What value does haptic technology add to multimodal HMI in automotive?
Executive Summary

The automotive industry is on the cusp of a ‘perfect storm’ of trends driving radical design change. Mary Barra (CEO of General Motors) predicts more change in the industry in the next five to ten years than in the previous fifty.¹

At the same time, increasingly sophisticated haptic technologies are coming to market – including Ultraleap’s own ultrasonic mid-air technology.

The use of haptics is still under-explored in automotive human-machine interfaces (or HMIs). As such, it offers opportunities to create unique, market-leading products that effectively respond to a changing landscape.

Haptics are an intuitive and non-visual mode of interaction, and are one way of reconciling the contradictory market trends of greater connectivity and better safety. Next-generation automotive HMI will combine haptics with hand tracking and gesture control to reduce driver distraction and “eyes off the road” time.

Looking further into the future, it’s clear that the quality of the XR experiences on offer in autonomous vehicle cabins will provide a new dimension to brand experience and differentiation between car manufacturers. Haptics – the ability to touch, not just see, virtual objects – will make interacting with AR, VR, or holographic displays more immersive and intuitive.

Passengers are also likely to want to avoid touching screens or buttons in mobility-as-a-service and other shared vehicles. Our own ultrasound-based haptics (which creates the sensation of touch in mid-air) will be a key technology helping manufacturers meet this challenge.

At Ultraleap, we believe haptics will change user interfaces in ways we are only just beginning to imagine. We look forward to developing the next generation of automotive HMI with you.

Steve Cliffe
CEO and President, Ultraleap

The 4 trends driving next-generation automotive HMI

1. CONNECTIVITY AND DIGITIZATION

The evolution of the connected car continues to accelerate. Centre stacks feature more and more electronics and larger visual displays, while instrument clusters and heads-up displays (HUDs) are becoming more three-dimensional and interactive.

2. DRIVER DISTRACTION

Driver distraction is estimated to contribute to nearly 3,000 deaths every year in the US alone. Reconciling safety with connectivity is a key challenge driving the development of next-generation automotive UI.

3. MULTIMODAL HMI

We increasingly understand that for interfaces to be intuitive, they have to be multimodal. Future automotive UI will leverage multiple new technologies and machine learning to fuse inputs and outputs targeting different human senses.

4. AUTONOMOUS DRIVING

It is widely accepted that autonomous vehicles will be a commercial reality sometime in the 2020s. Cabins will become mobile extensions of our future immersive workspaces and virtual social environments, and passengers will expect to interact seamlessly with family, friends, and colleagues, wherever they are.

“Nearly 70 per cent of US adults say that they want the new technology in their vehicle, but only 24 percent feel that the technology already works perfectly.”

AAA survey, 2017

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2 https://www.nhtsa.gov/risky-driving/distracted-driving
Haptics in multimodal HMI

Our senses complement each other and are designed to work together. Incorporating haptics into control systems complements the primarily visual task of actually driving a car. Adding mid-air haptic feedback to gesture control has been shown to reduce “eyes off the road” time and mental load. Humans also respond instinctively and emotionally to touch. Haptic warnings are hard to miss and drivers react quickly to them. Vibrotactile haptic technology in advanced driver-assistance systems (ADAS) has been shown to improve lane-keeping by 30%.

Haptic technology is also an effective way of increasing people’s sense of control and connection. Drivers express a strong preference for automotive HMI that combines mid-air haptic feedback with gesture control, compared to just gesture control.

“Non-visual modalities for secondary information make a lot of sense.”

Gary Burnett, Professor of Transport Human Factors, Faculty of Engineering, University of Nottingham, UK

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Haptic strengths and limitations

**Haptic strengths**

- **Non-visual:** Secondary information can be communicated to drivers and tasks completed without taking eyes off the road.

- **Intuitive control:** Controls incorporating haptic feedback are more intuitive, reducing mental load.

- **Personalization and privacy:** Haptic technologies can transmit information to the driver alone, without disturbing passengers.

- **Sensitivity:** A 2013 study showed that human fingertips can distinguish a pattern as thin as 13 nanometres from a smooth surface.  

- **Reaction time:** Reaction times to haptic stimuli are faster than to visual stimuli.  

- **Engagement:** Haptics are proven to increase user engagement.

**Haptic limitations**

- **Short-range:** We can see objects a relatively long distance away, but we can only feel things within reach.

- **May require physical contact:** Until recently, touch-based interfaces required physical contact with a screen or other device.

- **Limited bandwidth:** Detailed information or instructions cannot be conveyed through touch (unless using a specialist language such as Braille).

- **Potentially intrusive:** Drivers need to have a choice whether or not to receive haptic feedback. This should be a design consideration.

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Haptics at different levels of autonomy

The sense of touch has been instrumental in the development of our tools and technology. Drivers already rely on haptic feedback every time they turn a steering wheel or press a pedal.

However, creating tactile sensations through electronics is a relatively new field. Today, consumer electronics are moving beyond simple vibrotactile effects, force feedback devices are increasingly sophisticated, and ground-breaking technologies such as ultrasound-based haptics are entering the market.

As automotive design evolves through different levels of autonomy, legacy haptics such as mechanical control systems and basic vibrotactile and surface haptics will be combined with and eventually supplanted by these new technologies. Haptics will become fully integrated into automotive HMI (and also car configurator kiosks and automotive design software), enabling manufacturers to deliver increasingly intuitive, personalized, and innovative user experiences.

Passengers are likely to want to avoid touching screens or buttons in mobility-as-a-service and other shared vehicles. Ultrasound-based haptics (which creates the sensation of touch in mid-air) will be a key technology here.

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LEVELS OF AUTONOMY

- **LEVEL 0**: No automation
- **LEVEL 1**: Automation of driver assist functions
- **LEVEL 2**: Partial automation of central driving functions
- **LEVEL 3**: Fully automated but a human may be required to take over
- **LEVEL 4**: Fully automated but vehicle is constrained to specific use-cases
- **LEVEL 5**: Fully automated in all driving scenarios

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MECHANICAL CONTROL SYSTEMS: Traditional mechanical controls such as steering wheels and pedals already rely on haptics.

ELECTRONIC CONTROL SYSTEMS: Surface and mid-air haptics will be fused in increasingly sophisticated ways with gesture control and machine learning in centre stacks, passenger-centred infotainment systems, HUDs, seat and window controls, and security systems.

ADVANCED DRIVER-ASSISTANCE SYSTEMS (ADAS): Vibrotactile technology is already widely used in ADAS. Haptics will increasingly become the dominant mode for driver alert systems.

CUSTOMER EXPERIENCES: Haptic effects will become commonplace in customer experiences across all sectors and form an integral part of interaction with AR, VR, or holographic displays in car configurator kiosks.

COMPUTER-AIDED DESIGN (CAD): Haptics will be incorporated into CAD programs in combination with AR and VR across all sectors including automotive.

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Ultrasound mid-air haptics

HOW MID-AIR HAPTICS WORKS

Ultraleap’s patented algorithms modulate ultrasound waves to create haptic sensations in mid-air. No controllers or wearables are needed: the “virtual touch” technology uses ultrasound transducers to project shapes and textures directly onto the user’s hands.

The transducers can provide the sensation of touch up to 1 metre (3 feet) away from the surface. The accuracy of the sensation is less than a finger-width apart, and can track hand position, hand shape, and gestures.

In-car installations typically include an array of ultrasound transducers mounted under the fascia of a product or in a separate control panel. The technology is combined with a hand tracking system (often Ultraleap’s own world-leading tracking software and hardware).

Ultraleap’s technology means that every cubic centimetre of the space within a car can potentially be turned into a programmable haptic interface.

CASE STUDY: HARMAN

HARMAN combined gesture control, Ultraleap’s mid-air haptic technology, and their custom graphical user interface (GUI) to develop an intuitive system that can control multiple in-vehicle systems, including audio infotainment. The system responds to the driver’s gesture commands with tactile sensations confirming instructions have been recognized and accepted.

Ultrasonic mid-air haptics provides the sensation of touch up to 1 metre (3 feet) away from a surface.

KEY BENEFITS OF ULTRASONIC MID-AIR HAPTICS

Safety:
Reduces cognitive load, driver distraction, and “eyes off the road.”

Flexible:
Virtual controls and alerts that can change from second to second according to user needs.

Enables innovative design:
Reduces the need for screens, buttons, and knobs, enabling sleek, contemporary design solutions.

No physical contact:
No touchscreens, controllers, or wearable devices needed.

Three-dimensional interaction:
Allows the development of innovative user interfaces.

Product differentiation and wow factor:
A ground-breaking technology that makes experiences memorable and products unique.

“Our haptic feedback solution makes the driving experience safer by enabling drivers to keep their eyes on the road while still maintaining intuitive control of infotainment and audio systems.”

Stefan Marti, VP, Future Experience, Harman
CASE STUDY: DS AERO SPORT LOUNGE

Ultraleap’s mid-air haptics and hand tracking technology were incorporated into Groupe PSA’s premium brand, new luxury car the DS Aero Sport Lounge in February 2020.

Driven by the spirit of the avant-garde and backed by exceptional heritage – that of the 1955 DS, the DS Brand, launched in 2015, aims to embody French luxury savoir-faire in the automotive industry. DS is Groupe PSA’s Premium brand.

The futuristic car’s central armrest contains a revolutionary human-machine interface using gesture controls and haptic feedback which uses ultrasound focused on the user’s hands to create the sense of touch in mid-air. The technology interprets hand gestures enabling the driver, or passengers, to control a range of systems - from managing the car’s entertainment systems in the vehicle, to the navigation system.

“Working with Ultraleap on mid-air haptics and gesture control has given us the opportunity to opt for solutions that are both avant-garde and high tech, yet the purely technical element is concealed for the benefit of beauty in the cockpit.”

Thierry Metroz, Design Director at DS Automobiles
Quantifying the impact of mid-air haptics

ACADEMIC STUDY

In a collaborative study by Ultraleap and the University of Nottingham, adding mid-air haptic feedback to automotive UI reduced error rates, “eyes off the road” time, and mental load. It was also strongly preferred by users for some types of interaction.

Two different types of interactions were tested: a slider bar and button presses.

48 participants each did four simulated drives while using four different types of interface:
- touchscreen
- touchscreen + mid-air haptics
- gesture control
- gesture control + mid-air haptics

-~17% reduction in mental load for gesture control + haptics compared to all other options**

- >80% increase in preference score for gesture control + haptics compared to all other options*

The study used a medium-fidelity driving simulator with a right-hand drive Audi TT car positioned within a curved screen.


* Relates to slider-bar task
** Relates to both button presses and slider-bar tasks

~3x more accurate

GESTURE CONTROL + HAPTICS IS ALMOST 3 TIMES MORE ACCURATE THAN A TOUCHSCREEN*

25% reduction in glance time

FOR GESTURE CONTROL + HAPTICS COMPARED TO A TOUCHSCREEN*

USES OF ULTRASONIC MID-AIR HAPTICS IN AUTOMOTIVE

HAPTIC USE-CASES: DRIVERS

3D centre stack controls: Invisible 3D interaction zones that float in mid-air above the centre console.

Hand positioning and guidance for gesture control: Tactile cues to assure users their hands are in the right position.

Haptic alerts: Silent and hard-to-miss alerts

Tactile heads-up displays (HUDs): 3D virtual displays you can touch.

HAPTIC USE-CASES: PASSENGERS, BACK SEATS, RIDESHARE, & AUTONOMOUS VEHICLES

3D passenger infotainment controls: Personalized, contactless, and invisible 3D interaction zones that float in mid-air.

XR entertainment, advertising, marketing, and productivity
Combine with AR, VR, or glasses-free 3D to create multi-sensory entertainment, advertising, or marketing experiences, and productivity and collaboration tools.

HAPTIC USE-CASES: PRODUCT DESIGN & SHOWROOMS

Car configurator kiosks: Add a memorable extra dimension to XR customer experiences.

Immersive product design: Accelerate design and innovation through intuitive, high-quality naturalistic interaction within XR workflows.

CASE STUDY: BOSCH CONCEPT CARS

Recent Ultraleap demo showcasing how ultrasound transducers can be split and configured to seamlessly integrate into a centre stack.

Ultraleap's mid-air haptic technology was combined with gesture-recognition infotainment controls in Bosch concept cars. When drivers reach out to give a gesture command, the system uses tactile sensations to assure them their hands are in the right place. A second haptic response is then given to confirm that the command has been accepted.
About Ultraleap

NO WEARABLES. NO CONTROLLERS. JUST NATURAL INTERACTION, USING ONLY YOUR HANDS. IT’S TRANSFORMING USER EXPERIENCE ACROSS SECTORS.

Ultraleap brings together the world’s most powerful hand tracking with the only haptic technology able to create the sensation of touch in mid-air.

Together, these technologies are a powerful combination.

We have a team of more than 150 spread across the world, with locations in Silicon Valley, US and Bristol, UK. Our team includes world-leading experts in interface design, acoustics, machine learning, and computer vision.

Automotive Design Acceleration Program (ADAP)

We have a specialist five-stage R&D program for automotive customers:

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<th>Stage</th>
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<td>Finalise and prove concept</td>
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Delivers:
- Technology demonstrator for internal evaluation.
- Easy access to technology
- Documented use-case analysis and example builds
- Bespoke concept specification
- Proof of principle demonstrator / BUC
- Refined system specification
- Vehicle integration concept
- Proof-of-concept demonstrator
- In-house system design competence

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