Exploring Tangible User Interfaces in Human-Robot Interaction

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ABSTRACT

Mouse, keyboard and graphical user interfaces are commonly used in the field of human-robot interaction (HRI) for robot control. Although these traditional user interfaces are being accepted as the standard for the majority of computational tasks, their generic natural and interaction styles may not fit well with robot navigation tasks. In our proposed research, we intend to explore alternative UIs that could take the advantage of human innate skills in physical object manipulation and spatial perception to overcome the problems associated with traditional UIs. We suggest the use of tangible user interfaces (TUIs) for HRI applications, especially for one-to-many robot navigation tasks. We hope our proposed idea will give insight on future HRI interface design.

1. INTRODUCTION

Robots are digitally controlled physical entities that exist in both the virtual realm and the physical world. They are capable of interpreting bits and bytes and converting them into physical outputs to interact with their surroundings, and are also capable of sampling and sensing physical phenomena and translating it into digital information. As technology accelerates, advanced functionalities have been added to current robots that not only enhanced their abilities to interact with a wide range of physical objects, but also grant them the ability to communicate with humans as well.

In the past, when researchers devoted much effort into robot development, the problem of how to enhance human operators' situation awareness when controlling robots has often been overlooked. This problem magnifies especially when a human operator needs to remotely operate one or multiple robots that have low autonomy and high intervention ratio [9]. The problem can be addressed by a set of design guidelines based on empirical studies [2,10]. Although the guidelines are valuable for improving the operators' awareness of robots and their surroundings, they may not be well supported by the traditional user interface, that is, the mouse, keyboard and graphical user interface (GUI) paradigm which are still widely used in the field of HRI (from here on we will refer to the traditional user interface as the traditional UI),.

Although the traditional UI is used abundantly in human computer interaction (HCI) tasks it may not fit well with certain HRI tasks. Firstly, the mouse, keyboard, and graphical user interfaces separate user input from computer output, uncoupling action and perception space, and potentially breaking the flow of users' cognitive engagement when performing certain tasks. [8] For instance, when typing on a keyboard, most people need to look at both the keyboard and the computer screen to ensure they entered the correct letter. In terms of telerobotics, the human operators have to solely rely on the image and sensor data transmitted back by the robot to determine their next operation. Constantly switching attentions back and forth between the input device and the data display screen is not ideal especially when the robot is in critical conditions. Secondly, the motor skills required for manipulating a mouse and typing on a keyboard are not intuitive to learn. A sufficient amount of time is required for people to memorize the layout of the keyboard and repeatedly practice in order to type without looking at the keys. When it comes to robot control, the longer it takes a human operator to master certain motor skills, the greater the cost (time, money and labor) of training. Also, the amount of attention the operator needs to spend on the input device is likely to be higher, which may hinder the overall performance. Thirdly, the two-dimensional traditional UI limits people's spatial abilities when interacting with three dimensional objects. It can be difficult to control a robot that is capable of moving in three dimensions (for example, an unmanned aerial vehicle) using the traditional UI. In order to effectively and efficiently interact with robots, we suggest looking for alternative UIs to overcome the aforementioned problems for a certain set of HRI tasks.

One alternative solution to the traditional UI for human robot interaction is tangible user interfaces (TUIs). TUIs couple digital information and function with physical objects [5] allowing a virtual entity in the digital realm to be manipulated through a physical medium. TUIs make effective use of the affordances [6] of physical objects which may allow us to fuse user input and robotic functional output together. For instance, the shape, size and weight along with other physical properties of an object imply the way we interact with it. If we can appropriately map the physical properties (such as physical constraints) of a robot to the physical properties of an object, then the potential functionalities and mechanism of a robot can be directly revealed to the operator. Moreover, the spatial orientation and the position of a physical object in relation to its surroundings can reveal additional information and provide interaction insight and task awareness to the manipulator. When remotely navigating a robot, maintaining good spatial awareness [10] is crucial to the human operator. If a physical object can be translated into a tool for navigating a robot, then the orientation and position of the object in the physical space can be utilized to provide spatial information about a robot. Furthermore, our innate abilities allow us to interact with physical objects easily. There is no specific knowledge or memorization required for us to move, manipulate, assemble and disassemble simple physical objects. Overall, we see great potential to applying TUIs in HRI.

2. PRELIMINARY STUDY

In order to explore the possibility of applying TUIs to robotic control, we have designed and conducted a user study comparing the usability of generic tangible user interfaces – Nintendo Wii Remote (Wiimote) and Nunchuk [5] with a generic input device – keypad in terms of speed and accuracy in two different tasks. [3] We have chosen a high-level navigation task and a low-level posture control task for the study. (Figure 1)

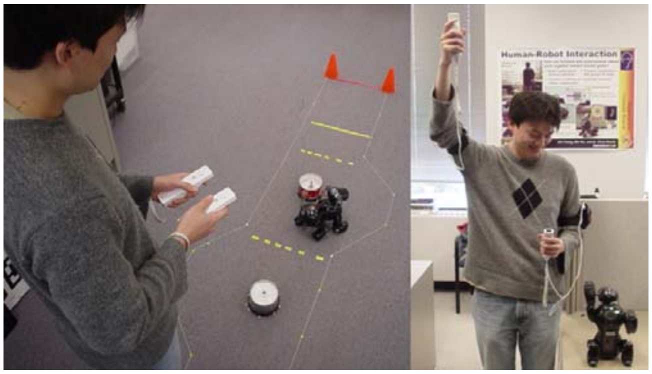

Figure 1. On the left, the user is navigating a Sony AIBO robot dog [7] through an obstacle course using two Wiimotes. On the right, the user is controlling the AIBO to perform a posture using one Wiimote and one Nunchuk on each arm.

The result has shown that the Wiimote and Nunchuk interface outperformed the keypad interface in speed and accuracy in both tasks. Also, the majority of the participants have reported that they prefer to use the Wiimote and Wiimote & Nunchuk interface for both tasks.

3. USING *RICONS* FOR ROBOTIC GROUP CONTROL

We are encouraged by the result discovered from the preliminary study. Our next step is to find a specific set of tools to construct a tangible user interface for remote control of multiple robots. We intend to explore the possibilities of using small set of physical objects which resemble the shape of real robots as *Ricons* (robotic icons, based on Ishii & Ullmer's "Phicons" [4]) to provide a physical handle to an operator for interacting with multiple robots. First of all, an appropriate *Ricon* should provide a tight spatial mapping [8] between itself and a real robot. As mentioned earlier, the shape, size and weight of a *Ricon* should reflect the physical properties of the robot it represents. Also, it is important and beneficial if we can utilize the physical constraints of the *Ricons* to prevent navigation accidents from happening. One obvious example is that each *Ricon* occupies a portion of the physical space. Thus, two *Ricons* can never "collide into" each other. This physical constraint can be immediately perceived by the operator if two robots are about to collide. Secondly, by manipulating a *Ricon* directly, the human operator should be able to adjust the position and orientation of a single or group of robots. For instance, when a robot or a group of robots needs specific attention, the operator can use a *Ricon* to give specific movement orders to one or multiple robots that are the same type. The operator can simply move a *Ricon* or rotate it on a 2D surface to move or rotate a robot in the 3D space. Thirdly, the operator can use *Ricons* to configure different group formations of multiple robots. Multiple *Ricons* can be placed at different locations on a 2D region to represent the team formation of multiple robots.

To aid the human operator with sensor data and live video feedback for remote navigation, we want to utilize a digital tabletop interface for direct interaction with the *Ricons* as well as with image, map and other related data. To closely combine the digital information with the *Ricons*, we intend to put the *Ricons* on top of a touch screen based digital table and use a vision tracking system to keep tracking of their locations. This hybrid interface will not only allow I/O unification on the same surface, but also provides the ability to the operator to interact with digital and physical entities at the same time.

4. CONCLUSION

In summary, our proposed interface will utilized both tangible user interfaces and a digital table to allow an operator to remotely navigate multiple robots. This hybrid interface will allow an operator to control individual robot behaviors and uniform group behaviors with physical *Ricons*. This interface should allow people to intuitively control multiple robots without specific trainings. Also, the interface takes the advantage of people's spatial ability to allow the operator to adjust robot orientation and group formation easily. We hope our future work on the proposed system will provide new insight on human robot interface design, especially for one to many robot navigation tasks.

5. REFERENCES

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