TUIBot: A Tangible Interface to Improve Situation Awareness

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Abstract

Keyboard, joystick and mouse are conventional interfaces in human robot interaction (HRI) that are commonly used in teleoperated robots such as the urban search and rescue (USAR) robots. But these interfaces are inadequate in providing useful feedback about the pose of the robot, which is crucial when accomplishing a critical task under time constraints such as USAR. When a key on a keyboard is pressed to turn the robot or pan the camera, as soon as the key is released, the robot or camera are off centered and the operator will have to recall the robot's pose in order to maintain situational awareness. We present a tangible interface that aids the user in maintaining awareness of the robot's pose. The interface incorporates human kinesthetics, which is feedback on the movement and pose of our limbs and other body parts [18]. Kinesthetic feedback can be an intuitive way of knowing the robot's pose, reducing the amount of effort spent by the operator on maintaining situational awareness.

Introduction

Imagine a chemical accident in a laboratory or factory. The toxic fumes make the environment hazardous. Some of the workers cannot leave the building under their own strength and are in need of help. A rescue team has arrived at the scene and their first and most vital task is to search and rescue those victims stuck in the building. Because of the potential danger to human life, the rescue team deploys robots to find victims and identify their location. This will reduce the rescue workers' exposure to the hazardous environment. These USAR robots will be teleoperated to locate the victims. The team of human rescuers will be notified as to their location so the victims can be quickly transported to safety. Good situation awareness (SA) is vital for safety-critical situations, like USAR, to effectively complete the task: A safety-critical situation is one in which an error or failure could result in death, injury, loss of property or environmental harm [4].

The generic definition of situation awareness (SA) is "the perception of the elements in an environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" [5]. The definition tailored for HRI is defined by Yanco and Drury [6] as "the perception of the robots' location, surrounding, and status; comprehension of their meaning; and the projection of how the robot will behave in the near future". Drury et al [7] noted that the problem encountered when navigating robots has resulted from the human's lack of awareness of the robot's location, surroundings and status. Yanco and Drury [6] found that acquisition of good SA is so critical that the operators will stop everything else they are doing and spend an average of 30% of their time doing nothing else but acquiring or re-acquiring SA, even when they are performing a time-sensitive search and rescue task. Acquiring good SA is accomplished by developing a user interface that the user will easily gather information about the robot's location, activities, surroundings, status and mission. This is the objective of this project, which describes a tangible interface that takes advantage of the affordances of the controllers and feedback from human kinesthetics thus making it much easier for the user to control, gather and comprehend information about the robot.

Background

Operating a remote controlled robot involves an interaction between two realms, the operator's environment and the remote location of the robot. The operator's attention is torn between the two. This is due to the traditional controllers such as the keyboard, mouse or joystick that are used to convert higher level commands such as move forwards into lower level events such as turn a motor. Its takes significant training and practice before an operator can feel comfortable relaying his/her goals to robot actions while maintaining SA. Dividing the attention between the two realms impacts an operator's ability to complete safety-critical tasks.

Human kinesthetics is feedback on movement and positions of body parts [18]. Human sensory system is divided into three categories: exteroceptors, proprioceptors and interoceptors [15]. Most of the sensing is done by the five exteroceptors eyes, ears, nose, tongue and skin. Information on body posture, motion and force is provided by the proprioceptors [16]. Using the feedback from the proprioceptors while operating a tangible user interface (TUI) can improve the operator's understanding of the robot's pose and, therefore, improve SA.

Tangible Interfaces

A tangible user interface (TUI) augments the physical world by coupling digital information to everyday physical objects and environments [1]. This project tailors this definition for HRI as an interface that bridges the information gap between the robot and the operator by using the affordances of physical objects to relay information of the robot to the operator through human kinesthetics. TUIs take advantage of affordances of physical objects and using these affordances to make intuitive controls. Baecker et al. defines affordances as the perceived and actual properties of a thing, primarily those fundamental properties that determine just how the thing could possibly be used [10].

A good TUI has to have close spatial mapping. Spatial mapping is defined as the relationship between the object's spatial characteristics and the way it is being used [17]. An example of a good tangible interface is the touch screen, such as the CNN "magic wall" that became so popular during the election season. A news anchor standing by this seven foot TV screen taps the state of Illinois and the state is highlighted and information about how many delegates are allotted to the each presidential candidates are displayed. This is much more favorable than the anchor sitting behind a computer, clicking a mouse to illustrate his/her point. It is much more intuitive to point to a screen and drag and drop objects across the screen than clicking a mouse or typing on a keyboard to perform the same task.

Guo and Sharlin present an example of a TUI used in HRI [2]: They use the Nintendos Wiimote and Nunchuck to capture human gestures and those gestures are used to control a robot dog (AIBO). The Wiimote and Nunchuck were used to navigate the dog through an obstacle course. The TUI was also used for posture task where the dog mimicked the operator's posture. In the comparative study, they compared the TUI to the more traditional interface of a keypad in controlling the AIBO. Their results showed that the Wiimote and Nunchuck interface allowed the participants to finish both tasks faster and with fewer errors than the keypad interface. They made an important point that we concur with in this paper. They mentioned that although the Wiimote does not appear to be a specialized TUI (see Ishii and Ullmer [1] for examples), they believe that it can be categorized as a generic tangible user interface due to its ability to capture physical input and to interact with digital entities.

An example of a TUI similar to ours is the Mitre Intergrated Vision System (MIVS). In this video system, video images from six cameras are stitched together to form a video sphere, 360 degree view of the cameras' surrounding. This system uses a head mounted sensor to alter the operator's field of view on the video image being displayed on the head mounted display. Their objective is to improve both safety and situation awareness of armored vehicle crew members and unmanned ground vehicle (UGV) operators [14].

Situation Awareness

As mentioned earlier, good situation awareness is an important aspect in remote controlled robots. Drury et al [7] noted that most problems encountered when navigating robots have resulted from the human's lack of awareness of the robot's location, surrounding or status. Yanco et al [6] made a distinction that it is much easier to direct a robot that a human can see rather than to perform so-called "remote" robot operation. Drury et al [6] performed a SA test on four participants who had no prior experience controlling robots. The objective was to find victims in a USAR test arena. In the test they found that the participants spent 12% to 63% of their time in each run acquiring SA. Even after spending this time acquiring SA, participants were still perplexed on their relative location to a landmark. Another problem they noticed is that after the camera was panned, it was left off-center once the operator resumed driving, which had a negative effect on the operator's SA. In their graphical interface, they had video feed from the robot and a map generated by the robot. They noted that the subjects found the maps useless and paid most of the attention to the video feed.

The TUI uses body movements and postures as inputs to control the robot. The affordances and the kinesthetic feedback of the person's body position, which are natural aspects of tangible interfaces, will provide the operator continuous feedback as to the robot's placement in the environment i.e. robot's pose. This in turn improves the operator's SA.

Design and Implementation of TUIBot (Tangible User Interface Robot)

In any teleoperated robot there has to be a command post and the teleoperated robot. Communication between these two entities is through a wireless network.

TUIBot

The design of TUIBot is similar to RoboCam, a web-based telepresence camera platform built on the iRobot Create. By using a web browser, the robot can be remotely controlled [12]. TUIBot consists of an IRobot Create platform, Eeepc and a Logitech Orbit webcam. The Eeepc is connected to the Create through a USB to serial interface connector and is the “middle – man” controller.

Fig. 1. TUIBot.

The Eeepc receives commands from the command post. The commands are in two categories: navigation and vision system commands. The robot has six navigational directions: forwards, backwards, forward left, forward right, left and right. These commands are translated from the Nintendo Wii Balance Board, which the operator is standing on and changing his/her posture in order to convey his/her navigational goals. The Eeepc will break down these high level commands into lower level calls to the Create API.

The vision system commands consist of pan left, right and tilt up and down commands. Video is captured from the webcam on the robot, compressed and sent through the network and displayed on the command post. Due to video compression complexity, LeadTools Multimedia Software Development Kit (SDK), a wrapper DirectShow library was implemented [19]. DirectShow API calls are made to pan and tilt the webcam in 30 degree steps.

Command Post

The command post communicates with TUIBot. It consists of three devices: the Wii Balance Board, an Oceanserver digital compass and head mounted video visor. These interface devices capture human gestures and body movements and interpret them as commands to the robot.

The Wii Balance Board is a device that is used in Nintendo gaming applications where the user leans back and forth and those gestures are used as commands in a game. The balance board is used to navigate the robot. By leaning forward, the robot moves forward, by leaning back, the robot slows down or stops, by leaning left or right the robot turns left or right. The board has four pressure sensors attached to each of its four legs. As the operator leans a certain way, the pressure sensor readings change accordingly. Using an open source Wii Balance Board library (Wiiuse) [13], sensor readings from the board are acquired via Bluetooth wireless communication.

Fig. 2. Operator using the TUI to control TUIBot.

A calibration process starts where the operator’s normal posture readings are taken. The normal posture of the operator is interpreted as the stop command to the robot. To engage the robot in the forward direction, the top sensors readings i.e. top left and top right sensors have to be 40% greater than the bottom sensor readings i.e. bottom left and bottom right sensors. As the operator leans harder in the forward direction, the forward speed of the robot changes continuously. While the robot is moving forward, the forward left and forward right directions are engaged by comparing the top right and top left sensor readings. If either of the readings are 70% greater than the other, the respective direction is engaged. To turn the robot left or right, both left and right sensor readings i.e. top and bottom sensors on either side are compared. If either side’s readings are 110% greater than the opposite side then the respective direction was engaged. The backward direction is engaged when the bottom sensor readings are 21% greater than the normal posture bottom sensor readings.

A digital compass is used for camera control. This is a device that can measure pitch, yaw and rotate angles. For this project, the yaw and pitch angles of the operator’s head are the angles of interest. The compass is attached onto the visor of the head mounted display and when the operator would like to view left of the camera view, he/she will turn his/her head to the left and the camera will mimic the same gesture. When the operator would like to view objects below the camera’s view, he/she will move his head downwards or vice versa for the other upward direction. Panning and tilting are done in 30 degree steps. Therefore the operator has an allowance of 15 degrees in which he/she can move his/her head before the camera turns. The compass is a Honeywell two-axis AMR sensor for X, Y plane sensing and Honeywell z-axis AMR sensor and a tilt sensor accelerometer. It communicates with a pc using serial communication.

Since the operator will be moving his/her head around and will not be able to keep his/her eyes stuck on the screen to view the streaming video of the robot's environment, the head mounted video visor aids by bringing the video image right up to the operator's eyes. This will give the operator an impression of mimicking the robot's pose and actually being like the robot. The head mounted visor is a 1024 x 768 VGA output. The graphical user interface displayed on the visor consists of a full screen video image and overlaid on the video is status information about the robot.

FutureWork

Formal testing of TUIBot is currently being done to determine the impact of kinesthetics feedback on SA. While the testing is yet to be completed, we have noted that training time is minimal, reflecting on the intuitiveness of TUIBot. Because of the control's natural affordances, no memorization is required compared to using the conventional interfaces (keyboard, joystick or mouse). A comparative study using two types of interfaces is being done; one with the traditional user interface i.e. joystick and the other with a TUI.

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