# Advances to In-Car Human Machine Interface Systems

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## Abstract

***Given recent trends, it is inevitable that there will be more and more computers in vehicles: built-in, brought-in, worn, etc. Many of these devices will want to interact with us—and we with them. If not designed and engineered appropriately, the user interfaces (UIs) of these devices may become increasingly complex and distracting to the driver. To avoid this, careful attention has to be paid to designing appropriate in-vehicle interaction methods and human-machine interfaces (HMIs). We suggest that at this point, updates to in-vehicle HMIs cannot be just incremental, but have to be dramatic in order to reduce distraction and driver cognitive load. This paper will cover recent significant developments at Harman International that will be game-changing for in-car HMIs.***

## Author Keywords

HMI; pseudo-holography; view-dependent rendering; gesture control; input-output coincidence; load balancing human senses; video see-through; tactile feedback; parametric array of ultrasound transducers.

## 1. Introduction

Today's consumers use, and are used to, a variety of computations platforms on a daily basis: in addition to traditional computers and tablets, we use smart phones, smart watches, head mounted display devices, body worn activity trackers of all kinds, and many more. All these devices vie for the attention of the user, and tempt the user to interact with them—be it situationally appropriate or not.

In an automotive setting, it becomes important to manage the attention and interaction that brought-in and built-in devices demand. Although car manufacturers may not be able to influence the user interfaces of brought-in devices, it is clear that some in-vehicle interaction methods need serious attention, and potentially re-engineering.

One approach is to expand beyond the traditionally used human senses: currently, almost all communication from vehicle to driver is based on our preferred human senses of hearing and seeing. This could overload the driver's senses. Therefore, we have been exploring methods to "load-balance" human senses, and even include proprioception and equilibrioception.

Another approach is to use the human senses in a more holistic way, such as considering input-output coincidences and the spatial nature of our senses. The former, which refers to interfaces that avoid spatial discontinuity between user input and system output [1], requires direct gestural interaction with visual and auditory elements. The latter, which takes into account that we perceive the world spatially [2], is core for our work in using pseudo-holographic displays and 3D sound in vehicles.

In the following sections, we will describe four efforts for advanced systems in the domain of future in-car HMI.

## 2. Pseudo-holographic Display Systems

We have created systems which take advantage of the volumetric space between the driver and their steering wheel. Alerts and important information, such as a speeding notification, can then become more prominent by growing and getting closer to the driver. Machine intelligence decides which information is most relevant, and dynamically determines priority and position in space (Figure 1).


**Figure 1.** Timely or important information may be placed dynamically in proximity of the driver, emphasizing the importance.

An example implementation illustrating the user experience, created by the Future Experience (FX) team at Harman, is shown in Figure 2. This system, based on an off-the shelf display, provides the driver with a pseudo-holographic 3D Instrument Cluster (IC) in front of a 3D third-person-view navigation system. The system can modify the depth position of all user interface elements and layers with respect to the surface of the physical display, positioning them at any desired distance from the driver's face. For example, alerts and important information, such as a speeding notification, may become more prominent by growing and getting closer to the driver's eyes.

In a vehicular implementation, the display element may be positioned at the location of the traditional instrument cluster, although occlusion issues may occur because of the steering wheel (Figure 3, upper). Therefore, secondary display elements may be placed on the steering wheel (e.g., projected) (Figure 3, left), complementing the primary display. Note that primary and secondary 3D displays are not required to be co-planar to create a seamless 3D effect. We have explored alternative display locations, such as above the steering wheel (Figure 3, right).


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**Figure 2.** Example of a transparent instrument cluster (this illustration is in 2D, the actual system renders in 3D).

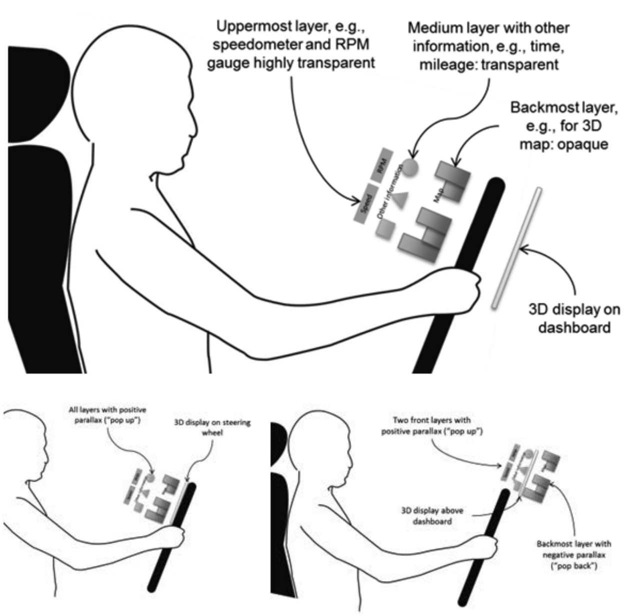


**Figure 3.** Upper: 3D field in front of steering wheel, with display behind steering wheel (seen through opening in steering wheel). Left: some secondary display elements may be located on the steering wheel. Right: 3D field above steering wheel.

## 3. Gestural Control of In-Vehicle Sounds

Spatial interfaces are best combined with spatial interaction methods. For that reason, Harman's FX team created a system where a driver can use intuitive gestures, such as grasp and pull, to control volume and perceived location of audio events (Figure 4 shows the concept). The system can also be used to activate audio events, such as answering a phone call. This interaction method is best combined with a spatial display such as the above mentioned pseudo-holographic 3D instrument cluster.

Rendering sound objects as distinct sound events in 3D space requires a sophisticated 3D sound system, such as Harman's QuantumLogic Surround 3D [3][4]. Alternatively, surround sound systems with crosstalk cancellation may be used to increase high-spatial-fidelity reproduction of sound events through loudspeakers.

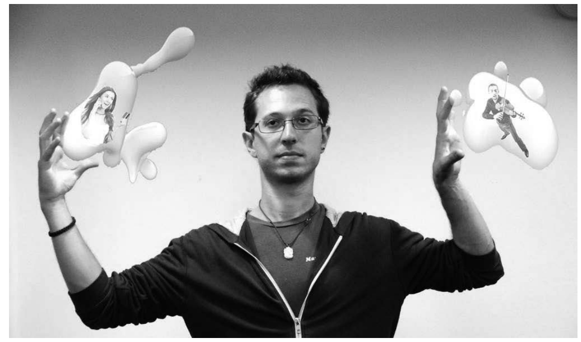

**Figure 4.** Conceptual illustration of the UX of sounds as tangible (manipulable) entities, using the concept of input-output coincidence.

One use case is in a vehicular setting where multiple sound sources are rendered simultaneously. For example, the user may be listening to music, and a phone call comes in (Figure 5). The user may use a simple hand wave gesture to move the music to one side of the sound field (e.g., to the left), and then pull the icon of the ringing phone, together with the actual phone ringing sound, towards their face to pick up the call. In this scenario, the intelligibility of simultaneous voice and music will be increased by the spatial separation of the two audio sources. The Harman FX team created also more complex systems where the user may split an incoming conference call with multiple speakers into separate streams of voices, each positioned separately along the stereo or surround sound panorama.

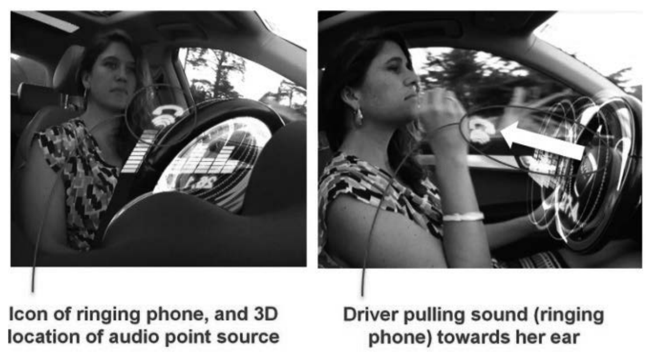


**Figure 5.** Use case of driver receiving a phone call.

A different use case would cover in-vehicle audio systems which can render sound zones per person, such as Harman's Individual Sound Zones system (ISZ) [5]. In such systems, the driver may, for example, pass an incoming phone call to a passenger, using the above mentioned grasp-and-pull methods. In another example, a passenger may share her music with the rest of the people in the car using a fanning gesture.

We have built a proof-of-concept system (Figure 6) which is based on an off-the-shelf gesture sensor (Microsoft Kinect). It allows a user to grab and place multiple individual sound sources all around them. Although the system currently uses a ring of speakers around the user, the software framework is fully 3D capable.

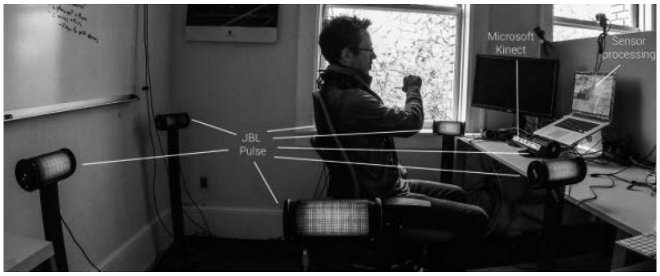


**Figure 6.** Early proof-of-concept system.

## 4. See-Through-Dash Display Systems

In this project, we combine the above mentioned pseudo-holographic instrument cluster display system with robotic stereo cameras for an additional purpose: to allow the driver to "see through" their car. Being able to see through the dash gives the driver an augmented field of view of the road in front of the vehicle, increases the immersion of the driver with the environment while driving, and improves the driver's situational awareness.

We have implemented multiple versions of this system, some using a spatial display combined with robotically actuated stereo cameras that mirror the driver's head position, allowing for view-dependent rendering of real-time content.

This system provides the driver with an augmented field of view of the road in front of the vehicle (Figure 7) by delivering an augmented reality, 3D video see-through perspective of the front of the vehicle. The targeted area is the front of the car which us usually not visible to the driver due to the presence of the hood, engine/front-trunk, and instrumentation (Figure 8). From a UX perspective, the system aims to convey a similar effect to a virtual hole through the engine or a partial glass-cockpit.

**Figure 7.** Illustration of an instrument cluster showing a pseudo-holographic real-time rendering of area in front of vehicle.

In order to achieve the most realistic augmented reality effect of the front of the vehicle that is as similar as possible to looking at reality directly, the video see-through content is 3D and conveyed through a pseudo-holographic stereoscopic 3D, view dependent rendering, parallax enabled display.

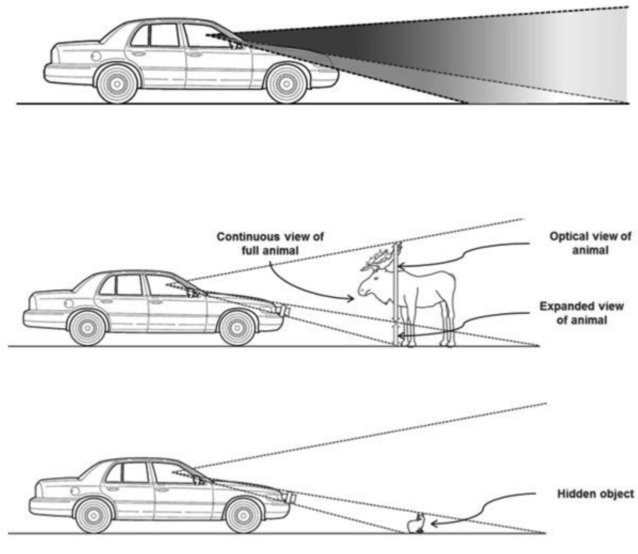


**Figure 8.** Expanding the driver's field of view with spatially correct depth rendering of the outside view.

Unlike [6], our stereoscopic display system allows the driver to perceive the scenery in front of the vehicle with visual depth. View dependent rendering means the driver's head is tracked by the system in real-time in order to deliver a spatially correct 3D rendering of the objects that accounts for the viewer's dynamically changing point of view. The resulting parallax motion effect conveys the driver a realistic feel for the distance of objects in front of the vehicle: when moving laterally, objects closer to the driver will move faster than objects farther away.

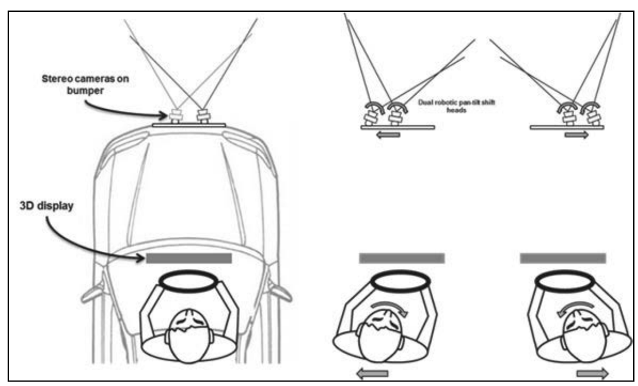


**Figure 9.** Robotically actuated cameras mirroring user face position.

In order to adjust for the driver's head position, the position and orientation of the cameras has to be updated in real-time, ideally with 6 degrees of freedom (DOF). Our experiments have shown, though, that using 3 DOF suffice to create an immersive illusion. Our robotic system pans and tilts both cameras (2DOF of rotational motions), and shifts them sideways (1 DOF of translational motion) (Figure 9). Figure 10 shows our proof-of-concept working prototype with 3 DOF.

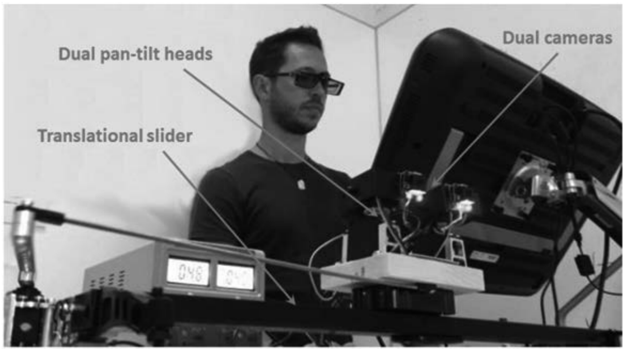


**Figure 10.** Proof-of-concept working prototype, combining robotic stereo cameras with pseudo-holographic display.

Alternatively, a linear array of cameras may be used (Figure 11) which emulates both the translational motions, as well as the panning, using well-known vision processing methods.

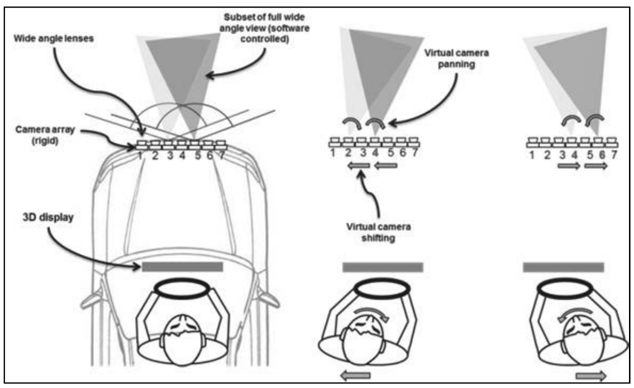


**Figure 11.** Linear array of imagers emulating sideways view point motion, as well as panning and tilting.

## 5. In Mid-Air Tactile Feedback Systems

In order to provide the user with a natural interaction experience even when using in-air gestures to interact with virtual content, such as visual or auditory, it is necessary to close the interaction loop and provide the user with actual tactile feedback (Figure 12). From the known methods that can provide tactile feedback at a distance [7][8], using ultrasonic parametric transducer arrays is more practical since it can render tactile feedback even without direct line of sight. In addition, the transducers do not need to be grouped, or be co-planar, but can be distributed around the driver where there is space in the cabin.

A phased array of ultrasound transducers creates tangible spots in mid-air using waves of ultrasound which displace the air, creating a pressure difference. By causing multiple waves to arrive at the same location simultaneously, a noticeable pressure difference is created at that point.

The obvious use case is to provide tactile feedback for the driver in sync with visual and auditory 3D user interfaces. For example, a visual icon or user interface element of a 3D display will becomes tangible, in mid-air. This closes the interaction loop of spatial displays and spatial sound with haptic experience.

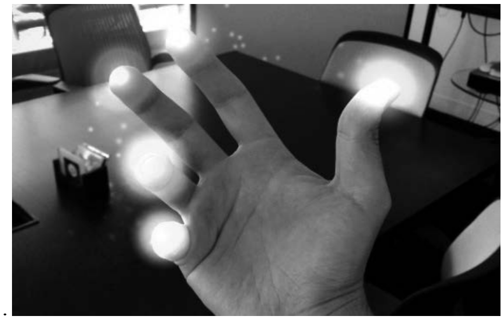

**Figure 12.** Conceptual image of direct fingertip stimulation at a distance, closing the UX interaction loop when using gesture interaction methods.

## 6. Conclusion

In this paper, we describe four projects that demonstrate advanced HMI methods in an automotive setting. The Harman FX team has created multiple proof-of-concept working prototypes that demonstrate the UX as well as the engineering feasibility of these approaches. We believe that in-car HMI systems need to improve significantly in order to reduce cognitive load and driver distraction. In order to achieve that, novel interaction methods and user interfaces need to be researched, developed, and deployed in vehicular settings.

## 7. References

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