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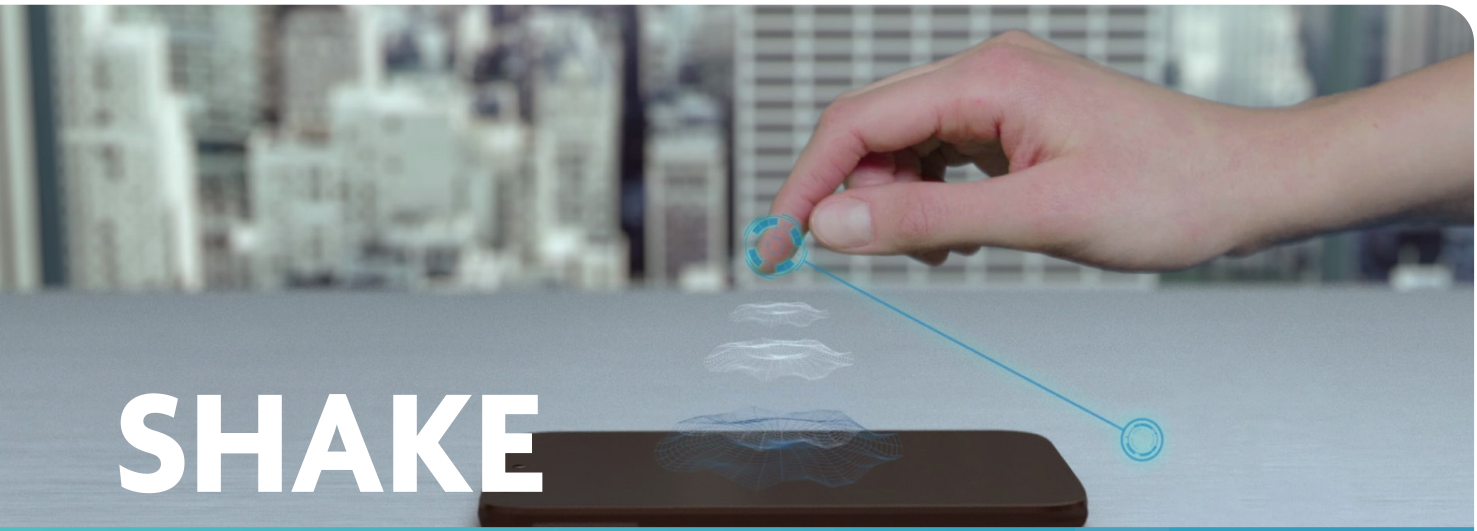
An imec.icon research project | project results

SMART INDUSTRIES



SHAKE

User experience of haptic mid-air feedback systems

Haptic feedback is a form of human-machine interface where the machine can "touch" its operator by triggering mechanoreceptors in the skin. It is familiar to many via the vibration they feel when touching their mobile phone's screen. The quality of haptic feedback depends largely on the correct interplay between tactile, visual and auditory patterns. With the rise of gesture interfaces and augmented / virtual reality (AR/VR) applications, there is a need for non-contact haptic feedback – particularly with the global pandemic making touchless interfaces very relevant. A novel approach uses focused ultrasound to generate local pressure fields in mid-air, enabling a sensation on the skin without physical contact between machine and operator. However, there are many questions around the user experience of this mid-air haptic feedback: What does the user feel? What interactions can be realized? etc. In addition, the bulky hardware currently available would be an obstacle to widespread adoption.

The SHAKE project addressed the identification and understanding of how mid-air haptic feedback enhances the user experience in a range of application domains, particularly aspects such as learnability, effectiveness and controllability. It demonstrated how a user-friendly interface relies on the correct balance between tactile, auditory and visual feedback. The project explored potential applications of mid-air haptic feedback such as mixed reality interfaces, home automation and gaming, characterizing the user experience in these various domains. To generate haptic patterns, thin film ultrasound transducer arrays are being developed, enabling frequency control and integration in flat panel displays.

THE OUTCOMES

1. Better understanding of mid-air haptic feedback

The project studied various aspects of the users' experience of mid-air haptic feedback. We identified potential application categories for the technology in home and AR/VR environments. We also defined specific parameters that can be experienced by different types of users, such as shapes that are easier to identify. For example, sensitivity to mid-air haptic feedback was seen to decrease with age. Finally, we gained insights into the user experience and acceptance of long-term mid-air haptic feedback, showing that mid-air haptics mainly increases enjoyment even accounting for a novelty effect. However, it does not make applications easier to use. These insights will enable the design of novel (haptic) user interfaces with a better experience and longevity.

2. Improved large-area ultrasound array performance and an innovative process platform for low-frequency ultrasound transducers

Few large-area ultrasound arrays are currently available. Our approach provides focused ultrasound beams in mid-air, with ultrasonic frequencies in the 100 – 600 kHz range, enabling very precise haptic patterns. Maximum pressure at the focal point is around 200 Pa, on the way to the detection threshold for haptic sensations. Moreover, fabricating ultrasound transducers in polymer is a novel technology not yet developed in commercial solutions. It allows the fabrication of ultrasound transducer arrays compatible with display fabs, enabling reasonably priced, very large (meter-sized) arrays. The arrays fabricated in the SHAKE project show this technology can be a key technology for haptic feedback applications.

3. Mid-air haptic demonstrators

With the COVID-19 pandemic, contactless user interfaces have become even more relevant. We developed a haptic hand positioning system that could be used in future touchless biometric authentication systems. Current biometric authentication systems such as palm scanners require the hand to be placed in the correct position. This is done with physical hand/wrist holders which could lead to hygiene and discomfort issues. Mid-air haptic feedback allows the user to position their hand correctly without physical contact. The interplay between haptic, visual, and auditory feedback enables a realistic interface.

NEXT STEPS

NXP's contribution to the SHAKE project led to a Smart Haptic Driver for generating strong and sharp haptic vibrations with linear resonant actuators (LRAs) in mobile devices. Verhaert aims to add innovative gesture interfaces to its portfolio, serving the healthcare and appliances markets. Nokia is continuing to develop the cloud-based object management system for mixed reality applications. Imec is pursuing an improved acoustic output of the piezoelectric micromachined ultrasound transducer (PMUT) platform by switching to alternative piezoelectric materials. Mintlab will continue publishing results of the project and is open to setting up new research projects on related topics.

SHAKE project partners:

KU LEUVEN NXP NOKIA Bell Labs VERHAERT

FACTS

NAME	**SHAKE**
OBJECTIVE	Demonstrate the use of mid-air haptic feedback for human-machine interaction
TECHNOLOGIES USED	Haptic feedback, tactile feedback, touch haptics, mid-air haptics, ultrasound, phased array, user experience, PMUTs, AR/VR, HCI, Human-Computer Interaction
TYPE	imec.icon project
DURATION	01/06/2018 – 31/05/2020
PROJECT LEAD	Bert Braeckman, Verhaert
RESEARCH LEAD	David Geerts, Mintlab KU Leuven
BUDGET	1,955,647 euro
PROJECT PARTNERS	Verhaert New Products & Services, NXP Semiconductors Belgium, Nokia Bell
RESEARCH GROUPS	imec – LAE, imec - LST, KU Leuven – mintlab

WHAT IS AN IMEC.ICON PROJECT?

The imec.icon research program equals demand-driven, cooperative research. The driving force behind imec.icon projects are multidisciplinary teams of imec researchers, industry partners and/or social-profit organizations. Together, they lay the foundation of digital solutions which find their way into the product portfolios of the participating partners.

The SHAKE project was co-funded by imec, with project support from Agentschap Innoveren & Ondernemen.

AGENTSCHAP INNOVEREN & ONDERNEMEN Vlaanderen is ondernemen

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