Cherry, The Little Red Robot… with a Mission … AND a Personality!

Sarah M. Brown, Christine L. Lisetti, Andreas H. Marpaung

Computer Science Department
University of Central Florida
Orlando, Florida 32816
sbrown@cs.ucf.edu; Lisetti@cs.ucf.edu; marpaung@cs.ucf.edu

Abstract

In this article, we describe the development of an autonomous robot, Cherry the Little Red Robot, whose functionality we designed so that she could socially interact with humans on a daily basis in the context of an office suite environment. Cherry has a given set of office-tasks to accomplish, from giving tours of our computer science faculty suite to visitors, to serving beverages to those faculty and staff, and to engaging them in social interaction. We describe (1) our motivation for social informatics in human-robot interaction, (2) the hardware additions that we implemented for ActivMedia robot for our purposes, as well as (3) the Cherry's multi-modal anthropomorphic interface that we developed capable of combining speech, face recognition, and emotional facial displays, and finally (4) our future research efforts.

Introduction

With increasing advances in robotics in behavior-based robotics (Brooks, 1989; Arkin, 1998), sensor fusion (Murphy, 1996a, 1996b, 1998, 2000), robot vision (Horswill, 1993), emotion-based architectures (Breazeal, 1998; Velasquez, 1999; Murphy, Lisetti et al., 2002), a variety of domains and applications for human-robot interaction and collaboration are emerging: planetary exploration, urban search and rescue (USAR), military robotic forces, personal care and service robots (e.g. hospital assistance, home elderly care, robotic surgery), home appliances, entertainment robots, and more (Rogers and Murphy, 2002).

Furthermore, recent progress in artificial intelligence, speech simulation and understanding, graphics and computer vision have made it possible to design computer systems that have "social expertise" in order to naturally bring the human – a principally social animal (albeit engineering formal training has altered natural preferences) – into the loop of human-computer interaction. Social informatics has indeed been considered a critical, unexplored area in the domain of human-robot interaction (Rogers, Murphy, 2002) which we currently set out to explore and to focus our contribution on.

In this article, we consider social expertise in terms of (1) external communicative behavior and (2) internal motivational goal-based abilities (Lisetti, 2002). We describe the development of a service application on an autonomous robot, Cherry the Little Red Robot shown in Figure 1. Cherry's functionality has been designed so that she could socially interact with humans on a daily basis in the context of an office suite environment.

Figure 1: Cherry, our AAAI 2000 Prize

Cherry has a given set of office tasks to accomplish, from giving tours of our computer science faculty suite to visitors, to serving beverages to those faculty and staff and to engaging them in social interaction. In the remainder of this article, we describe:

(1) our motivation for focusing our design, hardware, and user interface on social informatics and emotional intelligence,
(2) the basic hardware included in our ActivMedia robot as well as the hardware additions that we implemented for our purposes,
(3) Cherry's multi-modal anthropomorphic interface capable of combining speech, face recognition, and emotional facial displays so that she is

socially engaging to humans from the very start of her functional design and implementation,

(4) and finally our future software developments to complete our project.

Relevant Background on Human-Robot Interaction and Social Informatics

Ten years ago, it was predicted that robots would become important factors in home and office environments (Ralston, 1993). As documented in the Final Report for DARPA/NSF Study on Human-Robot Interaction (Rogers and Murphy, 2002), although complete robot autonomy has not yet been accomplished, "the feasibility of integrating various robot entities into people's daily lives is coming much closer to reality. […] robots now have the potential to serve not only as high-tech workhorses in scientific endeavors, but also as more personalized appliances and assistants for ordinary people."

However, it has also been noted (Rogers and Murphy, 2002) that before autonomous and intelligent robots are fully integrated into our society, the nature of human-robot relationships and the impact that these relationships may have on our future need to be very carefully considered.

Indeed, robots differ from simple machines or computers in that they are mobile, have varying levels of autonomy, and therefore are not as predictable, and can furthermore interact within a user's personal physical space. When such a robot has autonomy, the social interaction that results is unlike any previous man-machine relationships.

From our perspective, an interesting modeling issue therefore becomes that of social relations. In particular, we have chosen to focus our contribution to the field in addressing the technical goals of (1) understanding how to embody affective social intelligence and of (2) determining when embodied affective social intelligence is useful. Toward that goal, we have identified a collection of relevant questions and we have categorized them into three main categories discussed below:

1. Robot social intelligence: for example, can "no personality" in an intelligent agent (software or robot) be perceived by humans as a cold, insensitive, indifferent agent? If so, do these perceptions differ by specific groups of people, differentiated by age, gender, culture, etc.? Is it important to change the perceptions mentioned above in humans so that agents can be viewed as personable, helpful, maybe even compassionate? If such is the case, can we identify the various contextual situations and applications when that is beneficial, or even necessary? If emotions and personality are embodied in a robot, does it affect how the people respond to it? If so, how so, and in what contexts? Should they resemble that of humans, or should they be depart from them?

2. Human social intelligence: on the other hand, one may also ask how do the personality of the human affect how the human interacts with the robot? If so, how? Does it arouse specific emotions, behaviors? Which ones? In what contexts does this happen? Are these effects consistently observable, predictable, positive, or negative? Can we improve on these toward the positive? How so?

3. Human-Robot social relationship: finally, looking at the relationships themselves, questions arise as to what kind of taxonomy of human-robot social "relationships" can be established, identifying numeric (eg. 1:1, 1:m, m:m), special (eg. remote, robo-immersion, inside), and authority (eg. supervisor, peer, bystander) relationships (Rogers and Murphy, 2002) to determine what levels of "interpersonal skills" a robot would need in order to perform its role effectively.

Affective Social Intelligence

In order to understand when these social relationships are needed or when the perception of such relationships need to be changed, social relations must be modeled. Emotions have an evolutionary crucial functional aspect in intelligence without which complex intelligent systems with limited resources cannot function nor behave efficiently (Simon, 1967).

Emotions are carriers of important messages which enable an organism to maintain a satisfactory relationship with its environment. *Fear*, for example, serves the function of preparing an organism physiologically for a flight-or-fight response (blood flow increases to the limbs, attentional cues are restricted, etc.). *Anxiety*, on the other hand, serves the function of indicating that further preparation for the task at hand is needed. Other examples of the functions of emotions abound (Lisetti, 2002).

Emotions greatly influence decision making (although sometimes dysfunctionally), more often than not for improved efficiency and flexibility toward a complex changing environment (Lisetti and Gmytrasiewicz, 2002). Indeed, pure reasoning and logic have proven to be insufficient to account for true intelligence in real life situations. In the real world with all its unpredictable events for example, there is not always time to determine which action is best to choose, given an infinite number of possible ones and a set of premises.

Furthermore, different personalities will incline individuals to have different mental and emotional pattern tendencies. An agent with an *aggressive* personality, for example, will be predisposed to a *fight* response when experiencing fear, whereas one with a *meek* personality will be predisposed to *flee*. Predispositions, however, can be altered by conscious repression and/or adaptation.

Furthermore, **personality predisposes** an agent toward a certain set of emotional states and action tendencies: We consider personality as representing characteristics of an autonomous self-motivated organism that account for consistently chosen patterns of reaction over situations and time including behavior, emotions, and thoughts.

Relevant Applications for Social Human-Robot Interaction

As mentioned before, many applications involving human-robot interaction may not benefit from including social intelligence in the robot portion of the interaction.

However, some applications intuitively lend themselves to it, such as personal care and service robots (e.g. home elderly care, office assistant), entertainment robots (e.g. toys, pets, museum docents). Indeed, "Within a decade, robots that answer phones, open mail, deliver documents to different departments, make coffee, tidy up and run the vacuum could occupy every office".

Military Applications

The question as to whether military robotic forces might also benefit from robots with social intelligence may not be as intuitive and might require more inquiry. These kinds of applications are very likely to depend on the type of numeric relationships and authority relationships (Rogers and Murphy, 2002).

For certain types of applications, modeling emotions and personality of robots, agents, and humans is therefore crucial to:

- render the robots/agents more efficient themselves in terms of self-motivation, monitoring progress toward their goals, and adapt their behavior flexibly to unpredictable environments;
- work with and train humans in a more realistic environment in team work where robots can embody personality traits and emotion-like states to provide test-bed for adaptation/learning to specific personality types, emotional coping behaviors.
- predict team behaviors in terms of likelihood of task success/failure given specific mixes of agent personality types (e.g. team consisting of aggressive members only vs. team consisting of ½ aggressive and ½ meek members, altruistic vs. selfish), external environmental inputs (e.g. high stress vs. low stress, various drugs), internal individual beliefs (e.g. self-confidence levels), various emotions and moods (e.g. discouragement vs. anger).

The Office Assistant Application: Cherry's Job

In order to begin our inquiry on the modeling aspect of human-robot social relationships, we identified one specific application which we believe is intuitively enough "social" to start generating interesting relevant results.

Cherry, our little red robot, is being designed and programmed to have a variety of social roles to include being a gopher for the department and giving tours of the building.

In addition, Cherry is also being designed to have a variety of internal states and external behaviors such as:

(1) maintaining and expressing a consistent personality throughout the series of interactions;
(2) experiencing different inner emotional-like states in terms of her progress toward her goals;
(3) choosing (or not) to express these inner states in an anthropomorphic manner so that humans can intuitively understand them;
(4) having an internal representation of her social status as well as the social status of her "bosses".
(5) adapting to the social status of the person she is interacting with by following acceptable social etiquette rules.

Furthermore, to evaluate Cherry's performance and perception by humans, both during and after implementing Cherry's mission and personality, we are conducting surveys, questionnaires and experiments to begin to answer the three categories of questions mentioned earlier (human social intelligence, robot social intelligence, human-robot social interaction).

Introducing Cherry, the Little Red Robot

We won Cherry (anthropomorphically named for her social role), shown in Figure 1, at the AAAI Mobile Robot Competition entitled *Hors D'Oeuvres Anyone?* where our joint USF-UCF entry consisted of two heterogeneous human-sized cooperating Nomad robots serving hors d'oeuvres at the conference main reception (Murphy et al., 2002). Contrary to the Nomads, Cherry is a very small robot of the ActivMedia AmigoBot family (ActivMedia, 2002).

The Robot Hardware Itself

An AmigoBot is an intelligent mobile robot, capable of autonomous or user defined movement and behavior. It not only has an operating system on the robot (the AmigoOS), but is packaged with several programs that allow the user to manipulate the robot. The AmigoBot is intended for use in areas such as schools, labs, offices, and any place that is wheelchair accessible.

In our case, Cherry is intended to navigate our Computer Science Faculty Offices Suite located on the second floor of our UCF Computer Science Building. One of the main advantages of the AmigoBot is that it is highly maneuverable with 2 rubber tires, each driven by a reversible DC motor, and a rear caster for support.

Furthermore, she has a red polycarbonate body that resists damage from running into obstacles.

Cherry has 8 sonars with 6 in the front and 2 in the rear (the round circles seen in Figure 1 above). Not only are AmigoBots robots able to detect if there are objects in front of, to the side of, or behind them, but to also determine how far away they are.

Human-Robot Communication and Control

The AmigoBot line also offers users the choice of connection types. Since winning Cherry, we have acquired a second AmigoBot, Lola (shown in Figure 2), which has in addition to Cherry's hardware, a camera and image transmitting device.

Figure 2: Lola featuring the antenna of the wireless modem, camera, and image transmitting device.

In addition, both of our robots have wireless capabilities provided by a pair of wireless modems for each. One modem is connected to the robot and stored underneath between the wheels, the other is connected to the serial port of a PC.

These modems have a range of approximately 300ft, but it is considerably less in areas with many walls or sharp turns. The other option for communication with the robot is via a direct connection from the PC serial port, to one inside (or on top of) the robot shown in Figure 3.

While using a tether does offer a much faster and more reliable method of transferring information, the length of the cable significantly reduces the overall uses that the robot can perform.

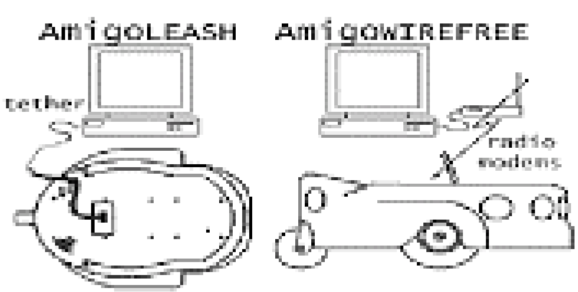

Figure 3: AmigoLeash and AmigoWireFree

Using the *ActivMedia Saphira* software (ActivMedia, 2002), we have been able to create short navigational programs for Cherry, demonstrating her motor precision and turning ability. While these programs have been useful for demonstration purposes and to work with the way in which the robot rotates, the overall usefulness for navigating the Computer Science Building is minimal.

More "Brain Power" for Cherry: Hardware Additions

Indeed straight from the factory, the Amigobot sensors are powered and processed from a single controller, driven by a high-performance, I/O rich 20MHz Hitachi H8 microprocessor. Even though acceptable for short navigations, in order to build a meaningful system with multimedia abilities, we equipped Cherry with additional processing power.

Because the robot is able to carry a payload of up to 2 lbs, we mounted a small and light laptop on top of it, which not only provides the direct connection to the robot but also the mobility since it too runs off of battery power. We equipped Cherry with a Sony Vaio Picturebook laptop in order to boost the processing power of the robot (see Figure 4).

Because the laptop is directly connected to the robot, there is no loss of data with commands as there can be using wireless modems.

However, because the laptop is designed to be extremely small, many accessories ports, such as serial and network, are either nonexistent or only present when using a port replicator. Because the robot requires a serial connection, we had to "create" a serial port using a USB to serial converter, and then use a serial cable to connect to the robot.

Another significant hardware obstacle was the addition of an OrangeMicro iBot, a FireWire camera that required a 6-pin connection with the laptop. Since our compact laptop only had a 4-pin connection, we used a FireWire hub and modified it to draw power off of the robot's battery to link the camera to the computer.

All of these cables made the robot look unsightly so we had a mount created for Cherry out of a honeycomb aluminum product that would be strong without adding much weight. This way, all of the cables are now tucked underneath the mount and out of sight: looks are important for social interactions… Furthermore the mount also provides a platform for the laptop to be mounted onto, as well as a base for installing a camera.

Indeed, because Cherry is interesting to us principally for social interaction in an office suite, we wanted to be able to mount a camera at human-eye level on the robot, to enable it to process people's faces with computer vision algorithms (described later). The final result of our hardware configuration is shown in Figures 4 and 5.

Figure 4: Cherry with laptop

Figure 5: Cherry with platform and eye-level camera

Not only has the laptop boosted the capabilities of the Amigobot, but it has also opened new doors for controlling Cherry's whereabouts.

Cherry the Little Red Robot … With a Mission…

As mentioned earlier, our current interest working with Cherry is to involve her in social interactions in an office environment while performing useful simple tasks such as, in our current project, giving a tour to computer science visitors by introducing professors and research interests as she accompanies visitors down the faculty suite, or delivering beverages and documents to professors and staff, etc.

Cherry, our little red robot, is being designed and programmed to have a variety of social roles:

(1) her master's favorite office gopher (a 1-1 master-slave human-robot relationship);
(2) her department favorite gopher (a many-1 masters-slave human-robot relationship);
(3) her department tour guide (another many-1 human-robot relationship).

We used *ActivMedia Mapper* software to create a map of our Computer Science office suite in order to (1) have the ability for simple point-and-click navigation, and to (2) have a built-in grid system that we are going to be using in the navigational portion of our interface.

Computer Science Faculty Suite Map Creation

Only walls and large permanent obstacles had to be drawn in, since the robot is able to use its sonar to navigate around smaller or moving items (and soon its vision system for collision avoidance describe later under future development).

To draw the walls, either the robot can be used to take measurements, or standard methods such as a measuring tape or blue prints can be used. We used standard methods to generate our map of the Computer Science faculty suite shown in Figure 6.

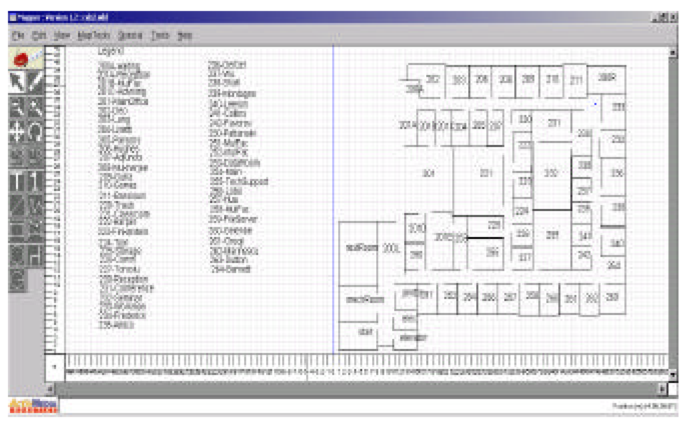

Figure 6: Map of UCF Computer Science Building Second Floor

The created map shown Figure 6, displays on the right handside each office number positioned in respectively, whereas the left handside displays the name of each professor or staff working in that office so that the user can point and click on the office to send Cherry to.

The map therefore provides quick and simple direction for Cherry. Because our map is very accurate, it also provides the basis for our (x,y) coordinate system, has been used to generate the button based map in the C++

user interface as seen in Figure 7 below, and it can furthermore be loaded in the simulator as described next.

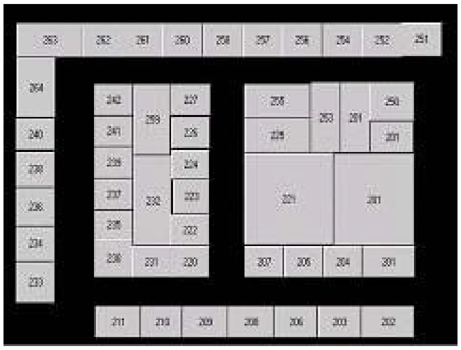

Figure 7: Button Based Map in Interface

Cherry's Navigation Simulator

The created map can also be loaded into the *ActivMedia Navigator* software (whose user interface is shown in Figure 8) in order to run and test our code in simulation rather than with the actual robot.

Indeed, given that our Affective Social Computing Lab is located on the first floor of the Computer Science building, we are making use of simulation to avoid carrying Cherry upstairs on the second floor at each step of implementation.

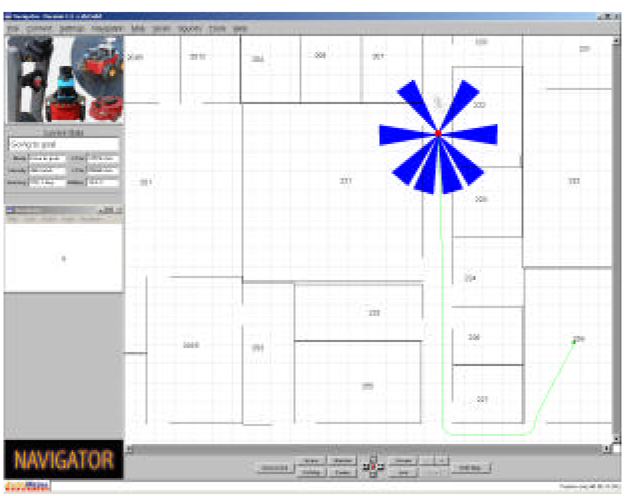

Figure 8: Navigation Simulator Interface

The *ActivMedia Navigator* software is a basic navigation module that lets you control the robot's actions with point-and-click or with menus.

As shown in Figure 8, the robot center is displayed with a red circle, the robot's sonar readings are displayed in blue and its speed and status readings (displayed on the left handside) change as it moves. The user can point on the map to the desired location, and a green dot marks it. A green line from the robot center to its final destination shows the robot path.

Web-based Interface for Cherry Command-and-Control

In order to allow users to control Cherry from their desktop (rather than having to crawl around on the floor to manipulate the laptop), we connected the laptop to the UCF network via a wireless Ethernet card.

Using WinVNC, a free piece of remote desktop control software, a user can view what is being displayed on Cherry's laptop screen and control her actions by clicking on the map interface from their desktop computer. It is important to note that WinVNC runs on all win32-based systems, and that it only requires a VNC client or a java-enabled web browser in order to view the laptop's screen. It allows both single and mu ltiple users to connect to the laptop at our discretion. Additional users can interfere with the primary user of the laptop since they share a single view of the machine. This problem only grows larger as more people attempt to use VNC to control the robot, which is the reason we are currently restricting access only to the primary user of the robot.

We are researching better ways of displaying the web interface in order to (1) reduce potential interferences, and to (2) get a better refresh rate and color display than WinVNC can provide due to the subtle coloration and frequent movement of the avatar.

Web-based Cherry's-eye-view of the world

In addition, using the iBot camera and the wireless Ethernet capabilities of the laptop, we are able to stream video of the people and environment that Cherry encounters. This and another camera mounted nearer to her base can provide a "Cherry's-eye-view" of the world for users to access via the web.

Because an ongoing broadcast on the web of Cherry's view may not be of much interest to a large group of people, and because it would most likely raise societal privacy issues related to "Big Brother Technology", we are really using this feature solely as a very convenient way to give remote demonstrations. Future uses of the feature might emerge in the future, and will need to be cleared through subject consent forms with computer science faculty suite inhabitants.

Cherry, the Little Red Robot with a Mission… AND her Personality!!

The laptop addition also allowed us to install several other pieces of software to enhance the functionality and social behavior of our robots.

Cherry as our favorite Computer Science Tour Guide

In order to give Cherry knowledge of who works where so that she could give meaningful and instructive tours of our faculty offices, we also linked each office on the map we created with each professor or staff's facial image and current research interests (available from our UCF Computer Science web site). Now Cherry has information to introduce each person once she reaches their office.

Cherry as my favorite office gopher

We also thought that one important task for Cherry to be able to perform on our floor, was to bring soda cans to a specific professor or staff member.

First, we created a copy of the Computer Science map onto Cherry's laptop interface to enable users (for now only one) to point and click which location on the map they want Cherry to go to (see Figure 7). Users can therefore point and click on one of the map of offices drawn, which has the effect of dispatching Cherry to that office.

Figure 9: Introducing Cherry's Face

In addition, in order to facilitate the social interaction with humans, an anthropomorphic avatar has been created for Cherry to represent "her". The avatar (shown in Figure 9) is present on the laptop/Cherry's user interface and has voice ability so that she can speak to the user in natural language. She explains a variety of facts, from who she is and what her mission is, namely the UCF computer science tour guide, to which professor works in what office, to what that particular professor is researching.

Taking a social informatics co-evolutionary approach to the study and design of technology and social structures, we adopted both a bottom-up and a top-down approach to designing Cherry. We have given her social expertise in terms associating a variety of *external expressive behaviors* with her various inner states. These inner states – measured in terms of her current relationship with her environment and goals – will need to be integrated with the external behavior for a consistent system (Ortony, 2001).

From a co-evolutionary perspective, however, our bi-directional approach enables us to start testing and evaluating our interface design with human subjects while Cherry's functionality is being designed to ensure maximum success in both her functionality and interface.

Currently, Cherry can display different facial expressions corresponding to her different inner states:

- **Frustration:** Cherry expresses frustration (see Figure 10) when she finds that the office to which she was sent to has its door closed, or the door is open but she cannot recognize the faculty inside the office.

Figure 10: Cherry Frustrated

- **Discouraged**: Cherry shows discouragement (see Figure 11) when, after waiting for a while (a parameter of her patience which can be adjusted), the door remains closed.

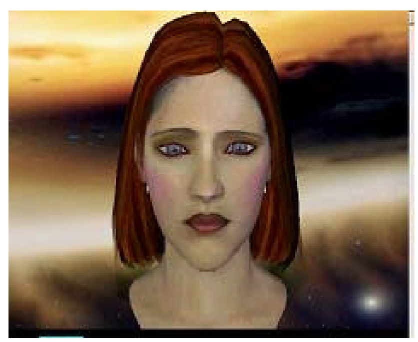

Figure 11: Cherry Discouraged

- **Angry:** Cherry can also express anger when, after waiting for a long time, the door still remains closed (Figure 12). This option was created in order to test how people might react to her anger differently: some might want to help her accomplish her goal, whereas others might not want to deal with her at all. We plan to study these issues through psychological experiments and surveys.

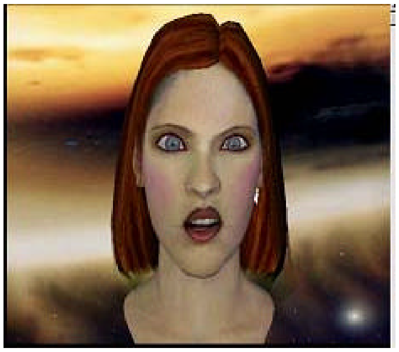

Figure 12: Cherry Angry

Good Morning, Doc!

Finally, we have also integrated our face recognition system using our existing MOUE system (Lis etti, 2002) and Visionics face recognition code. Cherry now has the ability to take pictures of people she encounters, match them to our existing database of people we know have offices in the computer science suite, and greet them by name, and social status.

Part of this system enables Cherry to greet different people according to their university status. For instance, a Full Professor is greeted with more deference than a 'mere" Graduate Student, following some social rules given to her.

Complete Interface

All of the components have been integrated into a single interface designed for ease of use for both the controller of the robot and those she encounters and to provide fun, social interactions with Cherry. All of the different aspects can be seen below in Figure 13.

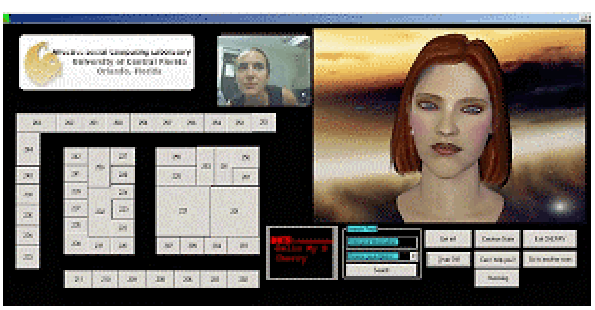

Figure 13: Cherry's User Interface

In addition to the point and click map, the avatar that is Cherry's "face", and the video components (both facial recognition and video streaming), other features have been added to assist in using the interface to control the robot. A search feature allows people to find a professor's office number and a text box displays everything that Cherry says to 1) allow hearing impaired individuals to read what is being said and 2) since remote users cannot hear anything from the laptop, they can instead read her speech. We have also added a series of buttons to allow users to ask for instructions on use, change Cherry's goals, and to exit the program.

Our Future Goals:

More Hardware and Software for Cherry: her new eyes… and vision system

To provide more autonomy for Cherry, we are going to use the Aria classes provided by ActivMedia to incorporate navigation with collision avoidance code (Horswill, 2001). Not only will we be able to dictate where she goes, but we can also use her sonar and her "eyes" to detect and avoid objects using a routine.

We also hope to orient her on a grid so that she will always "know" where she is using coordinate system. This will also assist us when attempting to have two or more robots cooperating together.

More Personality for Cherry

We also plan to create more "personality" for Cherry. Examples include: humming as she travels to and from offices, getting upset when she can't find someone in their office, getting frustrated when encountering obstacles, and getting excited when she finds who she is looking for.

Her comments and simple conversation could also in the future be tailored to individuals and their interests. We want to make Cherry interesting, lovable, and able to interact on a social level with the people who work in the building.

More Missions for Cherry

While it will be relatively simple to travel to an office with a Coke, and speak an offering, we would like to be able to have the professor select which beverage they would like. Cherry could then come back to us, tell us what she needs, and she would deliver what the professor their preferred drink.

After the "beverage offering" behavior is created and working, we plan on creating more options for the user to choose for the robot. Some of the options we have planned are: delivering a message to multiple staff members and being able to give directions to staff offices from anywhere on the second floor of the Computer Science Building.

ARIA

All of these additions will need to be developed with the ARIA software. ActivMedia Robotics Interface for Application (ARIA) is an object-oriented, robot control applications-programming interface for ActivMedia Robotics' mobile robots. ARIA is written in C++ and provides access to the robot server as well as to the robot's sensors and accessories. It makes an excellent foundation for higher-level robotics applications, to include Saphira. ARIA is released under the GNU public license, which means that if any work you do is distributed that uses ARIA, all of the source code must be distributed. The classes that comprise ARIA are available and can be used in other C++ code, provided that it is compiled under Microsoft Visual C++.

Figure 14: Cherry, Lola, and friends

Human-Robot Social Interaction: Experiments

Finally, we plan to conduct a series of psychologically sound experiments on how humans interact, appreciate, dislike, or like our social robots.

Interestingly, for examp le, we have already informally established that Cherry is a very attractive for children and young college students who find her looks and autonomy absolutely irresistible.

Gender, age, personality, context and other factors are likely to influence the nature of the interaction with our social robots. We are interested in studying these issues in further details.

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References

ActivMedia. www.activmedia.com, 2002

Arkin, R. C. *Behavior-Based Robotics*, Cambridge, MA: MIT Press, 1998.

Breazeal, C. and Scasslati, B. Infant-like Social Interactions between a Robot and a Human Caretaker. *Adaptive Behavior*, 1998.

Brooks, R and Flynn, A. "Fast, Cheap, and Out of Control", AI Memo 1182, MIT AI Laboratory, 1989.

Dyer, C. Getting Personal with Computers: How to Design Personalities for Agents. *Applied Artificial Intelligence*, 13:273-295, 1999.

Eysenck, H. Biological Dimensions of Personality. *Handbook of Personality: Theory and Research*, NY, NY: Guildord Press, 244-276.

Horswill, I. Polly: A Vision-Based Artificial Agent, In *Proceedings of the AAAI Conference*, 1993.

Lisetti, C. L. Personality, Affect and Emotion Taxonomy for Socially Intelligent Agents, In *Proceedings of the Florida International Artificial Intelligence Society Conference*, Menlo Park, CA: AAAI Press, 2002.

Lisetti, C. L. and Gmytrasiewicz, P. Can a Rational Agent Afford to be Affectless? A Formal Approach, *Applied Artificial Intelligence*, Vol. 16:577-609, 2002.

Murphy, R. R. *Introduction to AI Robotics*. Cambridge, MA: MIT Press, 2000.

Murphy, R. R. Use of Scripts for Coordinating Perception and Action, In *Proceedings of IROS-96* , 1996a.

Murphy, R. R. Biological and Cognitive Foundations of Intelligent Sensor Fusion, *IEEE Transactions on Systems, Man and Cybernetics*, 26 (1), 42-51, 1996b.

Murphy, R. R. Dempster-Shafer Theory for Sensor Fusion in Autonomous Mobile Robots, *IEEE Transactions on Robotics and Automation*, 14 (2), 1998.

Murphy, R. R., Lisetti, C. L., Irish, L., Tardif, R. and Gage, A., Emotion-Based Control of Cooperating Heterogeneous Mobile Robots, *IEEE Transactions on Robotics and Automation*, Vol. 18, 2002.

Ortony, A. On Making Believable Emotional Agents Believable . In *Emotions in humans and artifacts*, R. Trappl & P. Petta P. (eds.), MIT Press, Cambridge, 2001.

Ralston, A. and Reilly, E. D. (Eds) *Encyclopedia of Computer Science, 3rd*. Ed., Van Norstrand Reinhold: New York, 1993.

Rogers, E. and Murphy, R. Human-Robot Interaction. *Final Report for DARPA/NSF Study on Human-Robot Interaction*, www.csc.calpoly.edu/~erogers/HRI/HRI-report-final.html, 2002

Simon, H. Motivational and Emotional Controls of Cognition. (Originally published in 1967) Reprinted in *Models of Thoughts*, Yale University Press, 1979, 29-38.

Simon, H. Making Management Decisions: The Role of Intuition and Emotion. In W. H. Agor (Ed.), *Intuition in Organization*. 23-39. Newbury Park, CA: Sage, 1989.

Velasquez, J. From Affect Programs to Higher Cognitive Emotions: An Emotion-Based Control Approach. *In Proceedings of the Emotion-Based Agent Architecture Workshop at the International Conference on Autonomous Agents*, 1999.

Whehrle, T. The Grounding Problem of Modeling Emotions in Adaptive Artifacts. *Cybernetics and Systems: An International Journal*, 32: 561-580, 2001.

Whehrle, T. and Scherer, K. Toward Computational Modeling of Appraisal Theories. In *Appraisal Processes in Emotion*, Scherer, K., Schorr, A. and Jonhstone, (Eds.), New-York: Oxford University Press, 2001.