional pre-trial Wizard of Oz studies, where components of the robot are teleoperated or cued by a human researcher, can reveal much about the potential capabilities of a robot in a real world setting. Among the many examples of such studies include experiments in the domain of autism (Robins, Dautenhahn et al. 2005) and rhythmic play with children (Michalowski and Kozima 2007). This traditional approach works well; however, because often these Wizard of Oz studies require an expert knowledge of the system, they must be completed by the robot's own development team and not by the real front line staff who would be using the system on a day to day basis.

Today, the field of robot avatars poses an interesting opportunity to help researchers develop their own robotics applications. Robots such as the Geminoid (Sakamoto, Kanda et al. 2007), Quasi (Interbots), and the Muppet Mobile Labs (Yoshino 2007) are platforms built for communication. They allow a remote operator to interact with users through the robot primarily through vision and auditory systems. If such systems were combined with other sensory information from the robot and additional data collection features were employed, such robot avatars could serve as research platforms for human robot interaction. Additionally, if such systems featured layers of autonomy the operator could be free to focus on the

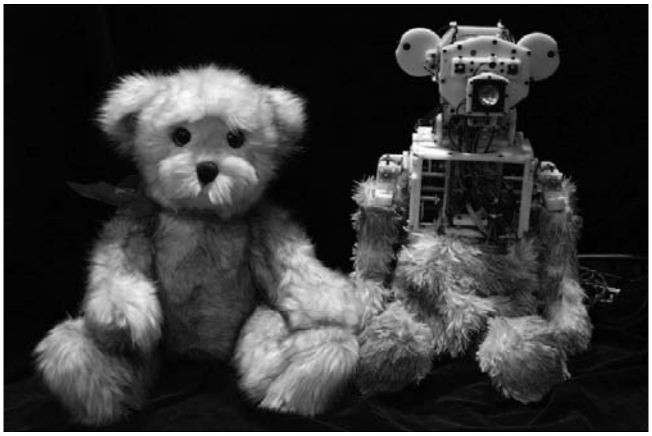

Fig. 1. The Current Huggable V3.0 Prototype (in development) (right) and the Concept Plush (left). In the current prototype only the underlying mechanics of the robot are shown. The sensitive skin system, soft silicone rubber beneath the fur, and final cosmetic fur exterior are not shown in this photo. When fully finished it will look like the concept plush at left.

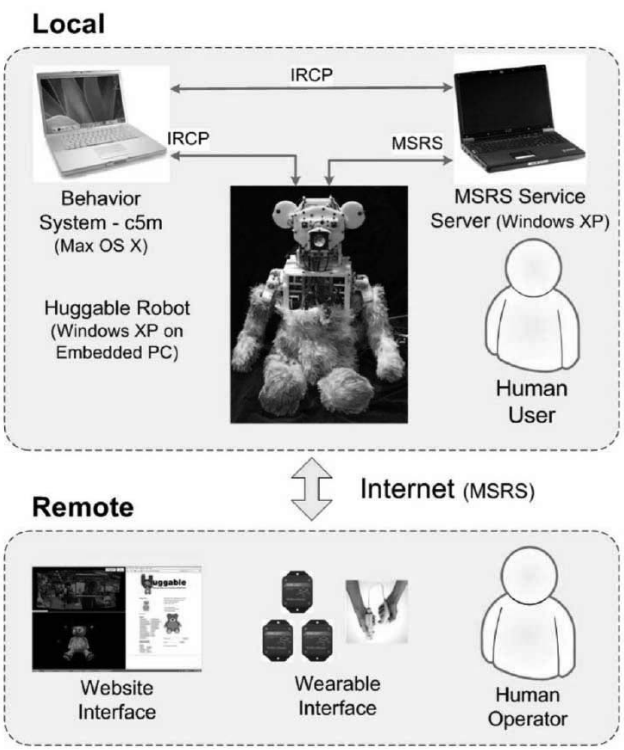

Fig. 2. The Huggable System. On the local side, all the visual, auditory, and somatosensory input from the human user is processed on the embedded PC inside the Huggable and sent to the MSRS service server which visualizes high level sensor information through the web interface. The c5m system receives inputs from the MSRS server, directs the autonomous behavior of the robot, and sends motor control information to the embedded PC. The human operator on the remote side controls the robot via the remote website. The operator may also wear orientation sensors (3DM—GX1) and hold Wii Remotes to control the Huggable via his or her own gestures

interaction without having to constantly control all of the degrees of freedom as if the robot was a puppet.

In this paper, we will present the Huggable platform – a new type of robotic companion being designed for family communication, education, healthcare, and entertainment applications. We believe that our conscious efforts to make the Huggable function as a semi-autonomous avatar for communication allow for the Huggable to serve as a very useful platform for research in the healthcare applications, specifically for eldercare, of companion robots. One goal of our approach is to create a system which is intuitive to use by doctors, teachers, family members, and other people who do not have an expert knowledge of the technical aspects of the system.

The Huggable Platform

The Huggable, shown in Figure 1, has been in development since January of 2005 (Stiehl, Lieberman et al. 2005). In our current approach, this robot is being designed to function both as a fully autonomous robot as well as a semi-autonomous robot avatar. For purposes of discussion in this paper we will be focusing on the latter case. In the semi-autonomous case, the Huggable robot is remotely controlled by a human operator. The human operator can be in the next room or anywhere else in the world via an Internet connection. Using the various systems on the robot, the operator can seamlessly communicate with the person interacting with the robot, see their face through the robot's eye cameras, hear their voice through the robot's microphones, observe how the robot is being held and interacted via a display of the live sensor information present on the robot, and cue animations, sound effects, and autonomous behaviors all through their operator terminal. The goal of such a system is to reduce the cognitive load on the operator and allow for the operator to focus on the interaction with the user. We will now describe the Huggable system briefly in more detail.

The Huggable features a combination of technologies which make it an interesting research platform for companion robots. In the head of the robot is an array of microphones, two cameras in the eyes (one color and one black and white), and a speaker in the mouth. In the body, the Huggable features an inertial measurement unit based upon (Morris 2004), passive potentiometers in the hips and ankles for joint angle position detection, an embedded PC with wireless networking. Additionally, the Huggable features a set of 8 quiet, backdrivable actuators using a hybrid belt/gear drive system. These degrees of freedom (DOF) are a 3 DOF neck (nod, tilt, and rotate), a 2 DOF shoulder mechanism in each arm (rotate and in/out), and a 1 DOF ear mechanism. The Huggable is also being designed with a full body, multi-modal, sensitive skin with over 1500 sensors all over the surface of the body

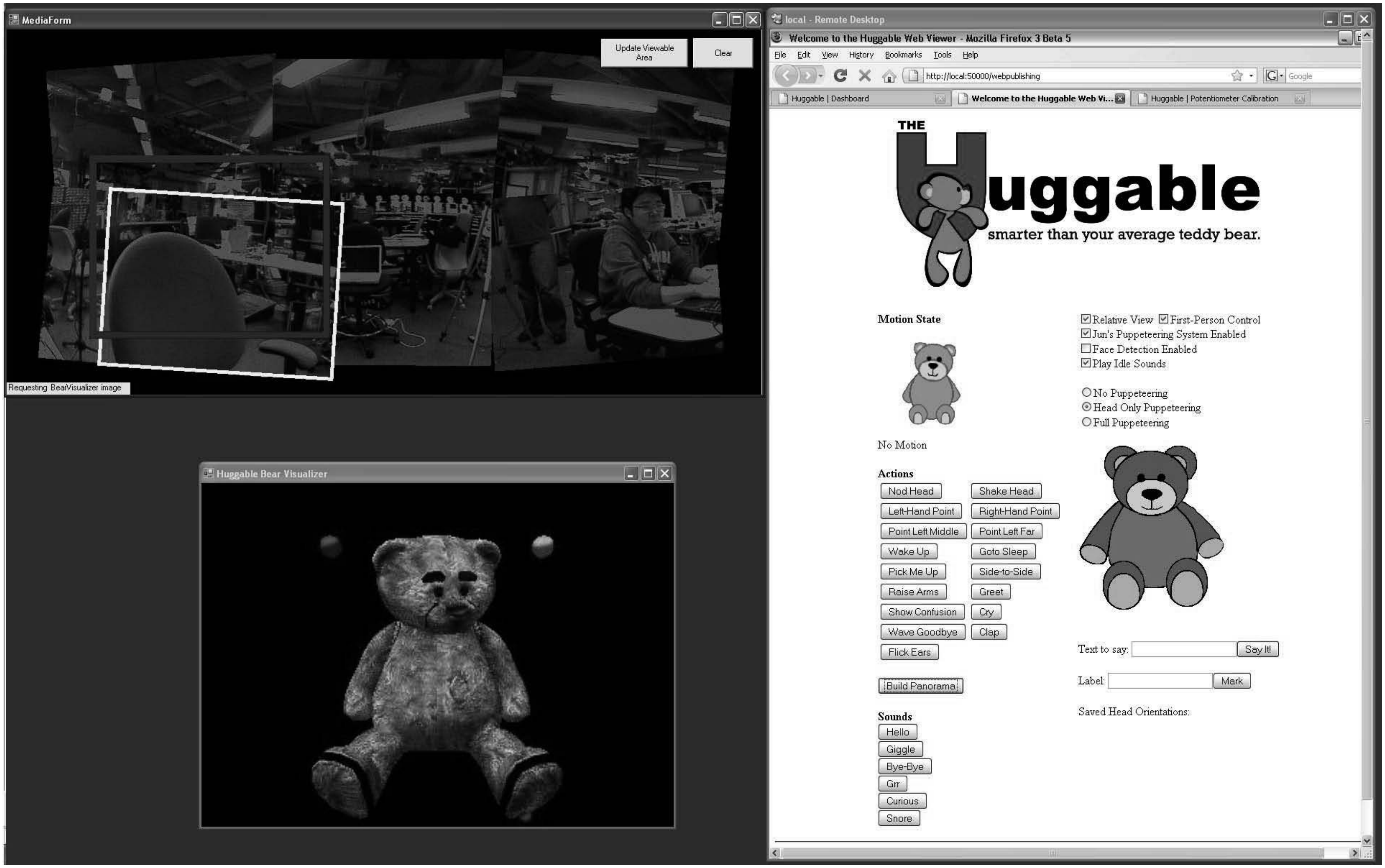

Fig. 3. A Screen-Shot of our Current Web Interface. The top left portion is the stale panorama.. The bottom left portion is a video stream of the three dimensional virtual model of the robot. The website on the right half of the screen-shot is the interface that the puppeteer uses to control and receive feedback from the robot. This website interface consists of a series of buttons to play back animations and sound effects on the robot, a button to build the panorama, check boxes to turn on and off other autonomous systems, an animated character display for the motion state of the robot, an display for the location of touch of the robot, and text boxes for the text to speech and look-at labeling systems..

underneath a layer of soft silicone rubber and fur (Stiehl and Breazeal 2006). Currently, the Huggable runs tethered to a 12V power supply but will ultimately be wireless.

Figure 2 shows our current system implementation for the development of the Huggable platform as a semi-autonomous robot avatar (Lee, Toscano et al. 2008). In our current vision for a potential research application, the Huggable would be placed with an elder in their room at a nursing home, hospital, or their own home. A pair of laptop computers connects to the Huggable via a wireless connection and are near the elder's location. A network connection then connects the Huggable system to a remote operator (potentially in the next room or via a network connection back at the university). In our scenario, the Huggable is controlled either through a website interface, a wearable interface, or a combination of the two.

The Huggable features a pair of software sub-systems to achieve its complex behavior. We use Microsoft Research's Robotics Studio (MSRS) to gather data from the various sensors on the robot and process it in real-time. Results of this processing are sent to the other software sub-system: C5M (Blumberg, Downie et al. 2002). The C5M software sub-system uses the aforementioned data to make high-level decisions about the robot's behavior, such as where to look, or how to move. The custom TCP protocol that MSRS uses, allows us to communicate with computers beyond our local subnet. This is necessary for communication across the Internet between the remote operator and the local user. Additionally, it is important to note that our current system design allows for scalability for research, it is very easy to add more computing power on the local side of the system to allow for more complex software systems.

Figure 3 shows the website interface used by the operator to control the Semi-Autonomous Huggable Robot Avatar.
A full detailed discussion of this interface can be found in (Lee, Toscano et al. 2008), but for purposes of this paper a brief explanation of some of the elements of the website interface is provided.

The upper left hand corner of the image consists of the Stale Panorama. This image is built as an autonomous process where the Huggable moves its head through the full range of motion and drops a still image from its eye cameras onto a larger canvas. Additionally, the live video feed, shown in the yellow box in Figure 3, is overlaid onto this canvas. The blue box, shown in Figure 3, is used by the operator to direct the robots attention to a specific location. Finally, during the interaction the panorama can be updated with new images overlaid onto the canvas automatically or the full panorama can be rebuilt at the push of the "Build Panorama" button by the operator. This system was designed for two purposes. First it expands the traditional tunnel view of the 320 x 240 live video feed from the eye camera and allows for a wider field of view to be presented to the operator. This wider field of view allows the operator to look at other landmarks in the room such as furniture or objects. Second, the ability to direct the robot's attention to a specific location using this interface prevents the problems of overshoot encountered by direct control of a robot across a network.

Fig 4. The Wearable Interface. The human operator is holding a Nintendo Wii Remote and a Nunchuk on both hands and wearing a set of 3DM-GX1 orientation sensors on both arms and the head.

The lower left hand corner of Figure 3 shows the Virtual Huggable. The Virtual Huggable allows the operator to see exactly what the real Huggable robot is doing in front of the user. It is a What You See Is What You Get (WYSIWYG) system with a one to one mapping of virtual joint angle position to physical robot actuator joint angle position. In addition to showing the current configuration of the robot, the Virtual Huggable presents real time sensor information. This sensor information includes the orientation that the Huggable is in as detected by the IMU system, the current position of the hips and ankles as detected by the passive potentiometers in these joints, and will soon map the interactions with the multi-modal sensitive skin sensory system.

The website shown on the right side of Figure 3 is the main operator interface. This website allows for the operator to see the classified gestures from the IMU indicating if the Huggable is being picked up, rocked, bounced, or shaken (as shown in the Motion State animated graphic). Additionally, the larger Teddy Bear cartoon graphic is used to indicate the location of touch in a different presentation. The website also features a set of push buttons for playback of animations and sound effects. There is a text box ("Text to Say") for the Cereproc text-to-speech system. A second text box ("Label") is used for the labeled look-at system. This system allows for specific head orientations, i.e. positions on the Stale Panorama, to be labeled with text button. For example, if the Huggable was to look at the elder and then at other objects in the room during a research interaction session, the location of the elder's face, and each object could be labeled and then at the push of a button the Huggable would automatically move its head to that labeled location. The series of check boxes at the top of the website are used to turn on and off the wearable puppeteering system, described in the next paragraph, the automatic face detection system which uses

OpenCV, and the automatic playback of idle sounds. Finally, the radial button directly above the cartoon Huggable is used to select which of three puppeteering modes is active. "No Puppeteering" is the fully autonomous case where the Huggable looks around the room, plays idle sounds (if the "Play Idle Sounds" box is checked), and executes other autonomous behaviors. "Head Only Puppeteering" allows for autonomous control of the body degrees of freedom but yields full control of the Huggable's head to the operator. "Full Puppeteering" allows for direct control of all the degrees of freedom.
In addition to the website interface of Figure 3, we have developed a wearable puppeteering system shown in Figure 4. This puppeteering system is used in two separate modes depending on the intended interaction. For direct control of the robot, the operator wears a set of 3DM-GX1 orientation which consist of 3 axes of acclerometers, 3 axes of magnetometers, and 3 axes of gyrometers. As the operator moves his or her head and arms, the robot moves its corresponding joints in a one to one fashion. In this control scenario, the ears are not directly controlled. The second mode of operator control is gesture based. Here the operator uses a Nintendo Wii controller and Nunchuck which feature 3 axes of accelerometer date in each device. Using an HMM based system, 6 gestures currently can be recognized and played back on the Huggable robot. These gestures are *arms up*, *arms forward*, *bye-bye* (one arm up and waiving), *crying* (wiggling both hands in front of eyes), *ear flickering* (wiggling both hands above the head), and *clapping* (with both arms forward repeating moving both hands left to right in an opposite direction). A further detailed discussion of the wearable puppeteering system can be found in (Lee, Toscano et al. 2008).

The Operator wearing a microphone can also speak directly through the Huggable using his or her own voice if so desired. The operator also can hear the user through the microphones of the Huggable.

Finally, in addition to these operator controlled systems, the Huggable features a series of autonomous behaviors which can be turned on and off by the puppeteer. These include automatic face detection and look-at behavior, automatic look-at of body parts based upon touch and passive potentiometer input, automatic correction of the video feed based upon IMU detection of robot orientation, and other systems further described in (Lee, Toscano et al. 2008). The goal of these autonomous systems when combined with the operator interfaces of Figures 3 and 4 helps to reduce the cognitive load required by the operator to control the robot and thus frees up the operator to focus on the interaction.

Eldercare Research Applications

One major goal for the Huggable project is to create a research platform that features the wide variety of software and hardware systems as previously described. By having this variety, we believe that studies will reveal which components of the Huggable are important for a specific application. While the focus of this paper is on eldercare, we are also exploring other applications in family communication, entertainment, education, and healthcare.

In addition to our current system described in this paper, the software infrastructure is designed to allow for new systems to easily be integrated into the current robot system shown in Figure 2 either on the local or remote side depending on the application. Finally, the Huggable is not only a communication device, but also can be used as a multi-modal data collection device. These features allow the Huggable system to be used as a powerful research platform for companion robot applications for eldercare.

Lessons learned from interactions using the semi-autonomous robot avatar can help influence and direct the design of fully autonomous robot systems. It is important to state that while the focus of this paper is on the full Huggable robotic system, we do not expect that all the features will be needed for a given application. Thus, we believe that there is the potential for a subset of components of the full Huggable robot platform to be combined in a specific version of the Huggable or a separate device. We call these separate devices Huggable technologies. A good example of one such system is the Squeeze Doll (Cheung 2007) which we are currently developing for healthcare applications.

It is also important to briefly state that while the focus of our research is on developing robotic companions, we do not believe that such systems should function as replacements to humans or animals. In our approach, the robotic companion functions as a tool which can be used by a parent to communication with their child, a doctor to monitor a patient to help provide a better quality of care, or a teacher to help a child learn. In all cases the robot is one aspect of a triad that includes two human beings.

In this section we will present four different scenarios of how the Huggable can be used for such research based upon our own discussions with doctors, nurses, and staff at hospitals and nursing homes in both the US and in Europe over the past three years. In each scenario, both the robotics researcher and the frontline staff at the nursing home or hospital facility could operate the robot. It is important to note that many other scenarios beyond these four are possible.

<u>Scenario #1 – Robot as Emotional Mirror:</u> Robots are evocative objects as discussed by Sherry Turkle in (Turkle 2005; Turkle, Taggart et al. 2006). In her studies she observed that some elders used the robotic toys, i.e. the My Real Baby, to work through emotional issues from their past. By talking to the doll and treating it as a loved one they were able to use it as a talking point to work through a difficult emotional experience. In addition, from our

interviews with Nursing home staff in Scotland, they described the need to understand the emotional mood of the residents in the facility. One way they currently did this was observe how they interacted with stuffed animals and other objects around them. Thus from a research standpoint can advanced robotic companions such as the Huggable be used as Emotional Mirrors? The ability of the Huggable to record not only audio and video information but gesture and other sensor information such as affective touch (Stiehl and Breazeal 2005) could allow such a system to record the emotional interaction an elder has with the robot and potentially share this with the staff to improve their quality of care.

Scenario #2 – Robot as Social Interaction Motivator: One benefit that companion animals (often cited as the model for companion robots) provide is the ability to get residents in a nursing home to interact with one another. The Paro has shown a similar effect as when it has been presented in facilities it attracts attention from the elders and gets them to interact with one another (Kidd, Taggart et al. 2006). This aspect can be greatly improved upon by using a robot such as the Huggable which can be remotely operated to prompt conversations and interactions, as well as pose questions to the elders. Additionally, the Huggable can be used by the staff as a reason for residents to congregate and interact with one another. From a research standpoint a few interest questions could be studied using the Huggable system. Does the use of the novel robotic companion as opposed to a familiar staff member have a different effect on social interaction? Additionally, what effect does the form chosen for the robot have on the ability for it to motivate social interaction?

Scenario #3 – Robot as Physical Therapy Motivator: Recently there has been focus on using autonomous robots for physical therapy sessions, i.e. socially assistive robots (Mataric 2006). A robot such as the Huggable system presented in this paper can be used as a research platform to better understand what aspects of the interaction are needed. In this scenario the person undergoing the therapy would wear the wearable interface shown in Figure 4. Their movements would be recorded and presented to the operator controlling the robot in a separate location away from the robot. Thus, the Huggable could allow for experimentations in the role of form, communication, character, and the autonomous systems required to motivate and sense the physical therapy session.

Scenario #4 – Robot as Home Health Monitor and Aid: Currently in Japan there is a huge research emphasis on developing robots to help care for the elder population. A system such as the Huggable can be placed in an elder's home and paired with other sensing devices in the home that can transmit their data via the Huggable to the remote operator. The remote operator can analyze the data stream and interact with the elder when appropriate through the Huggable. The technical needs of a fully autonomous home health aid could be studied using this system.

Conclusion

In this paper we have presented the Huggable in its current semi-autonomous robot avatar form. This system allows for a remote operator to easily control the Huggable robot and thus focus on the interaction without a high cognitive load requirement or expert knowledge of the technical workings of the system. Such a system can also be a great research tool for the design of robotic companions for eldercare. While we have yet to test these scenarios, we believe that such an approach can have much value to the larger HRI community.

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