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Researchers uncover physical limitation in haptic holography

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Haptic holography promises to bring virtual reality to life, but a new study reveals a surprising physical obstacle that will need to be overcome.

A research team at UC Santa Barbara has discovered a new phenomenon that underlies emerging holographic haptic displays, and could lead to the creation of more compelling virtual reality experiences. The team's findings are published in the journal Science Advances.

Holographic haptic displays use phased arrays of ultrasound emitters to focus ultrasound in the air, allowing users to touch, feel and manipulate three-dimensional virtual objects in mid-air using their bare hands, without the need for a physical device or interface. While these displays hold great promise for use in various application areas, including augmented reality, virtual reality and telepresence, the tactile sensations they currently provide are diffuse and faint, feeling like a "breeze" or "puff of air."

“Our new research explains why such holograms feel much more diffuse or indistinct than would be expected,” said Yon Visell, an associate professor at UCSB's College of Engineering, whose research focus is on interactive technologies with an emphasis on haptics, robotics and electronics.

The study led by Visell and Gregory Reardon, a doctoral student researcher, used high resolution optical imaging, simulations and perception experiments to study ultrasound-excited waves that are excited in the skin during haptic holography. They discovered that holographic displays excite widespread vibration patterns — shear shock waves — in the skin.

In haptic holography, Visell explained, shock waves are created when ultrasound waves are focused and scanned in mid-air, causing vibrations in the skin. These vibrations can interfere with each other in a way that amplifies their strength at some locations, a phenomenon known as constructive interference. The formation of shock waves creates a trailing wake pattern that extends beyond the intended focal point, reducing the spatial precision and clarity of the tactile sensations. As an analogy, according to the researchers, if the focused sound beam is a fast-moving boat on the water, the shock wave pattern is a wake trailing the boat. Current holographic haptic displays excite shock wave patterns that are so spread out in the skin that the sensations feel very diffuse.

“Our study reveals how holographic haptic displays, which are a promising new technology for virtual reality and telepresence, require new knowledge in acoustics innovations in design,” Visell said. “By understanding the underlying physics of ultrasound-generated shear shock waves in the skin, we hope to improve the design of haptic holographic displays and make them more realistic and immersive for users. Such haptic displays could enable us to augment our physical surroundings with a limitless variety of virtual objects, interactive animated characters, or graspable tools that can be not only seen, but also touched and felt with the hands.”

The team’s discovery of the previously unknown shock wave phenomena that underlie haptic holography provides an important step forward in creating haptic holographic displays that may enable users to more realistically and immersively interact in the future metaverse.

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