Floating Widgets: Interaction with Acoustically-Levitated Widgets

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Abstract

Acoustic levitation enables new types of human-computer interface, where the content that users interact with is made up from small objects held in mid-air. We show that acoustically-levitated objects can form mid-air widgets that respond to interaction. Users can interact with them using in-air hand gestures. Sound and widget movement are used as feedback about the interaction.

Author Keywords

Acoustic levitation; mid-air interaction

ACM Classification Keywords

H.5.2 [User Interfaces]: Input devices and strategies.

Introduction

Acoustic levitation can be used to position and move small objects in mid-air. We present a novel interactive display where acoustically-levitated objects are the 'atoms' that make up the content. In this case, we borrow the 'atom' terminology from Ishii's *radical atoms* concept [4], which we discuss in the next section. We use levitating objects to create *Floating Widgets*, in-air representations of virtual widgets. For example, a row of objects becomes a virtual button that users can interact with using mid-air gestures (Figure 1). The concept of virtual widgets are widely used with mid-air gesture systems (e.g., virtual buttons above a mobile phone screen [2]), but their visual representations are shown on a separate display. Our approach allows the visual representation of the widgets to exist in the same space that users interact in.

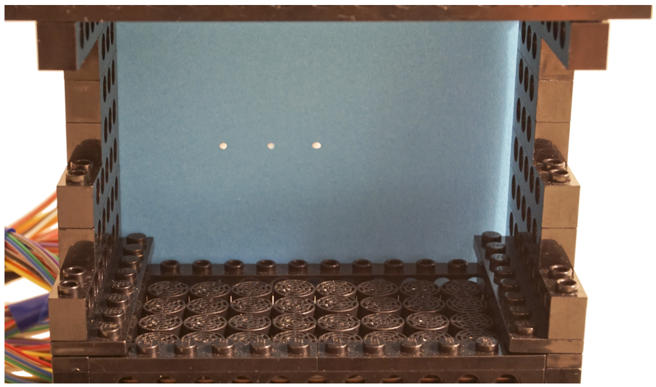

Figure 1. Our acoustic levitation system comprises two 8x4 opposing arrays of ultrasound transducers. Small beads (⌀1–2mm) are levitated within the space between the arrays. Here, three beads form the visual representation of a virtual button. The beads move in response to in-air gestures, moving like a physical button would when pressed.

This demo exemplifies our floating widgets concept: users can interact with a mid-air button composed of levitating objects. The button moves in mid-air as users 'press' it using gestures, with additional audio feedback given to mimic the mechanical sounds of a physical button being pushed.

Background

Computer interfaces based on object levitation are one realisation of Ishii's *radical atoms* concept [4]; this concept is of physical materials that can change form and appearance dynamically, to allow richer interactions with digital information. Levitating objects can be the 'atoms' that create physical objects that exist in mid-air and can change form dynamically as users interact with them.

This compelling vision has led to many approaches for levitating objects. *ZeroN* [5] used magnetic levitation, which was limited to a single large object but supported rich interactions via projections onto its surface. *Floatio* [12] and *Aerial Tunes* [1] used air jets to suspend and move objects in mid-air, although this offered limited control. *Pixie Dust* [7] used acoustic levitation, which supported larger numbers of smaller objects (⌀1–5mm) positioned close together (approximately 4.5mm apart).

The higher resolution of objects allowed by acoustic levitation means it has been more actively pursued in recent research. The state of the art has recently been advanced to allow multiple levitated objects to be moved independently [8] and to allow objects to be rotated as well [6, 11]. Not many applications using levitating objects have been explored, although physical visualisation has been considered [8, 9]. Our work is different because we use levitating objects as the building blocks of mid-air widgets, rather than as representations of data.

Floating Widgets

We present *Floating Widgets*, mid-air interactive widgets made from levitating 'atoms'. Floating Widgets are defined by the appearance and behaviour of their levitating atoms. For example, a 'button' and a 'slider' could both be composed of a horizontal row of atoms, but will respond to interaction in different ways. The atoms of a button might move together as it is being pressed, whereas the atoms in a slider might move from side to side between the leftmost and rightmost atoms. In this paper, we describe interaction with a floating button as an example of a Floating Widget.

Acoustically Levitated Floating Widgets

Our atoms are expanded polystyrene beads (⌀1–2mm), which are acoustically levitated using ultrasound arrays (like the current state of the art). Figure 1 shows our acoustic levitation hardware, two 40 kHz ultrasound transducer arrays that create a volume in which objects can be levitated and manipulated independently. Floating Widgets can be extended to any sort of levitating or self supporting objects, however: e.g. the large metallic ball from *ZeroN* [5] or the drones in *BitDrones* [3] could also be used to create widgets that respond to mid-air interactions.

Users cannot directly touch the levitating objects because the acoustic levitation force is not strong enough to overcome physical pressure. Users' hands would also disrupt the acoustic field, meaning that distal interaction is required (i.e., the hands must be a few cm away). We do not see this as a problem, since other virtual widgets (e.g., those shown on screens) can be used successfully with gestures, despite the visual representation being away from the users' hands. The success of this interaction relies on the levitating objects appearing to respond to touch before the user's hand reaches it: as a hand approaches a floating button, for example, it moves away from the hand, creating the illusion of the user pressing it.

Example Floating Widget: Mid-Air Buttons

This demonstration shows interaction with a floating button, consisting of a row of levitating beads. When inactive, the beads are static within the levitation volume (as in Figure 1). Users initiate interaction with the button by pointing an extended finger towards it (sensed using a Leap Motion). When this happens, a short audio tone is used to confirm that the user's finger is recognised. When the user 'pushes' their finger towards it, the levitating objects move in the same direction as their finger; at their furthest position (20mm from their initial location), a mechanical click sound is played, to create the impression of a physical button being fully pressed. When the user takes their hand away, the button moves back to its original position, accompanied by another sound.

In this case, the audio feedback is delivered by a separate loudspeaker, but it is possible for the ultrasound transducers to produce the audio feedback as well as the acoustic levitation forces. This is possible due to the 'parametric audio loudspeaker effect', where an ultrasonic carrier wave is modulated with the desired audio signal [10]. Research is ongoing to enable this combination with acoustic levitation and there are several possible approaches: e.g., using sections of the transducer array to deliver just the audio feedback, or modulating the audio feedback directly onto the levitation field. Future versions of Floating Widgets could give audio feedback directly from the transducer array using these approaches, meaning users hear the sounds coming directly from the widgets.

Conclusion

This paper presented *Floating Widgets*, the concept of mid-air widgets composed of levitating objects. We described interaction with a floating button to exemplify this concept and this demonstration invites users to try this interaction. Our concept advances in-air gesture interaction by making it possible for the visual representations of virtual widgets to exist in mid-air, in the same space that users gesture in.

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References

[1] Alrøe, T., Grann, J., Grönvall, E., Petersen, M. G., and Rasmussen, J. L. Aerial Tunes: Exploring Interaction Qualities of Mid-air Displays. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction - NordiCHI '12*, ACM Press (2012), 514–523.

[2] Freeman, E., Brewster, S., and Lantz, V. Tactile Feedback for Above-Device Gesture Interfaces: Adding Touch to Touchless Interactions. In *Proceedings of the 16th International Conference on Multimodal Interaction - ICMI '14*, ACM Press (2014), 419–426.

[3] Gomes, A., Rubens, C., Braley, S., and Vertegaal, R. BitDrones: Towards Using 3D Nanocopter Displays as Interactive Self-Levitating Programmable Matter. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, ACM Press (2016), 770–780.

[4] Ishii, H., Lakatos, D., Bonanni, L., and Labrune, J.-B. Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials. *Interactions XIX.1* (2012), 38–51.

[5] Lee, J., Post, R., and Ishii, H. ZeroN: Mid-Air Tangible Interaction Enabled by Computer Controlled Magnetic Levitation. In *Proceedings of the 24th annual ACM symposium on User interface software and technology - UIST '11*, ACM Press (2011), 327–366.

[6] Marzo, A., Seah, S. A., Drinkwater, B. W., Sahoo, D. R., Long, B., and Subramanian, S. Holographic acoustic elements for manipulation of levitated objects. *Nature Communications 6* (2015), Article 8661.

[7] Ochiai, Y., Hoshi, T., and Rekimoto, J. Pixie Dust: Graphics Generated by Levitated and Animated Objects in Computation Acoustic-Potential Field. *ACM Transactions on Graphics 33*, 4 (2014), Article 85.

[8] Omirou, T., Marzo, A., Seah, S. A., and Subramanian, S. LeviPath: Modular Acoustic Levitation for 3D Path Visualisations. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, ACM Press (2015), 309–312.

[9] Omirou, T., Marzo Perez, A., Subramanian, S., and Roudaut, A. Floating Charts: Data Plotting using Free-Floating Acoustically Levitated Representations. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)*, IEEE (2016), 187–190.

[10] Pompei, F. J. *Sound from ultrasound: the parametric array as an audible sound source*. Phd thesis, Massachusetts Institute of Technology, 2002.

[11] Sahoo, D. R., Nakamura, T., Marzo, A., Omirou, T., Asakawa, M., and Subramanian, S. JOLED: A Mid-air Display based on Electrostatic Rotation of Levitated Janus Objects. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology - UIST '16*, ACM Press (2016), 437–448.

[12] Yui, T., and Hashida, T. Floatio: Floating Tangible User Interface Based on Animacy Perception. In *Adjunct Proceedings of the 29th Annual Symposium on User Interface Software and Technology - UIST '16 Adjunct*, ACM Press (2016), 43–45.