# Designing & Rapid Prototyping a Gesture-Enabled Steering Wheel

**Victoria Fang**
Intel Labs
Santa Clara, CA, USA
victoria.fang@intel.com

**Lucas Ainsworth**
Intel Labs
Hillsboro, OR, USA
lucas.b.ainsworth@intel.com

## ABSTRACT
As natural user interfaces become increasingly prevalent in everyday interactions, the Automotive Research team at Intel's Interaction and Experience Research Lab (IXR) sought to explore the potential of touch gestures in the in-car experience. Leveraging common gestures now standard with touch interfaces, we looked at how these standards might extend and adapt to provide a simpler in-car control interface. Through an iterative design process, we conceived, designed, developed, and prototyped an interactive driving demo controlled by a gesture-enabled steering wheel in 8 weeks.

### Author Keywords
Natural User Interfaces; Gesture; HUD; Touch; Interaction; Design; Prototyping.

### ACM Classification Keywords
H.5.2. [Information interfaces and presentation (e.g. HCI)]: User Interfaces – Interaction styles.

### General Terms
Human Factors; Design.

## INTRODUCTION
This paper describes the process of designing and prototyping a gesture-enabled steering wheel within the context of an intelligent, connected, HUD-enabled vehicle. Looking at familiar gestures from touch devices, we considered how we might leverage rough swipes and taps to provide a more accessible interface for drivers, with minimal cognitive burden. To support our conceptual vision, we pulled on a number of different skills, prototyping techniques, and off-the-shelf hardware pieces to develop a hi-fidelity proof of concept gesture-enabled steering wheel.

## CONCEPT DEVELOPMENT
The initial concept for a gesture-enabled steering wheel arose from several starting points.

1) With Heads Up Displays (HUD) becoming increasingly prevalent, the idea of direct manipulation within the natural touch and visual range of the driver was an interaction model that was identified for exploration, leading to the question of an appropriate input mechanism.

2) Placing controls directly on the steering wheel has become established practice to enable access to functionality without requiring the driver to take their hands away from the steering activity. However, the increasing number of buttons and the need to find and manipulate these directly drove us to consider the opportunity provided by an interface enabled by grosser touch gestures.

3) The prevalence of touchscreen devices has established a common lexicon of swipes and taps that are widely accepted and understood by users, making it a more viable interaction model for the cognitively demanding environment of the driver seat.

The following will describe the process we undertook in order to design, develop, and prototype the gesture wheel which was showcased in live demonstration for the first time at the Intel Developers Forum in Sao Paulo, Brazil in May, 2012 followed by presentation in San Francisco at Research @ Intel Days in June, 2012. The complete cycle from steering wheel concept to first live presentation was completed in 8 weeks.

**Figure 1. Interactive Demo Presentation at Research @ Intel Days. LCD TV simulates HUD notifications, while gesture pad embedded in upper right steering wheel spoke enables gesture interaction with the HUD.**

## RELATED WORK

The allure of touch gesture interfaces in the car is evident in the evolution of in-vehicle interfaces, ranging from research-based to commercial to user-modified. Earlier work in 2007 by Gonzelez et al. [4] looked at thumb-based steering wheel interactions, but focused on a cursor selection model for a long list in the center display. Given the explosion since then of simplified natural interfaces on our mobile devices and technological advances, the paradigm for these touch interactions has shifted and opened up new potential. Beyond providing a fluid and responsive experience, gesture integration can offer the possibility of greater functionality and lower driver distraction, and these benefits are being noted. Döring et al. [2,3] illustrated that gestural input on a touch screen steering wheel can reduce visual demand. Audi has already incorporated character recognition via a touch pad on the surface of the control dial in the center console [1]. Consumers themselves have taken to DIY modifications to incorporate their personal touch devices into their car to support gesture-based interactions while driving [5].

Our design and rapid prototyping efforts align with this landscape as we leverage available tools and technology to explore a high-fidelity gesture-enabled steering wheel experience in a short amount of time.

## USER EXPERIENCE DESIGN

The design process was a collaborative effort between several team members, with skill sets including interaction design, industrial design, technology development, ethnography, landscape analysis, and user experience assessment.

### Gesture Interaction

When exploring the idea of integrating gestures, we considered the challenging lack of ubiquitous vocabulary around interpretive gestures (meaning gestures that meaningfully translate into specific commands). For this reason, we focused on taps and swipes for easy comprehension, translating these basic, accepted interactions to an appropriate interaction within the context of the vehicle. For the first iteration of the gesture-enabled wheel, we surfaced visual and audio prompts in the HUD simulation that could be handled with the following gestures:

- *Tap* to accept the recommended action
- *Swipe Left* to dismiss
- *Swipe Up/Down* to select different available actions

### Visual Interface Design

For visual design, focus was on ease of interaction and communication of concept. Intended for demo rather than long term use, language tended to be more detailed than might actually be implemented in a vehicle.

There were three types of notifications, which dictated the visual language that was settled upon.


**Figure 2. Informational Notification with no action.**

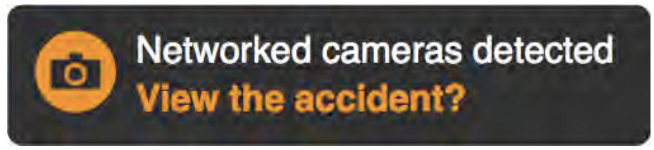


**Figure 3. Notification with one available action.**

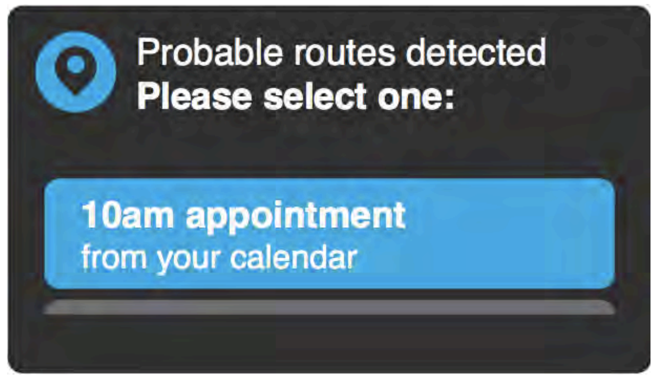


**Figure 4. Notification with multiple available actions.**

As can be seen from the visuals, color played a strong role in indicating interactivity and type of notification. Because the demo was simulated on an LCD television screen, the colors selected were for clarity of interaction and not for use in an actual in-car HUD.

### Input Technology Exploration

Looking into gestures inputs, several off-the-shelf touchpad solutions were considered. However, for greatest control over the form factor of the wheel and responsiveness, we ultimately opted to use the internal capacitive film from a touch sensitive mouse as a flexible input beneath the plastics of our choice.

**Figure 5. Capacitive film from off-the-shelf mouse**

### Industrial Design

Early explorations into the industrial design began with foam core to approximate shape and position on an off-the-shelf steering wheel.

**Figure 6. Early foam core prototype of steering wheel gesture pad.**

A slight angle felt most natural to us based on the position of the hand on the wheel with the swoop of the thumb. With this in mind, design of the plastics began.

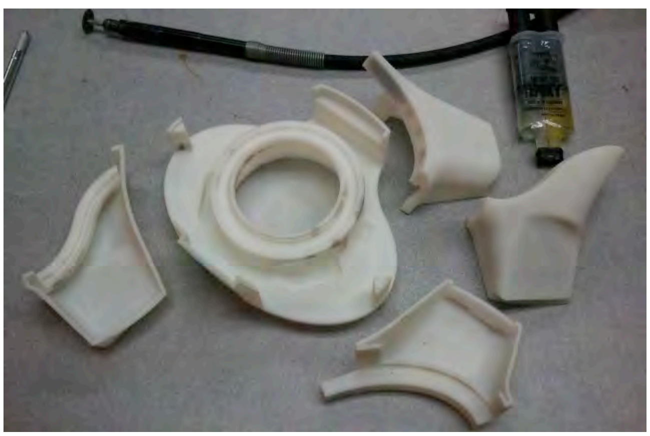

**Figure 7. 3D printed plastics to house electronic components and provide gesture pad surface.**

The design of the plastics were done in a CAD software program, and were designed with the limitations and of 3d printing in mind, keeping components modular and solid.

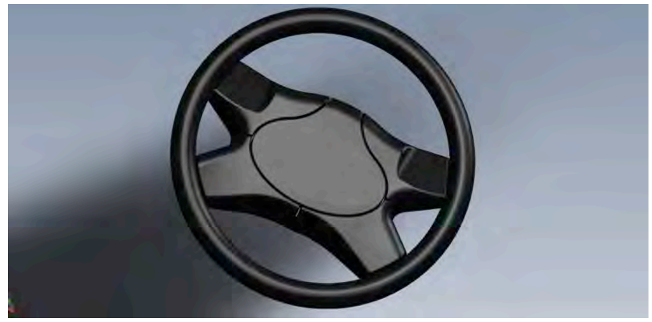

**Figure 8. CAD rendering of the first version of plastics.**

Plastics were printed in house, allowing for iterative revisions. Although symmetry was alluring both visually and conceptually (as can be seen from the CAD rendering in Figure 8), the interaction model was deemed more confusing (which hand should react when?) and difficult to control (how can I maintain my grip on the wheel and use both thumbs?) based on some quick experiments by team members. We ultimately settled on a division of labor model, where the left hand is the dominant steering hand and the right hand is the control adjustment hand. The final iteration of the wheel had one gesture pad, in the upper right corner of the wheel. Once complete, the electronic components were assembled inside the plastics and the entire construction was mounted on the steering wheel.

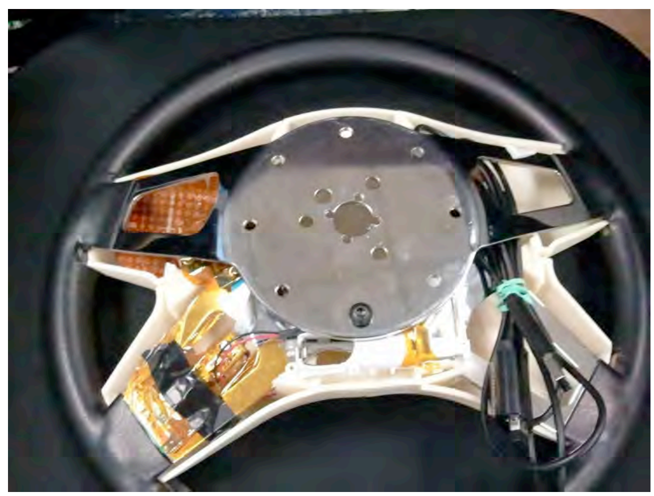

**Figure 9. Assembled electronics and plastics on the steering wheel (rear view).**

The final wheel was printed in black plastics, and was used to control a demo running on a 46" TV.

**Figure 10. Final wheel, mounted in demo simulator.**

### Software Development

Algorithms were developed to identify swipes and taps, accommodating for arcs or diagonals naturally incurred by users given the positioning of the gesture pad. Given the quick nature of the project, calibration was done based on feedback from various members of the team and other members of the lab.

## CHALLENGES & LESSONS LEARNED

The seamless integration of the gesture pad into the plastics actually created some challenges for new users who were not clear where the input was or how it worked. In future iterations, we will be looking at different textures, colors, or other solutions to provide intuitive affordances.

Communication and flexible iteration were key factors in achieving the final output. Being able to quickly gather insights and feedback from different team members and unrelated lab members meant that we were able to at least get some early feedback to support the design process in the absence of proper user testing.

Relying on internal resources and bootstrapped methods meant that we could iterate more quickly without waiting on vendors and services or feeling locked to fabrication methods. However, this did consume time to ramp up with unfamiliar techniques and processes.

## NEXT STEPS

Currently, the gesture-enabled steering wheel is undergoing design iterations and qualitative assessment in user interviews. Through these iterations, we are looking into some of the following questions:

- How can we more strongly suggest interactive actions vs. informational notifications?
- How might we strengthen the relationship between the gesture pad and the HUD?
- How can we better assess the viability of this system in a real-life driving situation and over a long term?
- How might we expand the functionality available through the gesture pad?
- How might we explore more complex gestures and do these provide value in this system?

## CONCLUSION

The design, development and prototyping of a gesture-enabled steering wheel provide a good case study for the application of available technologies to execute rapid experiential prototyping. With an iterative and collaborate process, the team was able to quickly implement a working prototype that allowed us to experience and observe others experiencing the desired interactions. The process also enabled us to quickly discover pitfalls in the interaction model and to demonstrate our concept in a tangible way. This paper presents an initial prototype created with a multi-disciplinary team in a short time frame. This prototype will lead to further design exploration, user assessment, and concept integration, leveraging the process and learning discovered in this first iteration.

## ACKNOWLEDGMENTS

Thanks to the Automotive Portfolio at Intel's Interaction and Experience Research Lab for contributions throughout the process: Tim Plowman, Alex Zafiroglu, Jennifer Healey, Carlos Montesinos, Dalila Szostak, and Brent Celmins. Thanks also the folks at Berg for the early concept development and Angry Little Dog for simulator design and development work.

## REFERENCES

1. Audi Technology Defined http://microsites.audiusa.com/ngw/09/experience/technology/?csref=inid_technology, 07.10.2012
2. Döring, T., Kern, D., Marshall, P., Pfeiffer, M., Schöning, J., Gruhn, V., and Schmidt, A. Gestural interaction on the steering wheel: reducing the visual demand. In Proc. of CHI'11, ACM, 2011.
3. Döring, T., Pfleging, B., Kienast, M., and Schmidt, A. SpeeT: A Multimodal Interaction Style Combining Speech and Touch Interaction in Automotive Environments. In Proc. of AutomotiveUI'11, ACM, 2011.
4. Gonzales, I., Wobbrock, J., Chau, D., Faulring, A., and Myers, B. Eyes on the Road, Hands on the Wheel: Thumb-based Interaction Techniques for Input on Steering Wheels. In Proc. of Graphics Interface 2007, ACM, 2007.
5. iPad - Keeping Your Eyes on the Road with Gestures. http://www.youtube.com/watch?v=VgxeTF3zETQ, 06.16.2010