Improving Mobile Robot Control: Sensory Feedback for Touch Interfaces

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Extended Abstract—In recent years, touch screen technology has progressed rapidly and has increased in popularity with developers and consumers alike. Touch screen devices, in the forms of shopping kiosks, ATMs, tablet PCs, and smart phones, are now a very prevalent fact of everyday life. Ironically, in more technologically advanced applications such as telerobotics, touch screens are infrequently utilized. Specifically, in a military context, even Foster-Miller's popular Talon robot has more conventional controls (i.e. joystick and keyboard). Despite their minimal use in robotics, touch screens offer unique advantages over the conventional keyboard and mouse. Touch screens eliminate the need for additional physical devices and allow the user to interact in a direct and natural manner with the system at hand. Conversely, the problems associated with touch screen use are also becoming more apparent. Perhaps the greatest challenge that needs to be addressed is the lack of haptic feedback provided to the user by touch screen interfaces. While visual and auditory feedback is integrated into many devices [1, 2], our sense of touch is oftentimes not stimulated. Even one of the most widely used touch screen devices, Apple's iPhone, provides limited, if any, tactile feedback. Without any kind of contoured surface or button, inputting information on a touch screen is difficult and many times imprecise. Additionally, the user must look directly at the device to avoid pressing the wrong item. This limitation creates a dilemma with regard to telerobotics, which requires that the user pay attention to and guide the physical movement of the robot. The aim of this work is to devise a system that adds haptic feedback to touch screens without a separate physical device in order to improve teleoperated mobile robot control and eliminate the nuisance of non-essential feedback. To attain this goal, this paper presents and tests a solution that integrates a "smart" wireless vibration circuit with a touch screen system.

Current haptic implementations center on producing mechanical stimulation as the preferred feedback signal [3]. One popular example of this type of feedback is the force feedback used in many console games [4, 5]. Similar systems have also been used to aid telerobotics operators [6, 7]. Poupyrev et al. [8] developed a touch screen device that provides a response for every interaction using thin actuators beneath touch-sensitive glass. In this way, almost any interactive feature on the device could be programmed to trigger a touch sensation. Unfortunately, vibrations are far from exact and do little to simulate a "natural" interaction. In most everyday applications of touch screen devices, every button or switch seems to produce a similar, repetitive result when touched. This type of "positive" feedback, a response for every graphical user interface (GUI) control, is a common complaint of touch screen users who state that "beeps" and "buzzes" for every interaction become tedious and annoying. Overstimulating one's senses does not only induce stress [9], but also might cause the user to overlook essential feedback. This is due to the fact that continuous positive feedback does not allow the user to distinguish between ordinary and urgent matters. Nevertheless, a considerable amount of research has been directed towards providing users with "positive" feedback [10, 11]. The solution presented in our work differs in that it provides the user with feedback only when an error has occurred. Examples of negative feedback in everyday life are ample. Electric fencing, car parking systems, dog bark collars, and home security systems are a few common examples. Negative feedback devices have the potential to greatly benefit human-robot interaction. In this project, we seek to advance this concept in the context of teleoperated mobile robot control.

With regard to the experimental set-up, the proposed project involves guiding a mobile robot through a maze using a numerical keypad which can be found on any standard keyboard (see figure 1). Three variations of the "keypad" control are tested. A standard numerical keypad is "graded" against a software touch screen keypad both with and without haptic augmentation (see figure 2). The software portion of this project is accomplished through Matlab GUIs run on a desktop workstation, but interacted with via an iPhone/iPad through remote desktop. The GUI replicates the common 9-button number keypad and is designed using identical dimensions. The tactile feedback is enabled by a circuit (see figure 3) whose main elements are a PIC12F675 processor, two Xbee modules, and a small 3V vibration motor that is attached to the touch screen. The Xbee modules are used to wirelessly transmit an ASCII string to the processor which converts it to an integer (analog voltage) output that toggles the motor on or off.

Figure 1: Sample maze with mobile robot

Figure 2: Conventional keypad and “soft” keypad

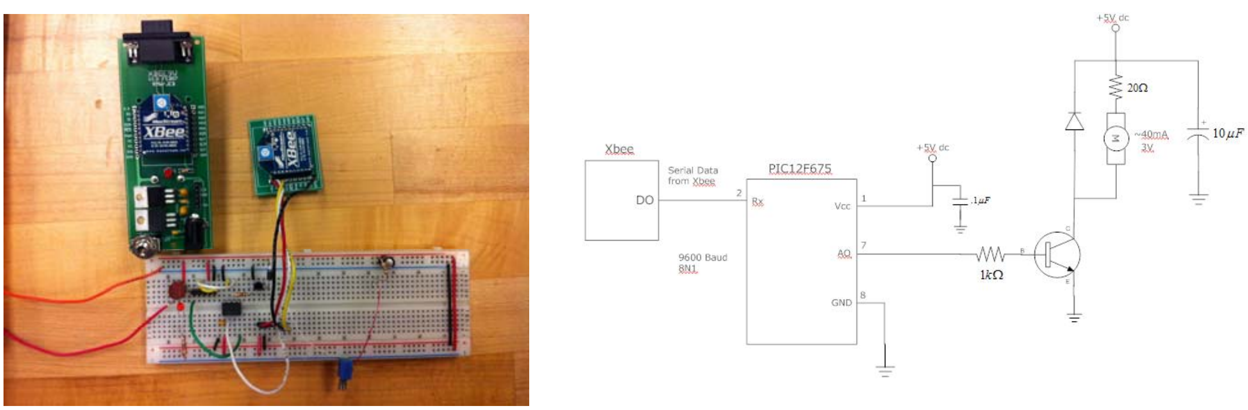

Figure 3: Experimental system (left) and wireless vibration motor circuit (right)

Both quantitative and qualitative testing on the system design will be performed. A human subjects research protocol is pending approval from the institutional review board. Quantitatively, the keyboard interfaces will be tested in three separate phases. First, a user will drive a mobile robot platform (iRobot Create) through a maze using a hard keypad. Next, the user will navigate the same course using a software keypad without any augmentation. Finally, the process will be repeated using the same software keypad with vibration feedback. These three methods will be randomized for each user to minimize any learning effects. Different factors such as the number of barrier collisions and incorrectly pressed buttons will be recorded. Deviations from defined paths and time to completion will also be compared. This experimental data will be analyzed using an ANOVA test to determine if there is a statistically significant difference between a conventional keypad, a "soft" keypad, and an augmented "soft" keypad. By analyzing these results, we hope to determine whether haptic feedback on a touch screen improves our ability to guide a mobile robot with a touch screen controller. With regard to qualitative testing, a NASA TLX questionnaire will be filled out by participants after each testing phase in order to measure perceived workload.

Our initial tests involved using all three interface options to input twenty-five 7-digit telephone numbers. For each set of numbers, we recorded the time to completion, the total number of key hits (gross hits), and key misses (error hits). This information was used to calculate the net hits (gross hits – error hits), net speed (net hits / time), and the accuracy (net hits * 100 / gross hits). This preliminary test was done by two users and the results are presented in Table 1 and Figure 4.

Table 1: Preliminary Results

User	Input Method	Time (sec)	Gross hits	Error hits	Net hits	Net speed (characters/min)	Accuracy (%)
1	Hard Keypad	117.2	182	2	180	92.15017	98.9011
2	Hard Keypad	181.3	175	9	166	54.93657	94.85714
1	Soft Keypad	81.6	183	49	134	98.52941	73.22404
2	Soft Keypad	168	176	98	78	27.85714	44.31818
1	Soft Keypad_V	101.5	182	46	136	80.39409	74.72527
2	Soft Keypad_V	243.3	196	85	111	27.37361	56.63265

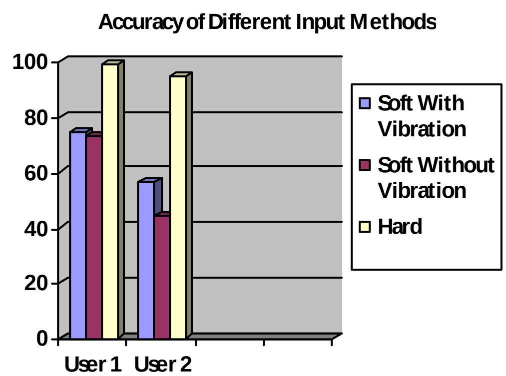

Figure 4: Accuracy of methods

As our preliminary results indicate, vibration feedback yields a higher accuracy percentage over a "soft" keypad without any feedback. As expected, a hard keypad outperforms both other methods. More tests will be performed with multiple users to validate our initial data. While both the fields of haptic augmentation for touch screen devices and mobile robot control have room for improvement, the ultimate goal of this project is to advance these areas and improve the interfaces that enable human-robot interaction.

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