Monitoring the Home Environment Using Domestic Robot

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ABSTRACT

Today, robots are no longer limited to laboratory experiments; they have found their way into our homes. Being a physical entity itself, a robot can provide the functionality a regular computer does not possess. In the *AIBO Monitor* project, we use a domestic robot dog as a mediator for people to remotely monitor their home environment. Several design ideas have been explored and are presented in an attempt to maximize the user awareness of the robot's interaction with the environment.

CR Categories: H.5.1 [Information Interfaces and Presentation]: User Interfaces—Graphical user interfaces;

Keywords: Human-Robot Interaction, User Interface

1 INTRODUCTION

Over the past few years, several robots have been introduced into the consumer market. Examples range from domestic service robots like the Roomba [1], to intelligent and toy-like robots such as the Sony AIBO [5]. Although the Roomba does not possess the same level of intelligence the AIBO has, it is capable of handling daily chores, such as carpet cleaning, without human intervention. On the other hand, the AIBO is a dog-like toy equipped with a variety of sensors and wireless capability. It is able to react to sound and visual changes and communicate with other wireless enabled devices. Although the AIBO has greater abilities, it does not have much practical value compare to the Roomba. The goal of the *AIBO Monitor* project is to take advantage of the AIBO platform to create an active and mobile home monitoring system, where people can be remotely aware of unusual events occurring in their homes. Also, we are exploring the possibilities of notifying collocated users about their home environment through the robot's motion and auditory feedback. The *AIBO Monitor* is a very tentative exploration into Human-Robot Interaction (HRI) for home monitoring systems and is still in its initial stages.

2 RELATED WORK

Human-Robot Interaction (HRI) is the study of how people control and interact with robots. Considerable HRI research efforts put an emphasis on the improvement of the graphical user interface (GUI) between humans and robots, for example in urban search and rescue (USRA) [2]. These efforts target enhancement of the human operators' awareness of the robot, reduction of the amount of information presented on the GUI and ways to minimize erroneous commands sent by the human operators during telecommunication.

Our design also involves previous research in the ubiquitous computing and general Human-Computer Interaction (HCI) domains. Mark Weiser's idea of calm technology [7] provides an insightful approach of "hiding" information in the periphery to harmonically integrate technology with the environment. Donald Norman's [4] vision of the future of robots addresses several key features that future robots would need to obtain in order to interact with humans intuitively and effectively. Weiser's and Norman's ideas have laid the foundation and guidelines to the overall design of the AIBO Monitor. The project is also informed by another project implemented by our group: the *AIBO surrogate* project [8].

3 THE AIBO PLATFORM

The AIBO is a robotic dog which has a cute look and feel. It is equipped with various sensors, which allows it to detect and respond to different inputs such as visual, audio and touch. Because of these qualities, we believe that the AIBO has some advantages over the traditional monitoring system:

1) The AIBO is not intrusive to home environments, compared to traditional monitoring system. The AIBO is an anthropomorphic robot that, to an extent, walks and acts like a real dog or puppy. When the AIBO is looking at a person, the person doesn't feel as if they're being monitored by a security camera. Thus, people are more comfortable living with an AIBO, compared to stationary cameras around the house. Moreover, traditional sensors, such as cameras and motion sensors do not have the ability to interact with people, but the AIBO can communicate with people around it using audio feedback, physical motions and changing the pattern of the LEDs on its face.
2) Robots are autonomous physical entities. They are capable of moving in the physical space. A small number of robots, or even a single one, can effectively patrol and monitor the home space. However, with a traditional home monitoring system setup, multiple cameras are required to cover the entire home from different angles.
3) Robots are physical entities which are capable of interacting with other physical objects. Even though the AIBO is limited by its form and functionality, it can interact with properly placed switches and sensors to alter its surroundings.
4) The AIBO is a wireless computing entity. Users can interact with it from any location, provided they are equipped with a computing platform and wireless access.

4 THE AIBO MONITOR

We designed an application called the *AIBO Monitor*, which allows people to remotely control the Sony AIBO robot dog to monitor their home environment. For the current project setup, the AIBO is autonomously patrolling inside a user-defined area and looking for changes at a specific location. The human operator can monitor the home environment at a remote place by receiving live video and audio feeds from the AIBO at the same time. If the AIBO detects a change in the home environment (for example, a door that was previously closed is now opened), the human

operator can take over the control of the AIBO and navigate it to investigate the change. In the following sections we describe how the *AIBO Monitor* works by walking through the system's interface (see Figure 1).

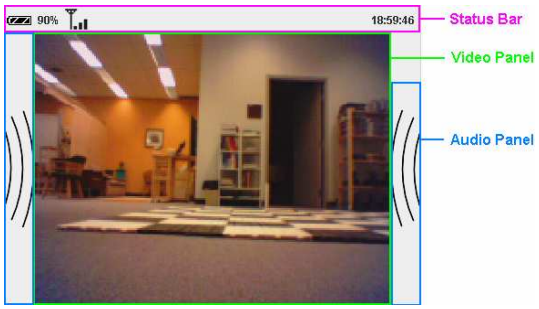

Figure 1. AIBO Monitor's Graphical User Interface.

4.1 Video Panel & Audio Panel

The streaming video and audio panels are the most crucial components of the *AIBO Monitor*'s graphical user interface (GUI) and thus are highlighted and occupy the most area. The video panel shows a real-time low-resolution streaming video of what the robot sees at any given time.

The audio panel is located on both sides of the video panel. It uses two "sound wave" icons to represent the left and right ears of the AIBO. If no sound is being heard, these indicators are turned off. Only when the AIBO hears a strong sound coming from either its left or right ear, the corresponding icon would start to flash. The audio panel can provide a rough measure of where a sound is generated, so that the user can manually control the AIBO to walk towards the sound.

4.2 Keyboard

To make the *AIBO Monitor* mobile and ubiquitous, we believe the program should be able to run on hand-held devices. Because of the prevalence of keypads and keyboards on hand-held devices, we choose the keyboard to be the primary input device. Through keyboard inputs, people are able to navigate the AIBO, adjust the position of the AIBO's head (video camera) and toggle between autonomous and manual control modes. Intuitive control is obtained by adopting controls similar to first-person-shooter (FPS) computer games. Users can control the movement of the AIBO via the keys, W, A, S and D. The W moves the AIBO forward. The S key stops the movement of the AIBO. The A and D key turn the AIBO to the left and right.

5 Implementation

The *AIBO Monitor* implementation is based on the Tekkotsu framework [6]. The *AIBO Monitor* sends and receives commands to and from the AIBO to help it complete its tasks.

Computer vision techniques are used to allow the AIBO to distinguish the different states of an object. In our current lab setting, the AIBO is able to tell if a door is opened or closed. The AIBO begins the inspection process by taking a high-resolution image of the door. Then, the *AIBO Monitor* program uses the SIFT application [3] to find a set of reference points on the image and match these points with a set of pre-defined images of the door. Once the best matching image is found, the new image is superimposed onto the matching image for comparison. Based on the difference between these two images the AIBO can deduce whether the door is open or closed.

The set of pre-defined images are taken from the possible angles where the AIBO might inspect the door. It is done by manually navigating the AIBO to the pre-defined marker which is in front of a door, and then adjusting the AIBO's position to take images of the door. When the AIBO is performing image registration, it has to take an image of an object close to the same positions as where the pre-defined images were taken in order to get the most accurate result. Thus, the larger the set of pre-defined images we take, the more accurate the result is.

6 AIBO's Behavior

The AIBO patrols an area designated by four pink markers in a rectangular fashion. It can inspect objects (a door in this case) that are behind the set of markers (see Figure 2).

Figure 2. Patrolling around the markers and inspecting the door.

When the AIBO is inspecting a door, it will raise its head and take a picture of the door. Then, it plays a "sniff" sound, indicating that it is trying to identify the current state of the door. If the door is closed, then the AIBO plays a "howl" sound effect. If the door is opened, the AIBO barks at the door to attract the human operator's attention. When a door is only slightly opened, the AIBO cannot confidently identify the state of the door. In this case, it will growl at the door. These emotional-like sounds can be easily understood by humans. Since these sounds reside in users' periphery, we believe the users will be able to easily shift their attention from the work at hand to the *AIBO Monitor*, and back.

7 Future Work

The lighting condition in the environment is crucial for allowing the image registration process to work correctly. Although we have tried to normalize the pre-defined images and the real-time screenshot image that the AIBO takes before running the image registration process, dramatic lighting changes in the environment are still likely to induce errors into the *AIBO Monitor* actions. Also, the current *AIBO Monitor* implementation does not have the intelligence to automatically locate and study different states of arbitrary objects. When the *AIBO Monitor* prototype implementation is complete, it will need to leave our laboratory's home space area and be deployed and tested in actual domestic environments.

8 References

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