Advancing In-vehicle Gesture Interactions with Adaptive Hand-Recognition and Auditory Displays

MOUSTAFA TABBARAH, Virginia Polytechnic Institute and State University, USA
YUSHENG CAO, Virginia Polytechnic Institute and State University, USA
YI LIU, Virginia Polytechnic Institute and State University, USA
MYOUNGHOON JEON, Virginia Polytechnic Institute and State University, USA

Competition for visual attention in vehicles has increased with the integration of touch-based interfaces, which has led to an increased crash risk. To mitigate this visual distraction, we designed an in-vehicle gesture-based menu system with different auditory feedback types and hand-recognition systems. We are conducting an experiment using a driving simulator where the participant performs a secondary task of selecting a menu item. Three auditory feedback types are tested in addition to the baseline condition (no audio): auditory icons, earcons, and spearcons. For each type of auditory display, two hand-recognition systems are tested: fixed and adaptive. We expect we can reduce the driver's secondary task workload, while minimizing off-road glances for safety. Our experiment would contribute to the existing literature in multimodal signal processing, confirming the Multiple Resource Theory. It would also present practical design guidelines for auditory-feedback for gesture-based in-vehicle interactions.

CCS Concepts: • **Human-centered computing → Auditory feedback**; **Gestural input**.

Additional Key Words and Phrases: HCI, Gesture Interaction, In-Vehicle, Auditory feedback, Adaptive Recognition

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1 INTRODUCTION

As car accidents rank among the leading causes of death in the United States, driver distraction and inattention are considered main factors of car accidents in the recent decade. Crashes often occur because of "inopportune glance", that is, when the driver looks away from the forward roadway at the wrong moment [4]. As the complexity of vehicle infotainment systems continues to increase, it has become more mentally demanding for drivers to perform secondary tasks while driving, thus causing more off-road glances when driving. The European Commission and National Highway Traffic Safety Administration [1] have suggested that in-vehicle interfaces, including navigation displays and media players, may be one reason why drivers look away from the forward roadway.

With gesture-based interactions becoming more involved with modern interfaces in the past decade, they have also been integrated with vehicle infotainment systems. It has been shown that gesture-based in-vehicle interaction results

Authors' addresses: Moustafa Tabbarah, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 24060, tabbarah@vt.edu; Yusheng Cao, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 24060, cyschris@vt.edu; Yi Liu, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 24060, yl2017@vt.edu; Myounghoon Jeon, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA, 24060, myounghoonjeon@vt.edu.

Table 1. Experimental Conditions

Auditory Feedback	Hand Recognition
Auditory Icon Earcon Spearcon No Auditory Feadback	Fixed Adaptive

in lower driver workload and significantly fewer glances toward the interface compared to the traditional touch-based interaction, thus suggesting that gestures are a positive alternative for in-vehicle interactions [3][6]. Gesture-based interactions effectively reduce driving risks by minimizing interactions with visual interfaces. Moreover, minimal interactions with visual interfaces can contribute to lowering crash rates [4].

Non-visual feedback has also shown to reduce visual distraction significantly. Research conducted by Shakeri et al [5] has shown that auditory feedback has performed best for reducing driver distraction. Given that gesture-based menu systems have recently become technologically feasible, it seems that a combination of gesture-based interaction and auditory feedback can give optimal results in reducing driver distraction. However, it is crucial to choose auditory feedback carefully because while well-implemented auditory systems have the potential to keep a driver's eyes on the road, poorly implemented systems may have the opposite effect by imposing high levels of mental demand on the driver with the potential to also incur long glances away from the roadway in order to check system status and understand it. To utilize the best of their potentials, auditory displays must be made sufficiently simple and accurate to reduce cognitive demand in the vehicle [2]. To achieve this goal, the system should be tested using various forms of sound feedback, including earcons, spearcons, and auditory icons.

During the initial pilot study, the participants all commented they felt serious mental workload while identifying the physical location of the gesture menu in mid-air. We do not intend to create a visual aid to create a more visual distraction, which may cause more unnecessary glances. Instead of letting the user find the location of the menu, we adjust the menu based on the user's hand's physical position. When the system recognizes the user's hand gesture, the system adjusts the menu and recognizes the area's physical position based on the user's desired position. We call this adaptive hand-recognition. It is designed to reduce the driver's cognitive workload further and improve the overall efficiency.

Different types of auditory displays have all shown the potential to improve menu navigation by reducing driver distraction. This research would like to investigate various combinations of earcons, spearcons, and auditory icons with gesture-based interactions for vehicle menu systems as shown in Table 1. We want to determine how these combinations will affect driving performance and driver distraction, and we are also interested in the performance of different gesture regonition systems.

2 USER INTERFACE DESIGN

We developed a 2x2 grid gesture menu selection system (Figure1). To cover more selections, we created additional two pages so that this system will allow users to access 3 (pages) * 4 (option) = 12 menu choices in total. Even though users are not suppose to have any visual feedback to use this system, we still provide a graphical user interface as a visual aid for the experiment as shown in Figure2.

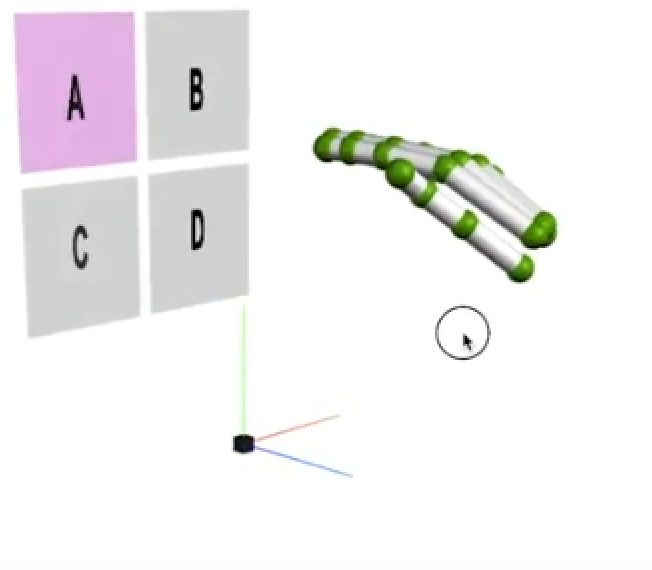

Fig. 1. 2x2 Grid Gesture Menu in Developer View

2.1 Auditory Display Design

The menu will have following choices to simulate in-vehicle secondary tasks: Radio, Phone, Messages, Phonebook, AUX, CD, Bluetooth, Music, A/C, Weather, Calendar and setting. We created three separate auditory displays for each of the menu selections.

Auditory Icon: We recorded the daily sounds, which well represent the menu selections—e.g., white noise during switching radio channel to describe radio, Dialing phone number sound to represent phone.

Earcon: We created four separate music tones to represent four different menu choices on the same page. We changed the instrument of the music to distinguish menu pages.

Spearcon: We used the text-to-speech software to convert menu text into spoken words. In addition, we compressed the speech to make it short.

2.2 Hand Gesture Design

We design four separate gestures to perform different interaction with the system:

Release Fist: Activating the hand-recognition and starting to use the system.

Grab fist: Confirming the current selection

Hovering: Hand hovering over vertical and horizontal axis for selecting.

Swiping: Navigate to right or left to switch between the menu pages.

3 EXPERIMENTAL DESIGN

To conduct the experiment, we will run the system along with the driving simulator. The participants will be asked to interact with the system during driving in different scenarios (highway/downtown, traffic/no-traffic). In the meantime,

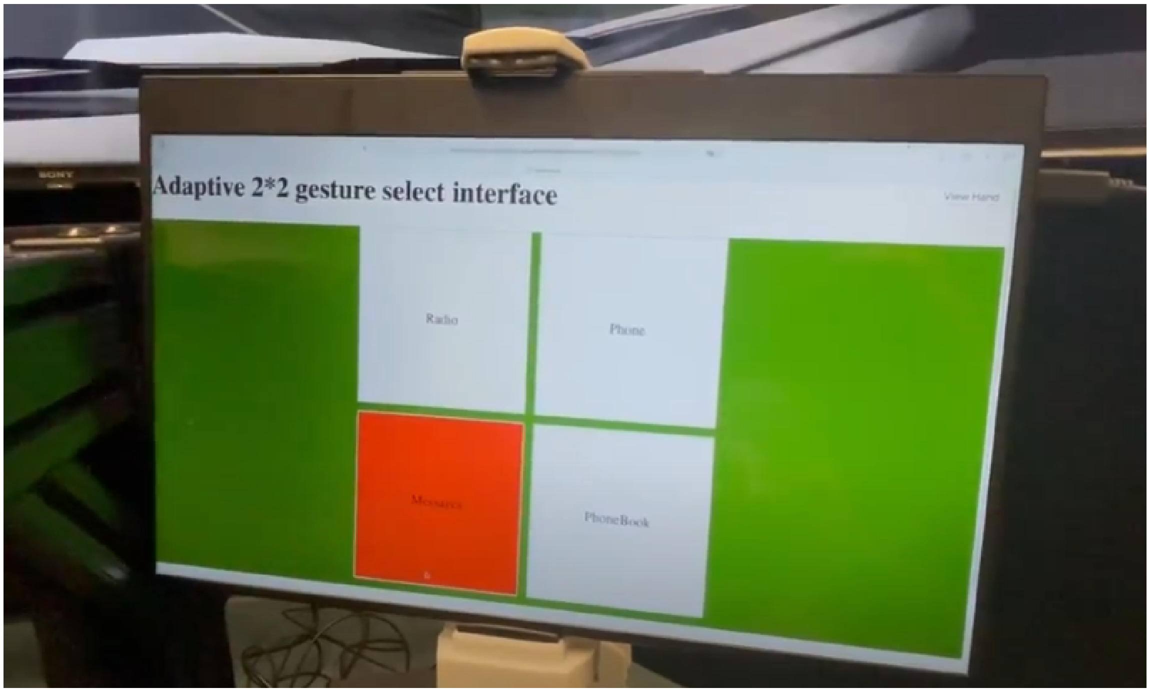

Fig. 2. Flat User Interface for Experiment Use

we will change the auditory feedback and hand recognition setting to generate a variety of experimental data. By analyzing the menu system performance data, driving performance data, and eye-tracking data, we will identify the combination which has the best overall performance. We expect the result can provide potential directions for gesture-based menu interaction system for in-vehicle use and some guidelines for corresponding auditory feedback development.

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