The Steering Wheel as a Touch Interface: Using Thumb-Based Gesture Interfaces as Control Inputs While Driving

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AutomotiveUI '14, Sep 17-19 2014, Seattle, WA, USA
ACM 978-1-4503-0725-3/14/09.
http://dx.doi.org/10.1145/2667239.2667299

Abstract
Different types of gesture interfaces have been investigated in the context of human vehicle interaction. This paper highlights the differences among current approaches and introduces a new interface using a small set of thumb-based gestures on the steering wheel in conjunction with explicit mode selection.

Author Keywords
Driver vehicle interfaces; automotive user interfaces; gesture interfaces; steering wheel input

ACM Classification Keywords
H.5.2 Information interfaces and presentation: User Interfaces - Input devices and strategies; H.1.2 User/Machine Systems – Human factors.

Introduction
Over the last decade, an increasing number of groups have investigated the potential of gesture interfaces for human vehicle interaction (HVI) within the context of secondary and tertiary vehicle controls. Gesture interfaces allow users to make simple hand or finger gestures to activate different controls. As an emerging

new field within HVI, gesture interfaces are still in their infancy and there are currently multiple gesture interaction methods under investigation. One major distinction concerns the degrees of freedom of the gestures, whether they are free-form gestures in 3D space, or contact-based gestures performed on or near a surface [10].

Gesture interaction methods

Good interfaces need to be easy to learn, the user needs to be aware what actions are available, user actions need to lead to predictable outcomes, unintentional activations of commands need to be minimized, and the system needs to be error tolerant with action effects being easily reversible. Direct manipulation interfaces achieve many of these goals through the continuous visibility of relevant objects, easily learnable, physical operations on these objects, and immediate feedback to the user about the consequences of the actions. In the context of gesture interfaces many of these elements are missing [6]. The user has to *discover* the set of gestures that the designer had in mind. In addition, unless the action is always tied to a particular object, the *object of a command* has to be identified in some way – either through abstract or deictic gestures, or through some other interaction style (e.g., speech). Finally, unlike most direct manipulation systems, *feedback* is not always explicit in the interaction. This can cause confusion on the user's side [10].

Given the issues raised above, why are gesture interactions attractive for in-car controls? The main reason is the ability of gesture interfaces to operate with no or limited visual engagement. In addition, many (but not all) secondary and tertiary controls within the car have clear physical targets that are continuously present and whose state changes are immediately evident. A successful gesture interaction to lower a window immediately leads to auditory and thermal feedback. Turning up the volume on the radio leads to immediate auditory feedback. In addition, the state of these systems is continuously present within the car environment, which makes the car a promising test bed for gesture interfaces.

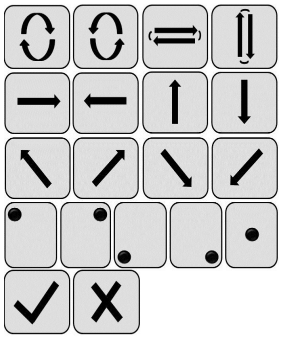
Some other in-vehicle systems, however, only provide physical feedback with a significant delay (e.g., temperature control). More abstract interactions like scrolling through a music playlist often require the driver to rely on additional visual feedback to keep track of the current selection. The availability of feedback is an important issue that all gesture interactions have to address.

The issue of discoverability differs substantially across the types of gesture interactions. It is important to recognize that there are few (if any) universally accepted and widely known gestures that would qualify as a "natural" gesture [6]. Instead, there are sets of cultural and technological conventions that can make a particular set of gestures easier to learn. Idiosyncratic sets of gestures for a particular interface will be difficult to discover and remember.

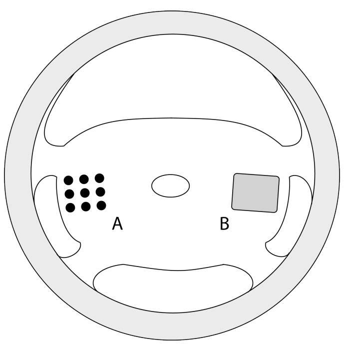
Types of Gesture Interfaces

Free-form gestures

Free-form gestures for in-vehicle control require users to perform gestures in an area of the car equipped with the necessary sensor recognition technology to register and interpret the driver initiated movements. [7] suggest that free-form gestures reflect a "natural" form



Set of simple thumb-gestures used in [11]



Schematic drawing of a bimanual control interface with button-based mode selection for the left hand (A) and contact-based gestures on a trackpad for the right hand (B).

of human communication and are easy to use. While free-form gestures enable drivers to keep their eyes on the road, they usually require drivers to remove one hand from the steering wheel. Similarly, [8][9] look at user-derived inventories of free-form gestures to control different aspects of tertiary controls. These studies clearly show that while some aspects of free-form gestures are quite predictable (e.g., location), the chosen gestures lack interindividual consistency. In addition, "gestures need to be chosen application specific" [9], leading to multiple, partially independent sets of gestures to be learned by the driver and increasing the likelihood of poor memory performance and interference across gesture sets.

Contact-based gestures

Unlike free-form gestures, contact-based gestures enable (and sometimes require) the user to have both hands on the steering wheel. The Geremin [3] system senses 17 distinct (index)finger movements away from the wheel as gestures. Angelini's [1] WheelSense system takes advantage of Wolf's [12] ergonomic analysis of hand positions on the steering wheel to evaluate four different wheel grip gestures (two rotations, dragging, and squeezing). Finally, [4] [2] and [11] use different variations of thumb-based gestures on a touch-sensitive surface on the steering wheel with small sets of gestures (4-19) to allow gesture interactions while holding the steering wheel with both hands. While overall considered safer, having the hands rest on the steering wheel while performing the gestures might also reduce muscular strain and fatigue compared to free-form gestures.

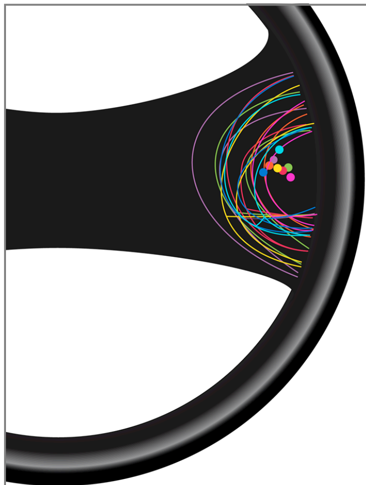
Unlike free-form gesture interfaces, all of the contact-based gesture interactions rely on a *small number* of distinguishable thumb or finger gestures as their main interaction technique. They can draw on culturally established conventions of simple tap- and swipe-based gestures. Users still have to discover the exact mappings of gestures to their intended goals within a particular domain, but conceptual similarity across domains can aid in the transfer of interaction knowledge.

THE IMPORTANCE OF CONCEPTUAL ABSTRACTIONS

Having to rely on a small set of basic gestures, thumb-based gesture interactions are necessarily limited in their expressiveness and need to be reused across system controls. A clear conceptual mapping of interactions between systems is therefore crucial. For example, increasing the volume for radio, mp3-player, and phone should rely on the same gesture. Increases in other systems (temperature, fan speed, brightness) should be mapped identically. This requires a clear understanding of the drivers' mental models for each system.

MODE SWITCHES AND MODE AWARENESS

It should be obvious that the reuse of the same gestures for different control functions requires an explicit shift of control mode. This can be achieved in multiple ways. In [11] we use button presses by the left hand to switch between modes (see figure in the side bar). This separation of function between the two hands is largely inspired by Guiard's [5] model of bimanual control, which emphasizes the different roles of the two hands. Buttons on the left side of the steering wheel can act as a mode selector while a touch pad on the right side of the wheel can be used to perform a limited but rich set of gestures to control specific functions within the selected mode. Obviously



Anthropometrics: To determine the optimal position and size of the touch pad we measured the thumb reach of eight individuals. The colored lines indicate the reach of the test persons' thumbs (the outer line indicates the max reach, the inner line a comfort–able reach). The colored dots indicate the comfortable resting position of the thumb.

the mode selection could also be implemented through thumb gestures or other methods (e.g., speech).

The ambiguity of gestural commands depending on the system's mode requires the driver's awareness of which mode the system is in. Visual feedback, e.g., through a peripheral display in the dashboard or other ambient displays can provide the necessary information without requiring drivers to take their eyes of the road.

Future evaluations of gesture HVIs will have to contrast the benefits of easy-to-learn, small sets of gestures requiring explicit mode changes against the complexity of multiple sets of application-specific gestures that get around mode selection.

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