Towards Mid-Air Haptic Widgets

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Introduction

Mid-air haptic technology has created new possibilities for in-air interaction, allowing users to experience rich haptic sensations without touching or wearing a tactile display. This means we can enhance mid-air interfaces with haptic feedback, potentially improving their usability as users feel cues that help them provide input. As interaction designers, we are faced with an exciting but little-explored design space, which needs to be better understood so that we can create effective cues for mid-air interfaces and their widgets. In this paper, we summarise research at the University of Glasgow into ultrasound haptics, focusing on how our research informs the effective design of mid-air haptic widgets. We then identify future work which will advance our understanding of how we can use mid-air haptics to improve the design of such interfaces.

Mid-Air Haptic Research at Glasgow

For mid-air haptic feedback to be used effectively, it is important to understand the perceptual limits afforded by ultrasound haptic displays. Knowledge of how the tactile sensations are perceived can be used to inform the design of mid-air interfaces; for example, by specifying the minimum distance required between haptic "pixels". Wilson *et al*. [3] investigated two fundamental perceptual aspects of ultrasound haptics: localisation of a static point and perception of movement. The hand lay on a desk facing palm-up towards an 8x8 ultrasound array that produced 25 focal points in a 5x5cm grid. For localisation, points were presented individually to the palm and perceived position was indicated. The average localisation error was 8.5mm, suggesting the spatial resolution of ultrasound haptic displays should be one "pixel" per ~1.5cm^2. Apparent motion was used to identify the number, and duration, of sequentially presented points required to produce convincing movement. More focal points (> 2), longer durations (50-200ms) and longer distances (3cm) all improve movement perception.

Vo and Brewster [2] built on this work by investigating how accurately users could localise a point of ultrasound haptic stimulus in mid-air, this time through active exploration above the haptic display. This work aimed to inform the design of mid-air haptic widgets by investigating how accurately users could locate a haptic "pixel". In the experiment, users were asked to locate a focal point of feedback using their middle finger; points were randomly positioned above the device. Average localisation error was 14.1mm, which was more than for passive 2D localisation on the palm of the hand [3].

We have also evaluated the use of ultrasound haptics during mid-air gesture interaction, comparing it with vibration from wearables. Freeman *et al*. [1] found that ultrasound haptics was more suitable for creating the feeling of being in contact with a mid-air button widget, rather than for presenting feedback about the interaction (e.g., a tactile message about gesture acceptance).

Designing Mid-Air Haptic Widgets

Our research is focused on a better understanding of ultrasound haptics. We have identified initial requirements for ultrasound haptic pixels, which are the building blocks for mid-air haptic widgets. We have also investigated dynamic aspects (e.g. movement [3]) to see how the properties afforded by such displays may be used effectively. More perceptual research is needed, however, as many aspects are still unexplored. For instance, identifying the JND for modulation frequency would inform the number of usable frequency bands; this could be used for different mid-air button states, for example. Knowing the force thresholds for detection across different frequencies could also inform design; for example, identifying the minimum force for output.

Findings about the perception of ultrasound haptic stimuli will inform the initial design of a set of mid-air haptic widgets. We will use these findings to investigate how mid-air haptic feedback can be used to create haptic features for these widgets. There is a rich design space with many questions to explore. For example, what should a mid-air button feel like? Should it be textured? How big should it be? Should mid-air haptics represent the edge of the button, its surface, or both? Could dynamic haptic feedback be used to mimic a push-button's mechanical feedback?

Our future work in this area will consider how mid-air haptics can be combined with other output modalities. Visual cues improved localisation of in-air haptic points [2], so visual feedback could be used to improve the usability of mid-air widgets. New display technologies, like mid-air displays and head-mounted mixed-reality displays, could be used to render visual cues in-situ rather than on a distal display. We will also look at using mid-air haptics in cars; for example, to help users interact with in-car systems eyes-free, minimising distraction so they can focus on driving.

Conclusions

We have summarised our research into mid-air haptic interaction and outlined our direction for research. We see mid-air haptics as a way of enhancing mid-air interfaces, by providing a tactile component for otherwise invisible and intangible widgets. However, there is a rich and complex design space which must be explored to ensure the effective design of such widgets.

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References

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